CANADA
DEPARTMENT OF MINES
HON. T. A. CRERAR, MINISTER; CHARLES CAMSELL, DEPUTY MINISTER

MINES BRANCH
JOHN MCLEISH, DIRECTOR

INVESTIGATIONS IN ORE DRESSING AND METALLURGY

(Testing and Research Laboratories)

January to June, 1935

OTTAWA
J. O. PATENAUDE, I.S.O.
PRINTER TO THE KING'S MOST EXCELLENT MAJESTY
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MINES BRANCH INVESTIGATIONS IN

ORE DRESSING AND METALLURGY, JANUARY TO JUNE, 1935

I

REVIEW OF INVESTIGATIONS

W. B. Timm
Chief of Division

During the half-yearly period ended June 30, 1935, some sixty-two major investigations were completed and reports thereon furnished to the parties submitting the ores or other materials for examination and test. In addition, numerous tests of minor importance were made.

Of the major investigations, the twenty-seven reports included in Section II were preprinted as separates. Thirty-four reports of somewhat lesser importance are synopsized in Section III.

Having as a basis for their flow-sheets the reports of investigations made in the Ore Dressing and Metallurgical Laboratories, six new milling plants have been erected by the mining companies concerned, changes and alterations resulting in increased recoveries made in four operating plants, two new milling plants are in course of erection and a number of others under consideration.

The investigations were carried out under the direction and supervision of W. B. Timm, Chief of the Division of Ore Dressing and Metallurgy. The microscopic examination and spectrographic analyses of ores and mill products were performed by M. H. Haycock. The test work on metallic ores was performed by C. S. Parsons, R. J. Traill, A. K. Anderson, J. D. Johnston, W. R. McClelland, H. L. Beer, and W. S. Jenkins. The test work on non-metallic minerals and industrial products was performed by R. K. Carnochan and R. A. Rogers. The metallurgical work on iron and steel products was performed by H. H. Bleakney. The chemical work was performed by a staff of chemists and assayers under the direction and supervision of H. C. Mabee, Chief Chemist.

Owing to the continued expansion of the gold mining industry, the majority of the investigations were conducted on gold ores, or ores in which gold was the chief valuable mineral. Many of the ores were complex, the gold being associated with the sulphide mineralization in a finely divided state or containing some cyanide-consuming mineral or minerals, which made treatment difficult and which required exhaustive study, extending the investigations over several months' time. A number of the investigations were on problems of plant operation where difficulties were being met with and increased recoveries hoped for by changes and alterations in flow-sheets and plant practice.

Included in the investigations are a number of base metal ores. The better market price for base metals and the upward trend in the price of silver during the year was responsible for consideration being given to the resumption of operations on the lead-zinc-silver ores of the Slocan district in British Columbia and the copper-zinc deposits in Manitoba and northwestern Quebec. In view of this outlook, the ore of the Mammoth mine was investigated for increased recoveries of the silver over those obtained under the former methods used, and further work was done on Abana ore to arrive at the relative value of bulk concentration as compared with selective concentration of the minerals. The further investigation of the copper-pyrite ore of the Eustis mine was carried out to determine whether milling costs could be reduced by a change in plant practice. A lowering of costs was essential to the continued operation of the mine. The silver-bearing copper concentrate produced by flotation of the gravity plant tailing from the pitchblende-silver ore of the Eldorado Gold Mines, Limited, Great Bear Lake, N.W.T., was investigated to determine a commercial process for the recovery of the silver. The silver is mostly contained in silver minerals other than native silver, which is largely concentrated with the pitchblende, and attempts to separate the silver minerals from the copper minerals by differential flotation, making a high-grade shipping concentrate with a good recovery, have not been successful. The investigation indicated what would appear to be a profitable method for the recovery of the silver at the property.

The investigation of the "Crocetol" frothing reagents manufactured by Shawinigan Chemicals, Limited was productive in establishing their use in the industry.

A brief synopsis and summary of the investigations on non-metallic and industrial minerals and in ferrous metallurgy are given in the report. A summary of the work of the mineragraphic and chemical laboratories will be given for the calendar year 1935 in the Report of Investigations, July to December, 1935.

II

INVESTIGATIONS THE RESULTS OF WHICH ARE RECORDED IN DETAIL

Ore Dressing and Metallurgical Investigation No. 609

GOLD ORE FROM THE ENGINEER MINE, ATLIN, B.C.

Shipment. A shipment of 500 pounds of ore was received on August 20, 1934, from the Mining Corporation of Canada, Limited. This sample was from the Engineer mine, Atlin, B.C.

Sampling and Analysis. The shipment was sampled and assayed, giving:

Gold	2·60 oz./ton
Silver	2·33 "
Lead	Trace
Copper	0·01 per cent
Zinc	0·05 "

Purpose of Experimental Tests. The Engineer mine has been in operation from time to time for over 17 years. There is a 50-ton mill on the property, the flow-sheet of which is briefly as follows: from a 50-ton ore bin, run-of-mine ore passes to a Dodge crusher, 7 inches by 11 inches, where it is reduced to ¾-inch size. Two ore feeders feed to two ball mills, 4 feet by 4 feet, in closed circuit with 30-inch Akins classifiers, the classifier overflow going to amalgamation plates. The sand returns of the classifier go to an elevator, whence they pass over an impact screen, the undersize of which goes over the plates and the oversize back to the ball mills, thus keeping the metallic gold from accumulating in the grinding circuit. The pulp from the plates goes through an amalgam trap and then to a double-cone type classifier, the sand from which goes to two No. 6 Wilfley tables, and the slime is thickened in a 12-foot Callow cone and tabled on a Deister slime table. Middlings from all tables go back to the elevator to screen and over the plates again.

This shipment of ore was sent for determining whether the present flow-sheet of the mill could be altered to increase the recovery of gold or to yield a greater profit from the ore.

Experimental Tests

The ore was found to be easy to treat. A series of straight cyanidation tests showed that 98 per cent of the gold could be extracted when the ore was ground to pass all through 48 mesh and approximately 50 per cent through 200 mesh. Tests also showed that between 60 and 75 per cent of the gold can be amalgamated, depending on how fine the ore is ground. Blanket concentration followed by flotation recovered over 98 per cent of the gold.

STRAIGHT CYANIDATION

Test No. 1

Two large samples of the ore were taken and ground to the following screen sizes in a small ball mill with water. Cyanide was added to the pulp after grinding, to make a 1 pound per ton KCN solution, and the pulp density maintained while cyaniding was 2·5 : 1.

The following table shows the extraction obtained and the reagent consumption:

Test No.	Assay, Au, oz./ton		Extraction, per cent	Reagents consumed, lb./ton	
	Feed	Tailing		KCN	CaO
1a	2·6	0·035	98·7	0·5	3·6
1b	2·6	0·035	98·7	0·5	3·6

Screen Test:

Mesh	Weight, per cent
+ 65	0·2
− 65 +100	7·1
−100 +150	17·7
−150 +200	27·5
−200	47·5
Total	100·0

AMALGAMATION

Test No. 2

Fifty-four pounds of ore was cut from the shipment and crushed through 14 mesh. The sample obtained was sized on the screens shown in the following table and each size was amalgamated separately.

Product	Weight, per cent	Feed		Amalgamation tailing		Extraction, per cent
		Assay, Au oz./ton	Units	Assay, Au oz./ton	Units	
−14+20	17·85	2·61	4·659	1·78	3·177	31·2
−20+35	25·96	2·41	6·256	1·53	3·972	36·6
−35+48	12·40	2·89	3·584	1·04	1·290	64·0
−48+65	10·69	3·39	3·624	0·69	0·738	79·6
−65	33·10	2·94	9·731	0·61	2·019	79·2
Total	100·00	2·78	27·854	1·12	11·196	63·4

In order to achieve the best results it is necessary to crush to pass 48 mesh.

BLANKET CONCENTRATION FOLLOWED BY FLOTATION

Test No. 3

A large sample of ore was cut from the shipment and ground in a small ball mill and then passed over a corduroy blanket. The blanket tailing was then concentrated by flotation.

Screen Test:

Mesh	Weight, per cent
+100	3·7
−100+150	10·6
−150+200	25·4
−200	60·3
Total	100·0

Results:

Product	Weight, per cent	Assay, oz./ton		Recovery, per cent
		Au	Ag	
Blanket concentrate	0·458	407·64	....	75·8
Flotation concentrate	2·84	19·46	31·0	22·5
Flotation tailing	96·70	0·045	....	1·7
Total	100·0	2·5	....	100·0

The recovery of gold in the blanket concentrate and in the flotation concentrate totals 98·3 per cent.

The ratio of concentration would be about 30 to 1, or for every 100 tons of ore milled 3·3 tons of concentrate would have to be shipped.

Amalgamation of the blanket concentrate will recover 95 to 96 per cent of the contained gold, so that about 70 to 72 per cent of the gold can be obtained as bullion at the property. The amalgamation tailing from the blanket concentrate, which will run about 10 to 12 ounces in gold per ton, can be mixed with the flotation concentrate for shipment to the smelter.

The flotation reagents used were: 2 pounds soda ash, about 0·02 pound Aerofloat No. 25, 0·10 pound amyl xanthate per ton, and a little pine oil.

CONCLUSIONS

If it is more profitable to produce bullion and to ship no concentrate, the ore can be easily cyanided and a high recovery of the gold obtained.

The flow-sheet of a cyanide mill should include grinding in cyanide solution and, as an additional safeguard, on account of the large proportion of coarse gold the classifier overflow should be passed over blankets. The use of blankets at this point will take care of any surges of gold over the classifier which might have a tendency to pass through the agitations before the coarser particles would have time to dissolve.

If, on the other hand, it is desired only to increase the recovery in the present mill, this can be done by the addition of flotation in place of the table operation. However, it would be well to keep in at least one sand table to take care of any coarse gold passing the amalgamation plates. The table could be used on the flotation tailing for this purpose.

Ore Dressing and Metallurgical Investigation No. 610

GOLD ORE FROM DUPARQUET MINING COMPANY, LIMITED, DUPARQUET, QUEBEC

Shipment. The shipment, consisting of 1,100 pounds of ore, was received on December 3, 1934. It was submitted by George Miller, Manager, Duparquet Mining Company, Limited, Duparquet, Quebec.

Purpose of the Experimental Tests. The ore was submitted for test work to determine the best method of treatment to recover the gold.

Characteristics of the Ore. Six polished sections were prepared and examined microscopically for the purpose of determining the character of the material.

The gangue is fine-textured, light greenish grey in colour, and siliceous, though a considerable amount of chloritic material is present. It has a well-defined schistosity.

Only two ore minerals, pyrite and arsenopyrite, are visible in appreciable amounts. These two minerals are finely disseminated, with a pronounced tendency to concentrate along lines parallel with the schistosity. The pyrite is somewhat altered, often along crystallographic directions, to a grey transparent mineral, possible leucoxene; its grain size varies from a few millimetres to less than a micron, the average probably falling well below 200 mesh. The arsenopyrite is much finer grained than the pyrite, the average grain size probably falling below 400 or 560 mesh; most of the arsenopyrite crystals are skeletal, only a diamond-shaped shell being present.

A few extremely tiny grains of chalcopyrite are present in pyrite, but the copper in the sample is probably far too small to be detected in ordinary chemical analysis. No gold was visible in the polished sections.

Sampling and Analysis. The shipment was crushed and sampled, and a representative portion assayed as follows:

Gold	0·31 oz./ton
Silver	0·05 "
Arsenic	0·75 per cent

Experimental Tests

1. Standard cyanidation test. (Test No. 1).
2. Flotation tests. (Tests Nos. 2, 3, 4, 5, 6, and 7).

CYANIDATION

Test No. 1

Representative samples of −14-mesh ore were dry-crushed to pass 48-, 100-, 150-, and 200-mesh screens. From each, 200-gramme portions were cyanided by agitation in a solution of sodium cyanide, dilution 3 : 1, equivalent in potassium cyanide strength to 1·0 pound per ton. Lime at the rate of 5·0 pounds per ton of ore was added to give protective alkalinity. Two tests were made on each size, one agitating for 24 hours, the other, 48 hours. The reagents were added as required to keep the solution up to strength.

Results:

Product, mesh	Agitation, hours	Assay Au, oz./ton		Extraction, per cent	Reagents consumed, lb./ton	
		Feed	Tailing		KCN	CaO
− 48	24	0·31	0·18	41·94	0·30	6·15
−100	24	0·31	0·16	48·39	0·30	6·60
−150	24	0·31	0·145	53·23	0·30	9·45
−200	24	0·31	0·12	61·29	0·63	10·30
− 48	48	0·31	0·175	43·55	0·60	8·65
−100	48	0·31	0·15	51·61	0·60	9·25
−150	48	0·31	0·15	51·61	0·90	12·25
−200	48	0·31	0·12	61·29	1·23	13·40

A screen analysis was made on the cyanide tailing.

Mesh	Weight, per cent		
	−48 mesh	−100 mesh	−150 mesh
− 48+ 65	12·2	....	....
− 65+100	25·0	....	....
−100+150	13·1	9·3	0·2
−150+200	11·2	17·1	14·2
−200	38·5	73·6	85·6
	100·0	100·0	100·0

STRAIGHT FLOTATION

Tests Nos. 2, 3, and 4

Three tests were made using identical amounts of reagents but varying the amount of grinding. Representative samples of −14-mesh ore were ground in jar mills, dilution 4 : 3, with the following reagents:

Soda ash	4·0 lb./ton
Aerofloat No. 31	0·14 "

The reagents to the cell were:

Potassium amyl xanthate	0·2 lb./ton
Pine oil	0·05 "

Results of Test No. 2:

Product	Weight, per cent	Assay		Distribution of gold, per cent	Ratio of concentration
		Au, oz./ton	As, per cent		
Feed	100·00	0·31	....	100·00	6·4 : 1
Flotation concentrate	15·57	1·75	4·60	90·2	
Flotation tailing	84·43	0·035	....	9·8	

Results of Test No. 3:

Feed	100·00	0·31	....	100·00	6·7 : 1
Flotation concentrate	14·85	1·83	4·92	91·51	
Flotation tailing	85·15	0·03	....	8·49	

Results of Test No. 4:

Feed	100·00	0·31	....	100·00	5·1 : 1
Flotation concentrate	19·47	1·51	4·02	93·60	
Flotation tailing	80·53	0·025	....	6·40	

The degree of grinding is shown by a screen analysis on each tailing:

Mesh	Tailing of Test No. 2	Tailing of Test No. 3	Tailing of Test No. 4
	Weight, per cent	Weight, per cent	Weight, per cent
− 48+100	1·2	....	....
−100+150	5·1	0·75	0·25
−150+200	16·1	8·25	5·05
−200	77·6	91·00	94·70
	100·0	100·00	100·00

Tests Nos. 5 and 6

Two tests were made to determine the effect of copper sulphate added to the cell. The reagents are otherwise identical with those used in the first three tests. The amount of grinding was increased in Test No. 6.

Representative samples of −14-mesh ore were ground in jar mills, dilution 4: 3, with the following reagents:

Soda ash	4·0 lb./ton
Aerofloat No. 31	0·14 "

The reagents to the cell were:

Copper sulphate	0·5 lb./ton
Potassium amyl xanthate	0·2 "
Pine oil	0·05 "

Results of Test No. 5:

Product	Weight, per cent	Assay		Distribution of gold, per cent	Ratio of concentration
		Au, oz./ton	As, per cent		
Feed	100·00	0·31	0·75	100·00	
Flotation concentrate	16·67	1·73	4·34	89·65	6·0 : 1
Flotation tailing	83·33	0·04	....	10·35	

Results of Test No. 6

Product	Weight, per cent	Au, oz./ton	As, per cent	Distribution of gold, per cent	Ratio of concentration
Feed	100·00	0·31	0·73	100·00	
Flotation concentration	16·84	1·66	4·73	93·07	5·9 : 1
Flotation tailing	83·16	0·025	....	6·93	

The degree of grinding is shown by a screen analysis on each tailing:

Mesh	Test No. 5 Weight, per cent	Test No. 6 Weight, per cent
− 48+100	0·45	......
−100+150	4·35	1·90
−150+200	14·50	11·05
−200	80·70	87·05
	100·00	100·00

Test No. 7

A representative sample of −14-mesh ore was ground in a Denver ball mill, dilution 4: 3, to give a product 85 per cent −200 mesh.

The reagent added to the mill was:

Soda ash.. 4·0 lb./ton

The Aerofloat was omitted from this test.

The reagents added to the cell were:

Copper sulphate.. 0·5 lb./ton
Potassium amyl xanthate...................................... 0·2 "
Pine oil.. 0·075 "

Results of Test No. 7:

Product	Weight, per cent	Assay		Distribution of gold, per cent	Ratio of concentration
		Au, oz./ton	As, per cent		
Feed	100·00	0·31	0·75	100·00	
Flotation concentrate	16·06	1·89	4·87	92·33	6·2 : 1
Flotation tailing	83·94	0·03	....	7·67	

Screen Analysis on Flotation Tailing:

Mesh	Weight, per cent
− 48+100	0·65
−100+150	2·00
−150+200	10·40
−200	86·95
	100·00

SUMMARY OF EXPERIMENTAL TESTS

1. Cyanidation at −200 mesh gives 61 per cent extraction.

2. Flotation on ore crushed 77 per cent −200 mesh gives 90 per cent recovery, and on ore crushed 95 per cent −200 mesh the recovery is 94 per cent.

CONCLUSIONS

The results of the mineragraphic examination and the experimental tests show that the ore is very similar to the Beattie ore. It will be noted that fine grinding will be required to liberate the gold-bearing sulphides.

In view of the fact that no better method than that used at Beattie has been evolved for this type of ore, it is recommended that the Beattie practice be followed but that the ore be ground finer than at present.

Ore Dressing and Metallurgical Investigation No. 611

GOLD ORE FROM THE ATLIN PACIFIC MINING COMPANY, LIMITED, BIGHORN CREEK, ATLIN MINING DIVISION, B.C.

Shipment. The shipment, consisting of 500 pounds of ore, was received on December 3, 1934. The ore is said to be from the property of the Atlin Pacific Mining Company, Limited, formerly the Norgold Mines, Limited, of British Columbia, situated on the west side of Bighorn creek, Atlin mining division, British Columbia. The shipment was submitted by J. E. R. Wood, President, Atlin Pacific Mining Company, Limited, 610 Pacific Building, Vancouver, B.C.

Purpose of Experimental Tests. The experimental tests were made to determine the best method of recovering the gold.

Characteristics of the Ore. Six polished sections were examined microscopically to determine the character of the ore.

The gangue consists of fine-textured white vein quartz and green to brown altered country rock. A considerable amount of light carbonate is present.

The ore minerals present in the polished sections are, in the order of their abundance: pyrite, sphalerite, galena, chalcopyrite, "limonite", marcasite, covellite, and native gold.

Pyrite is abundant and occurs as coarse to fine disseminated grains. It contains numerous small inclusions of gangue, and irregular grains and veinlets of sphalerite, galena, and chalcopyrite.

Sphalerite occurs in rather large masses, as grains and small stringers in quartz, and as noted under pyrite. The massive type contains numerous dots of chalcopyrite.

Galena occurs in small amount, as grains and stringers in quartz and as noted under pyrite. Marcasite is present in small amount as narrow veinlets, chiefly in sphalerite.

Chalcopyrite, also in small amount, is present as irregular grains in quartz, and as noted under pyrite and sphalerite. It is, in some places, altered to covellite; here cores of chalcopyrite are surrounded by thin shells of covellite which are in turn surrounded by shells of "limonite". The amount of these two minerals is probably very small.

Only one grain of native gold is visible in the polished sections. This is approximately 8 microns (slightly below 1,600 mesh) in size, and occurs in dense pyrite.

Sampling and Analysis. The shipment was crushed and sampled by standard methods and a representative portion assayed as follows:

Gold	0·35 oz./ton
Silver	0·76 "
Copper	0·01 per cent
Lead	0·55 "
Zinc	0·53 "
Arsenic	0·04 "
Sulphur	3·50 "
Iron	4·50 "
Carbon dioxide	1·20 "

Experimental Tests

1. Amalgamation.
2. Straight cyanidation.
3. Cyanidation with pre-aeration.
4. Blanket concentration followed by flotation.
5. Similar to No. 4, except using finer grinding.

AMALGAMATION

Test No. 1

Representative samples of the ore were crushed dry to pass 48- and 100-mesh screens. Portions of each were barrel-amalgamated in jar mills.

After separating the mercury and amalgam, the tailings were sampled and assayed.

A screen analysis on each shows the degree of grinding.

Results:

Mesh No.	Assay, Au, oz./ton		Extraction of gold, per cent
	Feed	Tailing	
− 48	0·35	0·245	30·00
−100	0·35	0·23	34·29

Screen Analysis:

Mesh	−48-mesh tailing, weight, per cent	−100-mesh tailing, weight, per cent
− 48+ 65	8·70	......
− 65+100	24·30	......
−100+150	15·75	9·65
−150+200	15·00	22·95
−200	36·25	67·40
	100·00	100·00

STRAIGHT CYANIDATION

Test No. 2

Representative samples of the ore were crushed dry to pass 48-, 100-, 150-, and 200-mesh screens. Portions from each were treated by agitation in a solution of sodium cyanide, dilution 3 : 1, for periods of 24 and 48 hours. The strength of the solution was equivalent to 1·0 pound potassium cyanide per ton. Lime was added at the rate of 5·0 pounds per ton of ore, to give protective alkalinity. Frequent additions of reagents were required to maintain the strength of the solutions.

Results:

Mesh No.	Agitation, hours	Assay, Au, oz./ton		Extraction of gold, per cent	Reagents consumed, lb./ton	
		Feed	Tailing		KCN	CaO
− 48	24	0·35	0·065	81·43	1·44	11·80
−100	24	0·35	0·06	82·86	2·94	11·95
−150	24	0·35	0·03	91·43	2·85	14·10
−200	24	0·35	0·015	95·71	2·85	15·45
− 48	48	0·35	0·085	75·71	1·44	12·10
−100	48	0·35	0·07	80·00	2·94	11·65
−150	48	0·35	0·025	92·86	3·48	14·25
−200	48	0·35	0·015	95·71	3·63	17·90

Screen Analysis:

Mesh	−48-mesh, weight, per cent	−100-mesh, weight, per cent	−150-mesh, weight, per cent
− 48+ 65	8·60	....	....
− 65+100	23·95	....	....
−100+150	15·70	9·00	....
−150+200	13·75	21·55	17·3
−200	38·00	69·45	82·7
	100·00	100·00	100·00

CYANIDATION, PRE-AERATION TESTS

Test No. 3

Three tests were made to determine the effect of pre-aeration on the consumption of reagents and the recovery of gold.

Representative samples of the ore were ground in jar mills, dilution 4 : 3, to give a product approximately 75 per cent −200 mesh.

Test No. 3a

The pulp from the grinding mill was washed into a large Winchester bottle with excess water. After settling, the excess water was decanted and the pulp made up to a dilution of 5 : 2, with fresh water. Sodium cyanide was added to make the strength of the solution equivalent to 1·0 pound potassium cyanide per ton. Lime at the rate of 5·0 pounds per ton of ore was added to give protective alkalinity. The pulp was agitated for 24 hours.

Results:

Assay, Au, oz./ton		Extraction, per cent	Reagents consumed, lb./ton	
Feed	Tailing		KCN	CaO
0·35	0·055	84·29	1·30	4·77

Test No. 3b

In this test, the pulp from the grinding mill was washed into a pressure aerator and subjected to 25 pounds gauge pressure for 4 hours. After aeration the pulp was treated as in Test No. 3a.

Results:

Assay, Au, oz./ton		Extraction, per cent	Reagents consumed, lb./ton	
Feed	Tailing		KCN	CaO
0·35	0·015	95·71	1·80	5·27

Test No. 3c

In this test the pulp from the grinding mill was added directly to the bowl of a Denver super-agitator. Agitation without reagents was maintained for 4 hours, after which sodium cyanide was added to make the strength of the solution equivalent to 1·0 pound potassium cyanide per ton. Lime at the rate of 5·0 pounds per ton of ore was added to give protective alkalinity.

Results:

Assay, Au, oz./ton		Extraction, per cent	Reagents consumed, lb./ton	
Feed	Tailing		KCN	CaO
0·35	0·035	90·0	2·76	6·85

The results of this test are not satisfactory on account of higher consumption of reagents and a higher tailing than in Aeration Test No. 3b.

BLANKET CONCENTRATION FOLLOWED BY FLOTATION

Test No. 4

A representative sample was ground in jar mills, dilution 4 : 3, to give a product which was approximately 73 per cent −200 mesh.

The ground pulp was concentrated on a corduroy blanket, which had a slope of 2½ inches in 12 inches.

The blanket tailing was treated by flotation, using the following reagents:

Soda ash.. 3·0 lb./ton
Potassium amyl xanthate.. 0·2 "
Pine oil.. 0·1 "

Results of Blanket Concentration:

Product	Weight, per cent	Assay, oz./ton		Distribution of gold, per cent	Ratio of concentration
		Au	Ag		
Feed............................	100·00	0·35	0·76	100·0	
Blanket concentrate.............	0·40	29·72	12·46	34·2	250 : 1
Blanket tailing..................	99·60	0·23	....	65·8	

Results of Flotation:

Product	Weight, per cent	Assay, oz./ton		Distribution of gold, per cent	Ratio of concentration
		Au	Ag		
Feed............................	100·0	0·23	....	100·00	
Flotation concentrate............	8·6	2·12	5·61	78·44	11·6 : 1
Flotation tailing.................	91·4	0·055	....	21·56	

Summary of Results:

Recovery of gold by blankets.................................. 34·2 per cent
Recovery of gold by flotation, 78·44 × 65·8..................... 51·6 "

Overall recovery of gold............................... 85·8 per cent

Test No. 5

This test was similar to Test No. 4 except for finer grinding. The pulp was ground to approximately 84 per cent −200 mesh.

The same reagents were used for flotation, i.e.,

Soda ash.. 3·0 lb./ton
Potassium amyl xanthate.. 0·2 "
Pine oil.. 0·1 "

Results of Blanket Concentration:

Product	Weight, per cent	Assay, oz./ton		Distribution of gold, per cent	Ratio of concentration
		Au	Ag		
Feed............................	100·00	0·35	....	100·0	
Blanket concentrate.............	0·35	33·04	13·77	35·6	286 : 1
Blanket tailing..................	99·65	0·21	....	64·4	

Results of Flotation:

Product	Weight, per cent	Assay, Au, oz./ton,	Distribution of gold, per cent	Ratio of concentration
Feed	100·0	0·21	100·0	
Flotation concentrate	8·6	2·06	84·7	11·6 : 1
Flotation tailing	91·4	0·035	15·3	

Summary of Results:

Recovery of gold by blankets	35·6 per cent
Recovery of gold by flotation, 84·7 × 64·4	54·6 "
Overall recovery of gold	90·2 per cent

Flotation Concentrate:

Copper	0·31 per cent
Lead	5·00 "
Zinc	6·87 "

SUMMARY RESULTS OF EXPERIMENTAL TESTS

1. The recovery by amalgamation at 67 per cent −200 mesh was 34 per cent of the gold.
2. The recovery by straight cyanidation was 96 per cent of the gold in 24 hours on −200-mesh ore.
3. Pre-aeration of pulp followed by cyanidation gave a recovery of 96 per cent of the gold, using less than one-half the amount of cyanide on 75 per cent −200-mesh ore.
4. Blanket concentration followed by flotation gave an overall recovery of 86 per cent of the gold on ore crushed 73 per cent −200 mesh.
5. A similar test using 84 per cent −200-mesh grind gave an overall recovery of 90 per cent of the gold.

CONCLUSIONS

The results of the investigation show that to obtain the maximum recovery of gold by cyanidation it will be necessary to grind in water from 75 to 80 per cent −200 mesh, followed by aeration prior to cyanidation.

Pre-aeration reduces the amount of cyanide consumed and gives a better recovery of gold than straight cyanidation.

Fouling of solutions and excessive consumption of cyanide may be expected in straight cyanidation.

The blanket concentration tests show that about 35 per cent of the gold can be recovered on blankets at a 75 per cent −200-mesh grind.

The best method to use will probably be to grind with lime, concentrate the classifier overflow on blankets to remove free gold, and treat the blanket tailing similarly to the Dome milling practice of pre-aeration and cyanidation.

The small volume of blanket concentrate may be treated by barrel-amalgamation and the residues reground and cyanided.

Ore Dressing and Metallurgical Investigation No. 612

CONCENTRATION OF SILVER FROM THE LEAD-ZINC ORE OF THE MAMMOTH MINE, SILVERTON, B.C.

Shipment. A shipment consisting of two bags of ore weighing 160 pounds was received by freight December 12, 1934, from the Western Exploration Company, Ltd., Silverton, B.C., A. M. Ham, manager. This sample was said to have been taken from the Mammoth mine, Silverton.

The shipment was made to determine if the silver held in the zinc concentrate of a selective lead-zinc flotation process could be isolated from the zinc. As this silver product would be united with the lead concentrate for shipment, the problem therefore is to make a lead-silver concentrate, and by re-treatment of the zinc concentrate, to obtain a further concentration of silver.

Characteristics of the Ore. Specimens were selected from the shipment and six polished sections prepared and examined in the mineragraphic laboratory.

The ore consists of a gangue composed of dark, fine-textured country rock which contains finely disseminated carbonate, veinlets of white quartz, and veinlets of white carbonate. The sulphides appear to occur most abundantly in close association with the veinlets of quartz which they have invaded.

The most abundant ore mineral is sphalerite, which is present in large masses and grains. This mineral has invaded country rock and quartz and contains grains and veinlets of galena, tetrahedrite, chalcopyrite, and marcasite. Galena and tetrahedrite are present in moderate amounts and both occur as grains and veinlets, chiefly in the sphalerite, though a small amount of each occurs in the gangue. Moreover, most of the galena contains small grains of tetrahedrite. Chalcopyrite is rare, but occurs as occasional grains in galena and sphalerite; the absence of characteristic numerous small dots of chalcopyrite in the sphalerite is noteworthy. A very small amount of pyrrhotite is present as irregular grains in galena and sphalerite, and these grains are in some places surrounded by a thin shell of marcasite that has probably resulted from the alteration of the pyrrhotite. Occasional grains and veinlets of marcasite occur in the sphalerite.

The zinc-bearing mineral is sphalerite and this occurs in large masses and coarse grains. As is usually the case, it may be assumed that the tetrahedrite accounts for a large part of the silver, though probably galena contains a considerable portion of this metal. In order to gain some idea of the grain size of these two minerals a quantitative microscopic grain analysis was made of the galena and tetrahedrite occurring in sphalerite, with the results shown in the following table, in which the percentages are shown by volume.

Mesh	Galena	Tetrahedrite	
		Free	Combined with galena
+ 6	7·7	....	....
− 6+ 8	11·0	....	....
− 8+ 10	6·0	....	....
− 10+ 14	5·5	....	....
− 14+ 20	10·2	....	....
− 20+ 28	6·5	....	....
− 28+ 35	6·6	....	0·9
− 35+ 48	4·2	0·7	1·9
− 48+ 65	5·4	0·8	2·2
− 65+100	3·4	1·1	1·9
−100+150	0·8	0·7	1·6
−150+200	1·0	0·6	1·6
−200+280	0·5	0·5	1·2
−280+400	1·1	0·4	2·0
−400+560	1·6	0·3	4·6
−560	1·0	0·2	4·3
Totals	72·5	5·3	22·2

It is seen from the table that 4·2 per cent of the lead occurring within sphalerite is finer than 200 mesh; 1·4 per cent of the free tetrahedrite and 12·1 per cent of that combined with galena are also finer than 200 mesh. This indicates that considerable silver will be contained in the minerals finer than 200 mesh.

Experimental Tests

The shipment was crushed, ground and sampled. Analysis showed the ore to contain:—

Gold	0·005	oz./ton
Silver	25·70	"
Zinc	40·5	per cent
Lead	1·74	"
Copper	0·22	"

The investigation was one consisting wholly of flotation tests. An endeavour was made to obtain a lead concentrate containing most of the silver. In several tests, the zinc concentrate was re-treated to make a concentration of silver. This analysis shows a lead to zinc ratio of 1 : 23·2. This is a very adverse condition for obtaining a lead-silver concentrate low in zinc. The large bulk of zinc mineral will undoubtedly entangle grains of silver-bearing mineral.

The results obtained show that 99 per cent of the lead and approximately 65 per cent of the silver can be recovered in a concentrate carrying approximately 200 ounces of silver per ton, 20 per cent lead, and 35 per cent zinc.

A zinc concentrate containing 58 per cent zinc and 15 ounces of silver per ton can also be made. This represents an approximate recovery of 90 per cent of the zinc.

Test No. 1

A sample of the ore was ground wet in a jar mill containing iron balls until 86·5 per cent passed 200 mesh; 6 pounds of soda ash, 0·10 pound of cyanide, and 1·0 pound of zinc sulphate per ton were added to the mill before grinding. The pulp was then transferred to a flotation machine and conditioned with 0·10 pound of butyl xanthate and 0·09 pound of pine oil per ton, and a lead-silver concentrate removed; 1·0 pound of copper sulphate, 0·20 pound of sodium xanthate, and 0·12 pound of pine oil per ton were then added and a zinc concentrate removed.

Results:

Product	Weight, per cent	Assay			Distribution, per cent		
		Ag, oz./ton	Pb, per cent	Zn, per cent	Ag	Pb	Zn
Feed (cal.)	100·00	24·91	1·64	39·81	100·0	100·0	100·0
Lead concentrate	7·81	209·92	20·84	39·03	65·8	99·1	7·7
Zinc concentrate	61·87	13·27	Trace	58·75	33·0	....	91·3
Tailing	30·32	1·00	0·05	1·36	1·2	0·9	1·0

Test No. 2

In this test, no zinc sulphate was added in the grinding mill. In all other respects, the test is the same as Test No. 1.

Results:

Product	Weight, per cent	Assay			Distribution, per cent		
		Ag, oz./ton	Pb, per cent	Zn, per cent	Ag	Pb	Zn
Feed (cal.)	100·00	24·83	1·58	39·61	100·0	100·0	100·0
Lead concentrate	8·85	181·74	17·87	42·24	64·9	99·0	9·4
Zinc concentrate	58·85	13·79	Trace	59·35	32·7	....	88·2
Tailing	32·30	1·94	Trace	2·94	2·4	....	2·4

Test No. 3

This test is the same as Test No. 1 with a finer grind, 94·8 per cent −200 mesh.

Results:

Product	Weight, per cent	Assay			Distribution, per cent		
		Ag, oz./ton	Pb, per cent	Zn, per cent	Ag	Pb	Zn
Feed (cal.)	100·00	24·50	1·56	39·46	100·0	100·0	100·0
Lead concentrate	11·09	150·31	13·93	41·75	68·0	99·2	11·7
Zinc concentrate	56·76	12·81	Trace	58·89	29·7	....	84·7
Tailing	32·15	1·73	0·04	4·38	2·3	0·8	3·6

Test No. 4

The only difference between this test and the preceding one is that in this test the soda ash was reduced from 6 pounds to 3 pounds per ton.

Results:

Product	Weight, per cent	Assay			Distribution, per cent		
		Ag, oz./ton	Pb, per cent	Zn, per cent	Ag	Pb	Zn
Feed (cal.)	100·0	24·68	1·58	39·27	100·0	100·0	100·0
Lead concentrate	11·3	149·30	13·73	41·65	68·4	99·0	12·0
Zinc concentrate	54·2	12·91	Trace	59·40	28·3	....	82·0
Tailing	34·5	2·36	0·07	6·89	3·3	....	6·0

Test No. 5

The reagents for the flotation of the lead-silver minerals were changed from xanthate to Aerofloat No. 31; 0·20 pound per ton of this reagent was added to the grinding mill together with soda ash and cyanide as in Test No. 2. Other conditions were unchanged.

Results:

Product	Weight, per cent	Assay			Distribution, per cent		
		Ag, oz./ton	Pb, per cent	Zn, per cent	Ag	Pb	Zn
Feed (cal.)	100·00	24·82	1·54	39·51	100·0	100·0	100·0
Lead concentrate	8·35	190·68	18·50	38·22	64·1	99·0	8·1
Zinc concentrate	61·11	13·83	Trace	58·34	34·0	....	90·2
Tailing	30·54	1·49	Trace	2·21	1·9	....	1·7

Test No. 6

This test is similar to Test No. 5 with the exception that the grind was somewhat finer, 94·8 per cent −200 mesh.

Results:

Product	Weight, per cent	Assay			Distribution, per cent		
		Ag, oz./ton	Pb, per cent	Zn, per cent	Ag	Pb	Zn
Feed (cal.)	100·00	25·32	1·63	39·62	100·0	100·0	100·0
Lead concentrate	7·85	201·36	20·80	36·12	62·4	99·0	7·2
Zinc concentrate	60·60	14·87	Trace	57·74	35·6	....	88·3
Tailing	31·55	1·60	Trace	5·68	2·0	....	4·5

Test No. 7

To note the result of strongly depressing the zinc minerals on the silver recovery, a sample was ground wet with 6·0 pounds of soda ash, 1·0 pound of cyanide and 1·0 pound of zinc sulphate per ton to pass 96 per cent through 200 mesh. Flotation was effected with 0·10 pound of butyl xanthate and 0·09 pound of pine oil per ton; 2·0 pounds of copper sulphate, 0·20 pound of sodium xanthate, and 0·12 pound of pine oil then were added and a zinc concentrate removed.

Results:

Product	Weight, per cent	Assay			Distribution, per cent		
		Ag, oz./ton	Pb, per cent	Zn, per cent	Ag	Pb	Zn
Feed (cal.)	100·00	24·58	1·71	37·19	100·0	100·0	100·0
Lead concentrate	5·33	283·17	30·20	28·50	61·4	94·0	4·1
Zinc concentrate	17·82	14·67	0·15	71·40	10·6	1·6	34·2
Tailing	76·85	8·94	0·10	29·86	28·0	4·4	61·7

Test No. 8

In this test, a lead concentrate and a zinc concentrate were made as in Test No. 1. The zinc concentrate was then reground with 2·0 pounds of soda ash, 0·20 pound of cyanide per ton, and refloated to make a further concentration of silver from the zinc concentrate.

Results:

Product	Weight, per cent	Assay			Distribution, per cent		
		Ag, oz./ton	Pb, per cent	Zn, per cent	Ag	Pb	Zn
Feed (cal.)	100·00	21·89	1·77	39·63	100·0	100·0	100·0
Lead concentrate	5·94	261·08	28·33	32·52	70·8	95·1	4·9
Zinc concentrate	9·19	18·50	0·19	61·04	7·8	1·0	14·2
Zinc middling	55·42	7·72	0·10	57·04	19·4	3·1	79·2
Tailing	29·45	1·47	0·05	2·36	2·0	0·8	1·7

Test No. 9

This test is much the same as Test No. 8. The cyanide and soda ash used in the re-treatment of the zinc concentrate were doubled and the grinding time prolonged until practically all passed 325 mesh.

Results:

Product	Weight, per cent	Assay			Distribution, per cent		
		Ag, oz./ton	Pb, per cent	Zn, per cent	Ag	Pb	Zn
Feed (cal.)	100·00	24·61	1·71	40·65	100·0	100·0	100·0
Lead concentrate	7·30	217·54	22·51	38·26	64·5	96·2	6·9
Zinc concentrate	6·21	22·34	0·26	61·56	5·6	0·9	9·4
Zinc middling	57·65	12·09	0·05	58·48	28·3	1·7	82·9
Tailing	28·84	1·30	0·07	1·13	1·6	1·2	0·8

Test No. 10

In this test, a bulk flotation concentrate was made. The concentrate was then conditioned and floated to effect a separation of the lead and the zinc.

A sample of the ore was ground 90 per cent −200 mesh in a jar mill together with 4·0 pounds of soda ash, 0·30 pound of sodium xanthate, and floated with 0·12 pound of pine oil per ton. The concentrate was then ground −325 mesh and conditioned with 0·50 pound of cyanide, 2·0 pounds of soda ash, and 1·0 pound of zinc sulphate per ton. A flotation concentrate was then removed, leaving a middling or zinc concentrate.

Results:

Product	Weight, per cent	Assay			Distribution, per cent		
		Ag, oz./ton	Pb, per cent	Zn, per cent	Ag	Pb	Zn
Feed (cal.)	100·00	25·26	1·76	40·8	100·0	100·0	100·0
Lead concentrate	5·90	263·61	26·71	36·63	61·6	89·4	5·3
Lead middling	53·69	15·45	0·33	57·15	32·8	10·1	75·2
Bulk tailing	40·41	3·49	0·02	19·75	5·6	0·5	19·5

Many other tests were made using various reagents such as sodium acid phosphate, sodium sulphide and sulphite. None of these gave results equal to those in the report.

SUMMARY AND CONCLUSIONS

It is apparent that approximately 65 per cent of the silver can be recovered in a flotation concentrate containing most of the lead and a considerable proportion of zinc. Choice of reagents does not seem to vary the proportion of silver recovered. The main loss of this metal is with the zinc concentrate. Fine grinding of the zinc concentrate and conditioning does not cause the silver to float freely. The extremely large quantity of zinc sulphides present is the main factor governing this condition.

Tests Nos. 8 and 9 show that re-treatment of the zinc concentrate produces a product lower in grade than the feed. This, if added to the lead concentrate, would dilute it.

The conclusion drawn from this investigation is that the ratio of zinc minerals to lead-silver minerals is too great to allow a high recovery of silver by selective flotation.

Ore Dressing and Metallurgical Investigation No. 613

GOLD ORE FROM THE CANADIAN RESERVE MINE, LARDER LAKE, ONTARIO

Shipment. Two shipments of ore were received, one on October 8, 1934, and one on November 23, 1934. The first shipment consisted of 8 bags of ore, net weight 400 pounds. The second shipment, of one carload, represented two types of ore, as follows:

Porphyry	45,700 pounds
Graphitic material	6,355 "

The samples were submitted by Harlan H. Bradt, 67 Wall Street, New York.

Characteristics of the Ore. The eight lots (bags) of gold ore in the first shipment, were, on arrival, numbered consecutively from 1 to 8, but were subsequently combined into three samples as follows:

Sample No. 1: "Porphyry" ore (Lots Nos. 1 to 5 inclusive).
" " 2: Graphitic ore (Lots Nos. 6 and 7).
" " 3: Graphitic ore—special sample (Lot No. 8).

Specimens were selected from each of the three samples and 18 polished sections were prepared and examined microscopically to determine the character of the ore.

In the hand specimen the *porphyry ore* is light pink in colour and appears to consist essentially of pink feldspar and quartz, giving a mottled appearance resembling a porphyry. It contains abundant, disseminated sulphide and is penetrated by veins of white quartz.

Polished sections show that the most abundant sulphide is pyrite and that arsenopyrite is present in considerable quantity; that there is a small amount of magnetite (?), probably mostly altered to leucoxene (?); and that there are traces of graphite, chalcopyrite, covellite, and native gold.

The pyrite occurs in poorly formed crystals and irregular grains, most of which are about 200 mesh in size. It is commonly quite dense and unfractured, and contains abundant small inclusions of gangue, a few small crystals of arsenopyrite, rare tiny grains of chalcopyrite, and extremely rare tiny grains of native gold.

Crystals of arsenopyrite are abundant in some sections, their grain size being slightly less than that of the pyrite.

Chalcopyrite is rare, and besides the small amount present within pyrite small grains occur within the gangue. In some sections, which represent ore that has obviously been exposed to weathering, the chalcopyrite has been altered to covellite.

Graphite is present along occasional sinuous, thread-like lines of shearing. It is quite brown, its somewhat abnormal colour probably being due to the presence of ferric oxide as an impurity.

Six grains of native gold were seen. One occurs in the gangue, the rest within pyrite. Rough calculations give the following:

Gold in gangue	52 per cent
Gold in pyrite	48 "

Mesh	Au, per cent
− 200 + 325	52
− 325 + 1600	35
−1600 + 2300	10
−2300	3
	100

Pyrite and arsenopyrite are the only abundant ore minerals, and it is probable that the trace of copper in the chalcopyrite and covellite is not sufficient to cause trouble in treatment. Only moderate grinding should be required to free the pyrite and arsenopyrite as their grain sizes are comparatively coarse.

The presence of native gold was detected by panning a fraction of the ground ore. The microscopic examination has shown that the gold does occur in a very finely divided state, both in pyrite and in gangue, and some of this will be very difficult to extract on account of its extremely finely divided state and its occurrence within dense pyrite.

The content of graphite in this sample is very low, and it is probable that this will not affect the treatment to any extent.

The *graphitic ore* is composed chiefly of grey to white quartz with narrow, slickensided zones of greyish black, finely banded schist, which presents shiny graphitic surfaces and which contains considerable carbonate. Sulphides are very sparingly present in the quartz, but are rather abundant along bands in the schist.

Under the microscope the only abundant sulphide observed is pyrite. This mineral tends to form occasional massive aggregates in the quartz and is very finely disseminated along bands in the schist. Chalcopyrite and covellite are very rare and occur as small grains in the quartz; chalcopyrite also is present as rare tiny grains in pyrite.

A considerable amount of graphite is present along narrow bands in the slickensided shear zones. It is brown in colour and occurs as tiny grains and flakes, oriented parallel to the shearing directions, or banding, and these are often much contorted. The brown colour of the graphite indicates that it probably contains considerable ferric oxide as an impurity.

Only one tiny grain of gold was seen in this sample, and this occurs within pyrite. Its size is approximately 800 mesh.

The pyrite is probably much more finely divided than that of the "porphyry" ore, and would thus require finer grinding for liberation.

Chalcopyrite and covellite are present in such small amounts that their presence is of no importance.

Although gold was seen only within pyrite, it is probable, from the favourable character of the quartz, that it occurs free within this gangue.

The amount of graphite, while small, may be sufficient to affect treatment of the ore.

Sample No. 3, which was a special sample of graphitic ore, is very similar to Sample No. 2. However, the following points of difference are to be noted: (a) there appears to be a somewhat higher content of graphite; (b) the amount of chalcopyrite is slightly higher; (c) there is somewhat more pyrite and it tends to occur in masses; (d) a few grains of sphalerite were seen associated with tiny grains of chalcopyrite and carbonate gangue; and (e) there appears to be a higher content of carbonate.

The higher graphite content of this sample may be expected to cause trouble. Although the chalcopyrite content is relatively high, its amount is probably too small to affect the treatment. The fact that pyrite tends to form masses indicates that rather coarse grinding should free this mineral. No free gold was seen, and hence no information was obtained concerning its mode of occurremce.

The characteristics of the ore, of which three samples were examined microscopically, may be summarized as follows:

The predominant types of gangue are the pink siliceous "porphyry" and white to grey vein quartz, through which a small amount of carbonate is distributed somewhat erratically. Pyrites and arsenopyrite are rather abundantly disseminated, and are not particularly finely divided, indicating that comparatively coarse grinding should free them. Traces of chalcopyrite and covellite (the latter only in oxidized portions) contribute a trace of copper, but this is probably not sufficient to affect treatment. A small amount of graphite, which is very finely divided, occurs along sheared zones, particularly associated with the quartz gangue, and may to some extent affect treatment.

A small amount of native gold was seen in both the pyrite and the gangue. This is extremely fine, a condition which in commercial practice may cause difficulty. As free gold was found by panning, it is probable that this fine gold forms only a small percentage of the metal in the ore.

The ore of Shipment No. 2 (one carload), received on November 23, 1934, was similar in character to that of Shipment No. 1 but assayed lower in gold. No microscopic examination of the ore of the second shipment was made.

Sampling and Assaying. The samples assayed as follows:

—	Au, oz./ton	Ag, oz./ton	Graphite, per cent
Porphyry (Lots Nos. 1 to 5)	0·36	0·06	....
Graphitic (Lots Nos. 6 and 7)	1·12	0·09	0·48
Graphitic (Lot No. 8)	0·44	0·08	0·20
Porphyry (carload lot)	0·24	....	0·21
Graphitic (3-ton lot)	0·76	....	0·33
Graphite fault material	Trace	....	1·57

Experimental Tests

A series of small-scale tests was carried out on the ore to find out how it could be treated to recover the gold. The work consisted of flotation and cyanidation tests, both alone and in combination. No test work was done on Lot No. 8.

Approximately 85 per cent of the gold was extracted by straight cyanidation from the porphyry ore represented by Lots Nos. 1 to 5 and also from the graphitic ore represented by Lots Nos. 6 and 7. By flotation, 96·9 per cent of the gold was recovered from the porphyry ore in a sulphide concentrate assaying 1·91 ounces per ton in gold and amounting to 19·6 per cent of the weight of feed used. By flotation of the graphitic sample, 85·6 to 87·6 per cent of the gold was recovered in two concentrates amounting to about 10 per cent of the weight of feed used. In this case a graphite concentrate was taken off first and then a sulphide concentrate.

Further work was done on a mixture of porphyry and graphitic ores consisting of 100 pounds of porphyry and 25 pounds of Lots Nos. 6 and 7. A graphite and a sulphide concentrate was taken off and as much as 96·4 per cent of the gold was so recovered. The pyrite concentrate was reground 95 per cent through 200 mesh and agitated in cyanide solution. An extraction of 88·8 per cent of the gold was obtained in 48 hours.

From a composite sample of graphite concentrates produced in Tests Nos. 2, 3, and 7, 96·1 per cent of the gold was extracted by cyanidation in 24 hours.

Some cyanidation tests were made on the ore, using kerosene oil to render the graphite inactive as a precipitant, but this did not bring about any appreciable increase in extraction.

A composite sample of bulk flotation concentrate and blanket concentrate, assaying 2·47 ounces per ton in gold and containing 96·4 per cent of the gold in the ore, was reground 99 per cent through 325 mesh and cyanided for 24 hours. An extraction of 93·5 per cent of the gold in the sample, or 90·1 per cent of the gold in the ore, was made. No further extraction occurred when agitation was continued for an additional 24 hours.

By cyaniding the ore and floating the cyanide tailing, about 98 per cent of the gold can be recovered, about 10 per cent of which will be in the form of a low-grade bulk concentrate. In order to effect any worthwhile recovery by floating the cyanide tailing it is necessary to float all the sulphides, with the result that the concentrate is rather too voluminous and low grade.

The remainder of the work was done on the carload shipment and consisted of large-scale flotation tests with large- and small-scale cyanidation tests on the concentrates. About 98 per cent of the gold was recovered in the concentrates, leaving flotation tailings assaying 0·005 ounce per ton in gold. Net recoveries by cyanidation of concentrates are estimated to be in the neighbourhood of 90 per cent of the total gold.

Details of the tests follow:

Porphyry Ore

Test No. 1

A sample of the ore was ground approximately 75 per cent through 200 mesh and then floated. The products were assayed for gold, copper, and graphite.

Charge to Ball Mill:

Ore	1,000 grms. −14 mesh
Water	750 c.c.
Soda ash	2·0 lb./ton
Barrett No. 4	0·26 "

Reagents to Cell:

Potassium amyl xanthate	0·20 lb./ton
Pine oil	0·15 "

Results:

Product	Weight, per cent	Assay			Distribution of gold, per cent
		Au, oz./ton	Graphitic carbon, per cent	Copper, per cent	
Flotation concentrate	19·6	1·91	0·48	0·03	96·9
Flotation tailing	80·4	0·015	0·20	0·05	3·1
Feed (cal.)	100·0	0·39	....	0·03	100·0

Graphitic Ore

Test No. 2—(Lots Nos. 6 and 7)

A sample of the ore was ground 64 per cent through 200 mesh and then floated. The products were assayed for gold, graphitic carbon, and copper.

Charge to Ball Mill:

Ore	1,000 grms.−14 mesh
Kerosene oil	0·20 lb./ton

Reagents to Cell:

Graphite Float—

Pine oil	0·30 lb./ton
Cresylic acid	0·07 "

Sulphide Float—

Potassium amyl xanthate	0·20 lb./ton
Soda ash	2·0 "
Cresylic acid	0·07 "
Pine oil	0·15 "

Results:

Product	Weight, per cent	Assay			Distribution of gold, per cent
		Au, oz./ton	Graphitic carbon, per cent	Copper, per cent	
Graphite concentrate	3.8	13·34	9·00	0·42	42·2
Pyrite concentrate	5·9	9·40	1·85	0·90	45·4
Tailing	90·3	0·165	0·10	Trace	12·4
Feed (cal.)	100·0	1·21	....	....	....

Test No. 3—(Lots Nos. 6 and 7)

A sample of the ore was ground 64 per cent through 200 mesh and then floated. The products were assayed for gold, copper, and graphitic carbon.

Charge to Ball Mill:

Ore	1,000 grms. −14 mesh
Water	750 c.c.
Soda ash	2·0 lb./ton

Reagents to Cell:

Graphite Float—

Cresylic acid	0·70 lb./ton

Pyrite Float—

Potassium amyl xanthate	0·20 lb./ton
Pine oil	0·20 "

When the pyrite float appeared to be finished with the above reagents, copper sulphate was added at the rate of 0·5 pound per ton of ore. No further flotation occurred as a result of this addition.

Results:

Product	Weight, per cent	Assay			Distribution of gold, per cent
		Au, oz./ton	Graphitic carbon, per cent	Copper, per cent	
Graphite concentrate	6·2	5·90	8·00	0·39	36·7
Pyrite concentrate	3·9	12·66	1·21	0·90	48·9
Tailing	89·9	0·16	0·15	0·02	14·4
Feed (cal.)	100·0	1·00			

CYANIDATION

Tests Nos. 4 and 5

Samples of porphyry and graphitic ore were ground in ball mills approximately 80 per cent through 200 mesh and then agitated in cyanide solution, 1·0 pound of potassium cyanide per ton for 24 hours. The cyanide tailings were assayed for gold. Test No. 4 was made on porphyry ore and Test No. 5 on graphitic ore.

Results:

Test No.	Feed sample assay, Au, oz./ton	Tailing assay, Au, oz./ton	Extraction, per cent	Reagents consumed, lb./ton	
				KCN	CaO
4	0·36	0·055	84·7	1·0	5·1
5	1·12	0·16	85·7	3·1	4·8

FLOTATION

Further test work was done on a mixture of porphyry and graphitic ores, 100 pounds of the porphyry ore being mixed with 25 pounds of the graphitic ore known as Lots Nos. 6 and 7.

Test No. 6

A sample of the above mixture was ground in a ball mill about 75 per cent through 200 mesh and then floated. The products were assayed for gold, copper, and graphite.

Charge to Ball Mill:

Ore	1,000 grms. −14-mesh
Water	750 c.c.
Soda ash	2·0 lb./ton

Reagents to Cell:

Graphite Float—

Cresylic acid	0·50 lb./ton

Pyrite Float—

Potassium amyl xanthate	0·20 lb./ton
Copper sulphate	0·50 "
Cresylic acid	0·07 "

Results:

Product	Weight, per cent	Assay			Distribution of gold, per cent
		Au, oz./ton	Graphitic carbon, per cent	Copper, per cent	
Graphite concentrate	0·8	15·37	4·0	1·43	23·5
Graphite middling	3·1	2·0	0·81	....	12·5
Pyrite concentrate	15·0	1·9	0·14	....	58·2
Tailing	81·1	0·035	0·07	....	5·8
Feed (cal.)	100·0	0·49	....	....	100·0

Test No. 7

A sample of the mixed ore was ground 75 per cent through 200 mesh in a ball mill and then floated. The flotation tailing was passed over a corduroy blanket set at a slope of 2·5 inches per foot. A portion of the pyrite concentrate was reground 95 per cent through 200 mesh and cyanided for periods of 24 and 48 hours.

Charge to Ball Mill:

Ore	6,000 grms. −14 mesh
Water	4,500 c.c.
Soda ash	2·0 lb./ton

Reagents to Cell:

Graphite Float—

Cresylic acid	0·50 lb./ton

Pyrite Float—

Potassium amyl xanthate	0·20 lb./ton
Copper sulphate	0·50 "
Cresylic acid	0·07 "

Results:

Product	Weight, per cent	Assay		Distribution of gold, per cent
		Au, oz./ton	Graphitic carbon, per cent	
Graphite concentrate	2·9	7·84	2·02	40·1
Pyrite concentrate	13·9	2·14	0·20	52·5
Blanket concentrate	0·4	3·25	....	3·7
Tailing	82·8	0·025	0·08	3·7
Feed (cal.)	100·0	0·67	....	100·0

NOTE.—Coarse gold was seen in the blanket concentrate.

Cyanidation of Pyrite Concentrates:

Feed sample.. 2·14 Au, oz./ton
24-hour cyanide tailing.. 0·26 "
Extraction..87·9 per cent
48-hour cyanide tailing.. 0·24 Au oz./ton
Extraction..88·8 per cent
Extraction per cent total gold in 48 hours=46·6 per cent.

Test No. 8

A sample of the mixed ore was ground 75 per cent through 200 mesh and then floated. The products were assayed for gold, graphitic carbon, and copper.

Charge to Ball Mill:

Ore..1,000 grms.—14 mesh.
Water.. 750 c.c.
Soda ash.. 2·0 lb./ton
Kerosene oil.. 0·16 "

Reagents to Cell:

Graphite Float—
Pine oil.. 0·20 lb./ton

Pyrite Float—
Potassium amyl xanthate.. 0·20 lb./ton
Cresylic acid.. 0·07 "

Results:

Product	Weight, per cent	Assay			Distribution of gold, per cent
		Au, oz./ton	Graphitic carbon, per cent	Copper, per cent	
Graphite concentrate	3·5	9·6	1·84	0·38	58·6
Pyrite concentrate	12·9	1·68	0·14	....	37·8
Tailing	83·6	0·025	0·05	....	3·6
Feed (cal.)	100·0	0·57	....	....	100·0

Test No. 10

A sample of the mixed ore was ground 75 per cent through 200 mesh and then floated. The flotation tailing was passed over a corduroy blanket set at a slope of 2·5 inches per foot. Free gold was found in the blanket concentrate.

Charge to Ball Mill:

Ore	1,000 grms.—14 mesh
Water	750 c.c.
Lime	1·0 lb./ton
Kerosene oil	0·10 "

Reagents to Cell:

Graphite Float—

Pine oil	0·15 lb./ton

Pyrite Float—

Barrett No. 4	0·36 lb./ton
Potassium amyl xanthate	0·20 "
Pine oil	0·20 "

Results:

Product	Weight, per cent	Assay		Distribution of gold, per cent
		Au, oz./ton	Graphitic carbon, per cent	
Pyrite concentrate	15·5	2·20	0·17	64·8
Graphite concentrate	2·3	6·97	2·84	30·5
Blanket concentrate	0·1	8·415	....	1·6
Blanket tailing	82·1	0·02	0·07	3·1
Feed (cal.)	100·0	0·53	....	100·0

Test No. 11

A composite sample of graphite concentrate was prepared by mixing together portions of the graphite concentrates produced in Tests Nos. 2, 3, and 7. The calculated assay of this composite sample was 7·70 ounces per ton in gold. This sample was agitated in cyanide solution, 5·0 pounds of potassium cyanide per ton, for 24 hours, and the cyanide tailing was assayed for gold.

Results:

Feed sample	7·70 Au, oz./ton
Cyanide tailing	0·30 "
Extraction	96·1 per cent of total gold.

Reagents Consumed:

KCN = 20·2 lb/ton of concentrate
CaO = 7·75 " "

CYANIDATION

Test No. 12

A sample of the mixed ore was ground approximately 85 per cent through 200 mesh and agitated in cyanide solution for periods of 24 and 48 hours. Kerosene oil was added at the rate of 0·4 pound per ton of ore. The tailings were filtered, washed, and assayed for gold.

Results:

Feed sample: gold, 0·495 oz./ton.

Product	Assay, Au, oz./ton	Extraction, per cent	Reagents consumed, lb./ton ore	
			KCN	CaO
24-hour cyanide tailing	0·06	87·9	1·6	5·10
48-hour "	0·055	88·9	1·9	5·50

FLOTATION AND CYANIDATION

Test No. 13

A sample of the mixed ore was ground 75 per cent through 200 mesh and then floated. The flotation tailing was passed over a corduroy blanket the tailing from which went to waste. The flotation concentrate and the blanket concentrate were united, reground all through 325 mesh, and cyanided for 24 hours. Longer agitation than this did not result in higher extraction.

Charge to Ball Mill:

Ore..2,000 grms. −14 mesh
Soda ash..2·0 lb./ton

Reagents to Cell:

Potassium amyl xanthate..0·20 lb./ton
Copper sulphate..0·50 "
Cresylic acid..0·70 "

Results:

Product	Weight, per cent	Assay, Au, oz./ton	Distribution of gold, per cent
Flotation and blanket concentrates	21·1	2·47	96·4
Blanket tailing	78·9	0·025	3·6
Feed (cal.)	100·0	0·34	100·0

The mixed concentrate was cyanided down to 0·16 ounce gold per ton in 24 hours, representing an extraction of 93·5 per cent of the gold in the concentrate, or 90·1 per cent of the total gold in the ore.

CYANIDATION FOLLOWED BY BULK FLOTATION

Test No. 14

A sample of the mixed ore was ground 75 per cent through 200 mesh and then agitated in cyanide solution, 1·0 pound of potassium cyanide per ton, for 24 hours. The cyanide tailing was then floated with the following reagents:

Soda ash..3·0 lb./ton
Potassium amyl xanthate..0·20 "
Copper sulphate..1·0 "
Cresylic acid..0·70 "

The flotation concentrate and tailing were assayed for gold.

Results:

Product	Weight, per cent	Assay, Au, oz./ton	Distribution of gold, per cent
Flotation concentrate	16·2	0·31	85·7
Flotation tailing	83·8	0·01	14·3
Cyanide tailing (cal.)	100·0	0·059	100·0

Extraction by cyanidation........ 88·1 per cent
Recovered in flotation concentrate........ 10·2 "
Total recovery........ 98·3 "

Reagents Consumed:

KCN = 1·3 lb./ton
CaO = 5·0 "

STRAIGHT CYANIDATION

Tests Nos. 15 and 16

A sample of the mixed ore was ground approximately 80 per cent through 200 mesh and then agitated in cyanide solution, 1·0 pound of potassium cyanide per ton, for 24 hours. The cyanide tailings were filtered, washed, and assayed for gold.

Results:

Cyanide tailings........ 0·07 Au oz./ton
Extraction........ 85·9 per cent

Reagents Consumed:

KCN = 1·6 lb./ton
CaO = 5·1 "

Test No. 17

A sample of the mixed ore was ground approximately 80 per cent through 200 mesh and then agitated in cyanide solution, 1·0 pound of potassium cyanide per ton, for 24 hours. A graphite concentrate was then floated from the cyanide tailing. The flotation concentrate and tailing were assayed for gold. The following flotation reagents were used:

Soda ash........ 3·0 lb./ton
Potassium amyl xanthate........ 0·10 "
Cresylic acid........ 0·53 "

Results:

Product	Weight, per cent	Assay, Au, oz./ton	Distribution of gold, per cent
Flotation concentrate	1·4	0·27	6·0
Flotation tailing	98·6	0·06	94·0
Cyanide tailing (cal.)	100·0	0·063	100·0

Extraction by cyanidation........ 87·3 per cent
Recovered in concentrate........ 0·8 "
Total recovery........ 88·1 "

Reagents Consumed:

KCN = 1·5 lb./ton
CaO = 5·25 "

Mill Runs

All further work done was on the carload shipment of ore (Shipment No. 2) and consisted of large-scale flotation tests, with a few large- and small-scale cyanidation tests on some of the products. The flotation unit used consisted of a ball mill in closed circuit with a classifier, the overflow from which went to the flotation cells where a graphite and a pyrite concentrate were taken off in two stages or a bulk concentrate was taken off in one stage.

The ore was fed to the ball mill at the rate of 500 pounds per hour and suitable reagents were added to bring about flotation. Some changes were made in the reagent combination from test to test to see what difference, if any, were made in the ratio of concentration and recovery. The flotation tailings remained fairly constant at or near 0·005 ounce gold per ton for all tests, representing a recovery in the concentrates of approximately 98 per cent of the gold. Net recoveries as bullion were arrived at by calculating an average tailing from the flotation tailings and the cyanide tailings from the concentrates and deducting this from the feed sample assay. Recoveries so calculated were fairly constantly in the neighbourhood of 89 and 90 per cent of the total gold in the ore. The classifier overflow, as a rule, varied from 64 to 70 per cent through 200 mesh. Details of the tests will be given in the following pages.

Mill Run No. 1

In this run, the porphyry ore was fed to the ball mill at an initial feed rate of 500 pounds per hour. After three hours of running the feed rate was raised to 600 pounds per hour and left there until the end of the run. The classifier overflow, at 30 per cent solids, was fed into a conditioning tank with cresylic acid added at the rate of 0·17 pound per ton of ore to float off the graphite. The overflow from the conditioning tank went to the No. 2 cell in a battery of ten cells. From Cells Nos. 2 and 3, rougher concentrate was taken off and returned to Cell No. 1 in which it was cleaned and discharged as final graphite concentrate. From Cells Nos. 4 to 10, to which cresylic acid was added at the rate of 0·08 pound per ton of ore, a low-grade graphite concentrate was taken off and returned as feed to Cell No. 2. The graphite tailing from Cell No. 10 was pumped to a second conditioning tank, where it was prepared for pyrite flotation. Reagents used for this purpose were as follows:

To Tailing Pump:

Soda ash	0·80 lb./ton
Barrett No. 4	0·40 "

To Conditioning Tank:

Potassium amyl xanthate	0·17 lb./ton
Pine oil	0·022 "

To Cell No. 6:

Potassium amyl xanthate	0·044 lb./ton

The overflow from the conditioning tank went as feed to the first cell in a series of ten cells. From the first three cells in the series, final concentrate was taken off, and from the last seven cells a rougher concentrate was taken off and returned to the No. 1 cell to be cleaned.

Results:

—	Assay	
	Gold	Graphitic carbon
	oz./ton	per cent
Feed	0·24	0·21
Classifier overflow	0·16	0·19
Graphite concentrate	3·37	12·36
Graphite tailing	0·085	0·09
Pyrite concentrate	0·84	0·27
Flotation tailing	0·005	....

Summary:

Product	Weight, per cent	Assay, Au, oz./ton	Distribution of gold, per cent
Graphite concentrate	2·28	3·37	47·5
Pyrite concentrate	9·58	0·84	49·8
Flotation tailing	88·14	0·005	2·7
Classifier overflow (cal.)	100·00	0·16	100·0

If the graphite concentrate be roasted and cyanided, 93·85 per cent of its gold can be recovered, according to the results of such a test carried out. On this basis, the assay of the graphite concentrate would be reduced to 0·207 ounce of gold per ton. The pyrite concentrate can be expected to produce a cyanide tailing assaying 0·175 ounce of gold per ton. This figure is the average of the assays of the final samples from large-scale cyanidation tests, Nos. 1, 2, and 3, made on pyrite concentrate. These two end-products and the flotation tailing will give an average tailing loss of 0·026 ounce per ton in gold which, deducted from the feed sample assay, shows an overall recovery of 89·2 per cent of the gold for this test. These calculations are based on the assumption that the gold that has accumulated in the grinding circuit is free and readily recoverable as soon as it gets out of the grinding circuit.

Mill Run No. 2

In this run the feed rate was 500 pounds per hour throughout, and the ball mill discharge passed over corduroy blankets on the way to the classifier. The classifier overflow, at 30 per cent solids, went to the graphite cells through a conditioning tank where cresylic acid was added at the rate of 0·30 pound per ton of ore. To Cell No. 4, an additional 0·09 pound of cresylic acid per ton was added. The cells were operated in this run in the same way as they were in Mill Run No. 1.

The graphite tailing was then pumped to a second conditioning tank and went from there to a second battery of ten cells, where the pyrite was floated. This battery of cells was also operated in the same way as in Mill Run No. 1.

Reagents to Tailing Pump:

Soda ash	0·94 lb./ton
Barrett No. 4	0·21 "

To Conditioning Tank:

Potassium amyl xanthate	0·20 lb./ton
Pine oil	0·026 "

Reagents to Cell No. 4:

Potassium amyl xanthate	0·058 lb./ton
Pine oil	0·026 "

Results of Run No. 2:

—	Assay	
	Gold, oz./ton	Graphitic carbon, per cent
Feed	0·24	0·21
Classifier overflow	0·155	0·24
Blanket concentrate	7·64	....
Graphite concentrate	5·68	12·60
Pyrite concentrate	0·53	0·39
Flotation tailing	0·01	....
Graphite tailing	0·08	....

Summary:

Product	Weight, per cent	Assay, Au, oz./ton	Distribution of gold, per cent
Blanket concentrate	1·14	7·64	36·3
Graphite concentrate	1·32	5·68	31·2
Pyrite concentrate	13·13	0·53	29·0
Flotation tailing	84·41	0·01	3·5
Feed (cal.)	100·00	0·24	100·0

From the results of small-scale tests made on a mixture of blanket, graphite, and pyrite concentrates, it can be reasonably expected that 87·2 per cent of the gold in the concentrates can be extracted by cyanidation without roasting. Therefore, with 96·5 per cent of the gold in the concentrates the extraction by cyanidation of the concentrates would be 96·5 × 87·2=84·1 per cent.

Mill Run No. 3

Run No. 3 was the same as Run No. 2 in all respects except that copper sulphate, 0·53 pound per ton of ore, was added to the graphite tailing pump to promote flotation of the pyrite, and the pine oil to the conditioning tank was reduced to 0·013 pound per ton.

Results:

—	Assay	
	Gold, oz./ton	Graphitic carbon, per cent
Feed	0·24	0·21
Classifier overflow	0·175	0·22
Blanket concentrate	5·88	....
Graphite concentrate	4·40	11·72
Pyrite concentrate	0·94	0·33
Flotation tailing	0·005	....
Graphite tailing	0·13	....

Summary:

Product	Weight, per cent	Assay, Au, oz./ton	Distribution of gold, per cent
Blanket concentrate	1·14	5·88	27·9
Graphite concentrate	1·03	4·40	19·1
Pyrite concentrate	13·08	0·94	51·2
Flotation tailing	84·75	0·005	1·8
Feed (cal.)	100·00	0·24	100·0

Extraction by cyanidation of concentrates, calculated as in Mill Run No. 2, would be 85·6 per cent of the total gold.

Mill Run No. 4

Run No. 4 was the same as Run No. 3 except that no copper sulphate or Barrett No. 4 was added.

Results:

—	Assay	
	Gold, oz./ton	Graphitic carbon, per cent
Feed	0·24	0·21
Classifier overflow	0·19	....
Blanket concentrate	5·95	....
Graphite concentrate	4·06	12·32
Pyrite concentrate	1·08	0·38
Flotation tailing	0·005	....
Graphite tailing	0·15	....

Summary:

Product	Weight, per cent	Assay, Au, oz./ton	Distribution of gold, per cent
Blanket concentrate	0·87	5·95	21·5
Graphite concentrate	1·01	4·06	17·1
Pyrite concentrate	13·23	1·08	59·6
Flotation tailing	84·89	0·005	1·8
Feed (cal.)	100·00	0·24	100·0

Extraction by cyanidation of the concentrates, calculated as in Run Nos. 2 and 3, would be 85·6 per cent of total gold.

Mill Run No. 5

The feed was made up of a mixture of the two types of ore in the carload shipment. One bag of the graphitic ore was mixed with eight bags of the porphyry ore and fed to the ball mill at the rate of 500 pounds per hour. This and the re-introduction of copper sulphate into the reagent combination, are the only differences between this run and Run No. 4.

Results:

—	Assay	
	Gold, oz./ton	Graphitic carbon, per cent
Feed	0·30	0·22
Classifier overflow	0·205	....
Blanket concentrate	8·51	....
Graphite concentrate	3·18	13·24
Pyrite concentrate	1·27	0·35
Flotation tailing	0·01	....
Graphite tailing	0·155	....

Summary:

Product	Weight, per cent	Assay, Au, oz./ton	Distribution of gold, per cent
Blanket concentrate	1·14	8·51	32·3
Graphite concentrate	1·63	3·18	17·3
Pyrite concentrate	11·19	1·27	47·5
Flotation tailing	86·04	0·01	2·9
Feed (cal.)	100·00	0·30	100·0

Extraction by cyanidation of concentrates, calculated as in Runs Nos. 2, 3, and 4, would be 84·7 per cent of the total gold.

Mill Run No. 6

The feed was the same as was used in Run No. 5 but the blankets were taken out of the circuit, allowing the ball mill discharge to go direct to the classifier. The pine oil to Cell No. 4 in the pyrite circuit was raised from 0·026 pound per ton to 0·04 pound per ton. In all other respects the run was the same as Run No. 5.

Results:

—	Assay	
	Gold, oz./ton	Graphitic carbon, per cent
Feed	0·30	0·22
Classifier overflow	0·23	....
Graphite concentrate	2·80	11·36
Graphite tailing	0·195	....
Pyrite concentrate	1·46	0·33
Flotation tailing	0·008	....

Summary:

Product	Weight, per cent	Assay, Au, oz./ton	Distribution of gold, per cent
Graphite concentrate	1·34	2·80	16·3
Pyrite concentrate	12·71	1·46	80·7
Flotation tailing	85·95	0·008	3·0
Classifier overflow (cal.)	100·00	0·23	100·0

Extraction by cyanidation of the concentrates, calculated as in Run No. 1, would be 89·7 per cent of total gold.

Mill Run No. 7

This was the same as Run No. 6 except that the pine oil to the No. 2 conditioning tank was increased from 0·013 pound per ton to 0·026 pound per ton.

Results:

—	Assay	
	Gold, oz./ton	Graphitic carbon, per cent
Feed	0·30	0·22
Classifier overflow	0·215	....
Graphite concentrate	2·28	9·76
Pyrite concentrate	1·52	0·36
Graphite tailing	0·19	....
Flotation tailing	0·008	....

Summary:

Product	Weight, per cent	Assay, Au, oz./ton	Distribution of gold, per cent
Graphite concentrate	1·20	2·28	12·7
Pyrite concentrate	11·90	1·52	84·1
Flotation tailing	86·90	0·008	3·2
Classifier overflow (cal.)	100·00	0·215	100·0

Extraction by cyanidation of concentrates, calculated as in Runs Nos. 1 and 6, would be 90·3 per cent of the total gold.

Mill Run No. 8

Lime was fed to the ball mill with ore to prevent, as far as possible, flotation of the pyrite with the graphite. Pine oil to the conditioning tank in the pyrite flotation circuit was raised from 0·026 pound per ton to 0·04 pound per ton; and Barrett No. 4, 0·09 pound per ton, was added to the same conditioning tank. The operation of the cells was the same as in all previous runs.

Results:

—	Assay	
	Gold, oz./ton	Graphitic carbon, per cent
Feed	0·30	0·22
Classifier overflow	0·231	....
Graphite concentrate	5·41	13·10
Pyrite concentrate	1·28	0·27
Graphite tailing	0·19	....
Flotation tailing	0·005	....

Summary:

Product	Weight, per cent	Assay, Au, oz./ton	Distribution of gold, per cent
Graphite concentrate	0·79	5·41	18·5
Pyrite concentrate	14·40	1·28	79·7
Flotation tailing	84·81	0·005	1·8
Classifier overflow (cal.)	100·00	0·231	100·0

Extraction by cyanidation of the concentrates, calculated as in Runs Nos. 1, 6, and 7, would be 89·3 per cent of the total gold.

Other mill runs were devoted to the production of a bulk concentrate from a feed sample composed of one bag of the graphitic ore mixed with 12 bags of the porphyry ore. The ball mill discharge went direct to a classifier, the overflow from which went through a conditioning tank to a battery of ten flotation cells.

The feed entered Cell No. 1 and moved along progressively to Cell No. 10. Final concentrate was taken from the first three cells and from Cells Nos. 4 to 10 a rougher concentrate was taken off which was returned to the feed of No. 1 cell for cleaning. The feed rate was maintained at 500 pounds per hour and the following reagents were added:

To Ball Mill:

Soda ash.. 1·20 lb./ton
Potassium amyl xanthate.. 0·10 "

To Conditioning Tank:

Pine oil.. 0·04 lb./ton
Potassium amyl xanthate.. 0·10 "

To Cell No. 6:

Pine oil.. 0·04 lb./ton
Potassium amyl xanthate.. 0·03 "

To Classifier Overflow:

Copper sulphate.. 0·34 lb./ton

Mill Run No. 9

Run No. 9 was made for the purpose of building up and adjusting the circuit to the new operating conditions and will, therefore, not be reported as a test.

Mill Run No. 10

Run No. 10 was made under the above conditions, and the results are as follows:

—	Assay	
	Gold oz./ton	Graphitic carbon, per cent
Feed	0·29	0·22
Classifier overflow	0·16	0·26
Bulk concentrate	1·37	1·36
Flotation tailing	0·005	0·007

Summary:

Product	Weight, per cent	Assay, Au, oz./ton	Distribution of gold, per cent
Bulk concentrate	11·35	1·37	97·2
Flotation tailing	88·65	0·005	2·8
Classifier overflow (cal.)	100·00	0·16	100·0

Assuming a cyanide tailing from the bulk concentrate of 0·19 ounce of gold per ton, and averaging that with the flotation tailing, the net recovery as bullion is calculated to be 90·7 per cent of the total gold. The assay, 0·19 ounce of gold per ton, used here as the value of the cyanide tailing from a bulk flotation concentrate, was taken from the final samples of Large-Scale Cyanidation Tests Nos. 4 and 5, pages 48 and 49.

A complete analysis of the bulk concentrate produced in this run was as follows:

Gold	1·37	oz./ton
Graphite	1·36	per cent
Iron	33·20	"
Alumina	8·38	"
Sulphur	33·24	"
Silica	15·36	"
Lime	0·44	"
Magnesia	0·66	"

Mill Run No. 11

This was the same as Run No. 10 except that Barrett No. 4 oil, 0·23 pound per ton, was added to the ball mill with the other reagents. The results of Run No. 11 are as follows:

—	Assays	
	Gold, oz./ton	Graphitic carbon, per cent
Feed	0·28	0·22
Classifier overflow	0·210	....
Bulk concentrate	1·45	....
Flotation tailing	0·005	....

Summary:

Product	Weight, per cent	Assay, Au, oz./ton	Distribution of gold, per cent
Bulk concentrate	14·18	1·45	98·1
Flotation tailing	85·82	0·006	1·9
Classifier overflow (cal.)	100·00	0·21	100·0

Assuming a cyanide tailing from the bulk concentrate assaying 0·19 ounce per ton in gold, and averaging this with the flotation tailing, the net recovery as bullion is calculated to be 89 per cent of the total gold.

A complete analysis of the bulk concentrate produced in this run was as follows:

Gold	1·45	oz./ton
Graphitic carbon	1·20	per cent
Iron	34·70	"
Alumina	11·55	"
Sulphur	37·57	"
Silica	10·17	"
Lime	4·60	"
Magnesia	0·30	"

Cyanidation of Mill Run Products

Some cyanidation tests were made on concentrates produced in the mill runs to find out how long the period of agitation should be in order to get maximum extraction, having in mind the possibility of reprecipitation of the gold by graphite.

CYANIDATION OF GRAPHITE CONCENTRATE

Test No. 18

Samples of the graphite concentrate produced in Mill Run No. 1 were agitated in cyanide solution, 5·0 pounds of potassium cyanide per ton for periods of 24 hours and 6½ hours in bottles, and another sample was agitated for 24 hours in a Denver super-agitator in solution of the same strength. The tailings were filtered, washed, and assayed for gold.

Summary:

Feed sample: gold, 3·37 oz./ton

Agitation	Tailing assay, Au, oz./ton	Extraction, per cent	Reagents consumed, lb./ton concentrate	
			KCN	CaO
24 hours in bottle	1·62	51·9	....	....
24 " "	1·72	49·0	24·7	6·8
6½ " "	0·825	75·6	....	....
6½ " "	0·91	73·0	11·9	5·4
24 hours in Denver super-agitator	1·53	54·6	24·25	10·25

Barrel amalgamation was attempted on another sample of this concentrate but no extraction at all was obtained.

ROASTING AND CYANIDING GRAPHITE CONCENTRATE

Test No. 19

A sample of graphite concentrate produced in Mill Run No. 2 was roasted at low temperature for about two hours, after which the temperature was raised to red heat for another hour. The calcine was washed and agitated for 24 hours in cyanide solution, 5·0 pounds of potassium cyanide per ton. Batch feed sample and cyanide tailing were assayed for gold.

Summary:

Feed sample of calcine	9·27 Au oz./ton
Cyanide tailing	0·57 "
Extraction	93·85 per cent

Reagents Consumed:

KCN = 0·50 lb./ton of calcine
CaO = 7·20 " "

CYANIDATION OF PYRITE CONCENTRATE

Test No. 20

A sample of pyrite concentrate produced in Mill Run No. 5 was taken for cyanidation tests. The sample was assayed and a screen test was made to determine the grinding. Four portions were agitated in cyanide solution, 5·0 pounds of potassium cyanide per ton, for periods of 24 hours. One sample was agitated without regrinding, and the others after 20, 30, and 60 minutes of regrinding in a Denver ball mill. The products were 95·7, 99·5, 99·9, and all through 200 mesh, respectively. The cyanide tailings were assayed for gold.

Summary:

Feed sample: gold, 1·03 oz./ton

Grinding, per cent through 200 mesh	Tailing assay, Au, oz./ton	Extraction, per cent	Reagents consumed, lb./ton concentrate	
			KCN	CaO
95·7	0·205	80·1	5·2	6·1
99·5	0·18	82·5	17·3	6·2
99·9	0·165	84·0	18·3	6·2
100·0	0·16	84·5	22·6	6·2

In the last three tests of Test No. 20 the increase in cyanide consumption is perhaps due to the grinding with steel balls in the Denver ball mill.

Tests Nos. 21 and 22

Two samples of pyrite concentrate produced in Mill Run No. 7 were agitated in cyanide solution, 5·0 pounds of potassium cyanide per ton, for 24 hours after they had been ground practically all through 200 mesh. The tailings were assayed for gold.

Results:

Feed sample	1·385 Au, oz./ton
Cyanide tailing (Test No. 21)	0·16 "
(Test No. 22)	0·20 "
Average tailing	0·18 "
Extraction	87·0 per cent

Reagents Consumed:

KCN = 19·0 lb./ton of concentrate.
CaO = 6·3 " "

CYANIDATION OF A MIXTURE OF PYRITE, GRAPHITE, AND BLANKET CONCENTRATES

Test No. 23

From the above-mentioned three products of Mill Run No. 5, a composite sample, supposed to approach the composition of a bulk concentrate, was prepared. The three products were mixed together in the proportion in which they were produced, as nearly as that could be estimated. The mixture was ground in a Denver ball mill for one hour and three lots of it were agitated in cyanide solution, 5·0 pounds of potassium cyanide per ton, for 24 hours. The remainder of the mixture was used as a feed sample. It assayed 1·89 ounces per ton in gold and was 99 per cent through 325 mesh.

Summary:

Feed sample	1·89 Au, oz./ton
Cyanide tailing (1)	0·23 "
(2)	0·235 "
(3)	0·27 "
Average tailing	0·243 "
Average extraction	87·2 per cent

Reagents Consumed (average):

KCN = 12·9 lb./ton of bulk concentrate.
CaO = 10·1 " "

CYANIDATION OF CLASSIFIER OVERFLOW

Test No. 24

A sample of the classifier overflow from Mill Run No. 7 was agitated in cyanide solution, 1·0 pound of potassium cyanide per ton, for 24 hours without regrinding. The sample was 70·1 per cent through 200 mesh.

Summary:

Feed sample	0·215 Au, oz./ton
Cyanide tailing	0·06 "
Extraction	72·1 per cent

Reagents Consumed:

KCN = 0·85 lb./ton
CaO = 9·10 "

CYANIDATION OF GRAPHITE TAILING

Test No. 25

A sample of the graphite tailing from Mill Run No. 7 was agitated in cyanide solution, 1·0 pound of potassium cyanide per ton, for 24 hours without regrinding. The sample was 69·5 per cent through 200 mesh.

Summary:

Feed sample	0·19 Au, oz./ton
Cyanide tailing	0·035 "
Extraction	81·6 per cent

Reagents Consumed:

KCN = 0·85 lb./ton
CaO = 9·3 "

CYANIDATION OF BULK CONCENTRATE

Test No. 26

Two samples of a bulk concentrate produced in Mill Run No. 10 were ground practically all through 325 mesh in jar mills with steel balls and then agitated in cyanide solution, 5·0 pounds of potassium cyanide per ton, for 24 hours. The tailings were assayed for gold.

Summary:

Feed sample	1·24 Au, oz./ton
Cyanide tailing: (1)	0·20 "
(2)	0·175 "
Average tailing	0·188 "
Extraction	84·9 per cent

Reagents Consumed:

KCN = 17·75 lb./ton of concentrate
CaO = 14·25 " "

Test No. 27

Another sample of bulk concentrate produced in Mill Runs Nos. 10 and 11 was ground with lime for one hour in a jar mill and then aerated under 40 pounds' pressure for four hours. The pulp was then transferred to a bottle and agitated in cyanide solution, 5·0 pounds of potassium cyanide per ton, for 8 hours. The tailing was assayed for gold.

Summary:

Feed sample	1·48 Au, oz./ton
Cyanide tailing	0·21 "
Extraction	85·8 per cent

Reagents Consumed:

KCN = 5·15 lb./ton of concentrate
CaO = 10·80 " "

The sample was ground 97·5 per cent through 325 mesh.

Test No. 28

Cyanide consumption was greatly reduced by the shorter agitation period or by pre-aeration or by both of these factors. Another test was carried out in which the concentrate was ground with lime and agitated in cyanide solution, 5·0 pounds of potassium cyanide per ton, for 8 hours but was not given any pre-aeration. This sample was ground 99·5 per cent through 200 mesh.

Summary:

Feed sample	1·48 Au, oz./ton
Cyanide tailing	0·20 "
Extraction	86·6 per cent

Reagents Consumed:

KCN = 6·3 lb./ton of concentrate
CaO = 11·7 " "

From the results of Tests Nos. 27 and 28, it is apparent that cyanide consumption can be greatly reduced by grinding in water and then giving a short period of agitation. The use of pebbles instead of steel balls in the regrind mills should tend further to reduce consumption of cyanide.

LARGE-SCALE CYANIDATION

Test No. 1

A large-scale cyanidation test was made on a composite sample of pyrite concentrate, prepared by mixing together the pyrite concentrates produced in Mill Runs Nos. 1, 2, 3, and 4. The composite feed sample assayed 0·87 ounce gold per ton.

This concentrate was ground in cyanide solution, 5·0 pounds of potassium cyanide per ton, in a pebble mill in closed circuit with a classifier. The classifier overflow, at approximately 30 per cent solids and 93 per cent through 325 mesh, was transferred to a Pachuca tank and agitated for 24 hours. The lime and cyanide were kept up to strength by additions of these reagents when necessary.

At the end of three hours and every two hours thereafter during the period of agitation, grab samples of the pulp were taken for assay. At the end of the run a final sample was taken while the contents of the tank were being discharged.

In the following tables are given a summary of the cyanide tailing assays and the number of hours' agitation from which they resulted.

Results:

Product	Agitation, hours	Assay, Au, oz./ton
Feed to pebble mill	....	0·87
Classifier overflow	....	0·30
Cyanide tailing	3	0·145
" "	5	0·14
" "	7	0·14
" "	9	0·14
" "	11	0·14
" "	13	0·135
" "	15	0·14
" "	17	0·14
" "	19	0·14
" "	21	0·14
" "	23	0·14
" "	23½ (Final)	0·19

Test No. 2

A second cyanidation test was made on a sample of the same mixture of pyrite concentrates. In this test the concentrates were ground 95 per cent through 325 mesh but otherwise the test was a duplicate of the first.

Results:

Product	Agitation, hours	Assay, Au, oz./ton
Feed to pebble mill	....	0·87
Classifier overflow	....	0·30
Cyanide tailing	3	0·14
" "	5	0·14
" "	7	0·14
" "	9	0·14
" "	11	0·14
" "	13	0·145
" "	15	0·15
" "	17	0·145
" "	19	0·145
" "	21	0·15
" "	23	0·145
" "	24 (Final)	0·15

Test No. 3

A third cyanidation test was made on a mixture of pyrite concentrates produced in Mill Runs Nos. 5 and 7, the calculated assay of the mixture being 1·435 ounces of gold per ton. The classifier overflow, at 30 per cent solids and 95 per cent through 325 mesh, was agitated in a Pachuca tank for 21 hours. Samples for assay were taken as in the former tests.

The object was to find out how the higher grade feed would respond to cyanidation as compared to that used in the first two tests. The results obtained show just as good a tailing from the higher grade concentrate as from the lower.

Results:

Product	Agitation, hours	Assay, Au, oz./ton
Feed to pebble mill	....	1·435
Classifier overflow	....	0·40
Cyanide tailing	3	0·245
" "	5	0·18
" "	7	0·165
" "	9	0·135
" "	11	0·125
" "	13	0·125
" "	13½	0·14
" "	15	0·125
" "	17	0·15
" "	19	0·13
" "	21 (Final)	0·185

Test No. 4

The next test was made on a mixture of pyrite and graphite concentrates. All such concentrates produced in Mill Runs Nos. 6 and 8 were mixed together, the calculated assay value being 1·65 ounces of gold per ton. The concentrates were reground as before and the classifier overflow agitated for 24 hours at 30 per cent solids. Samples for assay were taken every hour, to find when reprecipitation of the gold by graphite started, if at all.

Results:

Product	Agitation, hours	Assay, Au, oz./ton
Feed to pebble mill	....	1·65
Classifier overflow	....	0·49
Cyanide tailing	1	0·295
" "	2	0·21
" "	3	0·18
" "	4	0·175
" "	5	0·17
" "	6	0·175
" "	7	0·175
" "	8	0·175
" "	9	0·18
" "	10	0·18
" "	11	0·18
" "	12	0·18
" "	13	0·17
" "	14	0·17
" "	15	0·17
" "	16	0·17
" "	17	0·17
" "	18	0·17
" "	19	0·17
" "	20	0·17
" "	21	0·18
" "	22	0·185
" "	23	0·20
" "	24 (Final)	0·195

Test No. 5

Another composite sample of pyrite and graphite concentrates was prepared, the proportion of graphite concentrate being double that used in the previous test. Agitation was continued for only five hours, with samples taken every hour.

Product	Agitation, hours	Assay, Au, oz./ton
Feed to pebble mill	....	1·74
Classifier overflow	....	0·65
Cyanide tailing	1	0·27
" "	2	0·196
" "	3	0·185
" "	4	0·185
" "	5	0·19

CONCLUSIONS

There is little doubt as to the feasibility of concentrating this ore by flotation. In all the tests conducted low-grade flotation tailings were produced, with the ratio of concentration varying from 6·6 : 1 to 8·8 : 1. By careful operation of the cells, the ratio of concentration can be kept at or near the higher figure and 98 per cent of the gold recovered in a concentrate assaying from 1·5 to 2·0 ounces per ton.

The problem of treating the concentrate in order to recover the gold remains and this may be solved by cyanidation or smelting. By cyanidation of the concentrates, 85 to 90 per cent of the gold can be recovered as bullion at the property. If the concentrates are sold to a smelter practically all of the gold in them will be recovered at the smelter. Of these two schemes the one yielding the greater net return to the owners is the one to use.

If the concentrates are to be cyanided it will be necessary to regrind them practically all through 325 mesh, and to guard against excessive consumption of cyanide the regrinding had better be done in water, using pebbles as a grinding medium. The classifier overflow would go to a thickener and the thickener underflow to an agitator, where the lime and cyanide would be added. The period of agitation should not be longer than 8 hours.

In the cyanidation tests on bulk concentrates no serious trouble, such as precipitation of gold by graphite, was found, but unroasted graphite concentrate so treated by itself showed considerable evidence of pre-precipitation after 24 hours of agitation. There is, therefore, no reason to anticipate trouble if the graphite be floated with the pyrite as a bulk concentrate, but if a graphite concentrate be taken off separately it should be roasted and cyanided or else sold to a smelter.

Although no roasting tests were made on bulk concentrates it is reasonable to expect a somewhat higher extraction of gold by roasting than by treating them raw, but whether the additional extraction will more than repay the added cost of roasting is a matter that will have to be studied.

In the primary grinding circuit there will be a tendency for gold to accumulate in the mill and classifier, unless steps are taken to prevent it. This might be accomplished by passing the mill discharge through a hydraulic trap or a unit flotation cell or over corduroy blankets on its way to the classifier, but the device to be used for this purpose will depend, in some measure, on the nature of the primary grinding unit.

Ore Dressing and Metallurgical Investigation No. 614

GOLD ORE AND MILL PRODUCTS FROM PAYMASTER CONSOLIDATED MINES, LIMITED, SOUTH PORCUPINE, ONTARIO

Shipment. On January 2, 1935, a shipment of gold ore and mill products was received from the Paymaster Consolidated Mines, Limited, South Porcupine, Ontario.

The shipment comprised 190 pounds of ore, 10 pounds of mill tailing, and 7·4 pounds of tube mill feed (classifier sand). The samples were submitted by Bertrand Robinson, Mill Superintendent, Paymaster Consolidated Mines, Limited.

A second shipment, of 122 pounds of mill tailing, was received on February 4, 1935.

Characteristics of the Ore and Mill Products. The samples consisted of crushed ore containing a number of small hand-specimens. Several of these larger pieces were selected and twelve polished sections were prepared and examined microscopically. A sample of the tube mill feed was also mounted and polished and examined, but no native gold was visible in the two sections.

The ore samples examined microscopically consisted chiefly of dark green chloritic schist and white vein quartz; a considerable amount of white carbonate occurs in the quartz. An appreciable amount of rather finely disseminated crystalline pyrite occurs chiefly in the chloritic portions, and some magnetite is disseminated in the chloritic gangue; the magnetite commonly shows alteration to hematite, and, in some sections, to a transparent mineral which is probably leucoxene.

A very small quantity of chalcopyrite occurs as small irregular grains in gangue and pyrite, and rare tiny grains of pyrrhotite are present in the pyrite.

Only seven grains of gold were visible in the twelve sections studied. Some of these grains are associated with a soft grey mineral which occurs in about the same quantity as the gold and which is too finely divided to determine. The quantitative data concerning the gold, based on the very meagre information available, are shown below:

Grain size	Microns	Per cent
+ 800	+19	29
− 800+1100	−19+13	20
−1100+1600	−13+ 9	33
−1600+2300	− 9+ 6	11
−2300	− 6	7
		100

Mode of occurrence of the gold:

In dense pyrite:

(a) Alone	62 per cent
(b) Associated with small amount of unknown grey mineral	38 "
	100 per cent

It is probable that the above data are not representative and that coarse gold (not cut by the polished surfaces) is present in the ore, but this can better be determined during test treatment. That the presence of finely divided gold in the pyrite will be a factor in treatment is certain, but its order of magnitude cannot be estimated from the above data.

Sampling and Assaying. The ore was crushed and sampled and the mill products were sampled. The assays of the feed samples were as follows:

	Gold, oz./ton	Silver, oz./ton
Raw ore	0·28	0·12
Mill tailing	0·03	—
Tube mill feed	1·55	—
Mill tailing (2nd shipment)	0·03	—

Scope of Test Work. Experimental tests and examination of the mill products were carried out for the purpose of obtaining information covering the following points:

1. The form and association of the gold occurrences in the ore.
2. The range existing in the size of the particles of gold and gold minerals (if any).
3. The extractions obtainable under conditions with the following variables in a straight cyanide circuit:
    a. Grinding.
    b. Contact.
    c. Reagent strength.
    d. Agitation dilution.
4. The recovery effected by amalgamation prior to cyanidation—both by direct contact and by recovery from a blanket concentrate and/or a table concentrate.
5. The possibilities of differential grinding of a table concentrate.

While a few tests were carried out on the mill products, the larger number were made on the sample shipment of raw ore.

Experimental Tests

Test No. 1

Two samples (2,000 grammes each) were given a 30-minute grind in a water pulp. One lot was agitated in cyanide solution for 24 hours, the other for 48 hours. A cyanide strength equivalent to 1 pound of potassium cyanide per ton of solution was used. The pulp dilution was 2·5 : 1.

Product	Agitation, hours	Assay, Au, oz./ton		Extraction of gold, per cent	Reagents consumed, lb./ton	
		Feed	Tailing		KCN	CaO
Cyanide tailing	24	0·28	0·03	89·29	0·25	5·19
Cyanide tailing	48	0·28	0·02	92·86	0·25	5·13

Screen Test of Cyanide Tailing:

Mesh	Weight, per cent
+150	0·7
−150+200	4·2
−200	95·1
	100·0

The cyanide tailings were repulped and fed to a small laboratory Wilfley table. The results of this are shown in the following table:

Product	Weight, per cent	Assay, Au, oz./ton	Distribution, per cent	Ratio of concentration
Feed	100·00	0·025	100·0	
Concentrate	6·25	0·23	43·4	16 : 1
Tailing	93·75	0·02	56·6	

The table concentrate was reground and cyanided for 48 hours in a solution having an initial concentration equivalent to 2 pounds of potassium cyanide per ton of solution.

Product	Assay, Au, oz./ton		Extraction of gold, per cent	Reagents consumed, lb./ton		Pulp dilution
	Concentrate	Tailing		KCN	CaO	
Cyanide tailing	0·23	0·145	37·0	1·34	2·37	1·67 : 1

Gold recovery by primary cyanidation	92·86 per cent
Gold in table concentrate from cyanide tailing	3·10 "
Gold recovered by re-cyanidation of table concentrate	1·15 "
Overall recovery of gold, 92·86+1·15	94·01 "

Test No. 2

In this test the ore was given a coarser grind than in the preceding test. Other conditions were the same.

Product	Agitation, hours	Assay, Au, oz./ton		Extraction of gold, per cent	Reagents consumed, lb./ton		Pulp dilution
		Feed	Tailing		KCN	CaO	
Cyanide tailing	24	0·28	0·04	85·7	0·25	4·25	2·5 : 1
Cyanide tailing	48	0·28	0·04	85·7	0·13	4·12	2·5 : 1

Screen Test of Cyanide Tailing:

Mesh	Weight, per cent
+100	2·4
−100+150	5·0
−150+200	11·1
−200	81·5
	100·0

The cyanide tailings were repulped and fed to a small Wilfley table. A slightly larger concentrate was cut than in the previous test.

Product	Weight, per cent	Assay, Au, oz./ton	Distribution, per cent	Ratio of concentration
Feed	100·00	0·04	100·00	
Concentrate	7·43	0·35	58·41	13·46 : 1
Tailing	92·57	0·02	41·59	

The table concentrate was reground and cyanided for 48 hours in a solution having an initial concentration equivalent to 2 pounds of potassium cyanide per ton of solution.

Product	Assay, Au, oz./ton		Extraction of gold, per cent	Reagents consumed, lb./ton		Pulp dilution
	Concentrate	Tailing		KCN	CaO	
Cyanide tailing	0·35	0·195	44·28	0·1	3·8	3 : 1

Screen Test—Cyanide Tailing of Table Concentrate:

Mesh	Weight, per cent
+100	0·2
−100+150	2·9
−150+200	10·5
−200	86·4
	100·0

Gold recovered by primary cyanidation	85·7 per cent
Gold in table concentrate from cyanide tailing	8·35 "
Gold recovered by re-cyanidation of table concentrate	3·70 "
Overall recovery of gold, 85·7 + 3·70	89·4 "

The results of this test would indicate that fine grinding is an essential.

From the two above tests the sulphides are shown to carry about 50 per cent of the undissolved gold.

Test No. 3

In this test the ore sample was ground in a water pulp for 45 minutes. The pulp was cyanided in two lots, one for 24 hours and the other for 48 hours. The cyanide concentration was equivalent to 1 pound of potassium cyanide per ton.

The results are as follows:

Product	Agitation, hours	Assay, Au, oz./ton		Extraction of gold, per cent	Reagents consumed, lb./ton		Pulp dilution
		Feed	Tailing		KCN	CaO	
Cyanide tailing	24	0·28	0·03	89·29	0·25	4·25	2·5 : 1
Cyanide tailing	48	0·28	0·03	89·29	0·25	4·17	2·5 : 1

Screen Test on Cyanidation Tailing:

Mesh	Weight, per cent
+150	0·1
−150+200	0·8
−200	99·1
	100·0

The tailings from the above cyanidation tests, less the amounts cut out for assay, were repulped and fed to a laboratory Wilfley table.

Product	Weight, per cent	Assay, Au, oz./ton	Distribution, per cent	Ratio of concentration
Table feed	100·00	....	100·00	
Concentrate	2·49	0·43	26·79	40·16 : 1
Tailing	97·51	0·03	73·21	

Test No. 4

A sample of ore (1,000 grammes) was ground in a water pulp for 35 minutes. Two samples were cut out and then agitated for 24 hours and 48 hours respectively. The cyanide concentration of the solution was equivalent to 1 pound of potassium cyanide per ton.

Screen Test on Feed to Cyanidation:

Mesh	Weight, per cent
+150	0·2
−150+200	2·5
−200	97·3
	100·0

Product	Agitation, hours	Assay, Au, oz./ton		Extraction of gold, per cent	Reagents consumed, lb./ton		Pulp dilution
		Feed	Tailing		KCN	CaO	
Cyanide tailing	24	0·28	0·03	89·29	0·1	3·95	3 : 1
Cyanide tailing	48	0·28	0·025	91·07	0·3	4·10	3 : 1

Test No. 5

In this test the sample of ore was ground for 30 minutes and the cyanide strength of the solution was equivalent to 2 pounds of potassium cyanide per ton.

Product	Agitation, hours	Assay, Au, oz./ton		Extraction of gold, per cent	Reagents consumed, lb./ton		Pulp dilution
		Feed	Tailing		KCN	CaO	
Cyanide tailing	24	0·28	0·03	89·29	0·10	4·06	3·13 : 1
Cyanide tailing	48	0·28	0·025	91·07	0·33	4·01	3·30 : 1

There was no improved extraction due to the increase in the cyanide strength of the solution.

Test No. 6

A sample of the ore was ground in a water pulp for one hour. A screen test indicated that 99·5 per cent of the ore was ground to pass a 200-mesh screen. Agitation was carried out for 48 hours in cyanide solution having a strength equivalent to 2 pounds of potassium cyanide per ton. The pulp dilution was 2·5 : 1.

Product	Assay, Au, oz./ton		Extraction of gold, per cent	Reagents consumed, lb./ton	
	Feed	Tailing		KCN	CaO
Cyanide tailing................	0·28	0·03	89·29	0·27	4·25

Finer grinding alone and increased cyanide strength did not appear to influence the extraction of gold.

Test No. 7

In this test the ore was ground in a water pulp for 45 minutes and then cyanided for 69 hours in a solution the strength of which was equivalent to 2 pounds of potassium cyanide per ton. The pulp dilution was 3 : 1.

Product	Assay, Au, oz./ton		Extraction of gold, per cent	Reagents consumed, lb./ton	
	Feed	Tailing		KCN	CaO
Cyanide tailing................	0·28	0·015	94·64	1·01	5·99

The results of this test indicate that increased period of agitation (longer contact) may have a favourable influence on the extraction, and a further long contact test was made to check these results.

Test No. 8

In view of the results obtained in Test No. 7, a test was carried out with 72 hours' agitation on a sample ground to the same size as in the previous test. The cyanide strength, however, was reduced to 1 pound of potassium cyanide per ton.

Product	Assay, Au, oz./ton		Extraction of gold, per cent	Reagents consumed, lb./ton		Pulp dilution
	Feed	Tailing		KCN	CaO	
Cyanide product......	0·28	0·015	94·64	0·3	6·10	3 : 1

The screen size at this grinding was 99·1 per cent −200 mesh.

Discussion of Cyanidation Tests

In practically all of the cyanide tests a protective alkalinity was maintained by an initial charge of 5 pounds of CaO (lime) per ton of ore.

The consumption of cyanide was low.

Time of agitation influences the extraction favourably. Strength of cyanide solution does not appear to influence the final tailing. Fine grinding is an important consideration.

AMALGAMATION, BLANKET CONCENTRATION, AND FLOTATION

The following tests were made using plate amalgamation, blanket concentration, and flotation. The results indicate that there is no advantage to be gained by adopting any one of these methods.

Test No. 9

In this test a sample of the ore was ground wet in a pebble jar and the pulp fed over an amalgamation plate.

Gold in feed	0·28 oz./ton
Gold in amalgamation tailing	0·225 "
Recovery of gold by amalgamation	19·6 per cent

A screen test indicated that 84·8 per cent of the ore was ground to pass a 200-mesh screen.

Test No. 10

A sample of ore (2,000 grammes) was ground wet and the pulp was fed to a corduroy blanket.

The concentrate was barrel-amalgamated with mercury and the tailing was cyanided in two lots, one for 24 hours and one for 48 hours.

The results of this test are as follows:

Product	Weight, per cent	Assay, Au, oz./ton	Distribution, per cent	Ratio of concentration
Feed	100·00	0·28	100·00	
Concentrate	3·22	4·187	48·15	31·06 : 1
Tailing	96·78	0·15	51·85	

Amalgamation of Blanket Concentrate:

Gold in concentrate	4·187 oz./ton
Gold in amalgamation tailing	0·57 "
Recovery of gold	86·39 per cent

Screen Test on Blanket Tailing:

Mesh	Weight, per cent
+100	1·0
−100+150	3·6
−150+200	9·6
−200	85·8
	100·0

Cyanidation Tests on Blanket Tailing:

Initial solution:

Cyanide equivalent to 1 pound of potassium cyanide per ton.
Lime, 5 pounds per ton of ore.

Product	Agitation, hours	Assay, Au, oz./ton		Extraction of gold, per cent	Reagents consumed, lb./ton		Pulp dilution
		Feed	Tailing		KCN	CaO	
Cyanide tailing.......	24	0·15	0·025	83·3	0·1	4·04	3·2 : 1
Cyanide tailing.......	48	0·15	0·03	80·0	0·1	4·37	3·15 : 1

The results obtained from the blanket tests do not indicate that there are any advantages to be gained by their use.

Test No. 11

In this test the cyanide tailing was floated. Flotation is not very satisfactory, owing to the carbonates present in the gangue causing a bulky, soapy froth.

The results of the test are as follows:

Product	Agitation, hours	Assay, Au, oz./ton		Extraction of gold, per cent	Reagents consumed, lb./ton		Pulp dilution
		Feed	Tailing		KCN	CaO	
Cyanide tailing.......	24	0·28	0·025	91·07	0·1	3·75	2·5 : 1

Flotation of Cyanide Tailing:

Reagents added to Cell:

Soda ash..	4·0 lb./ton
Copper sulphate..	1·0 "
Potassium amyl xanthate......................................	0·4 "
Pine oil..	0·05 "

Product	Weight, per cent	Assay, Au, oz./ton	Distribution, per cent	Ratio of concentration
Feed..	100·00	....	100·00	
Concentrate.................................	8·85	0·08	20·57	11·3 : 1
Tailing.....................................	91·15	0·03	79·43	

Another flotation test was run on the cyanide tailing after regrinding for 5 minutes with 4 pounds soda ash per ton.

The results showed little concentration of gold.

The presence of carbonates and chloritic material in the gangue renders flotation both difficult and unsatisfactory.

TESTS ON MILL PRODUCTS

A few tests were carried out on the mill products submitted. Particular attention was paid to the mill tailing, and differential grinding tests were made on the table concentrate obtained from this product.

The tube mill feed was composed of primary classifier sand, bowl classifier sand, and spigot sand.

Test No. 12

A sample (1,000 grammes) was barrel-amalgamated with mercury, without regrinding, for one hour.

Gold in tube mill feed	1·55 oz./ton
Gold in amalgamation tailing	0·425 "
Recovery of gold	72·58 per cent

This would indicate that, at the grinding size shown below, slightly over 72 per cent of the gold is free-milling.

A screen test on this product was as follows:

Mesh	Weight, per cent
+ 28	1·3
− 28+ 35	3·0
− 35+ 48	4·3
− 48+ 65	5·9
− 65+100	17·5
−100+150	23·7
−150+200	20·6
−200	23·7
	100·0

Several cyanidation tests were carried out on the tube mill feed product.

The cyanide strength of the solutions at the start was equivalent to 1 pound of potassium cyanide per ton. Two tests were run on the material as received, and two tests were made on reground product.

Test No. 13 (Material as received)

Product	Agitation, hours	Assay, Au, oz./ton		Extraction of gold, per cent	Reagents consumed, lb./ton		Pulp dilution
		Feed	Tailing		KCN	CaO	
Cyanide tailing	24	1·55	0·16	89·68	0·1	4·10	3 : 1
Cyanide tailing	48	1·55	0·155	90·00	0·1	4·25	3 : 1

Test No. 14 (Material reground)

Product	Agitation, hours	Assay, Au, oz./ton		Extraction of gold, per cent	Reagents consumed, lb./ton		Pulp dilution
		Feed	Tailing		KCN	CaO	
Cyanide tailing	24	1·55	0·10	93·55	0·3	8·1	3 : 1
Cyanide tailing	48	1·55	0·05	96·77	0·6	8·9	3 : 1

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Screen Test on Reground Product:

Mesh	Weight, per cent
+100	0·3
−100+150	2·6
−150+200	11·7
−200	85·4
	100·0

The mill tailing product was subjected to a screen test, the results of which are as follows:

Mesh	Weight, per cent
+100	1·3
−100+150	4·1
−150+200	13·3
−200	81·3
	100·0

Test No. 15 (First shipment)

A sample of the tailing was agitated for 24 hours in a solution having a concentration of cyanide equivalent to 1 pound of potassium cyanide per ton. Four pounds of lime (CaO) per ton was added at the beginning of the test. The pulp dilution was 2·5 : 1.

The tailing was lowered from 0·03 ounce of gold per ton to 0·025 ounce, indicating an extraction of 16·6 per cent. The reagent consumption was:

KCN	0·1 lb./ton
CaO	3·75 "

Test No. 16 (Second shipment)

A charge of mill tailing (10,000 grammes) was fed to a laboratory Wilfley table. A concentrate, containing the sulphide minerals, was cut out and the tailing was largely composed of slime.

The concentrate was reground for 20 minutes and then cyanided for 48 hours in a solution having a strength equivalent to 2 pounds of potassium cyanide per ton.

The results of the test follow:

Table Test:

Product	Weight, per cent	Assay, Au, oz./ton	Distribution, per cent	Ratio of concentration
Feed	100·00	0·03	100·0	
Concentrate	3·25	0·30	33·5	30·76 : 1
Tailing	96·75	0·02	66·5	

Screen Test on Table Tailing:

Mesh	Weight, per cent
+150	0·3
−150+200	5·2
−200	94·5
	100·0

Cyanidation of Table Concentrate:

Product	Assay, Au, oz./ton		Extraction of gold, per cent	Reagents consumed, lb./ton		Pulp dilution
	Feed	Tailing		KCN	CaO	
Cyanide tailing	0·30	0·16	46·66	0·9	8·25	3 : 1

Screen Test on Cyanide Tailing:

Mesh	Weight, per cent
+200	0·2
−200	99·8
	100·0

Summary of Results:

Gold recovery by primary cyanidation........................ 90 per cent (approx.)
Gold concentrated in sulphides in table concentration, 33·5 × 10.. 3·35 per cent
Gold recovery by cyanidation of reground table concentrate, 46·66 × 3·35.. 1·56 "
Overall recovery by cyanidation, tabling, regrinding concentrates, and re-cyanidation, 90·00+1·56..............................91·56 "

Test No. 17

In this test, a sample of mill tailing (gold = 0·03 ounce per ton) was run over the small laboratory Wilfley table with the object of lowering the table tailing by increasing the amount of the concentrate cut. The concentrate by weight represented 28·08 per cent of the feed, which was higher than anticipated. The tailing assayed: gold, 0·015 ounce per ton.

Test No. 18

This test was a duplication of the previous test, excepting that the concentrate cut was lowered to 10·12 per cent of the feed. This was the percentage considered most satisfactory.

An assay of the table tailing showed: gold, 0·02 ounce per ton.

The results of the tailing assays would indicate that a comparatively large concentrate must be cut on the table in order to produce a low tailing.

CONCLUSIONS

A review of the results obtained from the tests conducted on the ore and mill products submitted establishes a number of important points relative to the condition and association of the gold in the ore and to the method of its recovery.

The gold is associated largely with the pyrite. The amount of free-milling gold is limited, probably not exceeding 25 per cent. A test (*see* Test No. 9) in which the ore was plate-amalgamated gave a recovery of 19·6 per cent.

From the microscopic examination, the mode of occurrence of the gold indicated that 62 per cent was in the dense pyrite, while the remainder was associated with a small amount of an unknown grey mineral. An analysis of the grain size indicated that 71 per cent was −800 mesh.

The information obtained from the microscopic examination establishes the fact that extremely fine-grained gold is associated with the pyrite. Tabling tests on cyanidation tailings further confirmed this. A partial recovery of this fine gold associated with the pyrite was effected by regrinding the sulphide concentrate from the table tests and subjecting it to further cyanidation. In this way, a small increase in the overall recovery of the gold was obtained.

Fine grinding of the ore is a primary consideration; the fincr the grind, especially of the sulphides, the higher the extraction.

Reagent strength and pulp dilution did not appear to be important factors.

Time of contact, however, would appear to have a definitely important bearing on the extraction. The tailing resulting from 48 hours' agitation was never less than 0·02 ounce of gold per ton. At 69 hours' agitation the tailing was 0·015 ounce of gold per ton, and at 72 hours' agitation the tailing was the same.

The use of amalgamation prior to cyanidation, or of concentration on corduroy blanket strakes, does not appear to offer any advantages. The fine grain size of the gold and its close association with the pyrite render the above-mentioned methods unsuitable.

The results of a barrel-amalgamation test on the sample of tube mill feed show that 72 per cent of the gold in this product is present as free gold. The sample submitted was too small to indicate whether there would be any advantage in removing this free gold by traps, or by blanket or table concentration of this product.

Ore Dressing and Metallurgical Investigation No. 615

GOLD ORE FROM THE MILLER INDEPENDENCE MINE, BOSTON CREEK, ONTARIO

Shipment. One box containing 350 pounds of gold ore was received December 15, 1934, from the Miller Independence Mines (1924), Boston Creek, Ontario, sent on instructions from the Northern Securities Company, Bank of Toronto Building, London, Ontario, per H. H. Childs. The shipment was made for the purpose of determining the most suitable metallurgical practice to follow for the recovery of the contained gold.

Characteristics of the Ore. Representative specimens of the shipment were chosen and six polished sections prepared and examined microscopically in the mineragraphic laboratory. The gangue consists chiefly of fine-textured, greenish grey rock through which occur abundant small grains and tiny veinlets of carbonate. A small amount of white quartz is present.

Pyrite is the only abundant sulphide mineral. It occurs as medium to fine grains disseminated in the chloritic type of gangue and contains numerous inclusions of gangue, very tiny grains of chalcopyrite, and a few tiny grains of native gold. Chalcopyrite is present in the pyrite and gangue as rare tiny grains, and a few grains of galena were seen in the pyrite.

Only two grains of gold were visible, both being within pyrite. They measured 20 and 12 microns in diameter, corresponding approximately to theoretical 560 and 1100 meshes respectively.

The examination shows the ore to be very simple in nature. Chalcopyrite and galena are present in quantities too small to cause complications in treatment. As only two grains of native gold were visible in the sections, it is impossible to draw any conclusions as to the mode of occurrence of the gold in the ore. At least some of the gold is very finely divided and occurs within pyrite.

Experimental Tests

The lot was ground, sampled, and assayed, showing the shipment to contain 0·955 ounce of gold and 0·14 ounce of silver per ton.

The investigation included cyanidation, flotation, blanket concentration, Wilfley table concentration, and amalgamation, singly and in combination.

The results showed that approximately 55 per cent of the gold is freed at −100-mesh grinding and can be amalgamated.

Straight cyanidation extracts 82 per cent of the gold from the ore when ground 70 per cent −200 mesh.

Blankets remove 51 per cent of the gold from the ore ground 56 per cent −200 mesh. Flotation of the blanket tailing recovers an additional 41 per cent.

Cyanidation followed by flotation of the cyanide tailing and cyanidation of the reground concentrate give 87·8 per cent recovery. When the coarse gold is removed by blankets prior to the initial cyanidation of the raw ore, followed by flotation and cyanidation of both blanket and flotation concentrate, 96·9 per cent of the gold is recovered.

The detailed tests follow:

Test No. 1

A sample of the ore ground to pass 48 mesh was amalgamated. The amalgamation tailing was then cyanided for 24 hours, 1 : 3 dilution with a 1·0 pound of potassium cyanide solution. Seven pounds of lime per ton was added as protective alkalinity.

Grind:

Mesh	Per cent
+ 65	6·8
− 65+100	23·2
−100+150	16·5
−150+200	14·3
−200	39·2
	100·0

Results:

Feed	0·955 Au oz./ton
Amalgamation tailing	0·535 " "
Recovery	44·0 per cent
24-hour cyanide tailing	0·285 Au oz./ton
Total recovery	70·2 per cent

Test No. 2

A sample ground −100 mesh was treated similarly.

Grind:

Mesh	Per cent
+150	7·6
−150+200	20·8
−200	71·6
	100·0

Results:

Feed	0·955 Au oz./ton
Amalgamation tailing	0·43 " "
Recovery	55·0 per cent
24-hour cyanide tailing	0·285 Au oz./ton
Total recovery	70·2 per cent

Test No. 3

Representative portions of the ore were ground dry to pass various meshes and then cyanided for 48 hours, 1 : 3 dilution, with a 1·0 pound per ton cyanide solution. Seven pounds of lime per ton was added to supply protective alkalinity.

Results:

Mesh	Period of agitation, hours	Assay, Au oz./ton		Extraction, per cent	Reagents consumed, lb./ton		Grind				
		Feed	Tailing		KCN	CaO	−48 +65	− 65 +100	−100 +150	−150 +200	−200
− 48......	24	0·955	0·245	74·3	0·3	5·5	7·3	23·3	17·0	14·9	37·5
− 48......	48	0·955	0·20	79·1	0·3	5·5	......	......	......	......	......
−100......	24	0·955	0·245	74·3	0·3	6·2	......	......	8·0	21·1	70·9
−100......	48	0·955	0·17	82·2	0·3	6·2	......	......	......	......	......
−150......	24	0·955	0·24	74·9	0·3	6·0	......	......	......	16·2	83·8
−150......	48	0·955	0·19	80·1	0·6	6·2	......	......	......	......	......
−200......	24	0·955	0·285	70·2	0·3	6·7	......	......	......	......	......
−200......	48	0·955	0·205	78·5	0·6	6·4	......	......	......	......	......

Test No. 4

A sample was ground wet in a ball mill until 56 per cent passed 200 mesh. The pulp was then run over a corduroy blanket. The concentrate obtained was panned free from gangue which was added to the blanket tailing, the combined product being then floated after conditioning with 3·0 pounds of soda ash and 0·10 pound of amyl xanthate per ton; 0·06 pound of pine oil per ton was used to froth.

Grind:

Mesh	Per cent
+100..	6·6
−100+150..	12·7
−150+200..	24·2
−200..	56·5
	100·0

Results:

Product	Weight, per cent	Assay, oz./ton		Distribution of metals, per cent	
		Au	Ag	Au	Ag
Feed (calculated)...............	100·00	1·02	0·16	100·0	100·0
Blanket concentrate.............	1·07	49·11	2·46	51·4	16·8
Blanket tailing..................	....	0·555	0·13	....	....
Flotation concentrate............	10·37	4·07	0·83	41·3	54·9
Flotation tailing................	88·56	0·085	0·05	7·3	28·3

Ratio of concentration: Blankets....................................... 93·5 : 1
Flotation....................................... 9·6 : 1
Combined blankets and flotation................ 8·7 : 1

This test indicates that with a comparatively coarse grind, 92·7 per cent of the gold can be concentrated by blankets and flotation in a product weighing 11·44 per cent of the total weight of ore milled. This concentrate contains 8·28 ounces of gold per ton.

Test No. 5

This test is similar in most respects to Test No. 4, the difference being that the ore was more finely ground. A screen analysis shows that 93·1 per cent passed 200 mesh.

Results:

Product	Weight, per cent	Assay, Au, oz./ton	Distribution of gold, per cent
Feed (calculated)	100·00	0·845	100·0
Blanket concentrate	2·76	17·08	55·8
Blanket tailing	....	0·42	....
Flotation concentrate	8·81	3·69	38·5
Flotation tailing	88·43	0·055	5·7

These results show that fine grinding yields higher recovery. In this test 94·3 per cent of the gold is found in the blanket and flotation concentrates, with a ratio of concentration of 8·6 : 1. The combined concentrates have a calculated value of 6·89 ounces of gold per ton.

Test No. 6

In this test, the blankets used prior to flotation in Tests Nos. 4 and 5 were replaced by an amalgamation plate. The amalgamation tailing was floated. Other conditions, such as grinding and flotation reagents used, were the same as in preceding tests.

Results:

Product	Weight, per cent	Assay, oz./ton		Distribution of metals, per cent	
		Au	Ag	Au	Ag
Feed	100·00	0·955	0·14	....	....
Amalgamation tailing	....	0·63	0·14	....	....
Amalgam	....	....	....	45·8	....
Flotation concentrate	12·44	3·46	0·92	45·1	76·6
Flotation tailing	87·56	0·10	0·04	9·1	23·4

On the amalgamation plate 45·8 per cent of the gold is recovered. An additional 45·1 per cent is contained in the flotation concentrate, with a ratio of concentration of 8·0 : 1.

A similar test on ore ground 93 per cent −200 mesh did not show so high a recovery; 30·2 per cent of the gold was recovered by amalgamation and 50·5 per cent by flotation.

Test No. 7.

This test shows the result of floating the raw ore. A sample was ground wet in a ball mill containing iron balls, together with 3·0 pounds of soda ash and 0·10 pound of amyl xanthate per ton. To the flotation machine 0·12 pound of pine oil per ton was added. The grinding was such that 81·7 per cent of the ore passed 200 mesh.

Results:

Product	Weight, per cent	Assay, Au, oz./ton	Distribution of gold, per cent
Feed (calculated)	100·00	1·355	100·0
Concentrate	12·09	7·21	64·3
Tailing	87·91	0·55	35·7

The calculated feed value of the ore is high. This is due to the free gold giving erratic assays. The results obtained serve to show that flotation alone will not give high recoveries. Free gold does not float readily.

Test No. 8

This test is one embodying cyanidation and table concentration of the cyanide tailing. The concentrate was reground and cyanided.

A sample of the ore was ground in a jar mill containing iron balls, 8 pounds of lime per ton of ore, and cyanide solution of 1·0 pound of potassium cyanide per ton. After grinding, 84·9 per cent passed 200 mesh. The pulp was then diluted to 2·5 : 1 and the solution strength brought up to 1·0 pound of potassium cyanide per ton. No additional lime was added, as the solution was found to contain 0·6 pound of lime per ton. Agitation was carried on for 24 hours, after which the pulp was passed over a small Wilfley table. The concentrate obtained was reground to pass 95 per cent through 325 mesh and then cyanided with a 5·0 pound of potassium cyanide per ton solution.

Results:

Cyanidation of Raw Ore:

Feed	0·955 Au, oz./ton
24-hour cyanide tailing	0·16 " "
Extraction	83·2 per cent
Reagent consumption: KCN	0·45 lb./ton
CaO	6·5 "

Table Concentration:

Product	Weight, per cent	Assay, Au, oz./ton	Distribution of gold, per cent
Feed = cyanide tailing	100·00	0·16	100·0
Table concentrate	9·43	0·76	44·2
Table tailing	90·57	0·10	55·8

Cyanidation of Concentrate:

Feed = table concentrate	0·76 Au, oz./ton
48-hour cyanide tailing	0·27 " "
Extraction	64·5 per cent
Reagent consumption: KCN	3·6 lb./ton
CaO	6·5 "

From these results, it appears that 83·2 per cent of the gold is extracted by the first cyanide treatment, leaving 16·8 per cent in the tailing. Table concentration recovers 44·2 per cent of this, or 7·4 per cent of the original gold. Cyanidation of this concentrate extracts 64·5 per cent of its gold content, or 4·7 per cent of the original. This figure added to 83·2 per cent gives a total recovery of 87·9 per cent.

Test No. 9

A sample was cyanided as in the preceding test. The cyanide tailing was well washed to remove cyanide solution and a concentrate was recovered by flotation. Before the concentrate was removed, the cyanide tailing was conditioned with 4·0 pounds of soda ash, 1·0 pound of copper sulphate, 0·10 pound of amyl xanthate, and 0·09 pound of pine oil per ton. The concentrate was filtered, reground to about 95 per cent −325 mesh, and cyanided with a 5·0 pound potassium cyanide solution.

Results:

Cyanidation of Raw Ore:

Feed	0·955 Au, oz./ton
24-hour cyanide tailing	0·209 " "
Extraction	78·1 per cent

Flotation of Cyanide Tailing:

Product	Weight, per cent	Assay, Au, oz./ton	Distribution, of gold, per cent
Feed = cyanide tailing	100·00	0·209	100·0
Flotation concentrate	14·90	0·55	39·1
Flotation tailing	85·10	0·15	60·9

Cyanidation of Flotation Concentrate:

Feed = flotation concentrate	0·55 Au, oz./ton
24-hour cyanide tailing	0·465 " "
Extraction	15·5 per cent
Total recovery	79·4 "

It is apparent that the result of this test is unsatisfactory. Flotation left most of the gold in the tailing, and cyanidation of the concentrate gave a poor extraction. These erratic results can be laid to the presence of free gold, which during grinding becomes flattened, dissolves slowly in cyanide solution, and is hard to float.

Test No. 10

To remove the troublesome coarse gold from the circuit, a sample was ground as in Tests Nos. 8 and 9 and then passed over a corduroy blanket. The concentrate obtained was panned free from gangue which was added to the blanket tailing. This was then thickened to 2·5 : 1 dilution and the strength of cyanide solution made up to 1·0 pound of potassium cyanide per ton. Six pounds of lime per ton was added to supply protective alkalinity and the pulp was agitated for 48 hours.

The cyanide tailing was then filtered and washed with water to remove cyanide solution, conditioned, and floated in the same manner as in Test No. 9.

The blanket concentrate was amalgamated to remove coarse free gold and the tailing united with the flotation concentrate. These concentrates were then reground to about 95 per cent −325 mesh. A small quantity of lime was added to the grinding mill. The pulp was then diluted to 3·4 : 1 with a 5·0 pound of potassium cyanide per ton solution. Approximately 10 pounds of lime per ton of concentrate was added to furnish protective alkalinity.

Results:

Cyanidation of Raw Ore:

Feed	0·955 Au, oz./ton
48-hour cyanide tailing	0·09 "
Extraction by blanket concentration and cyanidation	90·6 per cent
Reagent consumption: KCN	0·36 lb./ton
CaO	9·9 "

Flotation of Cyanide Tailing:

Product	Weight, per cent	Assay, Au, oz./ton	Distribution of gold, per cent
Amalgamated blanket concentrate combined with flotation concentrate	11·64	2·40	96·9
Flotation tailing	88·36	0·01	3·1

These results give a calculated feed value of 0·288 ounce gold per ton for the combined amalgamated blanket concentrate and cyanide tailing. This cyanide tailing, as shown above, has a gold content of 0·09 ounce per ton. The increase in assay value is, therefore, caused by the amalgamated blanket concentrate, the value of which, owing to its small bulk, was not determined.

Cyanidation of Reground Flotation Concentrate and Amalgamated Blanket Concentrate:

Feed	2·40 Au, oz./ton
48-hour cyanide tailing	0·18 " "
Extraction	92·5 per cent
Reagent consumption: KCN	3·78 lb./ton
CaO	8·0 "

These results show quite conclusively the necessity of removing the coarse gold from the circuit, in test work, before it reaches the cyanide agitators or flotation cells. After removing this gold, a 48-hour agitation period reduces the residue to 0·09 ounce of gold per ton.

Flotation of the cyanide tailing leaves a residue containing 0·01 ounce of gold per ton and representing 88·36 per cent of the weight. This is discarded. The remaining 11·64 per cent is made up of flotation concentrate and blanket concentrate from which the coarse free gold has been removed by amalgamation. By cyanidation, 92·5 per cent of the gold in these combined concentrates is extracted, leaving a residue assaying 0·18 ounce of gold per ton.

The mill tailing, therefore, consists of 88·36 per cent of the mill feed assaying 0·01 ounce of gold per ton and 11·64 per cent assaying 0·18 ounce of gold per ton. The sum of these is therefore 0·0297 ounce of gold per ton, an overall recovery of 96·9 per cent by the three steps, i.e. amalgamation of the blanket concentrate, cyanidation of the blanket tailing, and cyanidation of the combined blanket and flotation concentrates.

SUMMARY AND CONCLUSIONS

The results obtained in this investigation show that the ore contains both rather coarse and very fine gold associated with a considerable amount of pyrite in the form of fine- to medium-size grains. An indicated ratio of concentration of from 8 : 1 to 10 : 1 is evident. To obtain maximum extraction, this tonnage must be ground −325 mesh. The free gold must either be finely ground in the mill or be removed from the circuit prior to the main treatment, as it is slow to dissolve in cyanide solution.

Tests Nos. 1 and 2 show that from 44 to 55 per cent of the gold is free at a coarse to medium grind.

Tests Nos. 4, 5, and 6 indicate that from 45 to 50 per cent of the gold can be removed by blanket concentration or plate amalgamation.

Straight flotation, alone, is not applicable but when it is preceded by blanket concentration a combined recovery, as concentrates, of 94 per cent is possible.

Straight cyanidation of the raw ore is not satisfactory. Test No. 3 shows the highest extraction obtained, 82·2 per cent, to be from ore ground 70 per cent −200 mesh.

By removal of the coarse gold and by cyanidation of the residue a recovery of 83 per cent of the gold can be made. It is necessary, therefore, to give attention to the fine gold contained in the pyrite.

Test No. 8 shows that 83·2 per cent is extracted by cyanidation from the raw ore. Table concentration recovers 44·2 per cent of the gold in the cyanide tailing, and 64·5 per cent of this can be recovered by re-cyanidation. This gives a total recovery of 87·9 per cent.

Flotation of the cyanide tailing will give a higher recovery of sulphides than will table concentration.

When the coarse gold has been removed prior to flotation, maximum recoveries are achieved by cyanidation, flotation concentration, and re-cyanidation of the finely ground sulphides. (*See* Test No. 10.)

To obtain high gold recovery from this ore it is essential to grind the sulphides to −325 mesh. This may be achieved by locking the sulphides in the grinding circuit by a system of bowl classifiers and secondary grinding mills until the concentrated sulphides are reduced to 325 mesh. This system will produce a product that can be cyanided directly. No coarse gold will escape from the grinding circuit.

The highest recovery will, doubtless, result from regrinding the sulphides in a separate circuit, followed by cyanidation. If flotation concentration is adopted, great care must be taken that the cyanide tailing be thoroughly washed before flotation.

A diminution in the amount of free gold in the ore milled will affect the recoveries indicated in this investigation. Therefore, in order to obtain results in practice similar to those obtained in the tests, the ore to be milled should closely correspond to the sample furnished.

Ore Dressing and Metallurgical Investigation No. 616

GOLD ORE FROM THE VIMY GOLD MINES, LIMITED, RAMORE, ONTARIO

Shipment. A shipment of ore, weighing 1,950 pounds, was received on January 18, 1935. A second shipment of 412 pounds was received on January 21, 1935. The ore is said to be from the property of the Vimy Gold Mine, Limited, Ramore, Ontario, and was submitted for test work by Joseph Borini, Secretary-Treasurer, Vimy Gold Mines, Limited, P.O. Box 2730, Timmins, Ontario.

Purpose of Experimental Tests. The purpose of the experimental tests was to determine the best method of treatment for the recovery of the gold in the ore.

Characteristics of the Ore. Six polished sections were prepared from specimens of each shipment and were examined microscopically for the purpose of determining the character of the ore. Since, microscopically, there are no significant differences between the two shipments they will be treated under one description.

The gangue is quite complex and was not studied in detail. It consists chiefly of mottled reddish brown to greenish, siliceous material which contains considerable carbonate; some portions are green and schistose. This assemblage is cut by a ramifying network of quartz veinlets.

Pyrite, which is the most abundant metallic mineral, is rather sparingly disseminated as small irregular grains and poorly formed cubes. A small portion is very finely divided, but most of the pyrite is of moderate grain size (around 200 mesh and larger).

Hematite is quite abundant as needles, which in places are extremely fine. Probably much of the red colour of the ore is due to included hematite "dust".

A very small amount of chalcopyrite occurs as tiny irregular grains in gangue and pyrite.

Only three tiny grains of native gold were visible in the twelve sections. These occur within pyrite and measure 20, 7, and 4 microns respectively.

Sampling and Analysis. The two shipments were sampled separately by standard methods, and representative portions assayed as follows:

Shipment No. 1	Gold, 0·10 oz./ton Silver, 0·06 "
Shipment No. 2	Gold, 0·26 oz./ton Silver, 0·07 "

EXPERIMENTAL TESTS

Tests on Shipment No. 2:

Amalgamation.
Straight cyanidation.
Blanket concentration followed by flotation.
Straight flotation.
Cyanidation with pre-aeration.

Tests on Mixed Ore from Shipments Nos. 1 and 2:

The ore was thoroughly mixed, in the ratio of five parts of Shipment No. 1 to one part of Shipment No. 2, for further tests. A feed sample of the mixture assayed 0·11 ounce gold per ton.

The tests were:

Flotation followed by cyanidation of reground flotation concentrate.

Straight cyanidation followed by table concentration of cyanide tailing. The table concentrate was reground and then treated by cyanidation.

AMALGAMATION

Test No. 1

Representative samples of −14-mesh ore from Shipment No. 2 were crushed dry to pass 48- and 100-mesh screens and were then amalgamated with mercury in jar mills, dilution 1 : 1, with water.

After separating the mercury and amalgam from the pulp, the amalgamation tailing was sampled and a representative portion was assayed. A screen analysis was made on each tailing to show the grinding.

Results:

Mesh	Assay, Au, oz./ton		Extraction, per cent
	Feed	Tailing	
− 48	0·26	0·17	34·62
−100	0·26	0·15	42·31

Screen Analysis:

Mesh	Weight, per cent	
	Minus 48	Minus 100
+ 48	....	....
− 48+ 65	6·5	....
− 65+100	26·7	....
−100+150	13·3	9·6
−150+200	13·5	18·4
−200	40·0	72·0
	100·0	100·0

STRAIGHT CYANIDATION

Test No. 2

Representative samples of −14-mesh ore from Shipment No. 2 were crushed dry to pass 48-, 100-, 150-, and 200-mesh screens for treatment by cyanidation.

The ore was agitated for periods of 24 and 48 hours in a solution of sodium cyanide equivalent in strength to 1·0 pound of potassium cyanide per ton of solution, and lime at the rate of 5 pounds per ton of ore was added to give a protective alkalinity to the pulp. The ratio of dilution was 3 : 1.

Results:

Mesh	Agitation, hours	Assay, Au, oz./ton		Extraction, per cent	Reagents consumed, lb./ton	
		Feed	Tailing		KCN	CaO
− 48	24	0·26	0·05	80·77	0·30	6·65
−100	24	0·26	0·03	88·46	0·30	9·25
−150	24	0·26	0·03	88·46	0·30	10·65
−200	24	0·26	0·025	90·38	0·30	11·95
− 48	48	0·26	0·08	69·23	0·30	7·25
−100	48	0·26	0·03	88·46	0·30	9·25
−150	48	0·26	0·05	80·77	0·60	11·25
−200	48	0·26	0·03	88·46	0·60	12·10

The screen analysis shown below gives the degree of grinding:

Screen Analysis:

Mesh	Weight, per cent		
	Minus 48	Minus 100	Minus 150
+ 48			
− 48+ 65	6·5		
− 65+100	26·7		
−100+150	13·3	9·6	
−150+200	13·5	18·4	17·5
−200	40·0	72·0	82·5
	100·0	100·0	100·0

BLANKET CONCENTRATION FOLLOWED BY FLOTATION

Test No. 3

A representative sample of −14-mesh ore from Shipment No. 2 was ground in jar mills, dilution 4 : 3, to give a product of 60 per cent −200 mesh.

The ground ore was concentrated on a corduroy blanket sloping 2·5 inches in 12 inches. The blanket concentrate was panned to remove gangue and excess sulphides and then was assayed. The blanket tailing was treated by flotation, using the following reagents:

Soda ash	3·0 lb./ton
Potassium amyl xanthate	0·2 "
Pine oil	0·05 "

Results of Blanket Concentration:

Product	Weight, per cent	Assay, Au, oz./ton	Distribution of gold, per cent	Ratio of concentration
Feed (cal.)	100·00	0·25	100·00	
Blanket concentrate	0·28	13·52	15·33	357 : 1
Blanket tailing	99·72	0·21	84·67	

Results of Flotation:

Product	Weight, per cent	Assay, Au, oz./ton	Distribution of gold, per cent	Ratio of concentration
Feed	100·00	0·21	100·00	
Flotation concentrate	5·90	2·80	85·42	17 : 1
Flotation tailing	94·10	0·03	14·58	

Summary of Results:

Recovery of gold by blanket .... 15·33 per cent
Recovery of gold by flotation, 85·42 × 84·67 .... 72·33 "

Overall recovery of gold .... 87·66 per cent

STRAIGHT FLOTATION

Test No. 4

A representative sample of −14-mesh ore was ground in a jar mill, dilution 4 : 3, to give a product approximately 74 per cent −200 mesh.

The following reagents were added to the grinding mill:

Soda ash .... 3·0 lb./ton
Aerofloat No. 31 .... 0·07 "

The following reagents were added to the flotation cell:

Potassium amyl xanthate .... 0·2 lb./ton
Pine oil .... 0·05 "

Results:

Product	Weight, per cent	Assay, Au, oz./ton	Distribution of gold, per cent	Ratio of concentration
Feed	100·00	0·26	100·00	
Flotation concentrate	9·43	2·48	91·19	10·6 : 1
Flotation tailing	90·57	0·025	8·81	

Test No. 5

A similar test was made, using the following reagents:

In the Grinding Mill:

Soda ash .... 3·0 lb./ton

In the Cell:

Potassium amyl xanthate.. 0·2 lb./ton
Pine oil.. 0·05 "

Results:

Product	Weight, per cent	Assay			Distribution of gold, per cent	Ratio of concentration
		Au, oz./ton	Ag, oz./ton	As, per cent		
Feed...............	100·00	0·26	0·07	....	100·00	
Flotation concentrate	6·32	3·59	1·72	0·03	87·37	16 : 1
Flotation tailing.....	93·68	0·035	....	....	12·63	

Silver in concentrate: 1·72 ounces per ton.

Test No. 6.

A representative sample of −14-mesh ore from Shipment No. 2 was ground in a jar mill, dilution 4 : 3, to give a product approximately 53 per cent −200 mesh.

The reagent added to the grinding mill was:

Soda ash.. 3·0 lb./ton

The reagents added to the flotation cell were:

Potassium amyl xanthate.. 0·2 lb./ton
Pine oil.. 0·05 "

Results:

Product	Weight, per cent	Assay, Au, oz./ton	Distribution of gold, per cent	Ratio of concentration
Feed..	100·00	0·26	100·00	
Flotation concentrate.........................	7·05	3·24	83·08	14 : 1
Flotation tailing.............................	92·95	0·05	16·92	

The results of the three flotation tests show that grinding to approximately 80 per cent −200 mesh is required in order to liberate the gold.

CYANIDATION WITH PRE-AERATION

Test No. 7

Because of the carbonates reported in the gangue minerals, tests were made to determine the effect of pre-aeration in reducing the consumption of lime.

A representative portion of −150-mesh ore was agitated in water for 3 hours and the pH of the solution was determined. The pH was approximately 8·8. Cyanide was added at the rate of 1·0 pound of potassium cyanide per ton of solution, and agitation was continued for 18 hours. The potassium cyanide was found to be reduced to 0·6 pound per ton.

Lime was added at the rate of 1·0 pound per ton of ore, potassium cyanide was made up to 1·0 pound per ton of solution, and the agitation continued for 6 hours.

Results:

Period of agitation, hours	Assay, Au, oz./ton		Extraction, per cent	Reagents consumed, lb./ton	
	Feed	Tailing		KCN	CaO
24	0·26	0·03	88·46	1·20	0·9

CYANIDATION

Test No. 8

A representative sample of −150-mesh ore was cyanided by agitating with a 1·0 pound of potassium cyanide solution for 16 hours. Lime was added at the rate of 1·0 pound per ton of ore, potassium cyanide then added to make up to 1·0 pound per ton of solution, and the agitation continued for 8 hours.

Results:

Period of agitation, hours	Assay, Au, oz./ton		Extraction, per cent	Reagents consumed, lb./ton	
	Feed	Tailing		KCN	CaO
24	20·26	0·025	90·38	21·32	0·90

The cyanide consumption is higher than in previous tests.

FLOTATION FOLLOWED BY CYANIDATION OF FLOTATION CONCENTRATE

Test No. 9

A representative sample of −14-mesh ore from mixed Shipments Nos. 1 and 2 was ground in jar mills, dilution 4 : 3, to give a product approximately 65 per cent −200 mesh.

The reagent added to the grinding mill was:

Soda ash........ 3·0 lb./ton

The reagents added to the flotation cell were:

Potassium amyl xanthate........ 0·2 lb./ton
Pine oil........ 0·05 "

The flotation concentrate was reground to approximately 100 per cent −200 mesh and then agitated in a solution of sodium cyanide equivalent in strength to 5·0 pounds of potassium cyanide per ton of solution. Lime was added at the rate of 15 pounds per ton of concentrate.

Results of Flotation:

Product	Weight, per cent	Assay, Au, oz./ton	Distribution of gold, per cent	Ratio of concentration
Feed..	100·00	0·11	100·00	
Flotation concentrate.........................	5·57	2·10	92·56	18 : 1
Flotation tailing.............................	94·43	0·01	7·44	

Results of Cyanidation of Flotation Concentrate:

Period of agitation, hours	Assay, Au, oz./ton		Extraction, per cent	Reagents consumed, lb./ton	
	Feed	Tailing		KCN	CaO
24...............................	2·10	0·08	96·20	5·40	13·67

Summary of Results:

Recovery of gold by flotation.......................	92·56 per cent
Cyanidation of flotation concentrate, 96·20 × 92·56...	89·04 per cent in 24 hours
Maximum overall recovery of gold by flotation and by cyanidation of flotation concentrate.............	89·04 per cent

STRAIGHT CYANIDATION AND TABLE CONCENTRATION

Test No. 10

A representative sample of −14-mesh ore from the mixed shipments was ground in jar mills, dilution 4 : 3, to give a product approximately 84 per cent −200 mesh.

The ground pulp was agitated in cyanide solution equivalent in strength to 1·0 pound of potassium cyanide per ton for 24 hours. Lime at the rate of 5·0 pounds per ton of ore was added to give protective alkalinity. The ratio of dilution was 5 : 2.

The cyanide tailing was filtered, washed, sampled, and concentrated on a Wilfley table to give the following products, concentrate, middling, and tailing.

The concentrate was reground to approximately 100 per cent −200 mesh and then cyanided for 72 hours in a solution equivalent to 5·0 pounds of potassium cyanide per ton, and lime at the rate of 15 pounds per ton of concentrate was added. The ratio of dilution was 3 : 1.

Results of Cyanidation of Ore:

Period of agitation, hours	Assay, Au, oz./ton		Extraction, per cent	Reagents consumed, lb./ton	
	Feed	Tailing		KCN	CaO
24...............................	0·11	0·01	90·91	0·55	4·4

Results of Table Concentration of Cyanide Tailing:

Product	Weight, per cent	Assay, Au, oz./ton	Distribution of gold, per cent	Ratio of concentration
Feed (cal.)	100·00	0·02	100·00	....
Table concentrate	7·76	0·10	50·06	12·89 : 1
Table middling	6·58	0·01	4·26	15·20 : 1
Table sand tailing	29·76	0·005	9·61	....
Table slime tailing	55·90	0·01	36·07	....

Results of Cyanidation of Table Concentrate:

Period of agitation, hours	Assay, Au, oz./ton		Extraction, per cent	Reagents consumed, lb./ton	
	Feed	Tailing		KCN	CaO
72	0·10	0·01	90·00	3·44	8·96

Summary of Results:

Recovery of gold by cyanidation of raw ore	90·91 per cent
Recovery of gold by table concentration of cyanide tailing, 50·06 × 9·09	4·55 "
Recovery of gold from table concentrate by cyanidation, 90·0 × 4·55	4·10 "
Overall recovery of gold:—	
Raw ore	90·91 per cent
Table concentrate cyanided	4·10 "
Total	95·01 "
Consumption of cyanide per ton of raw ore	0·55 pound
Consumption of cyanide per ton of concentrate	3·44 "
Consumption of cyanide on concentrate in terms of original feed	0·26 "
Total consumption of cyanide per ton of ore	0·81 "

Test No. 11 (Test No. 10 repeated)

To check the results obtained in Test No. 10, a similar test was made.

Results of Cyanidation of Ore:

Period of agitation, hours	Assay, Au, oz./ton		Extraction, per cent	Reagents consumed, lb./ton	
	Feed	Tailing		KCN	CaO
24	0·11	0·01	90·91	0·80	4·12

Results of Table Concentration of Cyanide Tailing:

Product	Weight, per cent	Assay, Au, oz./ton	Distribution of gold, per cent	Ratio of concentration
Feed (cal.)	100·00	0·02	100·00	
Table concentrate	11·82	0·09	54·64	8·46 : 1
Table middling	9·37	0·01	4·64	10·67 : 1
Table tailing	78·81	0·01	40·72	

Results of Cyanidation of Table Concentrate:

Period of agitation, hours	Assay, Au, oz./ton		Extraction, per cent	Reagents consumed, lb./ton	
	Feed	Tailing		KCN	CaO
72	0·09	0·01	88·89	1·82	8·20

Summary of Results:

Recovery of gold by cyanidation of raw ore	90·91 per cent
Recovery of gold in table concentrate, 54·64 × 9·09	4·97 "
Recovery of gold from table concentrate by cyanidation, 88·89 × 4·97	4·42 "
Overall recovery of gold:	
Raw ore	90·91 per cent
Table concentrate cyanided	4·42 "
Total	95·33 "
Consumption of cyanide per ton of raw ore	0·80 pound
Consumption of cyanide per ton of concentrate	1·82 "
Consumption of cyanide on concentrate in terms of feed	0·21 "
Total consumption of cyanide per ton of ore	1·01 "

SUMMARY

The recovery by amalgamation was 42 per cent on ore crushed 72 per cent −200 mesh.

The recovery by cyanidation was 90 per cent on ore crushed −200 mesh. The consumption of reagents was normal.

Blanket concentration gave a recovery of 15 per cent of the gold, and flotation of the blanket tailing gave a recovery of 72 per cent. The overall recovery of gold was 87 per cent.

Straight flotation on ore crushed 74 per cent −200 mesh gave a recovery of 91 per cent of the gold, with a ratio of concentration of 10 : 1, and 87 per cent of the gold with a ratio of concentration of 16 : 1.

When grinding was 53 per cent −200 mesh a recovery of 83 per cent of the gold was obtained with a ratio of concentration of 14 : 1.

Cyanidation with pre-aeration of −150-mesh ore gave a recovery of 88 to 90 per cent of the gold. The consumption of lime was low, with an increase in the cyanide consumption.

Flotation followed by cyanidation of the reground flotation concentrate gave an overall recovery of 89 per cent of the gold.

Straight cyanidation gave a recovery of 91 per cent of the gold. Tabling the cyanide tailing and treating the reground table concentrate by cyanidation gave an overall recovery of 95 per cent of the gold.

CONCLUSIONS

Straight cyanidation recovers approximately 91 per cent of the gold in the ore. The recovery can be raised to 95 per cent by concentration of the sulphides, followed by re-treatment. This is the process to adopt when a large daily tonnage is being milled.

For a small operation, flotation will recover approximately 90 per cent of the gold in a concentrate assaying from 2·5 to 3·5 ounces of gold per ton. The ratio of concentration should be in the neighbourhood of 18 : 1.

The success of a small flotation plant will depend on obtaining a feed high enough in value to offset mining and milling charges and a 10 per cent tailing loss plus smelter deductions. Approximately 80 per cent of the gold in the ore can be considered available to cover the operating, shipping, and treatment charges.

Ore Dressing and Metallurgical Investigation No. 617

GOLD ORE FROM THE THORNELOE MINE, THIBEAULT PROPERTY, PORCUPINE DISTRICT, ONTARIO

Shipment. A shipment of gold ore said to be from the Thorneloe mine, Thibeault property, Thorneloe township, Porcupine district, Ontario, was received on February 12, 1935. The shipment consisted of two boxes, designated Lots Nos. 1 and 2 and weighing approximately 89 and 85 pounds respectively. The sample was submitted by W. F. Wright and Company, Toronto, Ontario.

Characteristics of the Ore. The *gangue of Lot No. 1* consists chiefly of fine-textured grey quartz and green to brown country rock. A considerable amount of white carbonate (probably dolomite) occurs as stringers, patches, and small disseminated grains in both country rock and quartz.

The *metallic minerals*, in their order of abundance, are: pyrite, chalcopyrite, Unknown No. 1, pyrrhotite, and galena. *Unknown No. 1* gave the following tests:

Colour: Bright yellow.
Hardness: C to D.
Crossed nicols: Very strongly anisotropic.
Etch tests: HNO_3—weakly attacked, becoming slightly brown and pitted.
HCl, KCN, $FeCl_3$, KOH, $HgCl_2$—negative.

Pyrite, the most abundant mineral, is sparsely disseminated as irregular grains and poorly formed crystals up to two or more millimetres in size. Chalcopyrite and Unknown No. 1 are rare, and are individually disseminated as small irregular grains. Pyrrhotite and galena are rare as tiny irregular grains, the former associated with pyrite, the latter alone in quartz.

The *gangue of Lot No. 2* is fine-textured, grey to white quartz with some disseminated carbonate.

The *metallic minerals*, in their order of abundance, are: galena, pyrite, pyrrhotite, chalcopyrite, Unknown No. 2, native gold, Unknown No. 3, and Unknown No. 4. The tests on *Unknowns Nos. 2 and 3* are as follows:

Unknown No. 2:

Colour: Bright bronze.
Hardness: Soft—B minus; is somewhat sectile.
Crossed nicols: Moderately anisotropic.
Etch tests: HNO_3—action delayed for about 30 seconds, then slowly effervesces and turns brown with pitting.
KCN—quickly blackens.
$FeCl_3$—quickly tarnishes iridescent.
HCl, KOH, $HgCl_2$—negative.

Unknown No. 3:

Colour: Bright creamy-yellow.
Hardness: Soft—B.
Crossed nicols: Very strongly anisotropic.
Etch tests: HNO_3—practically negative—brown slightly.
HCl, KCN, $FeCl_3$, KOH, $HgCl_2$, aqua regia—negative.

Only one tiny grain of Unknown No. 4 was seen in galena. It is bright, white, and soft, with a scratched surface, and it may be native silver.

Galena is present in considerable amount as small irregular patches, stringers, and grains, which commonly occur in clusters in the quartz. The other metallic minerals, with the exception of pyrite, show a marked tendency to associate with it. Pyrite is disseminated very sparingly as small grains and crystals. Pyrrhotite and chalcopyrite occur as in Lot No. 1 and are quite rare. Small grains of Unknown No. 2 are present in galena, and also in quartz where some are associated with native gold. Only two tiny grains of Unknown No. 3 were seen; they are associated with galena.

A microscopic grain analysis of the native gold was carried out, with the results shown in the following table:

Mesh	Gold, per cent	Cumulative, per cent
+ 150	13·1	13·1 + 150 mesh
− 150+ 200	10·8	23·9 + 200 "
− 200+ 280	9·0	32·9 + 280 "
− 280+ 400	14·9	47·8 + 400 "
− 400+ 560	17·2	65·0 + 560 "
− 560+ 800	16·0	81·0 + 800 "
− 800+1100	9·8	90·8 +1100 "
−1100+1600	5·2	96·0 +1600 "
−1600+2300	3·5	99·5 +2300 "
−2300	0·5	
Total	100·0	

The modes of occurrence of the gold in the polished sections are as follows:

In quartz:	Alone	20·8 per cent
	Associated with galena	37·9 "
	Associated with Unknown No. 2	38·4 "
In galena		2·9 "
	Total	100·0 "

Summary of Characteristics of the Ore. The two shipments consist of a quartzose gangue through which the metallic minerals are sparingly disseminated. Pyrite, galena, chalcopyrite, pyrrhotite, and native gold were identified, and four additional undetermined minerals were seen. The gold is chiefly in the quartz, where it is often associated with small amounts of galena and Unknown No. 2. The gold shows a marked tendency to occur in close proximity to galena. A quantitative grain analysis of the gold shows that it is moderately finely-divided.

The microscopic examination indicates that (a) flotation would probably effect unsatisfactory recoveries, (b) cyanidation should effect high recoveries with moderately fine grinding, and (c) cyanicides are present in such small quantities that a low cyanide consumption may be expected.

Sampling and Assaying. The two lots were crushed separately and sampled for assay. Later, the two lots were mixed and a composite sample cut for assay. Test work was carried out on the mixture of Lots Nos. 1 and 2.

Assay Results:

—	Lot No. 1	Lot No. 2	Mixture of Lots Nos. 1 and 2
Gold	0·03 oz./ton	0·81 oz./ton	0·44 oz./ton
Silver	0·21 "	4·11 "	2·02 "
Lead	Trace	0·67 per cent	—
Arsenic	Nil	Nil	—

EXPERIMENTAL TESTS

Test work comprised standard amalgamation, blanket concentration, flotation, and cyanidation. Results indicated that about 60 per cent of the gold was free-milling; and an extraction of over 97 per cent was obtained by cyanidation, with a cyanide consumption under 1 pound of potassium cyanide per ton.

Test No. 1

A sample of ore (1,000 grammes) was ground wet for 20 minutes. The pulp was barrel-amalgamated with 100 grammes of mercury for 1 hour.

Results:

Gold in feed	0·44 oz./ton
Gold in amalgamation tailing	0·175 "
Gold recovery	60·23 per cent

Screen Test on Tailing:

Mesh	Weight, per cent
− 65+100	0·2
−100+150	2·0
−150+200	8·6
−200	89·2
	100·0

Test No. 2

In this test, a sample of ore was ground for 20 minutes and the pulp then run over a corduroy blanket. The results are as follows:

Product	Weight, per cent	Assay, Au, oz./ton	Distribution, per cent	Ratio of concentration
Feed	100·00	0·44	100·0	
Concentrate	5·22	4·80	63·8	19·16 : 1
Tailing	94·78	0·15	36·2	

Test No. 3

This was a flotation test in which a sample was ground wet with 6 pounds of soda ash per ton.

The reagents added to the cell were:

Potassium amyl xanthate	0·4 lb./ton
Pine oil	0·05 "

Results:

Product	Weight, per cent	Assay, Au, oz./ton	Distribution, per cent	Ratio of concentration
Feed	100·00	0·44	100·0	
Concentrate	6·44	5·70	92·9	15·53 : 1
Tailing	93·56	0·03	7·1	

Test No. 4

In this test the grinding time was increased to 30 minutes. Six pounds of soda ash per ton was used in the grinding, and 0·6 pound of amyl xanthate per ton was added to the cell.

Results:

Product	Weight, per cent	Assay, Au, oz./ton	Distribution, per cent	Ratio of concentration
Feed	100·00	0·44	100·00	
Concentrate	4·23	6·16	91·58	23·64 : 1
Tailing	95·77	0·025	8·42	

Screen Test on Tailing:

Mesh	Weight, per cent
+100	0·1
+150	1·1
+200	7·8
−200	91·0
	100·0

Test No. 5

A series of cyanidation tests was run on ore of different grinding sizes. The strength of cyanide solution was equivalent to 1 pound of potassium cyanide per ton at the start. Several additions of lime were made during the agitation, to maintain a protective alkalinity. The pulp dilution was 3 : 1.

Results:

24 Hours' Agitation:

Product	Assay, Au, oz./ton		Extraction of gold, per cent	Reagents consumed, lb./ton	
	Feed	Tailing		KCN	CaO
− 48 mesh	0·44	0·015	96·59	0·1	6·50
−100 "	0·44	0·01	97·73	0·6	6·80
−150 "	0·44	0·01	97·73	1·05	8·80
−200 "	0·44	0·01	97·73	1·35	11·10

Screen Tests of Cyanide Tailings:

−48 mesh		−100 mesh		−150 mesh	
Mesh	Weight, per cent	Mesh	Weight, per cent	Mesh	Weight, per cent
+ 65	3·7	+150	10·7	+200	18·0
+100	17·3	+200	20·1	−200	82·0
+150	11·8	−200	69·2		100·0
+200	12·7		100·0		
−200	54·5				
	100·0				

Test No. 6

In this test, the period of agitation was 48 hours.

Results:

Product	Assay, Au, oz./ton		Extraction of gold, per cent	Reagents consumed, lb./ton	
	Feed	Tailing		KCN	CaO
− 48 mesh	0·44	0·01	97·73	0·3	6·50
−100 "	0·44	0·01	97·73	0·6	6·65
−150 "	0·44	0·01	97·73	1·35	9·10
−200 "	0·44	0·01	97·73	1·35	11·25

Test No. 7

This was a tabling test, in which a sample of ore (3,000 grammes) was ground for 15 minutes and then fed to a small laboratory Wilfley table.

Results:

Product	Weight, per cent	Assay		Distribution of gold, per cent	Ratio of concentration
		Au, oz./ton	Pb, per cent		
Feed	100·00	0·44	....	100·00	
Concentrate	10·87	1·63	1·39	47·47	9·2 : 1
Middling	18·88	0·35	....	17·69	
Tailing	70·25	0·185	....	34·84	

Test No. 8

This was a blanket and amalgamation test. The ore sample was ground in an Abbé mill for 20 minutes and the pulp then run over a corduroy blanket. The concentrate was barrel-amalgamated with mercury for 1 hour.

The results of the test are as follows:

Product	Weight, per cent	Assay, Au, oz./ton	Distribution, per cent	Ratio of concentration
Feed	100·00	0·44	100·00	
Concentrate	2·59	8·526	50·19	38·61 : 1
Tailing	97·41	0·225	49·81	

Barrel Amalgamation of Blanket Concentrates:

Results:

Gold in blanket concentrate	8·526 oz./ton
Gold in amalgamation tailing	1·60 "
Gold recovery	81·23 per cent
Recovery of total gold by blanket concentration and amalgamation=81·23 × 50·19	40·77 "

CONCLUSIONS

The results of experimental tests on the sample submitted indicate that the ore can be satisfactorily treated by cyanidation, with a low consumption of cyanide and a gold extraction of over 97 per cent. Agitation for 24 hours and a grinding size of 69·2 per cent −200 mesh gave a tailing of 0·01 ounce of gold per ton.

At a grinding size of 89·2 per cent −200 mesh, a barrel-amalgamation test indicated that 60 per cent of the gold was free-milling.

Ore Dressing and Metallurgical Investigation No. 618

COPPER-GOLD ORE FROM THE MANITOBA AND EASTERN MINES, LIMITED, TIMAGAMI, ONTARIO

Shipment. A shipment consisting of 2,300 pounds of ore was received January 18, 1935, from the Manitoba and Eastern Mines, Limited, Timagami, Ontario—Stanley S. Saxton, Manager—and was from the same property as that previously reported on in 1934, in Investigation No. 551. It was stated to have been taken from the main vein on the 300-foot level.

Specimens of the ore were selected and polished sections made and examined microscopically in the mineragraphic laboratory.

The gangue in the present shipment is similar to that of the previous one, but a small amount of finely disseminated carbonate was detected. The important differences noted during the present examination are the absence of minerals indicative of surface alteration, and the detection of small grains of native gold in both gangue and sulphides. Some of the gold is very finely divided and of variable and complex occurrence. Six grains of the metal were observed in the sections examined, the size and occurrence being as follows:

No. of grains	Size		Occurrence
	Microns	Mesh	
2	6	2300	Rounded grains in quartz.
1 1	24 15	560 1100	Irregular grains in pyrrhotite associated with native bismuth.
1 1	50 40	280 400	Irregular grains in chalcopyrite associated with undetermined mineral.

Experimental Tests

The shipment was crushed, ground, and sampled. The analysis was as follows:

Gold	0·34 oz./ton
Silver	1·49 "
Copper	0·78 per cent
Arsenic	3·45 "
Lead	0·07 "
Zinc	0·15 "
Cobalt	0·02 "
Nickel	Trace

The analysis indicates that concentration of the copper is necessary. Straight cyanidation will not be applicable due to the presence of this metal. The investigation consisted of flotation tests to remove the copper followed by cyanidation of the tailing.

A recovery of 95 per cent of the copper and 73 per cent of the gold in a flotation concentrate can be made, with an additional 16 per cent of the gold extracted from the flotation tailing by cyanidation.

Test No. 1

A sample of the ore was ground wet in a jar mill containing iron balls until 82 per cent passed 200 mesh. Soda ash, 4·0 pounds, and 0·10 pound of cyanide per ton were added to the mill during the grinding period. The pulp was then conditioned with 0·10 pound of sodium xanthate and 0·08 pound of pine oil per ton and a concentrate removed.

Results:

Product	Weight, per cent	Assay			Distribution, per cent		
		Au, oz./ton	Ag, oz./ton	Cu, per cent	Au	Ag	Cu
Feed (cal.)............	100·00	0·28	1·63	0·74	100·0	100·0	100·0
Concentrate...........	4·50	3·92	22·44	15·10	62·7	61·9	92·2
Tailing...............	95·50	0·11	0·65	0·06	37·3	38·1	7·8

Cyanidation reduced the flotation tailing from 0·11 ounce of gold per ton to 0·05 within 24 hours—a total recovery of 85·3 per cent of the gold by the combined methods. Cyanide consumption was 1·7 pounds per ton of ore treated.

Test No. 2

In this test, 4·0 pounds of lime per ton was substituted for the soda ash used in Test No. 1. No cyanide was added. Other details were the same as in the previous test.

Results:

Product	Weight, per cent	Assay			Distribution, per cent		
		Au, oz./ton	Ag, oz./ton	Cu, per cent	Au	Ag	Cu
Feed (cal.)...........	100·00	0·31	1·65	0·78	100·0	100·0	100·0
Concentrate..........	5·37	3·52	18·40	14·28	60·6	59·9	97·6
Tailing...............	94·63	0·13	0·70	0·02	39·4	40·1	2·4

Cyanidation after 24 hours left a residue containing 0·04 ounce of gold per ton, representing a total recovery by flotation and cyanidation of 88·3 per cent. The consumption of cyanide was moderate, 0·9 pound of potassium cyanide being consumed; 5·0 pounds of lime was required for cyanidation.

Test No. 3

This test is the same as Test No. 2 with the exception that the grind was 96 per cent −200 mesh instead of 82 per cent.

Results:

Product	Weight, per cent	Assay			Distribution, per cent		
		Au, oz./ton	Ag, oz./ton	Cu, per cent	Au	Ag	Cu
Feed (cal.)............	100·00	0·33	1·46	0·82	100·0	100·0	100·0
Concentrate...........	5·72	4·24	18·40	13·68	73·0	72·0	95·4
Tailing...............	94·28	0·095	0·43	0·04	27·0	28·0	4·6

Cyanidation reduces the flotation tailing to 0·035 ounce of gold per ton within 24 hours. A total recovery of 89·7 per cent of the gold is obtained by flotation and cyanidation. No further extraction is obtained in any of the tests by increased time of agitation.

SUMMARY AND CONCLUSIONS

The copper minerals in the ore are strong cyanicides; 0·06 per cent of copper in the feed to cyanidation as shown in Test No. 1 results in a consumption of 1·7 pounds of potassium cyanide per ton; 0·02 per cent of copper, as in Test No. 2, consumes 0·9 pound of potassium cyanide. It is necessary therefore to remove the copper prior to cyanidation.

Flotation recovers 95 per cent of the copper in a rougher concentrate containing approximately 13·7 per cent of copper and 73 per cent of the gold. By recleaning, the copper content can be raised to shipping grade.

Ore Dressing and Metallurgical Investigation No. 619

ORE FROM THE COLE GOLD MINES, LIMITED, PIPESTONE BAY, RED LAKE, ONTARIO

Shipment. The shipment, consisting of 700 pounds of ore, was received on March 7, 1935. The ore was submitted by Cole Gold Mines, Limited, per E. Howard, from their property located at Pipestone bay, Red lake, Ontario.

Purpose of Experimental Tests. The experimental tests were carried out to determine the best method to recover the contained values.

Characteristics of the Ore. Six polished sections were prepared and examined microscopically for determining the character of the ore.

The *gangue* is dark green chloritic schist and white vein quartz.

The *metallic minerals* present in the polished sections are, in their order of abundance, pyrite, pyrrhotite, arsenopyrite, magnetite, chalcopyrite, and native gold.

Pyrite is moderately abundant and occurs as coarsely crystalline masses, stringers, and coarse grains. It locally contains crystals of arsenopyrite and small grains of pyrrhotite. Pyrrhotite occurs as above, but the major amount is present as small grains in the schist. Arsenopyrite was seen only as small crystals associated with pyrite.

Magnetite occurs as sparsely disseminated small grains, usually in the schist. Chalcopyrite occurs as small irregular grains in quartz.

Only a few grains of native gold were seen. Some are alone in quartz, others are associated with chalcopyrite. Their grain size varies from 400 mesh to 2300 mesh.

Sampling and Analysis. The shipment was sampled by standard methods and assayed as follows:

Gold	1·32 oz/ton
Silver	0·61 "
Copper	0·16 per cent
Arsenic	0·07 "

Experimental Tests

1. Amalgamation.
2. Straight cyanidation.
3. Concentration by hydraulic trap.
4. Concentration by trap followed by blanket concentration.
5. Blanket concentration followed by flotation.
6. Blanket concentration followed by cyanidation.
7. Blanket concentration followed by aeration and cyanidation.

AMALGAMATION

Test No. 1

Representative samples of −14-mesh ore were dry-crushed to pass 48- and 100-mesh screens. From each a 1,000-gramme representative portion was amalgamated with mercury in jar mills, dilution 1:1. After removing the mercury and amalgam, the tailings were sampled and a screen analysis was made on each to show the degree of grinding.

Screen Analysis:

Mesh	Weight, per cent −48	Weight, per cent −100
− 48+ 65	8·60	
− 65+100	23·10	
−100+150	16·50	9·00
−150+200	18·25	29·95
−200	33·55	61·05
	100·0	100·0

Results of Amalgamation:

Mesh	Assay, Au, oz./ton		Extraction, per cent
	Feed	Tailing	
− 48	1·32	0·175	86·74
−100	1·32	0·17	87·12

STRAIGHT CYANIDATION

Test No. 2

Representative samples of −14-mesh ore were dry-crushed to pass 48-, 100-, 150-, and 200-mesh screens. Samples from each were agitated in cyanide solution, equivalent in strength to 1·0 pound per ton of potassium cyanide at a dilution of 3:1 for periods of 24 and 48 hours. Lime at the rate of 5·0 pounds per ton of ore was added to give protective alkalinity. During the test several additions of reagents were required to maintain the strength of the solutions.

Results of 24 Hours' Agitation:

Mesh. No.	Assay, Au, oz./ton		Extraction, per cent	Reagents consumed, lb./ton ore	
	Feed	Tailing		KCN	CaO
— 48	1·32	0·12	90·91	1·83	6·8
−100	1·32	0·025	98·11	3·27	7·1
−150	1·32	0·015	98·86	4·26	6·7
−200	1·32	0·03	97·73	5·94	14·25

Results of 48 Hours' Agitation:

− 48	1·32	0·035	97·35	2·43	6·9
−100	1·32	0·01	99·24	3·87	7·25
−150	1·32	0·015	98·86	5·01	8·1
−200	1·32	0·01	99·24	7·89	14·95

Cyanide solution from 24-hour −200-mesh sample has 0·218 gramme copper per litre.

Pyrrhotite and copper minerals in the ore account for the high consumption of reagents.

A screen analysis on −150-mesh ore shows the following grind:

Mesh	Weight, per cent
−150+200	20·5
−200	79·5
	100·00

The screen analysis of the −48- and −100-mesh ore is shown under Test No. 1.

CONCENTRATION BY HYDRAULIC TRAP

Test No. 3

A representative sample of −14-mesh ore was ground in a jar mill, dilution 4 : 3, to give approximately 46 per cent −200-mesh product. The pulp then was concentrated in a hydraulic classifier.

Results:

Products	Weight, per cent	Assay, Au, oz./ton	Distribution of gold, per cent	Ratio of concentration
Feed	100·00	1·21*	100·00	
Trap concentrate	0·14	581·28	67·36	714 : 1
Tailing	99·86	0·395	32·64	

* Calculated value.

HYDRAULIC TRAP AND BLANKET CONCENTRATION

Test No. 4

A test similar to No. 3 was made, except that the grind was 68 per cent −200 mesh and the trap tailing was concentrated on a corduroy blanket sloping $2\frac{1}{2}$ inches in 12 inches.

Results:

Trap Concentration:

Products	Weight, per cent	Assay, Au, oz./ton	Distribution of gold, per cent	Ratio of concentration
Feed	100·00	1·12*	100·00	
Trap concentrate	0·06	1090·87	58·22	1667 : 1
Tailing	99·94	0·47	41·78	

Blanket Concentration:

Feed	100·00	0·47	100·00	
Blanket concentrate	0·36	75·38	59·85	278 : 1
Blanket tailing	99·64	0·19	40·15	

*Calculated value.

Summary of Results:

Recovery of gold by trap.. 58·22 per cent
" " " " blanket......................59·85 × 41·78 = 25·01 "

Overall recovery of gold.. 83·23 "
Loss of gold in blanket tailing....................40·15 × 41·78 = 16·77 "

100·00 "

BLANKET CONCENTRATION AND FLOTATION

Test No. 5

A representative sample of −14-mesh ore was ground in a jar mill, dilution 4 : 3, to give a product approximately 64 per cent −200 mesh.

The pulp was concentrated on a corduroy blanket sloping 2½ inches in 12 inches. The blanket tailing was dewatered and treated by flotation using the following reagents:

Soda ash.. 3·0 lb./ton.
Potassium amyl xanthate.. 0·2 "
Pine oil.. 0·05 "

Results:

Product	Weight, per cent	Assay			Distribution of gold, per cent	Ratio of concentration
		Au, oz./ton	Ag, oz./ton	Cu, per cent		
Feed	100·00	1·22*	0·61	0·16	100·00	
Blanket concentrate	0·40	249·69	272·26	....	82·01	250 : 1
Blanket tailing	99·60	0·22	....	....	17·99	

Flotation:

Feed	100·00	0·22	....	....	100·00	
Flotation concentrate	6·40	2·77	4·03	2·44	80·81	15·6 : 1
Flotation tailing	93·60	0·045	....	....	19·19	

*Calculated value.

Summary of Results:

Recovery of gold on blankets..................................		82·01 per cent
" " " in flotation concentrate.........80·81×17·99	=	14·54 "
Overall recovery of gold..		96·55 "
Loss of gold in flotation tailing....................19·19×17·99	=	3·45 "
		100·00 "

BLANKET CONCENTRATION AND CYANIDATION

Test No. 6

A representative sample of −14-mesh ore was ground in a jar mill, dilution 4 : 3, to give a product approximately 67 per cent −200 mesh.

The pulp was concentrated on a corduroy blanket similar to that in Test No. 5. The blanket tailing was dewatered and treated by cyanidation.

Representative portions of the blanket tailing were agitated in cyanide solution equivalent in strength to 1·0 pound of potassium cyanide per ton, at a dilution of 3 : 1, for periods of 24 and 48 hours. Lime at the rate of 5 pounds per ton of tailing was added to give protective alkalinity.

Additions of the reagents were necessary to maintain the strength of the solutions.

Results:

Blanket Concentration:

Products	Weight, per cent	Assay, oz./ton		Distribution of gold, per cent	Ratio of concentration
		Au	Ag		
Feed............................	100·00	1·40*	0·61	100·00	
Blanket concentrate............	0·62	185·37	20·97	82·22	161 : 1
" tailing..................	99·38	0·23	....	17·78	

Cyanidation:

Period of agitation, hours	Assay, oz./ton		Extraction, per cent	Reagents consumed, lb./ton tailing.	
	Feed	Tailing		KCN	CaO
24...............	0·25	0·01	96·0	2·63	8·49
48...............	0·25	0·01	96·0	3·53	8·92

* Calculated value.

Summary of Results:

Recovery of gold by blankets..................................		82·22 per cent
" " " " 24-hour cyanidation..........96·0 × 17·78	=	17·07 "
Overall recovery of gold..		99·29 "
Loss in cyanide tailing............................4·0 × 17·78	=	0·71 "
		100·00 "

BLANKET CONCENTRATION FOLLOWED BY AERATION AND CYANIDATION

Test No. 7

A representative sample of −14-mesh ore was ground in a jar mill, dilution 4 : 3, to give a product approximately 80 per cent −200 mesh. The ground pulp was concentrated on a corduroy blanket similar to that in Tests Nos. 5. and 6.

The blanket tailing was dewatered and repulped at a dilution of $2\frac{1}{2}$: 1 in the bowl of a Denver super-agitator and aerated with lime at the rate of 10 pounds per ton for four hours. The pulp was then transferred to a large Winchester bottle and agitated in a solution of cyanide equivalent in strength to 1·0 pound of potassium cyanide per ton, for a period of 24 hours. Lime at the rate of 4·0 pounds per ton of tailing was added to give protective alkalinity.

Results:

Blanket Concentration:

Products	Weight, per cent	Assay, Au, oz./ton	Distribution of gold, per cent	Ratio of concen-tration
Feed	100·00	1·32*	100·00	
Blanket concentrate	0·49	157·28	58·39	204 : 1
" tailing	99·51	0·55	41·61	

Aeration and Cyanidation:

Period of agitation, hours	Assay, oz./ton		Extraction, per cent	Reagents consumed, lb./ton tailing	
	Feed	Tailing		KCN	CaO
4					9·62
24	0·55	0·01	98·18	2·33	3·00
					12·62

* Calculated value.

Summary of Results:

Recovery on blankets		58·39 per cent
Recovery of silver by cyanidation	98·18 × 41·61 =	40·85 "
Overall recovery of gold		99·24 "
Loss in cyanide tailing	1·82 × 41·61 =	0·76 "
		100·00 "

The overall recovery is almost identical with that in Test No. 6, in which there was no aeration prior to cyanidation. There was a small saving in cyanide but a much greater consumption of lime. The tailing assays were the same in both tests.

SUMMARY

Amalgamation tests on ore crushed 61 per cent −200 mesh indicate that 87 per cent of the gold is free.

Straight cyanidation gave high recoveries but the consumption of reagents was high.

Concentration by traps recovered 67 per cent of the gold, which was augmented to 83 per cent by the use of blankets.

Blanket concentration followed by flotation gave a recovery of 96 per cent of the gold.

Blanket concentration followed by cyanidation for 24 hours, gave a recovery of 99 per cent. Treatment by aeration prior to cyanidation resulted in the same recovery.

CONCLUSIONS

The sample submitted for test work was found to contain a large proportion of free gold, which can be recovered easily by traps or blankets. The blanket tailing can be cyanided but owing to the presence of cyanicides, principally copper, the consumption of cyanide is fairly high. Cyanidation gives the highest overall recovery.

Consideration should be given to the fact that the sample submitted, assayed 1·32 ounces of gold. This, no doubt, is considerably higher than the average feed to the mill would run. The chief question in this connexion is, whether the same proportion of free gold will occur in the lower grade ore to be milled. Any sweetening of the grade is probably due to free gold, and, if so, will affect the recovery shown by these tests as obtained by trap and blanket concentration.

Ore Dressing and Metallurgical Investigation No. 620

GOLD-SILVER ORE FROM THE CHAPLEAU MINE OF THE REWARD MINING CO., LIMITED, SLOCAN CITY MINING DIVISION, B.C.

Shipment. A shipment of gold-silver ore consisting of three bags, weight 190 pounds, was received on February 27, 1935, from the old Chapleau mine of the Reward Mining Co., Limited, situated six miles southeast of Slocan City, Slocan City mining division, B.C. The shipment was submitted by C. S. Lord, 475 Howe Street, Vancouver, B.C., for experimental test to determine the best method of milling.

Characteristics of the Ore. The *gangue* is milky-white vein quartz.

The *metallic minerals* in their order of abundance are pyrite, galena, sphalerite, chalcopyrite, a grey mineral thought to be ruby-silver (?), and native gold.

Pyrite is the only abundant metallic mineral. It occurs as coarsely crystalline masses and coarse irregular grains, and contains galena, sphalerite, chalcopyrite, ruby-silver (?), and native gold.

Galena is present in small quantity as irregular grains and veinlets in pyrite and associated with, and rarely within, sphalerite.

Sphalerite occurs as small, irregular masses and grains associated with galena and rarely in pyrite. It contains tiny dots and spikes of chalcopyrite and rare grains of galena. The amount of sphalerite is very small.

Chalcopyrite is present only in traces, as dots and spikes in sphalerite, and as very rare tiny grains in pyrite.

Ruby-silver (?) is very rare, only a few tiny grains in pyrite being visible. There was insufficient material for conclusive identification.

Two grains of native gold were seen in the polished sections. One is a rounded bleb in pyrite and is approximately 280 mesh in size, and the other is a narrow vein-like structure in quartz and is about 10 microns in width and over 300 microns in length.

The character of the ore from the Chapleau mine, Slocan City, B.C., as seen in polished sections, is such that few inferences can be drawn as to its behaviour in the mill. It is probable that the gold is distributed in both pyrite and gangue, in which case concentration of the sulphides would recover only a part of the gold. It is possible that the silver is divided between galena and ruby-silver (?), both of which are associated with pyrite; if such be the case, concentration of the sulphides might effect high silver recoveries.

If the gold and silver have somewhat erratic modes of occurrence, as may be suspected in an ore of this type, only actual test treatment can ultimately determine the behaviour of the ore.

Sampling and Analysis. The ore was crushed and sampled by standard methods and the feed sample assayed as follows:

Gold	0·50 oz./ton
Silver	15·34 "
Lead	0·19 per cent
Zinc	Trace

Experimental tests were conducted with the object of determining a suitable method of mill treatment to provide a concentrate containing the gold and silver content of the ore. Flotation would appear to offer a satisfactory method for a small mill of from 25 to 50 tons capacity.

Experimental Tests

Test No. 1

This was a barrel-amalgamation test carried out for the purpose of determining the amount of free-milling gold in the ore. A sample of ore, 1,000 grammes in weight, was ground in an Abbé mill for 20 minutes. The pulp was amalgamated for 1 hour with mercury and after separation of the mercury the tailing was assayed for gold.

Gold in feed	0·50 oz./ton
Gold in tailing	0·24 "
Gold recovered by amalgamation	52·0 per cent

Screen Analysis of Tailings:

Mesh	Weight, per cent
+ 65	0·6
+100	7·3
+150	14·1
+200	24·5
−200	53·5
	100·0

The result of this test indicates that 52·0 per cent of the gold is free-milling at the grinding size shown in the above screen test.

Tests Nos. 2 and 3

These tests were run to determine the action of cyanide treatment on ore. The consumption of cyanide is high, which may be due to the silver minerals present.

Samples of different sizes of ore were agitated in cyanide solution of a strength equivalent to one pound of potassium cyanide per ton. Five pounds of lime were added at the start and additions made during the run to maintain a protective alkalinity. The pulp dilution was 3 : 1.

Test No. 2—24 Hours' Agitation:

Product	Assay, oz./ton				Extraction of gold, per cent	Extraction of silver, per cent	Reagents consumed, lb./ton	
	Au		Ag					
	Feed	Tailing	Feed	Tailing			KCN	CaO
−48 mesh	0·50	0·08	15·34	3·45	84·0	77·51	2·39	4·80
−100 "	0·50	0·015	15·34	2·67	97·0	82·59	3·08	4·10
−150 "	0·50	0·03	15·34	2·33	94·0	84·81	3·34	5·95
−200 "	0·50	0·025	15·34	2·90	95·0	81·10	3·47	6·10

Test No. 3—48 Hours' Agitation:

Product	Assay, oz./ton				Extraction of gold, per cent	Extraction of silver, per cent	Reagents consumed, lb./ton	
	Au		Ag					
	Feed	Tailing	Feed	Tailing			KCN	CaO
−48 mesh.........	0·50	0·03	15·34	3·39	94·0	77·90	2·69	5·10
−100 "	0·50	0·03	15·34	2·31	94·0	84·94	3·86	4·25
−150 "	0·50	0·02	15·34	2·01	96·0	96·90	3·82	6·10
−200 "	0·50	0·03	15·34	2·53	94·0	83·51	3·04	6·25

Screen Test of Cyanide Tailings:

−48 Mesh		−100 Mesh		−150 Mesh	
Mesh	Weight, per cent	Mesh	Weight, per cent		Weight, per cent
+65...........	6·8	+150...........	8·2	+200—........	10·0
+100..........	19·6	+200...........	25·4	−200...........	90·0
+150..........	11·2	−200...........	66·4		100·0
+200..........	16·0		100·0		
−200..........	46·4				
	100·0				

Test No. 4

This was a blanket concentration test on a sample of raw ore. The sample (2,000 grammes) was ground wet for 20 minutes and the pulp fed to a corduroy blanket strake.

The results indicate a poor recovery of the silver minerals in the ore.

Product	Weight, per cent	Assay, oz./ton		Distribution, per cent		Ratio of concentration
		Gold	Silver	Gold	Silver	
Feed...............	100·00	0·50	15·34	100·00	100·00	
Concentrate.........	3·81	9·28	45·38	58·57	10·97	26·25 : 1
Tailing.............	96·19	0·26	14·59	41·43	89·03	

Test No. 5

This was a flotation test carried out on a sample, ground in a soda ash pulp of 4 pounds of soda ash per ton.

The pulp was conditioned in the cell with 0·4 pound of potassium amyl xanthate per ton and 0·15 of pine oil per ton.

Product	Weight, per cent	Assay, oz./ton		Distribution, per cent		Ratio of concentration
		Gold	Silver	Gold	Silver	
Feed...............	100·00	0·50	15·34	100·00	100·00	
Concentrate.........	6·28	7·86	215·36	86·81	82·69	15·92 : 1
Tailing.............	93·72	0·08	3·02	13·19	17·31	

Test No. 6

In this test, 0·07 pound of Aerofloat No. 31 per ton was added to the grinding mill. The same amounts of soda ash and amyl xanthate were used.

Product	Weight, per cent	Assay, oz./ton		Distribution, per cent		Ratio of concentration
		Gold	Silver	Gold	Silver	
Feed	100·00	0·50	15·34	100·00	100·00	
Concentrate	6·31	7·74	217·86	89·68	81·82	15·85 : 1
Tailing	93·69	0·06	3·26	10·32	18·18	

Test No. 7

The grinding time of this test was increased to 30 minutes. The reagents added were the same as in Test No. 6. Finer grinding gave higher recoveries and a lower tailing in both silver and gold.

Product	Weight, per cent	Assay, oz./ton		Distribution, per cent		Ratio of concentration
		Gold	Silver	Gold	Silver	
Feed	100·00	0·50	15·34	100·00	100·00	
Concentrate	8·93	5·52	165·12	90·78	90·07	11·2 : 1
Tailing	91·07	0·055	1·785	9·22	9·93	

Screen Test on Tailing:

Mesh	Weight, per cent
+100	0·9
+150	5·3
+200	21·5
−200	72·3
	100·0

Test No. 8

Following the results of the previous test which indicated a high recovery with finer grinding, the sample in this test was ground for 40 minutes. In order to retrieve any gold not already recovered in the flotation concentrate, the flotation tailing was run over a corduroy blanket.

The reagents added were as follows:

To the Grinding Mill:

Soda ash	4·0 lb./ton
Aerofloat No. 31	0·14 "

To the Cell:

Potassium amyl xanthate	0·4 lb./ton
Pine oil	0·05 "

Product	Weight, per cent	Assay, oz./ton		Distribution, per cent,		Ratio of concentration
		Gold	Silver	Gold	Silver	
Feed	100·00	....	....	100·00	100·00	
Concentrate	6·47	8·84	221·56	83·60	86·61	15·45 : 1
Tailing	93·53	0·12	2·37	16·40	13·39	

Blanket Concentration of Flotation Tailing:

Product	Weight, per cent	Assay, oz./ton		Distribution, per cent		Ratio of concentration
		Gold	Silver	Gold	Silver	
Feed	100·00	....	....	100·00	100·00	
Concentrate	5·83	1·26	3·52	60·94	8·65	17·17 : 1
Tailing	94·17	0·05	2·30	39·06	91·35	

Mesh	Weight, per cent
+100	0·2
+150	3·1
+200	17·4
−200	79·3
	100·0

Recovery of gold and silver by combined flotation and blankets.

Gold recovery by flotation	83·60	per cent
Gold recovery by blanket, 60·94 per cent of 16·40 per cent	9·99	"
Overall gold recovery	93·59	"
Silver recovery by flotation	86·61	per cent
Silver recovery by blankets, 48·65 per cent of 13·39 per cent	1·16	"
Overall silver recovery	87·77	"

Test No. 9

In this test Barrett No. 4 reagent was used instead of Aerofloat No. 31 in the grinding. The amount of this reagent added was 0·176 pound per ton.

The results of the test are as follows:

Product	Weight, per cent	Assay, oz./ton		Distribution, per cent		Ratio of concentration
		Gold	Silver	Gold	Silver	
Feed	100·00	....	....	100·00	100·00	
Concentrate	6·51	8·52	214·88	73·86	85·93	15·36 : 1
Tailing	93·49	0·21	2·45	26·14	14·07	

Blanket Concentration of Flotation Tailing:

Product	Weight, per cent	Assay, oz./ton		Distribution, per cent		Ratio of concentration
		Gold	Silver	Gold	Silver	
Feed	100·00	....	....	....	....	
Concentrate	4·12	4·04	7·03	79·41	11·81	24·27 : 1
Tailing	95·88	0·045	2·255	20·59	88·19	

Recovery of gold and silver by combined flotation and blankets.

Gold recovery by flotation	73·86 per cent
Gold recovery by blanket, 79·41 per cent of 26·14 per cent	20·76 "
Overall gold recovery	94·62 "
Silver recovery by flotation	85·93 per cent
Silver recovery by blankets, 11·81 per cent of 14·07 per cent	1·66 "
Overall silver recovery	87·59 "

Test No. 10

This test was carried out using the same reagents as in Test No. 8.

Flotation:

Product	Weight, per cent	Assay, oz./ton		Distribution, per cent		Ratio of concentration
		Gold	Silver	Gold	Silver	
Feed	100·00	....	....	100·00	100·00	
Concentrate	7·13	6·54	186·46	66·76	86·61	14·03 : 1
Tailing	92·87	0·25	2·48	33·24	13·39	

Blanket Concentration of Flotation Tailing:

Product	Weight, per cent	Assay, oz./ton		Distribution, per cent		Ratio of concentration
		Gold	Silver	Gold	Silver	
Feed	100·00	....	....	100·00	100·00	
Concentrate	5·19	3·45	10·28	80·76	19·62	19·27 : 1
Tailing	94·81	0·045	2·305	19·24	80·38	

Recovery of gold and silver by combined flotation and blankets.

Gold recovery by flotation	66·76 per cent
Gold recovery by blankets, 80·76 per cent of 33·24 per cent	26·84 "
Overall gold recovery	93·60 "
Silver recovery by flotation	86·61 per cent
Silver recovery by blankets, 19·62 per cent of 13·39 per cent	2·63 "
Overall silver recovery	89·24 "

CONCLUSIONS

The results of the test work indicate that flotation followed by blanketing of the flotation tailing will account for a recovery of over 90 per cent of the gold and 85 per cent of the silver in the form of concentrate.

The best grinding size as indicated by the tests carried out would be around 75 per cent −200 mesh.

Ore Dressing and Metallurgical Investigation No. 621

(Supplementary to Investigation No. 593)

GOLD ORE FROM THE WENDIGO MINE, NEAR KENORA, ONTARIO

Shipment. A shipment consisting of 1,950 pounds of ore was received at the Ore Dressing and Metallurgical Laboratories on February 18, 1935. It was submitted by C. Spencer, Manager, on the instructions of H. G. Young, Vice-President, Wendigo Gold Mines, Ltd., 701 Dominion Bank Building, Toronto, Canada. The ore was said to be from the property of the Wendigo Gold Mines, Limited, situated one-half mile north of Witch bay, Lake of the Woods, Ontario.

Purpose of the Experimental Tests. The experimental tests were for checking those made on a shipment received from the same mine on August 9, 1934, the results of which are published in Investigation No. 593, and to comply with the company's request for table concentration tests on the flotation concentrate.

Characteristics of the Ore. Twelve polished sections were prepared and examined microscopically to determine the character of the ore.

The sample consists of green to grey chloritic schist, which contains a considerable amount of finely disseminated carbonate and patches and veinlets of grey transparent quartz. Considerable amounts of pyrite and chalcopyrite are present chiefly in the schist as small masses, and, more uncommonly, small grains and stringers. Pyrrhotite occurs as small grains in the schist, and arsenopyrite is present as rare small crystals in pyrite. No native gold was seen.

The sample submitted August 9, 1934, was examined and the following characteristics noted.

It consisted of greenish grey chloritic schist and associated quartz veins, through which pyrite and chalcopyrite were distributed rather abundantly as irregular grains, stringers, and small masses. The pyrite contained a small amount of pyrrhotite, the chalcopyrite a small amount of sphalerite. Native gold was present as relatively coarse grains only in grey translucent quartz.

Since no native gold was seen in the present shipment, its mode of occurrence is not known. It is possible, however, that it is present in the same form as that in the previous shipment, namely, as coarse gold in the quartz.

Sampling and Analysis. The shipment was sampled by standard methods and assayed as follows:

Gold	0·23 oz./ton
Silver	0·07 "
Copper	0·40 per cent
Arsenic	Nil.

EXPERIMENTAL TESTS

Blanket concentration followed by cyanidation.
Blanket concentration followed by flotation.
Blanket concentration followed by flotation and cyanidation of flotation tailing.
Blanket concentration followed by flotation.
Recleaning flotation concentrate to obtain as high-grade concentrate as possible and treating the flotation tailing by 10 cyanidation cycle tests to determine the amount of fouling in the solution.
Blanket concentration followed by cyanidation cycle tests to determine the amount of fouling in the solution.
Blanket concentration followed by flotation and re-treatment of the flotation concentrate by table concentration.

BLANKET CONCENTRATION AND CYANIDATION

Test No. 1

In this test a representative sample of −14-mesh ore was ground in a jar mill, dilution 4 : 3, to give a product approximately 68 per cent −200 mesh.

The ground pulp was concentrated on a corduroy blanket sloping 2½ inches in 12 inches. The blanket concentrate was panned to remove excess gangue and sulphides.

The blanket tailing was dewatered and representative portions were treated by cyanidation for 24 and 48 hours. They were agitated in cyanide solution equivalent in strength to 1·0 pound of potassium cyanide per ton at a dilution of 3 : 1. Lime at the rate of 5·0 pounds per ton of tailing was added to give protective alkalinity. Additions of reagents were required to maintain the strength of the solutions.

Results:

Blanket Concentration:

Products	Weight, per cent	Assay, Au, oz./ton	Distribution of gold, per cent	Ratio of concentration
Feed	100·00	0·19*	100·00	
Blanket concentrate	0·34	35·02	63·05	294 : 1
" tailing	99·66	0·07	36·95	

* Calculated values

Cyanidation:

Period of agitation, hours	Assay, Au, oz./ton		Extraction, per cent	Reagents consumed, lb./ton tailing	
	Feed	Tailing		KCN	CaO
24	0·07	0·01	85·71	2·68	8·74
48	0·07	0·005	92·86	4·26	9·07

Summary:

Recovery of gold by blankets		63·05 per cent
" " " " cyanidation in 24 hours	85·71 × 36·95 =	31·67 "
Overall recovery of gold		94·72 "
Recovery of gold by cyanidation in 48 hours	92·86 × 36·95 =	34·31 per cent
" by blankets		63·05 "
Overall recovery of gold		97·36 "

Test No. 2

This test was similar to No. 1, except that the ore was ground to give a product approximately 80 per cent −200 mesh.

Results:

Blanket Concentration:

Products	Weight, per cent	Assay, Au, oz./ton	Distribution of gold, per cent	Ratio of concentration
Feed	100·00	0·19*	100·00	
Blanket concentrate	0·37	38·03	73·86	270 : 1
" tailing	99·63	0·05	26·14	

*Calculated values.

Cyanidation:

Period of agitation, hours.	Assay, Au, oz./ton		Extraction, per cent	Reagents consumed, lb./ton tailing	
	Feed	Tailing		KCN	CaO
24	0·05	0·01	80·00	2·82	8·84
48	0·05	0·005	90·00	4·55	9·00

Summary:

Recovery of gold by blankets		73·86 per cent
" " " " cyanidation in 24 hours	80·00 × 26·14 =	20·91 "
Over all recovery of gold		94·77 "
Recovery of gold by cyanidation in 48 hours	90·00 × 26·14 =	23·53 per cent
" " " " blankets		73·86 "
Overall recovery of gold		97·39 "

BLANKET CONCENTRATION AND FLOTATION

Test No. 3

A representative sample of −14-mesh ore was ground in a jar mill, dilution 4 : 3, to give a product approximately 72 per cent −200 mesh.

The ground pulp was concentrated on a corduroy blanket and the blanket tailing was dewatered and treated by flotation using the following reagents:—

Soda ash	3·0 lb./ton
Potassium amyl xanthate	0·2 "
Pine oil	0·1 "

Results:

Blanket Concentration:

Product	Weight, per cent	Assay, Au, oz./ton	Distribution of gold, per cent	Ratio of concentration
Feed	100·00	0·27*	100·00	
Blanket concentrate	0·92	23·47	78·42	109 : 1
" tailing	99·08	0·06	21·58	

*Calculated value.

Flotation:

Products	Weight, per cent	Assay		Distribution, per cent		Ratio of concentration
		Au, oz./ton	Cu, per cent	Au	Cu	
Feed	100·00	0·06	0·43	100·00	100·00	
Flotation concentrate	10·63	0·48	3·82	85·14	93·81	9·4 : 1
Flotation tailing	89·37	0·01	0·03	14·86	6·19	

Summary:

Recovery of gold on blanket	78·42 per cent
" " " by flotation, 85·14 × 21·58	18·37 "
Overall recovery of gold	96·79 "

Test No. 4

A representative sample of −14-mesh ore was ground in a jar mill, dilution 4 : 3, to give a product approximately 83 per cent −200 mesh.

The ground pulp was concentrated on a corduroy blanket and treated by flotation similarly to Test No. 3.

Reagents for Flotation:

Soda ash	3·0 lb./ton
Potassium amyl xanthate	0·2 "
Pine oil	0·1 "

Results:

Blanket Concentration:

Products	Weight, per cent	Assay, Au, oz./ton	Distribution of gold, per cent	Ratio of concentration
Feed	100·00	0·24*	100·00	
Blanket concentrate	0·47	37·66	74·78	213 : 1
" tailing	99·53	0·06	25·22	

*Calculated value.

Flotation:

Products	Weight, per cent	Assay		Distribution, per cent		Ratio of concentration
		Au, oz./ton	Cu, per cent	Au	Cu	
Feed	100·00	0·06	0·44*	100·00	100·00	
Flotation concentrate	10·79	0·43	3·88	91·16	95·92	9·3 : 1
Flotation tailing	89·21	0·005	0·02	8·84	4·08	

*Calculated value.

Summary:

Recovery of gold by blankets	74·78 per cent
" " " flotation, 91·16 × 25·22	22·99 "
Overall recovery of gold	97·77 "

BLANKET CONCENTRATION FOLLOWED BY FLOTATION AND CYANIDATION

Four tests were made to show the effect of different flotation reagents and different amounts of each reagent. In each test the ground ore was concentrated on a corduroy blanket to remove particles of free gold before flotation. The flotation tailing was treated by cyanidation.

Representative samples were ground in jar mills, dilution 4 : 3, to give approximately 77 per cent −200-mesh products, and concentrated on a corduroy blanket.

Test No. 5

The blanket tailing was treated by flotation using the following reagents:—

Lime	1·0 lb./ton
Sodium ethyl xanthate	0·10 "
Pine oil	0·05 "

The flotation tailing was treated by cyanidation by agitating representative portions in cyanide solution equivalent in strength to 1·0 pound of potassium cyanide per ton at a dilution of 3 : 1. Lime at the rate of 5·0 pounds per ton of tailing was added to give protective alkalinity to the pulp.

Results:

Blanket Concentration:

Products	Weight, per cent	Assay		Distribution of gold, per cent	Ratio of concentration
		Au	Ag		
Feed	100·00	0·18*	0·07	100·00	
Blanket concentrate	0·62	16·66	3·74	56·49	161 : 1
" tailing	99·38	0·08	....	43·51	

*Calculated value.

Flotation:

Products	Weight, per cent	Assay		Distribution, per cent		Ratio of concentration
		Au, oz./ton	Cu, per cent	Au	Cu	
Feed	100·00	0·08	0·41	100·00	100·00	
Flotation concentrate	7·98	0·60	4·88	63·44	95·49	12·5 : 1
Flotation tailing	92·02	0·03	0·02	36·56	4·51	

Cyanidation:

Period of agitation, hours	Assay, Au, oz./ton		Extraction, per cent	Reagents consumed, lb./ton tailing	
	Feed	Tailing		KCN	CaO
24	0·03	0·005	83·33	0·82	4·36
48	0·03	0·002	93·33	1·48	4·37

Summary of Results:

Recovery of gold on blankets .... 56·49 per cent
" " " by flotation .... 63·44 × 43·51 = 27·60 "

" by blankets and flotation .... 84·09 "

Gold available for cyanidation .... 36·56 × 43·51 = 15·91 per cent
Recovery by cyanidation in 24 hours .... 83·33 × 15·91 = 13·26 "
" " " " 48 " .... 93·33 × 15·91 = 14·85 "

Overall recovery .... 84·09 + 13·26 = 97·35 per cent
" " .... 84·09 + 14·85 = 98·94 "

Test No. 6

The blanket tailing was treated by flotation using the following reagents:—

Lime .... 3·0 lb./ton
Sodium ethyl xanthate .... 0·10 "
Pine oil .... 0·05 "

Representative portions of the flotation tailing were treated by cyanidation similarly to Test No. 5.

Results:

Blanket Concentration:

Products	Weight, per cent	Assay, oz./ton		Distribution of gold, per cent	Ratio of concentration
		Au	Ag		
Feed	100·00	0·23	0·07	100·00	
Blanket concentrate	0·52	48·65	8·74	80·88	192 : 1
" tailing	99·48	0·06	....	19·12	

Flotation:

	Weight, per cent	Assay		Distribution, per cent		Ratio of concentration
		Au, oz./ton	Cu, per cent	Au	Cu	
Feed	100·00	0·06	0·43	100·00	100·00	
Flotation concentrate	4·96	0·70	7·62	54·91	88·84	20 : 1
Flotation tailing	95·04	0·03	0·05	45·09	11·16	

Cyanidation:

Period of agitation, hours	Assay, Au, oz./ton		Extraction, per cent	Reagents consumed, lb./ton tailing	
	Feed	Tailing		KCN	CaO
24	0·03	0·005	83·33	0·80	4·1
48	0·03	0·002	93·33	1·80	4·1

Summary of Results:

Recovery on blanket		80·88 per cent
" by flotation	19·12 × 54·91 =	10·50 "
" " blanket and flotation		91·38 "
Gold available for cyanidation	45·09 × 19·12 =	8·62 per cent
Recovery by cyanidation in 24 hours	83·33 × 8·62 =	7·18 "
" " " " 48 "	93·33 × 8·62 =	8·05 "
Overall recovery	91·38 + 7·18 =	98·56 per cent
" "	91·38 + 8·05 =	99·43 "

Test No. 7

The blanket tailing was treated by flotation using the following reagents:—

Lime	1·0 lb./ton
Sodium cyanide	0·10 "
Sodium ethyl xanthate	0·10 "
Pine oil	0·05 "

Representative portions of the flotation tailing were treated by cyanidation similarly to Test No. 5.

Results:

Blanket Concentration:

Products	Weight, per cent	Assay, Au, oz./ton	Distribution of gold, per cent	Ratio of concentration
Feed	100·00	0·23	100·00	
Blanket concentrate	0·69	20·61	64·17	145 : 1
" tailing	99·31	0·08	35·83	

Flotation:

Products	Weight, per cent	Assay		Distribution, per cent		Ratio of concentration
		Au, oz./ton	Cu, per cent	Au	Cu	
Feed	100·00	0·08	0·40	100·00	100·00	
Flotation concentrate	2·16	2·38	17·26	67·72	92·69	46 : 1
Flotation tailing	97·84	0·025	0·03	32·28	7·31	

Cyanidation:

Period of agitation, hours	Assay, Au, oz./ton		Extraction, per cent	Reagents consumed, lb./ton tailing	
	Feed	Tailing		KCN	CaO
24	0·025	0·005	80·00	0·82	4·21
48	0·025	0·002	92·00	1·82	4·23

Summary of Results:

Recovery on blanket			64·17 per cent
Recovery by flotation	35·83 × 67·72	=	24·26 "
" " blanket and flotation			88·43 "
Gold available for cyanidation	35·83 × 32·28	=	11·57 per cent
Recovery by cyanidation in 24 hours	80·0 × 11·57	=	9·26 "
" " " "48 "	92·0 × 11·57	=	10·64 "
Overall recovery	88·43 + 9·26	=	97·69 per cent
" "	88·43 + 10·64	=	99·07 "

Test No. 8

The blanket tailing was treated by flotation using the following reagents:—

Lime	3·0 lb./ton
Sodium cyanide	0·10 "
Sodium ethyl xanthate	0·10 "
Pine oil	0·05 "

Representative portions of the flotation tailing were treated by cyanidation similarly to Test No. 5.

Results:

Blanket Concentration:

Products	Weight, per cent	Assay, Au, oz./ton	Distribution, per cent	Ratio of concentration
Feed	100·00	0·23	100·00	
Blanket concentrate	0·49	37·96	75·70	204 : 1
" tailing	99·51	0·06	24·30	

Flotation:

Products	Weight, per cent	Assay		Distribution, per cent		Ratio of concentration
		Au, oz./ton	Cu, per cent	Au	Cu	
Feed	100·00	0·06	0·41	100·00	100·00	
Flotation concentrate	2·44	1·56	15·60	66·15	92·85	41 : 1
Flotation tailing	97·56	0·02	0·03	33·85	7·15	

Cyanidation:

Period of agitation, hours	Assay, Au, oz./ton		Extraction, per cent	Reagents consumed, lb./ton tailing	
	Feed	Tailing		KCN	CaO
24	0·02	0·003	85·00	0·82	4·0

Summary of Results:

Recovery of gold on blanket		75·70 per cent
" " " by flotation	24·30 × 66·15 =	16·07 "
Recovery of gold by blanket and flotation		91·77 "
Gold available for cyanidation, 33·85 × 24·3 = 8·23 per cent		
Recovery by cyanidation in 24 hours	85·0 × 8·23 =	7·00 "
Overall recovery of gold	91·77 + 7·00 =	98·77 per cent

BLANKET CONCENTRATION FOLLOWED BY FLOTATION AND CYANIDATION CYCLE TESTS ON FLOTATION TAILING

Test No. 9

Representative samples of −14-mesh ore were ground in jar mills, dilution 4 : 3, to give a product approximately 80 per cent −200 mesh. The ground pulp was concentrated on a corduroy blanket and the blanket tailing was treated by flotation using the following reagents:—

Lime	1·0 lb./ton
Sodium cyanide	0·1 "
Sodium ethyl xanthate	0·1 "
Pine oil	0·05 "

The flotation concentrate was cleaned in a smaller cell by the addition of lime only.

The re-cleaned concentrate assayed 4·36 ounces of gold per ton and 30 per cent copper.

The flotation tailing was treated by cyanidation. The same solution was used for 10 charges of tailing. Each charge was agitated for 24 hours at a dilution of 3 : 1.

The strength of the solution was 1·0 pound of potassium cyanide per ton and lime was added at the rate of 5·0 pounds per ton of tailing.

There was no appreciable fouling of the solution.

Results:

Blanket Concentration:

Products	Weight, per cent	Assay, Au, oz./ton	Distribution, per cent	Ratio of concentration
Feed	100·00	0·26*	100·00	
Blanket concentrate	0·25	75·87	73·10	400 : 1
" tailing	99·75	0·07	26·90	

*Calculated value.

Flotation:

Products	Weight, per cent	Assay		Distribution, per cent		Ratio of concentration
		Au, oz./ton	Cu, per cent	Au	Cu	
Feed	100·00	0·07	0·35*	100·00	100·00	
Flotation concentrate	0·85	4·36	29·90	55·46	71·93	118 : 1
Flotation tailing	99·15	0·03	0·10	44·54	28·07	

*Calculated value.

Summary of Results:

Recovery of gold on blanket.................................. 73·10 per cent
" " " by flotation..................26·90 × 55·46 = 14·92 "
" " " " blanket and flotation..................... 88·02 "

Gold available for cyanidation, 26·90 × 44·54 = 11·98 per cent
Maximum recovery in 24 hours..................83·33 × 11·98 = 9·98 "

Overall recovery of gold........................88·02 + 9·98 = 98·00 per cent

Results of Cyanidation of Flotation Tailing:

Cycle No.	Assay, Au, oz./ton. Feed	Assay, Au, oz./ton. Tailing	Extraction, per cent	
1	0·03	0·01	66·67	
2	0·03	0·005	83·33	Analysis of cyanide solution.
3	0·03	0·005	83·33	Reducing power =
4	0·03	0·01	66·67	685 c.c. N/10 $KMnO_4$ per litre
5	0·03	0·005	83·33	KCNS = 0·855 grm. per litre
6	0·03	0·01	66·67	Fe = 0·0006 grm. per litre
7	0·03	0·01	66·67	Cu = 0·324 grm. per litre
8	0·03	0·005	83·33	
9	0·03	0·005	83·33	
10	0·03	0·005	83·33	

BLANKET CONCENTRATION FOLLOWED BY CYANIDATION CYCLE TESTS

Test No. 10

Representative samples of −14-mesh ore were ground in jar mills, dilution 4 : 3, to give a product approximately 80 per cent −200 mesh.

The ground pulp was concentrated on a corduroy blanket and the blanket tailing was treated by cyanidation in a number of cycle tests similar to those in Test No. 9.

Results:

Blanket Concentration:

Products	Weight, per cent	Assay, Au, oz./ton	Distribution of gold, per cent	Ratio of concentration
Feed	100·00	0·22*	100·00	
Blanket concentrate	0·17	98·20	76·98	588 : 1
" tailing	99·83	0·05	23·02	

* Calculated value.

Summary of Results:

Recovery of gold on blanket		76·98 per cent
" " " by cyanidation	90·0 × 23·02 =	20·72 "
Overall recovery of gold		97·70 "

Results of Cyanidation of Blanket Tailing:

Cycle No.	Assay, Au, oz./ton Feed	Assay, Au, oz./ton Tailing	Extraction, per cent	
	0·05	0·005	90·0	Analysis of cyanide solution.
	0·05	0·001	98·0	Reducing power =
	0·05	0·01	80·0	729 c.c. N/10 $KMnO_4$ per litre
4	0·05	0·005	90·0	KCNS = 0·71 grm. per litre
5	0·05	0·005	90·0	Fe = 0·0007 grm. per litre
				Cu = 0·376 grm. per litre

BLANKET CONCENTRATION, AND TABLING OF THE FLOTATION CONCENTRATE

Test No. 11

Representative samples of −14-mesh ore were ground in jar mills, dilution 4 : 3, to give a product approximately 80 per cent −200 mesh.

The ground pulp was concentrated on a corduroy blanket and the tailing was treated by flotation using the following reagents:

Lime	1·0 lb./ton
Potassium amyl xanthate	0·2 "
Pine oil	0·05 "

The flotation tailing was sampled and assayed.

The flotation concentrate was reground and concentrated on a Wilfley table.

Results:

Blanket Concentration:

Products	Weight, per cent	Assay, Au, oz./ton	Distribution of gold, per cent	Ratio of concentration
Feed	100·00	0·19*	100·00	
Blanket concentrate	0·15	78·09	62·59	667 : 1
" tailing	99·85	0·07	37·41	

*Calculated value

Flotation:

Products	Weight, per cent	Assay, Au, oz./ton	Distribution of gold, per cent	Ratio of concentration
Feed	100·00	0·07	100·00	
Flotation concentrate	10·85	0·40	58·18	9·2 : 1
" tailing	89·15	0·035	41·82	

Table Concentration:

Products	Weight, per cent	Assay, Au, oz./ton	Distribution of gold, per cent	Ratio of concentration
Feed	100·00	0·40	100·00	
Table concentrate	14·08	0·94	35·50	7 : 1
" tailing	85·92	0·28	64·50	

Summary of Results:

Recovery of gold on blanket		62·59 per cent
" " " by flotation	53·18 × 37·41 =	21·77 "
Recovery by blanket and flotation		84·36 per cent
Loss in flotation tailing	41·82 × 37·41 =	15·64 "
		100·00 "
Gold available in flotation concentrate		21·77 per cent
Recovery of gold in table concentrate	35·50 × 21·77 per cent =	7·73 per cent
Loss of gold in table tailing	64·50 × 21·77 " =	14·04 "
		21·77
Recovery of gold on blanket		62·59 per cent
" " " in table concentrate		7·73 "
Overall recovery of gold		70·32 "

The grade of table concentrate is too low.

SUMMARY OF EXPERIMENTAL TESTS

Blanket concentration was made on each test prior to treatment by cyanidation or flotation, or both, in order to remove particles of free gold. The ore was ground to give products from 68 per cent to 80 per cent −200 mesh. The recovery on the blankets varied from 56 per cent to over 80 per cent of the gold. An average recovery of at least 70 per cent may be expected.

The blanket tailing may be treated by flotation to give a high-grade concentrate carrying over 4 ounces of gold per ton and 30 per cent of copper. The flotation tailing assayed 0·03 ounce of gold per ton.

Cyanidation of the flotation tailing gave an overall recovery of 98 per cent of the gold with high consumption of cyanide and lime. Cycle tests carried out on this tailing showed no appreciable fouling of solution.

Cyanidation of the blanket tailing gave a recovery of from 80 to 85 per cent of the gold in the tailing, and an overall recovery of 95 per cent. The consumption of reagents is high.

Cycle tests on the blanket tailing of Test No. 10 showed recoveries of from 80 to 98 per cent with no evidence of solution fouling. The consumption of reagents is high.

Table concentration of reground flotation concentrate gave a recovery of 35 per cent of the gold from this feed, and in a low-grade product.

CONCLUSIONS

There are two methods of treatment open for adoption. The first is a combination of blanket concentration, flotation of the blanket tailing, and cyanidation of the flotation tailing.

The second is a combination of blanket concentration and cyanidation of the blanket tailing.

The flow-sheet in method No. 1 is quite complicated and will entail high plant and operating costs. A high-grade flotation copper concentrate can be made. However, the distance of the property from a smelter will cause high freight rates to be charged against the flotation plant. This will be offset somewhat by the sale of the copper. The cyanide annex treating the flotation tailing will operate with a minimum of cyanide consumption.

Method No. 2. is less complicated. The gold in the ore is shown to be readily soluble and good extraction can be obtained within 24 hours. Cycle tests indicate that the extraction is not reduced by repeated use of the solutions provided they are freshened with a small quantity of new solution. There is an indicated consumption of approximately 3 pounds of potassium cyanide per ton of ore milled.

It is apparent from the data that method No. 2 is the more suitable for treatment of this ore, its nature and geographical position being taken into consideration.

The ore should be ground in water and passed over blankets. Classifiers should be installed in the circuit and the grinding adjusted to give a classifier overflow product containing 65 to 70 per cent through −200-mesh screen. The classifier overflow should be thickened and filtered before passing to cyanidation. The filter cake then should be re-pulped in cyanide solution, lime added, and the pulp agitated for approximately 24 hours. The remainder of the cyanide plant will consist of the usual machinery, thickeners, filters, etc.

The fact that the gold is readily soluble in a short period of agitation will tend to keep the cyanide solutions active and fairly free from excessive fouling. Wash water on the filters, in all probability, will be sufficient to keep the solutions fresh without the bleeding of solutions necessary on some ores of this type.

Ore Dressing and Metallurgical Investigation No. 622

GOLD ORE FROM THE MOOSHLA GOLD MINES, BOUSQUET TOWNSHIP, QUEBEC

Shipment. A shipment of gold ore, consisting of 50 bags, approximate weight 2,500 pounds, was received from the Mooshla Gold Mines, Limited, Bousquet township, Abitibi county, Quebec, on February 18, 1935. The shipment was submitted by D. M. Giachino, Noranda, Quebec.

Characteristics of the Ore. The *gangue* consists chiefly of fine-textured greenish grey siliceous rock with a minor quantity of grey quartz. A small amount of carbonate is finely disseminated in the rock.

The *metallic minerals*, in their order of abundance in the sections examined, are: pyrite, chalcopyrite, pyrrhotite, sphalerite, native gold, and galena.

Most of the pyrite occurs in coarsely-crystalline masses which contain veinlets of pyrrhotite, but a small quantity is disseminated as coarse to fine grains and crystals. A little pyrite which is probably of later origin is present as zones along fractures in the pyrrhotite, indicating that it has resulted from the alteration of the latter.

Chalcopyrite occurs as masses and irregular grains, and is mostly coarse. It veins the early pyrite.

Pyrrhotite is common as small masses and grains, and is usually associated with pyrite, which it veins. It contains sphalerite and, very rarely, chalcopyrite.

Sphalerite occurs as small irregular grains in pyrrhotite and more rarely in chalcopyrite. It does not contain dots of chalcopyrite, as is commonly the case.

Native gold is common, its chief associate being chalcopyrite. It occurs as: (a) irregular grains around the borders of, and also within, chalcopyrite; (b) irregular grains around the borders of, and within, pyrrhotite; (c) irregular grains within pyrite; (d) irregular grains within sphalerite; (e) irregular grains in gangue; and (f) rare tiny grains in gangue which appear to be sections of dodecahedra, and which may be crystals.

A quantitative microscopic analysis gives the following data on the occurrence of the native gold.

		Per cent
(a)	Associated with chalcopyrite:	
	1. Against chalcopyrite	68·70
	2. Within "	4·22
		72·92
(b)	Associated with pyrrhotite:	
	1. Against pyrrhotite	4·70
	2. Within "	0·34
		5·04
(c)	Within pyrite	1·54
(d)	Within sphalerite	1·28
(e)	Within gangue	19·22
	Total	100·00

Grain Size of the Gold. Table I shows the grain size of the gold, as determined by microscopic analysis. In all, 168 grains were measured, and the results are regarded as unusually accurate for such analyses.

TABLE I

Grain Size of the Gold

Mesh	Associated with chalcopyrite, per cent		Associated with pyrrhotite, per cent		In gangue, per cent	Within pyrite, per cent	Within sphalerite, per cent	Total gold, per cent
	Against	Within	Against	Within				
+ 48....	3·96	....	....	....	....	....	....	3·96
− 48 + 65....	6·26	....	....	....	....	....	....	6·26
− 65 + 100....	11·49	....	....	....	....	....	....	11·49
− 100 + 150....	17·05	....	....	....	1·34	....	....	18·39
− 150 + 200....	12·04	0·96	0·89	....	1·92	....	0·96	16·77
− 200 + 280....	8·86	0·68	1·10	....	2·55	....	....	13·19
− 280 + 400....	4·37	1·06	1·06	....	3·74	....	....	10·23
− 400 + 560....	1·97	0·46	0·80	0·34	2·38	....	....	5·95
− 560 + 800....	1·21	0·32	0·61	....	2·30	0·51	0·32	5·27
− 800 + 1,100....	1·19	0·33	0·24	....	2·00	0·38	....	4·14
−1,100 + 1,600....	0·30	0·31	....	....	1·71	0·41	....	2·73
−1,600 + 2,300....	....	0·09	....	....	0·82	0·18	....	1·09
−2,300	....	0·01	....	....	0·46	0·06	....	0·53
Totals..........	68·70	4·22	4·70	0·34	19·22	1·54	1·28	100·00
	72·92		5·04		19·22	1·54	1·28	100·00

The character of the ore from Mooshla Gold Mines is somewhat complex. Certain generalizations can be made as to the effect of this upon its treatment. The presence of cyanicides (chalcopyrite and pyrrhotite) in some abundance eliminates the possibility of extracting the gold by cyaniding the raw ore and indicates the advisability of attempting a separation of the metallic constituents.

About 73 per cent of the gold is associated with chalcopyrite which is comparatively coarse, and a copper flotation concentrate should carry a large percentage of the gold with only moderate grinding. As will be seen in the grain analysis, most of this gold is comparatively coarse and much of it should be amenable to amalgamation; it is possible, also, that the use of blankets to catch some of the coarser grains might be advisable.

The gold remaining in the flotation tailing is largely in the gangue (about 19 per cent) and associated with pyrrhotite (about 5 per cent). It would seem advisable to attempt to include the "pyrrhotite" gold also in the concentrate, in which case the treatment of the tailing by cyanide would be simplified. If this cannot be done, some method of rendering the pyrrhotite of the tailing inert must be employed or the consumption of cyanide will be excessive. It will be noted that the gold in the gangue is considerably finer than that with chalcopyrite. This suggests regrinding the flotation tailing before treatment with cyanide.

The above suggestions were based on the character of the ore as determined microscopically, and were advanced, tentatively, for the purpose of assisting the engineer in the investigation of methods of treatment.

Sampling and Assaying. The shipment was crushed and sampled by standard methods. The results of the assay on the feed sample were as follows:—

Gold	1·16 oz./ton
Silver	1·06 "
Copper	0·52 per cent
Arsenic	0·02 "

Experimental Tests

Experimental work embraced laboratory tests by amalgamation, blanket concentration, flotation, and cyanidation.

The results of the test work follow:

Test No. 1

This was a barrel-amalgamation test on the ore to determine the amount of free-milling gold present at the grinding size indicated.

A sample of crushed ore was ground and then amalgamated in a jar mill with 100 grammes of mercury for 1 hour.

Gold in the feed	1·16 oz./ton
Gold in amalgamation tailing	0·34 "
Recovery by amalgamation	70·69 per cent

Screen Test on Tailing:

Mesh	Weight, per cent
+ 48	0·2
+ 65	1·1
+100	10·3
+150	15·9
+200	19·4
−200	53·1
	100·0

The results indicate that at a grinding size of 53 per cent −200 mesh, 70 per cent of the gold is free-milling.

Test No. 2

This was a blanket test in which a sample (1,000 grammes) of ore was ground for 20 minutes and the pulp then run over a corduroy blanket. The tailing was reground for 10 minutes and cyanidation tests were made on the reground product, using a solution of concentration equivalent to 1 pound of potassium cyanide per ton.

Products	Weight, per cent	Assay, Au, oz./ton	Distribution of gold, per cent	Ratio of concentration
Feed	100·00	1·16	100·00	
Concentrate	7·22	8·80	60·88	13·85 : 1
Tailing	92·78	0·44	39·12	

Cyanidation of Blanket Tailing:

Period of agitation, hours	Assay, Au, oz./ton		Extraction, per cent	Reagents consumed, lb./ton		Pulp dilution
	Feed	Tailing		KCN	CaO	
24	0·44	0·16	63·64	2·70	7·99	3 : 1
48	0·44	0·10	77·27	3·30	9·45	3 : 1

Screen Test of Cyanide Tailing:

Mesh	Weight, per cent
+100	0·1
+150	1·4
+200	10·1
−200	88·4
	100·0

The results of the cyanidation tests indicate a rather high consumption of cyanide.

FLOTATION

The following two tests were bulk flotations:

Test No. 3

Charge to Mill:

14-mesh ore	1000 grammes
Soda ash	4·0 lb./ton
Grinding time	30 minutes

Reagents to Cell:

Potassium amyl xanthate	0·4 lb./ton
Soda ash	2·0 "
Pine oil	0·15 "

Product	Weight, per cent	Assay		Distribution, per cent		Ratio of concentration
		Au, oz./ton	Cu, per cent	Au	Cu	
Feed	100·00	1·16	0·52	100·00	100·00	
Concentrate	12·38	8·43	4·12	87·51	98·31	8·08 : 1
Tailing	87·62	0·17	0·01	12·49	1·69	

Screen Test of Tailing:

Mesh	Weight, per cent
+100	1·0
+150	5·8
+200	21·5
−200	71·7
	100·0

Test No. 4

In this test 6 pounds of soda ash per ton was added to the grinding along with 0·07 pound of Aerofloat No. 31 per ton.

Reagents to Cell:

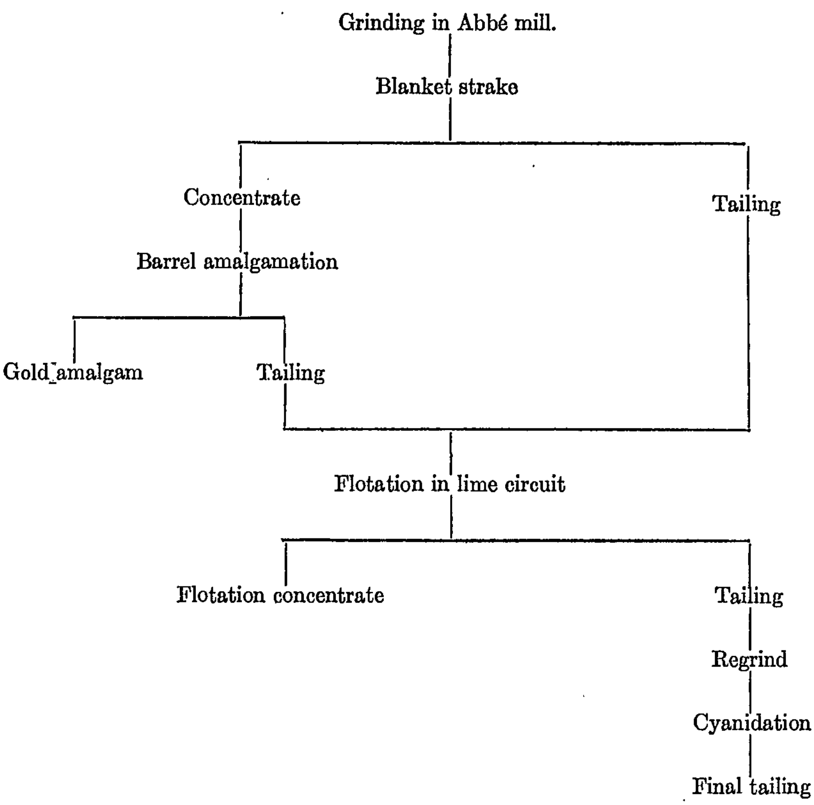
Potassium amyl xanthate	0·4 lb./ton
Pine oil	0·10 "

Product	Weight, per cent	Assay		Distribution, per cent		Ratio of concentration
		Au, oz./ton	Cu, per cent	Au	Cu	
Feed................	100·0	1·16	0·52	100·00	100·0	
Concentrate.........	13·8	7·46	3·56	87·22	95·0	7·25 : 1
Tailing..............	86·2	0·175	0·03	12·78	5·0	

Bulk flotation alone is not satisfactory, but the tests indicated that by re-floating the concentrate better results might ensue.

Test No. 5

In this test, a combination of blanket, amalgamation, flotation, and cyanidation tests was carried out. The flow-sheet was as follows:—



Blanket Test:

Product	Weight, per cent	Assay, Au, oz./ton	Distribution of gold, per cent	Ratio of concentration
Feed	100·00	1·16	100·00	
Concentrate	1·99	35·64	61·13	50·25 : 1
Tailing	98·01	0·46	38·87	

Barrel Amalgamation of Blanket Concentrate:

Gold in concentrate .... 35·64 oz./ton
Gold recovered in amalgamation .... 29·466 "
Gold recovery by amalgamation .... 82·68 per cent
Total gold recovered by amalgamation 82·68 per cent of 61·13 per cent. = 50·54 per cent

Bulk Flotation of Mixed Blanket and Amalgamation Tailings: For conditioning, the reagents added to the cell were:

Lime .... 8·0 lb./ton
Amyl xanthate .... 0·2 "
Pine oil .... 0·05 "

Product	Weight, per cent	Assay		Distribution, per cent		Ratio of concentration
		Au, oz./ton	Cu, per cent	Au	Cu	
Feed	100·00	0·49	....	100·00	100·00	
Concentrate	5·21	5·79	8·30	62·62	85·08	19·19 : 1
Tailing	94·79	0·19	0·08	37·38	14·92	

Cyanidation of Flotation Tailing. Cyanidation tests for periods of 24 and 48 hours were carried out on samples of the flotation tailing. The strength of cyanide solution was equivalent to 1 pound of potassium cyanide per ton at the start of the run.

Tests on Unground Tailing:

Period of agitation, hours	Assay, Au, oz./ton		Extraction, per cent	Reagents consumed, lb./ton		Pulp dilution
	Feed	Tailing		KCN	CaO	
24	0·19	0·06	68·42	1·5	5·95	3 : 1
48	0·19	0·05	73·68	2·58	6·25	3 : 1

Tests on Reground Tailing:

Period of agitation, hours	Assay, Au, oz./ton		Extraction, per cent	Reagents consumed lb./ton		Pulp dilution
	Feed	Tailing		KCN	CaO	
24	0·19	0·055	71·05	2·67	6·40	3 : 1
48	0·19	0·045	76·32	3·27	7·25	3 : 1

Screen Test on Reground Tailing:

Mesh	Weight, per cent
+150	0·1
+200	3·1
−200	96·8
	100·0

Summary of Results:

Gold recovered by blankets	61·13 per cent
Gold recovered by barrel amalgamation of blanket concentrate = 82·68 per cent of 61·13 per cent	50·54 "
Total gold recovered by flotation = 62·62 per cent of (100-50·54)	30·97 "
Total gold recovered by cyanidation of flotation tailing = 76·32 per cent of 100- (50·54+30·97)	14·11 "
Gold recovery by amalgamation and cyanidation	64·65 "
Gold recovered in flotation concentrate	30·97 "
Overall recovery of gold	95·62 "

Bulk flotation will not produce a high-grade copper concentrate. The following tests were devoted to the production of a high-grade copper concentrate by selective flotation. These tests were carried out on the straight ore, but there is no reason to suppose that they would differ if carried out on the mixture of blanket and amalgamation tailings. The gold would, of course, be lower, owing to the removal of free gold on the blankets prior to flotation.

Test No. 6

This flotation test was made on 2,000 grammes of ore, grinding being carried out in an Abbé grinding mill. A bulk float was made, which was cleaned in a smaller cell. The middling product (tailing from refloated bulk concentrate) was reground and floated. A lime circuit was used.

The reagents added were as follows:

To Grinding:

Lime	1 lb./ton

To Bulk Flotation:

Lime	2·0 lb./ton
Potassium amyl xanthate	0·3 "
Pine oil	0·025 lb./ton

Middling reground with 1 gramme of lime and conditioned with 0·05 gramme of amyl xanthate.

Product	Weight, per cent	Assay		Distribution, per cent		Ratio of concentration
		Au, oz./ton	Cu, per cent	Au	Cu	
Feed	100·00	1·16	0·52	100·00	100·00	
Copper concentrate	2·27	13·78	9·88	32·54	44·83	44·05 : 1
Concentrate of middling	1·23	18·82	15·04	24·08	36·97	
Middling	4·50	3·95	1·41	18·49	12·68	
Primary tailing	92·00	0·26	0·03	24·89	5·52	

The copper concentrate is lower grade than the middling concentrate which would indicate that a selective float and regrinding of the bulk concentrate should improve the grade of the copper concentrate. The following tests are selective floats.

Test No. 7

This was a selective flotation test in a soda ash circuit. The bulk float was reground and conditioned with cyanide. The reagents added were as follows:

To Grinding Circuit:

Soda ash.. 4·0 lb./ton

To Cell:

Amyl xanthate.. 0·30 lb./ton
Pine oil... 0·10 "

To Regrind of Bulk Concentrate:

Soda ash.. 1·0 lb./ton

To Conditioning of Reground Concentrate:

Sodium cyanide.. 0·5 lb./ton

Product	Weight, per cent	Assay		Distribution, per cent		Ratio of concentration
		Au, oz./ton	Cu, per cent	Au	Cu	
Feed	100·00	1·16	0·52	100·00	100·00	
Copper concentrate	3·13	16·25	9·40	47·15	55·11	31·95 : 1
Middling	6·82	4·595	3·25	29·05	41·52	
Primary tailing	90·05	0·285	0·02	23·80	3·37	

Test No. 8

This flotation test was similar to Test No. 7 with exception that a lime circuit was used instead of soda ash. The results showed a better selectivity, resulting in a higher grade copper concentrate.

To the primary grind, 4 pounds of lime per ton was added. To the bulk float, 0·3 pound of amyl xanthate and 0·025 pound of pine oil were added. The bulk concentrate was reground for 10 minutes with 1 pound of lime per ton and conditioned with cyanide and additional amyl xanthate.

Product	Weight, per cent	Assay		Distribution, per cent		Ratio of concentration
		Au, oz./ton	Cu, per cent	Au	Cu	
Feed	100·00	1·16	0·52	100·00	100·00	
Copper concentrate	2·15	37·14	20·58	79·64	84·62	46·31 : 1
Middling	5·85	1·21	1·06	7·06	11·86	
Primary tailing	92·00	0·145	0·02	13·30	3·52	

The copper in the tailing is sufficiently low to render this product a suitable one for cyanidation.

Test No. 9

This test is similar to the previous test with some small changes in the amount of reagents added.

In regrinding the bulk concentrate 0·5 pound of lime per ton was used. For conditioning, the reagents added were:

Sodium cyanide	0·15 lb./ton
Amyl xanthate	0·30 "
Cresylic acid	1 drop

Product	Weight, per cent	Assay		Distribution, per cent		Ratio of concentration
		Au, oz./ton	Cu, per cent	Au	Cu	
Feed	100·00	1·16	0·52	100·00	100·00	
Copper concentrate	1·76	31·48	25·76	62·74	86·30	56·82 : 1
Middling	4·72	4·595	0·93	24·56	8·36	
Primary tailing	93·52	0·12	0·03	12·70	5·34	

Mesh	Weight, per cent
+100	0·8
+150	5·6
+200	18·5
−200	75·1
	100·0

Test No. 10

This was a duplicate of Test No. 9.

Product	Weight, per cent	Assay		Distribution, per cent		Ratio of concentration
		Au, oz./ton	Cu, per cent	Au	Cu	
Feed	100·00	1·16	0·52	100·00	100·00	
Copper concentrate	1·94	33·50	23·80	59·41	86·80	51·55 : 1
Middling	5·74	4·52	0·58	23·72	6·26	
Primary tailing	92·32	0·20	0·04	16·87	6·94	

These tests indicate that the lime circuit has a decided advantage over the soda ash; producing a more satisfactory froth and yielding a good grade of copper concentrate.

The cyanidation tests on flotation tailing already carried out indicated a rather high consumption of cyanide. This is no doubt due to the pyrrhotite in the ore rather than to the small amount of copper present in the tailing.

A sample of flotation tailing was aerated in a lime pulp prior to cyanidation and the results of these tests indicated an appreciable reduction in the consumption of cyanide.

Test No. 11

A mixed sample of flotation tailings assaying 0·16 ounce of gold per ton was reground for 10 minutes and aerated in a lime pulp (dilution 3 : 1) for 15 hours.

Cyanidation tests for 24- and 48-hour periods were carried out on the pre-aerated tailing. A solution of cyanide concentration equivalent to 1 pound of potassium cyanide per ton was used.

Agitation, hours	Assay, Au, oz./ton		Extraction, per cent	Reagents consumed, lb./ton		Pulp dilution
	Feed	Tailing		KCN	CaO	
24	0·16	0·045	71·87	0·10	4·15	2·82 : 1
48	0·16	0·02	87·50	0·59	5·02	2·80 : 1

Screen Test Cyanide Tailing:

Mesh	Weight, per cent
+150	0·8
+200	8·2
−200	91·0
	100·0

CONCLUSIONS

The results obtained from the small-scale tests carried out on the sample of ore submitted indicate that a satisfactory method of treatment can be attained by a combination of blanket concentration, barrel amalgamation, flotation, and cyanidation.

At a grinding size at which 53 per cent passed a 200-mesh screen, about 70 per cent of the gold was found to be free-milling. Traps or blankets in the mill-classifier circuit will account for a considerable proportion of this gold and remove it before flotation.

Two-stage selective flotation in a lime circuit gave a copper concentrate carrying 20 to 25 per cent copper. The bulk sulphide concentrate was reground, conditioned with cyanide, and again floated, producing a copper concentrate and pyrite concentrate (middling product.)

The flotation tailings were sufficiently low in copper to be cyanided. The pyrrhotite present will act, however, as a cyanicide, and to overcome this a pre-aeration of the pulp is carried out. The results of tests without and with pre-aeration showed a cyanide consumption of over 3 pounds to less than one pound per ton respectively.

Ore Dressing and Metallurgical Investigation No. 623

GOLD ORE FROM LITTLE LONG LAC GOLD MINES, LIMITED, GERALDTON, ONTARIO

Shipment. Seven drums, containing 1,950 pounds of gold ore, were received February 22, 1935, from the Little Long Lac Gold Mines, Limited Geraldton, Ontario, per Abbott Renick, mill superintendent. One can of cyanide residue was also received on April 2nd.

The ore was submitted to investigate the cyanidation of the ore, and of the blanket concentrate and blanket tailing produced from it. Cyanide tests were also made on the sample of cyanide residue.

Experimental Tests

The entire lot was crushed to pass 14 mesh and sampled. Analysis showed that the ore contained 0·555 ounce of gold, 0·105 ounce of silver per ton, and 0·23 per cent of arsenic.

It was fed at the rate of 70 pounds per hour to a small rod mill. Grinding was adjusted to give a product 85 to 90 per cent −200 mesh. The mill discharged over a corduroy blanket. During the three days' run, the blanket concentrate was collected and a large sample of the blanket tailing was retained for cyanide test work.

BLANKET CONCENTRATION AND CYANIDATION

Feed	0·555 oz. Au/ton
Tailing	0·20 " "
Recovery	64·0 per cent

The blanket concentrate was amalgamated without regrinding, leaving a residue containing 6·75 ounces of gold per ton.

Samples of the amalgamated concentrate were cyanided, 1 : 3 dilution for 48 and 72 hours with a solution containing 5·0 pounds of potassium cyanide per ton. Twenty pounds of lime per ton of ore was added to supply protective alkalinity.

Results:

48-hour agitation:

Feed	6·75 oz. Au/ton
Tailing	2·67 " "
Extraction	60·4 per cent

72-hour agitation:

Feed	6·75 oz. Au/ton
Tailing	3·185 " "
Extraction	52·8 per cent

Reagents Consumed, lb./ton of concentrate:

Potassium cyanide	1·8
Lime	20·0

Samples of the amalgamated concentrate were reground 95 per cent −325 mesh and cyanided as above.

Results:

48-hour agitation:

Feed	6·75 oz. Au/ton
Tailing	1·23 " "
Extraction	81·8 per cent

72-hour agitation:

Feed	6·75 oz. Au/ton
Tailing	1·69 " "
Extraction	75·0 per cent

Reagents Consumed, lb./ton of concentrate:

Potassium cyanide	11·2
Lime	14·5

ROASTING AND CYANIDATION

A sample of the amalgamated blanket concentrate was roasted at a low temperature and then finished at about 800° C. The calcine was then ground in water until 91 per cent passed 325 mesh. It was then cyanided for 72 hours, 1 : 3 dilution, with 5·0 pounds of potassium cyanide per ton solution. Ten pounds of lime per ton was added to supply protective alkalinity.

Results:

Feed—calcine	11·35 oz. Au/ton
Cyanide tailing	0·55 " "
Extraction	95·1 per cent

CYANIDATION OF BLANKET TAILING

Samples of the blanket tailing were cyanided 1 : 3 dilution with 1·0 pound of potassium cyanide per ton solution. Lime was added to the tests at the rate of 10 pounds per ton of ore. Small additions of cyanide were made during the agitation periods to maintain the strength of solution at 1·0 pound of potassium cyanide per ton.

Results:

Agitation, hours	Assay, Au, oz./ton		Extraction, per cent	Titrations, lb./ton		Reagents consumed, lb./ton	
	Feed	Tailing		KCN	CaO	KCN	CaO
24	0·20	0·045	77·5	1·0	0·6	1·2	8·0
48	0·20	0·05	75·0	1·0	0·6	1·2	8·0
72	0·20	0·06	70·0	0·9	0·5	1·5	8·5

A similar series of tests was made on tailing ground 90 per cent −325 mesh.

Results:

Agitation, hours	Assay, Au, oz./ton		Extraction, per cent	Titrations, lb./ton		Reagents consumed, lb./ton	
	Feed	Tailing		KCN	CaO	KCN	CaO
24	0·20	0·045	77·5	1·0	0·4	0·9	8·6
48	0·20	0·04	80·0	1·0	0·35	0·9	9·0
72	0·20	0·04	80·0	0·8	0·3	1·5	9·1

CYANIDATION OF THE RAW ORE

Representative portions of the ore, ground to pass various meshes, were agitated 1 : 3 dilution with 1·0 pound of potassium cyanide per ton solution and sufficient lime to maintain the alkalinity of the solution at about 0·3 pound of lime per ton.

Results:

Mesh	Agitation, hours	Assay, Au, oz./ton		Extraction, per cent	Titrations, lb./ton		Reagents consumed, lb./ton	
		Feed	Tailing		KCN	CaO	KCN	CaO
48	24	0·555	0·085	84·7	0·9	0·3	0·3	5·1
48	48	0·555	0·05	91·0	0·9	0·3	0·3	4·1
100	24	0·555	0·075	86·5	0·9	0·3	0·3	5·1
100	48	0·555	0·045	91·9	0·9	0·25	0·3	4·1
150	24	0·555	0·07	87·4	0·8	0·25	0·6	7·3
150	48	0·555	0·045	92·8	0·9	0·3	0·3	8·1
200	24	0·555	0·05	91·0	0·8	0·25	0·6	9·3
200	48	0·555	0·03	94·6	0·8	0·25	0·6	8·1

A second series of tests was made with the pulp density and strength of solution the same as those in the Little Long Lac mill.

Samples were agitated with a pulp density of 1·35, approximately 41 per cent solids. The strength of solution was maintained at 1·5 pounds of potassium cyanide and 0·5 pound of lime per ton.

Results:

Mesh	Agitation, hours	Assay, Au, oz./ton		Extraction, per cent	Titrations, lb./ton		Reagents consumed, lb./ton	
		Feed	Tailing		KCN	CaO	KCN	CaO
48	24	0·555	0·085	84·7	1·5	0·6	0·5	7·1
48	48	0·555	0·07	87·4	1·4	0·65	0·5	9·1
100	24	0·555	0·07	87·4	1·5	1·0	1·1	10·5
100	48	0·555	0·075	86·5	1·3	0·55	1·55	11·3
150	24	0·555	0·065	88·3	1·5	1·2	1·7	14·3
150	48	0·555	0·05	91·0	1·3	0·55	2·2	15·2
200	24	0·555	0·07	87·4	1·3	0·6	2·6	15·2
200	48	0·555	0·05	91·0	1·3	0·5	3·6	18·5

MILL RESIDUES

The mill residue as received was sampled and assayed. This showed the sample submitted to contain 0·075 ounce of gold per ton. A second sample was cut from the shipment and screened on a 200-mesh sieve. Assays of the two portions are as follows:—

	Weight, per cent	Au, oz./ton
+200	21·0	0·03
−200	79·0	0·08

Samples of the residue as received were cyanided for 6, 12, and 24 hours, 1 : 3 dilution with a 1·0 pound of potassium cyanide per ton solution. Five pounds of lime per ton was added to supply protective alkalinity. A second series was ground 90 per cent −325 mesh and cyanided in the same manner.

Results:

Unground:

Agitation, hours	Assay, Au, oz./ton		Extraction, per cent	Titrations, lb./ton		Reagents consumed, lb./ton	
	Feed	Tailing		KCN	CaO	KCN	CaO
6	0·075	0·08	....	0·9	0·35	0·3	4·1
12	0·075	0·06	20·0	0·9	0·35	0·3	4·1
24	0·075	0·065	13·3	0·9	0·35	0·3	4·1

Reground, 90 per cent −325 mesh:

Agitation, hours	Feed	Tailing	Extraction, per cent	KCN	CaO	KCN	CaO
6	0·075	0·065	13·3	0·9	0·45	....	....
12	0·075	0·07	9·3	0·9	0·4	....	....
24	0·075	0·06	20·0	0·9	0·3	0·3	4·1

SUMMARY AND CONCLUSIONS

Cyanidation of amalgamated blanket concentrate, both unground and reground, produces a higher tailing loss after 72 hours' agitation than after 48 hours.

The need of fine grinding is indicated on both the blanket concentrate and blanket tailing with an agitation period on the blanket tailing of between 24 and 48 hours.

A good extraction of the gold in the blanket concentrate can be obtained by roasting followed by cyanidation.

Cyanidation of the raw ore yields a higher recovery when a more dilute pulp is used in the agitators than that at present employed. A strength of cyanide solution of about 1·0 pound of potassium cyanide per ton of solution and just sufficient lime to give satisfactory thickener operation is also indicated.

Analysis of the mill tailing shows that the -200-mesh portion contains $0 \cdot 08$ ounce of gold per ton, while the $+200$-mesh part carries $0 \cdot 03$ ounce, $90 \cdot 9$ per cent of the gold in the mill residue is contained in the -200-mesh portion.

Cyanidation of the mill residue reduces it by about $0 \cdot 015$ ounce per ton.

The highest recovery obtained in these tests was by straight cyanidation. The grind should be approximately -200 mesh. Classifiers should be adjusted to lock the sulphides in the grinding circuit until they are very finely ground before passing to the agitators.

Ore Dressing and Metallurgical Investigation No. 624

GOLD ORE FROM THE WAYSIDE CONSOLIDATED GOLD MINES, LIMITED, BRIDGE RIVER DISTRICT, B.C.

Shipment. A shipment comprising one sack of gold ore, weight 60 pounds, was received on March 27, 1935, from the Wayside Consolidated Gold Mines, Limited. The sample was submitted by P. E. Ritchie, Managing Director, 475 Howe Street, Vancouver, B.C.

Characteristics of the Ore. A microscopic examination of polished sections showed that small amounts of pyrite and arsenopyrite are present as medium to fine grains and crystals. They contain rare tiny grains of galena (?) and chalcopyrite, the latter of which also occurs in the gangue as very small rare grains. No native gold was seen in the sections. The gangue is extraordinarily complex and appears to be composed of grey impure quartz mottled with small patches of white feldspathic (?) material which may be considerably altered, green chloritic rock, and a considerable amount of light pink carbonate which occurs in the above constituents as stringers, small masses, and disseminated grains.

Sampling and Assaying. The shipment was crushed and sampled by standard methods and a feed sample cut out which assayed as follows:

Gold	0·44 oz./ton
Silver	0·11 "
Arsenic	0·13 per cent

Experimental Tests

In December 1933 two sample shipments of ore were received from the Wayside property and a report of experimental tests was made under date of January 9, 1934. Reference will be made to this earlier work in this report.

The scope of the work on the present shipment of ore covered the following points:

1. Straight cyanidation of the ore.
2. Density of pulp for agitation.
3. Strength of cyanide solution.
4. Consumption of cyanide.
5. Alkalinity of solutions.
6. Approximate consumption of lime per ton of ore.
7. Cyanidation without lime.
8. Blanket concentration and effect of aeration of the pulp prior to cyanidation.

9. Association of the gold in the tailing after cyanidation.
10. Settling tests on the pulps for cyanidation.
11. Blanket concentration and flotation concentration.
12. Cyanidation of flotation concentrate.

CYANIDATION

The following are straight cyanidation tests in which different pulp densities were used. In each test the initial cyanide strength was equivalent to 1 pound of potassium cyanide per ton of solution; 5 pounds of lime per ton of ore was added to each charge at the start of the tests, and additions were added during the tests to maintain an alkalinity in terms of lime of at least 0·2 pound of lime per ton of solution.

The tests were conducted in Winchester bottles and agitation was for a period of 24 hours. The ore was ground to −48 mesh.

The results of the tests are as follows:

Test No.	Pulp dilution	Assay, Au, oz./ton		Extraction, per cent	Reagents consumed, lb./ton	
		Feed	Tailing		KCN	CaO
1	1:1	0·44	0·045	89·7	0·50	4·80
2	1·5:1	0·44	0·045	89·7	0·60	4·70
3	2:1	0·44	0·05	88·7	0·40	4·50
4	3:1	0·44	0·05	88·7	0·30	4·10

The following three tests were carried out on finer grinds and at dilution ratios of 3 : 1. The time of agitation was 24 hours and the initial strength of cyanide solution was the same as for the previous tests.

Test No.	Ore size	Assay, Au, oz./ton		Extraction, per cent	Reagents consumed, lb./ton	
		Feed	Tailing		KCN	CaO
5	−100 mesh	0·44	0·045	89·7	0·15	6·10
6	−150 mesh	0·44	0·05	88·7	0·10	6·10
7	−200 mesh	0·44	0·035	92·1	0·66	8·95

Tests carried out on the 1933 shipment indicated that fine grinding was not essential for good gold recovery. In view of this, cyanidation tests were carried out on −48-mesh ore. Several tests, however, were made on ore ground to −100, 150, and 200 mesh and the results of the tests on this present ore shipment indicate that the extraction of gold was slightly higher in the case of the −200-mesh ore.

In connexion with the fineness of grinding, it was immediately observed that the pulp settled and filtered very slowly. Further reference will be made to this condition later in the report. (*See* Settling Tests).

From cyanidation tests carried out at different pulp densities, the results showed little variation in the gold extraction.

The consumption of cyanide is around 0·5 pound of potassium cyanide equivalent per ton of ore and the strength of solution 1 pound per ton.

The consumption of lime was from 4·5 to 8·0 pounds per ton of ore depending on the fineness of the ore in the pulp. The pulp itself is distinctly alkaline, indicating the presence of a water soluble alkaline mineral in the ore.

Cyanide Tests Without Lime. In view of the fact that the ore is alkaline in a water pulp, the following cyanidation tests were run without any additions of lime during agitation. Lime was only added at the end to increase settling during filtration of the pulp.

The tests were carried out at dilution ratios of 3 : 1 with initial cyanide strength of 1 pound of potassium cyanide per ton of solution.

Test No.	Agitation, hours	Size of ore	Assay, Au, oz./ton		Extraction, per cent	Reagents consumed, lb./ton
			Feed	Tailing		KCN
8................	24	−100 mesh	0·44	0·04	90·91	1·83
9................	48	−100 mesh	0·44	0·04	90·91	2·43
10................	24	−200 mesh	0·44	0·04	90·91	1·83

BLANKET CONCENTRATION AND CYANIDATION

Test No. 11

In this test a sample of ore (1,000 grammes) was ground wet for 10 minutes and the pulp fed to a corduroy blanket.

The blanket tailing was aerated in a Denver super-agitator for 1 hour before filtering. Aeration of the pulp appreciably increased the speed of filtration.

Samples of the filtered pulp were cyanided for 24- and 48-hour periods.

Blanket Concentration:

Product	Weight, per cent	Assay	Distribution of gold, per cent	Ratio of concentration
		Au, oz./ton		
Feed....................................	100·00	....	100·00	
Concentrate..............................	6·57	4·16	69·23	15·22 : 1
Tailing..................................	93·43	0·13	30·77	

Screen Test of Blanket Tailing:

Mesh	Weight, per cent
+48	1·5
+65	4·5
+100	14·6
+150	17·0
+200	20·3
−200	42·1
	100·0

Cyanidation of Blanket Tailing:

Initial cyanide strength equivalent to 1 pound of potassium cyanide per ton of solution, 3 pounds of lime per ton of ore added at beginning of test.

Agitation, hours	Assay, Au, oz./ton		Extraction, per cent	Reagents consumed, lb./ton		Pulp dilution
	Feed	Tailing		KCN	CaO	
24	0·13	0·035	73·08	0·30	4·10	3 : 1
48	0·13	0·025	80·77	0·30	4·95	3 : 1

Test No. 12

In this the ore was ground wet for 15 minutes. The remainder of the test was carried out as for Test No. 11.

Blanket Concentration:

Product	Weight, per cent	Assay, Au, oz./ton	Distribution of gold, per cent	Ratio of concentration
Feed	100·00	....	100·00	
Concentrate	4·34	7·40	67·72	23·04 : 1
Tailing	95·66	0·16	32·28	

Screen Test of Blanket Tailing:

Mesh	Weight, per cent
+65	0·3
+100	5·3
+150	13·2
+200	24·3
−200	56·9
	100·0

Cyanidation of Blanket Tailing Test No. 12:

Agitation, hours	Assay, Au, oz./ton		Extraction of gold, per cent	Reagents consumed, lb./ton		Pulp dilution
	Feed	Tailing		KCN	CaO	
24	0·16	0·035	78·13	0·30	4·10	3 : 1
48	0·16	0·02	87·50	1·05	6·10	3 : 1

Test No. 13

This test was run for the purpose of determining if the gold in the tailing was associated with the sulphides. A quantity of cyanide tailing was mixed and conditioned in a soda ash pulp with potassium amyl xanthate and Aerofloat No. 31 and floated. The results of the test are as follows:

Product	Weight, per cent	Assay, Au, oz./ton	Distribution of gold, per cent
Concentrate	20·08	0·06	42·98
Tailing	79·92	0·02	57·02

The test is not conclusive, but there is an indication of enrichment in the concentrate, which might indicate that the sulphides carry some of the gold remaining undissolved in the tailing.

SETTLING TESTS

The tests were carried out in a tall glass tube having an inside diameter of $2\frac{1}{8}$ inches. Two series of tests were run, one at a dilution of liquid to solids of 2 : 1, and the other at a dilution of 3 : 1. In the tests of each series different amounts of lime were used in order to provide an increasing alkalinity. The concentration of cyanide was the same for each test, being equivalent to 1 pound of potassium cyanide per ton.

In the first test of the series a sample of ore was ground in an Abbé pebble jar with the necessary water, lime, and cyanide to give a final 2 : 1 pulp having 2 pounds lime per ton solids and 1 pound of potassium cyanide per ton of solution.

The pulp was transferred to the glass tube and the level of solids in decimals of feet read every five minutes. Readings were made for a 2-hour period. At the end of the test the solution was titrated for cyanide and alkalinity. In subsequent tests, cyanide was added to bring the cyanide concentration of the solution to 1 pound of potassium cyanide per ton, and the lime additions were increased to 4 and 6 pounds per ton respectively.

The results of the tests are recorded in the following tables.

Series 1

Test A

Ratio of liquid to solid.................................. 2 : 1
Lime added per ton of solids............................ 2·0 lb.
Potassium cyanide..................................... 1·0 lb./ton of solution
Alkalinity of solution at end of test...................... 0·05 lb. CaO/ton of solution
Overflow solution, cloudy.
Rate of settling, 0·110 foot/hour.

Time	Settlement of solids in feet	Cumulative settlement
0 hour 5 minutes	0·005	0·005
0 " 10 "	0·015	0·020
0 " 15 "	0·005	0·025
0 " 20 "	0·015	0·040
0 " 25 "	0·010	0·050
0 " 30 "	0·010	0·060
0 " 35 "	0·010	0·070
0 " 40 "	0·010	0·080
0 " 45 "	0·010	0·090
0 " 50 "	0·010	0·100
0 " 55 "	0·005	0·105
1 hour 0 "	0·010	0·115
1 " 5 "	0·005	0·120
1 " 10 "	0·010	0·130
1 " 15 "	0·010	0·140
1 " 20 "	0·010	0·150
1 " 25 "	0·010	0·160
1 " 30 "	0·005	0·165
1 " 35 "	0·010	0·175
1 " 40 "	0·005	0·18C
1 " 45 "	0·010	0·190
1 " 50 "	0·005	0·195
1 " 55 "	0·010	0·205
2 hours 0 "	0·015	0·220

Test B

Ratio of liquid to solid.......................... 2 : 1 (33 per cent of dry solids)
Lime added per ton of solids.................... 4·0 lb.
Alkalinity of solution at end of test............. 0·05 lb. CaO/ton of solution.
Overflow solution, cloudy.
Rate of settling, 0·182 foot/hour.

Time	Settlement of solids in feet	Cumulative settlement
0 hour 5 minutes	0·010	0·010
0 " 10 "	0·000	0·010
0 " 15 "	0·015	0·025
0 " 20 "	0·015	0·040
0 " 25 "	0·015	0·055
0 " 30 "	0·025	0·080
0 " 35 "	0·010	0·090
0 " 40 "	0·020	0·110
0 " 45 "	0·020	0·130
0 " 50 "	0·020	0·150
0 " 55 "	0·015	0·165
1 hour 0 "	0·015	0·180
1 " 5 "	0·010	0·190
1 " 10 "	0·010	0·200
1 " 15 "	0·020	0·220
1 " 20 "	0·015	0·235
1 " 25 "	0·025	0·260
1 " 30 "	0·015	0·275
1 " 35 "	0·015	0·290
1 " 40 "	0·015	0·305
1 " 45 "	0·020	0·325
1 " 50 "	0·010	0·333
1 " 55 "	0·020	0·355
2 hours 0 "	0·010	0·365

Test C

Ratio of liquid to solid.......................... 2 : 1
Lime added per ton of solids.................... 6·0 lb.
Alkalinity of solution at end of test............. 0·375 lb. CaO/ton of solution
Overflow solution, clear.
Rate of settling, 0·310 foot/hour.

Time	Settlement of solids in feet	Cumulative settlement
0 hour 5 minutes	0·010	0·010
0 " 10 "	0·010	0·020
0 " 15 "	0·005	0·025
0 " 20 "	0·015	0·040
0 " 25 "	0·040	0·080
0 " 30 "	0·030	0·110
0 " 35 "	0·025	0·135
0 " 40 "	0·035	0·170
0 " 45 "	0·030	0·200
0 " 50 "	0·040	0·240
0 " 55 "	0·045	0·285
1 " 0 "	0·035	0·320
1 " 5 "	0·040	0·360
1 " 10 "	0·030	0·390
1 " 15 "	0·035	0·425
1 " 20 "	0·035	0·460
1 " 25 "	0·030	0·490
1 " 30 "	0·020	0·510
1 " 35 "	0·025	0·535
1 " 40 "	0·025	0·560
1 " 45 "	0·015	0·575
1 " 50 "	0·015	0·590
1 " 55 "	0·020	0·610
2 hours 0 "	0·010	0·620

The pulp from the tests, Series 1, was filtered and dried and a screen test on the solids gave the following sizes:

Mesh	Weight, per cent
+65	0·1
+100	3·1
+150	12·3
+200	25·0
−200	59·5
	100·0

The tests of this series indicate that the best rate of settling along with a clear overflow solution is obtained with a pulp having an alkalinity in terms of lime of around 0·37 pound of lime per ton of solution.

Series 2

The tests of this series were started as in Series 1. The ratio of liquid to solid was 3 : 1. The grinding size was finer than the previous tests. A screen test on the whole was as follows:

Mesh	Weight, per cent
+100	0·5
+150	1·7
+200	10·5
−200	87·3
	100·0

Test A

Ratio of liquid to solid............................ 3 : 1
Lime added per ton of solids...................... 2·0 lb.
Potassium cyanide................................ 1·0 lb. CaO/ton of solution.
Alkalinity of solution at end of test............... Nil
Overflow solution, cloudy.
Rate of settling, 0·100 foot/hour.

Time	Settlement of solids in feet	Cumulative settlement
0 hour 5 minutes	0·005	0·005
0 " 10 "	0·010	0·015
0 " 15 "	0·005	0·020
0 " 20 "	0·010	0·030
0 " 25 "	0·010	0·040
0 " 30 "	0·005	0·045
0 " 35 "	0·010	0·055
0 " 40 "	0·010	0·065
0 " 45 "	0·005	0·070
0 " 50 "	0·010	0·080
0 " 55 "	0·010	0·090
1 " 0 "	0·005	0·095
1 " 5 "	0·010	0·105
1 " 10 "	0·010	0·115
1 " 15 "	0·010	0·125
1 " 20 "	0·010	0·135
1 " 25 "	0·005	0·140
1 " 30 "	0·010	0·150
1 " 35 "	0·010	0·160
1 " 40 "	0·005	0·165
1 " 45 "	0·010	0·175
1 " 50 "	0·010	0·185
1 " 55 "	0·005	0·190
2 hours 0 "	0·010	0·200

Test B

Ratio of liquid to solid................................ 3 : 1
Lime added per ton of solids.......................... 4·0 lb.
Alkalinity of solution at end of test.................... 0·05 lb. CaO/ton of solution.
Overflow solution, cloudy.
Rate of settling, 0·127 foot/hour.

Time	Settlement of solids in feet	Cumulative settlement
0 hour 5 minutes	0·005	0·005
0 " 10 "	0·005	0·010
0 " 15 "	0·010	0·020
0 " 20 "	0·010	0·030
0 " 25 "	0·010	0·040
0 " 30 "	0·005	0·045
0 " 35 "	0·015	0·060
0 " 40 "	0·010	0·070
0 " 45 "	0·010	0·080
0 " 50 "	0·025	0·105
0 " 55 "	0·015	0·120
1 " 0 "	0·010	0·130
1 " 5 "	0·010	0·140
1 " 10 "	0·010	0·150
1 " 15 "	0·010	0·160
1 " 20 "	0·010	0·170
1 " 25 "	0·010	0·180
1 " 30 "	0·010	0·190
1 " 35 "	0·010	0·200
1 " 40 "	0·010	0·210
1 " 45 "	0·010	0·220
1 " 50 "	0·010	0·230
1 " 55 "	0·010	0·240
2 hours 0 "	0·015	0·255

Test C

Ratio of liquid to solids............................ 3 : 1
Lime added per ton of solids........................ 6·0 lb.
Alkalinity of solution at end of test................. 0·05 lb. CaO/ton of solution.
Overflow solution, clear.
Rate of settling, 0·307 foot/hour.

Time	Settlement of solids in feet	Cumulative settlement
0 hour 5 minutes	0·015	0·015
0 " 10 "	0·010	0·025
0 " 15 "	0·015	0·040
0 " 20 "	0·020	0·060
0 " 25 "	0·025	0·085
0 " 30 "	0·025	0·110
0 " 35 "	0·020	0·130
0 " 40 "	0·020	0·150
0 " 45 "	0·030	0·180
0 " 50 "	0·025	0·205
0 " 55 "	0·020	0·225
1 " 0 "	0·025	0·250
1 " 5 "	0·030	0·280
1 " 10 "	0·025	0·305
1 " 15 "	0·025	0·330
1 " 20 "	0·030	0·360
1 " 25 "	0·035	0·395
1 " 30 "	0·035	0·430
1 " 35 "	0·030	0·460
1 " 40 "	0·040	0·500
1 " 45 "	0·035	0·535
1 " 50 "	0·040	0·575
1 " 55 "	0·025	0·600
2 hours 0 "	0·015	0·615

Test D

In this test 8 pounds of lime per ton of solids was added to the pulp. The rate of settling was slowed up very appreciably, the total settlement for two hours being only 0·085 feet. It would appear from the results of this test that excess lime will retard the rate of settling.

Test E

The test was repeated on a fresh sample of ore, the lime, 8 pounds per ton, and the cyanide being ground with the ore. This made a marked difference. The pulp settled quickly leaving a clear liquid above the line of settlement.

The results of this test are given in the following table.

Rate of settling.................................... 0·277 foot/hour.
Alkalinity of solution at end of test.................. 0·20 lb. CaO/ton of solution.

Time	Settlement of solids in feet	Cumulative settlement
0 hour 5 minutes	0·015	0·015
0 " 10 "	0·020	0·035
0 " 15 "	0·030	0·065
0 " 20 "	0·030	0·095
0 " 25 "	0·025	0·120
0 " 30 "	0·035	0·155
0 " 35 "	0·020	0·175
0 " 40 "	0·030	0·205
0 " 45 "	0·025	0·230
0 " 50 "	0·025	0·255
0 " 55 "	0·025	0·280
1 " 0 "	0·025	0·305
1 " 5 "	0·020	0·325
1 " 10 "	0·020	0·345
1 " 15 "	0·025	0·370
1 " 20 "	0·020	0·390
1 " 25 "	0·020	0·410
1 " 30 "	0·020	0·430
1 " 35 "	0·025	0·455
1 " 40 "	0·020	0·475
1 " 45 "	0·020	0·495
1 " 50 "	0·020	0·515
1 " 55 "	0·020	0·535
2 hours 0 "	0·020	0·555

The results of these settling tests indicate a very slow rate of settlement. The fastest rate was on the coarsely ground ore, which showed a maximum of 0·3 foot per hour. On finer ground ore and under the most favourable conditions the rate was also 0·3 foot per hour. Attention, however, is drawn to the fact that if the ideal condition is not maintained, the settling rate indicated is on the average only 0·15 foot per hour. Taking the maximum rate, 21 square feet of thickener area would be required per ton of ore treated per 24 hours, and with the average condition, 45 or more square feet would be required.

This is a very large area in comparison with that required for the average gold ore. Most cyanide mills require 4 to 5 square feet per ton on siliceous ore and up to 10 square feet per ton on ores containing high alumina.

In addition to the above condition, attention is drawn to a filtration problem which undoubtedly presents greater difficulties than would be met with in thickening.

The colloidal slime present in the pulp, due probably to the presence of altered feldspar, would require three to four times the filter area usually required on the average gold ore.

BLANKET CONCENTRATION AND FLOTATION

On account of the difficulties encountered in the straight cyanidation of the ore, due to the presence of colloidal slime, which hindered both settlement and filtration, a series of tests using a combination of flotation and blanket concentration was made. The details of these tests follow:

Test No. 14

In this test a sample of −48-mesh ore was fed to a corduroy blanket. The blanket concentrate was barrel-amalgamated with mercury and the blanket tailing was floated. The amalgamation tailing and the flotation concentrate were combined and cyanided.

The results of the test are as follows:

Blanket Concentration:

Product	Weight, per cent	Assay, Au, oz./ton	Distribution of gold, per cent	Ratio of concentration
Feed	100·00	0·44	100·00	42·92 : 1
Concentrate	2·33	10·71	56·71	
Tailing	97·67	0·195	43·29	

The blanket concentrate was barrel-amalgamated for 1 hour.

Flotation of Blanket Tailing:

Reagents Added:

Soda ash	1·5 lb./ton
Potassium amyl xanthate	0·3 "
Aerofloat No. 31	0·07 "
Pine oil	0·025 "

Product	Weight, per cent	Assay, Au, oz./ton	Distribution of gold, per cent	Ratio of concentration
Feed	100·00	0·195	100·00	
Concentrate	3·43	4·84	85·14	29·24 : 1
Tailing	96·57	0·03	14·86	

The combined amalgamation tailing and the flotation concentrate were cyanided in a solution having a strength equivalent to 3 pounds of potassium cyanide per ton. The pulp dilution ratio was 3 : 1. Time of agitation was 24 hours.

The cyanide tailing assayed 0·35 ounce of gold per ton with a reagent consumption of 2·70 pounds of potassium cyanide per ton and 3·50 pounds of lime per ton.

The calculated assay on the combined blanket and flotation concentrates was 7·78 ounces of gold per ton.

The recovery by amalgamation and cyanidation was 95·5 per cent.

Screen Test Blanket Tailing:

Mesh	Weight, per cent
+65	14·4
+100	26·9
+150	15·2
+200	13·7
−200	29·8
	100·0

Summary of Results:

Gold recovered in blanket concentrate	56·71 per cent
" " " flotation concentrate 85·14 per cent of 43·29 per cent	36·86 "
Total gold recovered by blankets and flotation	93·57 "
Overall gold recovery, 95·5 per cent of 93·57 per cent	89·36 per cent

Test No. 15

This test was carried out on a finer ground ore in a similar manner to Test No. 14.

The results of the test follow:

Blanket Concentration:

Product	Weight, per cent	Assay, Au, oz./ton	Distribution of gold, per cent	Ratio of concentration
Feed	100·00	0·44	100·00	
Concentrate	2·02	11·11	51·01	49·5 : 1
Tailing	97·98	0·22	48·99	

The blanket concentrate was barrel-amalgamated for 1 hour.

Flotation of Blanket Tailing:

Reagents Added:

Soda ash	1·5 lb./ton
Potassium amyl xanthate	0·3 "
Aerofloat No. 31	0·07 "
Pine oil	0·025 "

Product	Weight, per cent	Assay, Au, oz./ton	Distribution of gold, per cent	Ratio of concentration
Feed	100·00	0·22	100·00	
Concentrate	3·21	5·80	84·6	31·15 : 1
Tailing	96·79	0·035	15·4	

Cyanidation of Flotation Concentrate:

The combined amalgamation tailing and flotation concentrate was cyanided under conditions similar to the previous test.

The cyanide tailing assayed 0·41 ounce of gold per ton, and the reagent consumption was 1·20 pounds of potassium cyanide and 4·10 pounds of lime per ton of ore respectively.

The calculated assay on the combined blanket and flotation concentrates was 8·40 ounces of gold per ton. The gold recovery by amalgamation and cyanidation was 95·12 per cent.

Screen Test of Blanket Tailing:

Mesh	Weight, per cent
+100	11·1
+150	17·8
+200	21·9
−200	49·2
	100·0

Summary of Results, Test No. 15:

Gold recovered in blanket concentrate	51·01	per cent
" " " flotation concentrate, 84·6 per cent of 48·99 per cent	41·45	"
Total gold recovered by blanket and flotation	92·46	"
Overall recovery of gold, 95·12 per cent of 92·46 per cent	87·95	"

Test No. 16

This was a further test on blanket concentration and flotation of the ore. A sample of ore was ground wet in an Abbé mill for 17 minutes and the pulp passed over a corduroy blanket. Free gold was observed in the blanket concentrate. The blanket tailing was dewatered and transferred to a flotation cell and conditioned with the following reagents:

Pine oil	0·025	lb./ton
Barrett No. 4	0·176	"
Potassium amyl xanthate	0·20	"

The results of the tests are as follows:

Blanket Concentration:

Product	Weight, per cent	Assay, Au, oz./ton	Distribution of gold, per cent	Ratio of concentration
Feed	100·00	0·44	100·00	
Concentrate	2·61	9·79	63·62	38·31 : 1
Tailing	97·39	0·15	36·38	

Flotation of Blanket Tailing:

Product	Weight, per cent	Assay, Au, oz./ton	Distribution of gold, per cent	Ratio of concentration
Feed	100·00	0·15	100·00	
Concentrate	3·22	4·04	81·75	31·06 : 1
Tailing	96·78	0·03	18·25	

Screen Tests:

Blanket Tailing:

Mesh	Weight, per cent
+65	0·6
+100	4·3
+150	10·5
+200	22·2
−200	62·4
	100·0

Flotation Tailing:

Mesh	Weight, per cent
+65	0·6
+100	6·3
+150	12·1
+200	24·4
−200	56·6
	100·0

Filtration of the flotation concentrate was slow.

Gold recovered in blanket concentrate........................	63·62 per cent
Gold recovered in flotation concentrate, 81·75 per cent of 36·38	29·74 "
Overall gold recovery in concentrate..........................	93·36 "

Test No. 17

In this test the ore was ground wet, as in Test No. 16, with 0·176 pound of Barrett No. 4 per ton and floated first. The following reagents were added to the pulp in the cell and conditioned.

Potassium amyl xanthate..	0·2 lb./ton
Cresylic acid...	0·35 "

The flotation tailing was then passed over a corduroy blanket and the concentrate containing visible grains of gold was further cleaned by panning.

A small amount of zinc sulphide added to the flotation concentrate as a coagulant, decreased slightly the time of filtration.

The results of the tests follow:

Flotation:

Product	Weight, per cent	Assay, Au, oz./ton	Distribution of gold, per cent	Ratio of concentration
Feed.......................................	100·00	0·44	100·0	
Concentrate................................	3·08	12·40	86·8	32·47 : 1
Tailing....................................	96·92	0·06	13·2	

Blanket Concentration of Flotation Tailing:

Product	Weight, per cent	Assay, Au, oz./ton	Distribution of gold, per cent	Ratio of concentration
Feed.......................................	100·00	....	100·00	
Concentrate................................	0·08	109·60	74·52	12·50 : 1
Tailing....................................	99·92	0·03	25·48	

Gold recovered in flotation concentrate.......................	86·8 per cent
" " " blanket concentrate, 74·52 per cent of 13·2 per cent..	9·84 "
Overall gold recovery in concentrate.........................	96·64 "

The results of Test No. 17 indicate that primary flotation followed by blanket concentration of the flotation tailing may result in a higher overall recovery of the gold, inasmuch as the results of Tests Nos. 14 and 15 show that 95·5 per cent of the gold in the blanket and flotation concentrate can be extracted by cyanidation. Therefore, using this figure, Test No. 17 indicates a 92·3 per cent overall recovery of the gold, if the flotation concentrate is cyanided.

CONCLUSIONS

A summary of results of the experimental work as outlined in the early part of this report is as follows:

1. The ore will cyanide, the extractions shown ranging from 89 per cent when the ore is ground to pass 48-mesh to 92 per cent when ground all to pass 200-mesh.

2. The strength of cyanide solution for raw ore is one pound of potassium cyanide per ton, and 3 pounds of potassium cyanide per ton of solution for concentrates.

3. The consumption of cyanide varies with the grinding size of the ore and the ratio of pulp dilution. Consumption is greater on −200-mesh ore than −100-mesh and less in a 3 : 1 dilution than a 1 : 1. The cyanide consumption ranges from 0·10 to 0·66 pound of potassium cyanide per ton of ore. Tests carried out on raw ore without additions of lime indicated a slightly improved extraction of gold, but an increase in cyanide consumption to almost 2 pounds of potassium cyanide per ton.

4. A water pulp of the ore is alkaline.

5. The approximate consumption of lime per ton of ore ranges from 6 to 8 pounds.

6. The pulp density for cyanide agitation does not appear to be an important factor, a pulp dilution of 3 : 1 being quite satisfactory.

7. Settling tests indicated that the pulp settles slowly. Additions of lime up to 6 pounds per ton of ore increased the settling rate, while amounts in excess of 6 pounds per ton had a retarding influence.

8. Aeration of the pulp prior to cyanidation does not materially affect the settling rate, or the recovery.

9. Removal of free gold by blankets, or tables, and flotation either preceding or following the blankets, offers decided advantages in the treatment of this ore.

10. Fine grinding of the ore is not necessary and will increase the amount of slime. Grinding to a size at which 60 per cent will pass a 200-mesh screen should be satisfactory for flotation and blanket concentration.

The results of the test work conducted on the sample of ore submitted indicate that direct cyanidation of the ore in plant operation will present difficulties in settling and filtration. The feldspathic constituents of the gangue tend to the formation of slime which filters very slowly.

Concentration of the ore by flotation and blankets, with treatment of the concentrates by barrel amalgamation and cyanidation, offers a method of treatment which overcomes largely the difficulties of settling and filtration.

In this connexion attention is directed to Test No. 17, the results of which indicate that blanket concentration of the flotation tailing gives higher recoveries than when blankets are used preceding flotation. In order to obtain these results in practice, it would be necessary to use a unit flotation cell placed between the ball mill and classifier to treat the discharge of the ball mill. Such a unit would have to be protected from tramp oversize discharging from the mill.

The overall recovery indicated by this method is 92·3 per cent (Reference Test No. 17).

Ore Dressing and Metallurgical Investigation No. 625

COPPER ORE FROM THE EUSTIS MINE, CONSOLIDATED COPPER AND SULPHUR COMPANY, EUSTIS, QUEBEC

Shipment. A shipment, containing 46,000 pounds of copper ore, was received on January 10, 1935, from the Consolidated Copper & Sulphur Company, Eustis mine, Eustis, Quebec. The arrangements for the shipment and experimental tests were made by F. W. Snow, manager of the Eustis mine.

Sampling and Analysis. The whole shipment was crushed and sampled in an automatic Vezin sampler, and the sample was found to contain:—

Copper	3·90 per cent
Iron	34·80 "
Sulphur	37·50 "
Pyrrhotite	0·08 "

Characteristics of the Ore. Samples were taken from the shipment and six polished sections were prepared and examined microscopically.

The gangue is greenish grey, fine-textured chloritic schist in which a considerable amount of very finely divided carbonate occurs.

The metallic minerals are chiefly pyrite and chalcopyrite. A small amount of sphalerite and a trace of galena are present. Very rare tiny grains of an unidentified mineral (which is possibly a lead mineral) gave the following tests:—

Colour: Light grey.
Hardness: Soft, about B.
Crossed nicols: Moderately anisotropic.
Etch tests: HNO_3 — instantly blackens.
HCl — slowly tarnishes differentially grey.
$FeCl_3$ — tarnishes differentially grey to iridescent.
KOH — negative to slowly differentially brown to iridescent.
KCN, $HgCl_2$ — negative.

Pyrite occurs as fine-textured, rather dense masses, which contain small grains of chalcopyrite. In some places it forms coarsely granular masses with a ramifying network of veinlets of chalcopyrite. The chalcopyrite of this mode of occurrence, which accounts for its greater part, is comparatively coarse, but a minor amount which occurs as small grains in pyrite is quite fine (below 200 mesh).

Sphalerite is present as small masses and grains in chalcopyrite. It contains very rare tiny grains of galena. Galena also occurs as rare small grains in chalcopyrite.

The unidentified light grey mineral occurs as very rare tiny ragged plates and irregular grains in chalcopyrite.

Purpose of Investigation. The present mill treats 250 tons of ore per 24 hours and produces a copper concentrate and an iron concentrate by selective flotation.

The ore is crushed to one inch in a jaw crusher and a 4-foot Symonds cone. The cone discharge is further ground in two 5 by 6 foot Kennedy ball mills, in closed circuit with one 6-by 30-foot Dorr Duplex, Model D classifier. Lime, 2·0 to 2·5 pounds, and Aero brand cyanide, 0·40 pound, are added to the grinding circuit. The ball mill density is maintained at 85 per cent of solids.

The classifier overflow, containing 30 per cent of solids, and having a fineness of 66 to 70 per cent −200 mesh, passes to a rectangular aerator, 6 by 6 by 12 feet deep, where 0·17 pound of amyl xanthate is added, and the pulp is given 15 minutes aeration by blowing air at high pressure through several submerged hose. The secondary rougher copper concentrate and the copper cleaner tailing are pumped back to the aerator.

The aerated pulp (now containing 24 per cent of solids owing to the middling return dilution) flows by gravity into the copper rougher circuit. This circuit consists of two 12-foot Callow primary roughers, the concentrate from which passes to one 12-foot Callow cleaner; and four 18-foot Callow secondary roughers, the concentrate from which is returned to the aerator together with cleaner tailing.

The secondary copper rougher tailing is conditioned in a 15-foot Forrester cell with 3·64 pounds of soda ash, 0·34 pound of Z-8, 0·90 pound of copper sulphate, and 0·50 of sodium sulphide per ton; after which the pyrite is floated in four 18-foot Callow cells. Two cells produce a finished pyrite concentrate, and the remaining two cells produce a middling which is returned to the Forrester conditioner.

The mill results have been very erratic with the present method of selective flotation. The grade of the copper concentrate has averaged between 22 and 24 per cent of copper, and the copper tailing between 0·2 and 0·4 per cent of copper. The iron concentrate at times contains as high as 1 per cent of copper, and varies between this figure and 0·3 per cent. The sulphur content of the iron concentrate averages about 50 per cent.

During the past year the company retained Booth-Thompson and Company of Salt Lake City to investigate the possibility of reducing the cost of treatment.

The results obtained by this investigation were encouraging and indicated that a substantial saving in the cost of reagents could be made by employing a *bulk flotation scheme* in place of the present system of selective flotation.

Experimental Tests

A summary of the Booth-Thompson investigation indicated the following results:—

Combined Average Results of Tests No. 11, 13, 18, and 22:

Product	Weight, per cent	Assay		Distribution, per cent	
		Cu, per cent	Fe, per cent	Cu	Fe
Cleaner copper	14·65	27·57	32·98	96·79	16·2
Iron product	54·10	0·21	44·05	2·69	80·0
Tailing	31·25	0·069	3·67	0·52	3·8
Feed	100·00	4·17	29·80	100·00	100·0

The method employed to obtain the above results was as follows:—

An average portion of the material was ground in a ball mill to 65 mesh (72 per cent −200 mesh), air-conditioned 15 minutes with 0·15 pound of Z-8 and 1 pound of sodium silicate and treated in an "Agitair" flotation machine (6 minutes) using 0·15 pound of S. D. pine oil per ton, then air-conditioned 2 minutes with 0·05 pound of Z-8 and 1 pound of sodium silicate and continued floating for 3 minutes, using 0·05 pound of S. D. pine oil per ton, producing the copper-iron concentrate and final tailing. Density 3 : 1.

The copper-iron concentrate was air-conditioned 5 minutes with 6 pounds of lime, 0·6 pound of Aero brand cyanide and 0·05 pound of Z-5 per ton and treated by roughing and cleaning in an "Agitair" flotation machine, producing a cleaner copper concentrate and a tailing iron product.

The following is a summary of the reagents used and their quantities:—

Sodium silicate	2·0 lb./ton of ore
Butyl xanthate Z-8	0·2 " "
Pine oil	0·2 " "
Lime	6·0 " "
Aero brand cyanide	0·05 " "
Amyl xanthate Z-5	0·05 " "

The American Cyanamid Company was asked to check the results obtained by the Booth-Thompson Company.

These results, while still encouraging, did not indicate as high recoveries as were obtained by Booth-Thompson and Company, as can be seen from the following table which gives an average result.

Product	Weight, per cent	Assay			Distribution, per cent		
		Cu, per cent	Fe, per cent	Insoluble, per cent	Cu	Fe	Insoluble
Copper concentrate	16·74	26·00	32·00	1·10	95·38	18·77	0·70
Iron concentrate	48·86	0·20	43·85	4·70	2·13	73·93	8·75
Tailing	34·40	0·33	6·15	69·22	2·49	7·30	90·55
Feed	100·00	4·56	28·98	26·29	100·00	100·00	100·00

On the whole the results of the laboratory tests indicated the possibility of a substantial saving in the cost of reagents and operation.

The staff of the Ore Dressing and Metallurgical Laboratories was, therefore, required to check the results obtained by large-scale continuous tests.

Continuous Tests

The ore was crushed to $\frac{1}{4}$ inch and fed by an automatic feeder to a small ball mill in closed circuit with a standard Dorr classifier. The feed rate in all tests was 500 pounds of ore per hour.

Flow-sheet: Runs Nos. 1 to 4 Inclusive

In this run a cylindrical tank equipped with air pipes was used for air-conditioning the pulp before flotation. The tank was placed so that the circulating load was air-conditioned, that is, the ball mill discharged into the tank and the tank overflowed into the classifier. The approximate length of time in the conditioning tank was 8 minutes.

The overflow of the classifier went to a surge tank where reagents as shown before were added. The surge tank discharged to a 10-cell mechanical flotation unit where the bulk float of copper and iron was made.

The bulk concentrate went to a pump which discharged into a second surge tank feeding a second 10-cell flotation machine where the copper separation was made. The tailing from this machine was the iron concentrate.

Reagents were added to both the pump and surge tank as shown below.

In making the bulk concentrate the first five cells produced finished concentrate, and the last five cells, rougher concentrate which was returned with the feed to the machine.

In making the copper separation the feed was brought into cell No. 2. The concentrate from cells No. 2 and No. 3 was recleaned in cell No. 1 which produced final copper concentrate. Cells Nos. 4 to 10 produced a rougher concentrate which was returned with the feed to cell No. 2.

This flow-sheet was used in Runs Nos. 1 to 4 inclusive.

Run No. 1

Reagents to Circuit No. 1—Bulk Flotation:

To Ball Mill Discharge:

Sodium silicate	1·0 lb./ton
Reagent No. 301	0·15 "

To Classifier Overflow:

Sodium silicate	1·0 lb./ton

To Surge Tank:

Pine oil	0·06 lb./ton
Reagent No. 301	0·16 "

To Cell No. 7:

Reagent No. 301	0·05 lb./ton

Reagents to Circuit No. 2—Copper-iron Separation:

To Discharge of Bulk Concentrate from Circuit No. 1:

Lime	8·0 lb./ton
Cyanide	0·10 "
Pine oil	0·02 "

To Surge Tank No. 2:

Potassium amyl xanthate	0·05 lb./ton
Classifier overflow	33 to 37 per cent solids.

Screen Test:

	Weight, per cent
+65	1·5
− 65+100	6·7
−100+150	9·9
−150+200	19·0
−200	62·9
	100·0

Assay	Cu, per cent	Fe, per cent	S, per cent
Classifier overflow	4·40	33·02	36·05
Bulk concentrate	8·20	39·40	43·25
Bulk tailing	0·38	18·70	17·85
Copper concentrate	28·42	31·24	35·25
Iron concentrate	0·36	40·39	44·65

Run No. 2

Reagents to Circuit No. 1—Bulk Flotation:

To Ball Mill:
Soda ash .... 2·9 lb./ton
To Surge Tank:
Reagent No. 301 .... 0·10 lb./ton
Pine oil .... 0·06 "

To Cell No. 5: Reagent No. 301 .... 0·08 lb./ton
To Cell No. 7: " " " .... 0·08 "
To Cell No. 9: " " " .... 0·05 "

Reagents to Circuit No. 2—Copper-iron Separation:

To Discharge of Bulk Concentrate from Circuit No. 1:
Lime .... 8·0 lb./ton
Cyanide .... 0·10 "
Pine oil .... Nil
To Surge Tank No. 2:
Potassium amyl xanthate .... 0·05 lb./ton
Classifier overflow .... 27 to 33 per cent solids

Screen Test:

	Weight, per cent
+ 65	0·8
− 65+100	3·4
−100+150	5·2
−150+200	15·7
−200	74·9
	100·0

Assay	Cu, per cent	Fe, per cent	S, per cent
Classifier overflow	4·40	31·04	33·25
Bulk concentrate	7·91	40·39	44·75
Bulk tailing	0·16	13·93	12·90
Copper concentrate	29·40	31·04	35·40
Iron concentrate	0·26	42·78	46·60

Run No. 3

Reagents to Circuit No. 1—Bulk Flotation:

To Ball Mill:
Soda ash .... 2·7 lb./ton
To Surge Tank:
Potassium amyl xanthate .... 0·10 lb./ton
Pine oil .... 0·06 "

To Cell No. 5: Amyl xanthate .... 0·08 lb./ton
To Cell No. 7: " " .... 0·08 "
To Cell No. 9: " " .... 0·05 "

Reagents to Circuit No. 2—Copper-iron Separation:

To Discharge of Bulk Concentrate from Circuit No. 1:

Lime	7·0 lb./ton
Cyanide	0·10 "

To Surge Tank No. 2:

Potassium amyl xanthate	0·05 lb./ton
Classifier overflow	36 to 38 per cent solids

Screen Test:

	Weight, per cent
+ 48	0·2
− 48+ 65	0·8
− 65+100	5·0
−100+150	6·6
−150+200	18·6
−200	68·8
	100·0

Assay	Cu, per cent	Fe, per cent	S, per cent
Classifier overflow	4·24	33·63	36·35
Bulk concentrate	5·54	43·59	47·30
Bulk tailing	0·42	10·54	8·10
Copper concentrate	29·48	31·24	35·20
Iron concentrate	0·30	45·58	49·60

Run No. 4

Reagents to Circuit No. 1—Bulk Flotation:

To Ball Mill Discharge:

Sodium silicate	2·1 lb./ton

To Surge Tank:

Potassium amyl xanthate	0·16 lb./ton
Pine oil	0·06 "

To Cell No. 4: Amyl xanthate	0·08 lb./ton
To Cell No. 7: Amyl xanthate	0·08 "
Pine oil	0·05 "
Copper sulphate	0·26 "
To Cell No. 9: Amyl xanthate	0·05 "

Reagents to Circuit No. 2—Copper-iron Separation:

To Discharge of Bulk Concentrate from Circuit No. 1:

Lime	7·0 lb./ton
Cyanide	0·10 "

To Surge Tank No. 2:

Amyl xanthate	0·05 lb./ton
Classifier overflow	35 to 38 per cent solids

Screen Test:

	Weight, per cent
+ 48	0·2
− 48+ 65	0·7
− 65+100	3·4
−100+150	7·4
−150+200	16·9
−200	71·4
	100·0

Assay	Cu, per cent	Fe, per cent	S, per cent
Classifier overflow	4·08	33·63	36·20
Bulk concentrate	5·58	43·18	48·10
Bulk tailing	0·14	4·98	1·80
Copper concentrate	28·42	32·03	35·80
Iron concentrate	0·30	45·37	49·50

Recoveries—Run No. 4

Product	Copper, per cent	Iron, per cent	Sulphur, per cent	Tons per 100 tons ore
Bulk concentrate	99·0	96·0	99·8	72·5
Tailing	1·0	4·0	0·2	27·5
Totals	100·0	100·0	100·0	100·0
Copper concentrate	94·7	14·3	16·3	13·6
Iron concentrate	4·3	81·7	83·5	58·9
Totals	99·0	96·0	99·8	72·5

Summary of Runs Nos. 1 to 4:

Total Amount of Reagents Used

Reagents, bulk flotation	Run No. 1	Run No. 2	Run No. 3	Run No. 4
Sodium silicate	2	....	....	2·1
Soda ash	....	2·9	2·7	....
Reagent No. 301	0·36	0·31	....	....
Amyl xanthate	....	....	0·31	0·37
Pine oil	0·06	0·06	0·06	0·11
Copper sulphate	....	....	....	0·26

Reagents, copper separation	Run No. 1	Run No. 2	Run No. 3	Run No. 4
Lime	8·0	8·0	7·0	7·0
Cyanide	0·10	0·10	0·10	0·10
Pine oil	0·02	Nil	Nil	Nil
Potassium amyl xanthate	0·05	0·05	0·05	0·05

It will be observed that no difficulty was encountered in separating the copper from the bulk concentrate. The loss of copper in the iron concentrate was fairly uniform in all four tests. However, it will also be observed that it was difficult to make a good recovery on the bulk flotation.

The tailing was high in iron and sulphur in the first three runs, and it was not until the collecting reagents were increased and a small amount of copper sulphate added that a good tailing from the bulk flotation was obtained.

The reagent cost on Run No. 4, the first test to give good metallurgical results, would be approximately 22 cents per ton of ore treated.

Run No. 5

Reagents were the same as for Run No. 4, but no air-conditioning was used.

Screen Test on Classifier Overflow:

	Weight, per cent
+ 48	0·4
− 48+ 65	0·9
− 65+100	3·2
−100+150	8·9
−150+200	16·1
−200	70·5
	100·0

Assay	Cu, per cent	Fe, per cent	S, per cent
Classifier overflow	4·04	33·63	36·50
Bulk concentrate	5·50	43·58	48·25
Bulk tailing	0·10	7·56	4·90
Copper concentrate	29·62	31·64	35·30
Iron concentrate	0·26	45·77	50·50

Recoveries:

Product	Copper, per cent	Iron, per cent	Sulphur, per cent	Tons per 100 tons ore
Bulk concentrate	99·4	94·0	96·4	73·0
Tailing	0·6	6·0	3·6	27·0
Totals	100·0	100·0	100·0	100·0
Copper concentrate	95·6	12·25	13·4	13·0
Iron concentrate	3·8	81·75	83·0	60·0
Totals	99·4	94·0	96·4	73·0

The results obtained in Test No. 5 indicate that air-conditioning is not necessary during the bulk float.

Run No. 6

The only radical change made in this run was the reduction in the quantity of lime and cyanide used on the copper separation from the bulk concentrate. The lime was reduced from 7 pounds to 4·7 pounds, and the cyanide from 0·10 pound to 0·05 pound.

This reduction apparently affected the copper separation as the results of the assays show that the iron concentrate contained 1·0 per cent copper.

Reagents to Circuit No. 1—Bulk Flotation:

To Ball Mill Discharge:

Sodium silicate	2·1 lb./ton

To Surge Tank:

Potassium amyl xanthate	0·16 lb./ton
Pine oil	0·05 "

To Cell No. 4: Amyl xanthate	0·05 lb./ton
To Cell No. 7: Amyl xanthate	0·03 "
Pine oil	0·02 "
Copper sulphate	0·26 "
To Cell No. 9: Amyl xanthate	0·05 "

Reagents to Circuit No. 2—Copper-iron Separation:

Discharge of Bulk Concentrate from Circuit No. 1:

Lime	4·7 lb./ton
Cyanide	0·05 "

To Surge Tank No. 2:

Amyl xanthate	0·05 lb/ton

To Cell No. 7: Amyl xanthate	0·03 "
Classifier overflow	30 to 34 per cent solids

Screen Test:

	Weight, per cent
+ 48	0·2
− 48+ 65	0·5
− 65+100	4·0
−100+150	6·0
−150+200	15·3
−200	74·0
	100·0

Assay	Cu, per cent	Fe, per cent	S, per cent
Classifier overflow	0·04	32·02	35·00
Bulk concentrate	5·62	42·78	47·85
Bulk tailing	0·16	6·96	4·25
Copper concentrate	29·40	31·64	34·90
Iron concentrate	1·00	45·57	51·10

Recoveries:

Product	Copper, per cent	Iron, per cent	Sulphur, per cent	Tons per 100 tons ore
Bulk concentrate	99·0	94·0	96·7	71·1
Tailing	1·0	6·0	3·3	28·9
Totals	100·0	100·0	100·0	100·0
Copper concentrate	85·0	....	....	11·56
Iron concentrate	14·0	....	....	59·54
Totals	99·0			71·10

Run No. 7

The flow-sheet used in this test differed from the previous runs in that a Genter thickener was used to thicken the bulk concentrate before the copper concentration.

It will also be noted that the quantity of lime and cyanide used was brought back to the same quantity which was used in Runs Nos. 1 to 5 inclusive.

Reagents to Circuit No. 1—Bulk Flotation:

To Ball Mill Discharge:	
Sodium silicate	2·1 lb./ton
Potassium amyl xanthate	0·16 "
Pine oil	0·05 "
To Cell No. 4: Amyl xanthate	0·03 lb./ton
To Cell No. 7: Amyl xanthate	0·05 "
Pine oil	0·02 "
Copper sulphate	0·26 "
To Cell No. 9: Amyl xanthate	0·05 "

Reagents to Circuit No. 2—Copper-iron Separation:

To Discharge of Bulk Concentrate from Circuit No. 1	
Lime	7·0 lb./ton
Cyanide	0·10 "
To Surge Tank No. 2:	
Amyl xanthate	0·05 lb./ton
To Cell No. 7: Amyl xanthate	0·02 "
Classifier overflow	35 per cent solids

Screen Test:

	Weight, per cent
+ 48	0·4
− 48+ 65	1·4
− 65+100	4·6
−100+150	10·3
−150+200	15·9
−200	67·4
	100·0

Assay	Cu, per cent	Fe, per cent	S, per cent
Classifier overflow	3·94	32·83	36·00
Bulk concentrate	5·42	42·79	47·98
Bulk tailing	0·08	4·38	1·15
Copper concentrate	29·60	31·24	35·30
Iron concentrate	1·05	44·78	49·80

The recoveries were not calculated for this test as it is quite obvious that they are practically the same as obtained in Run No. 6. The conclusion therefore drawn is that thickening the bulk concentrate prior to the copper separation is detrimental.

Runs Nos. 8, 9, and 10

These were a series of selective flotation tests made in a soda ash-cyanide circuit. The results obtained were very poor and they are not of sufficient interest to be reported.

Runs Nos. 11 to 13 inclusive

A change from the flow-sheets previously used was introduced in these tests. The air-conditioning tank was placed to air-condition the pulp overflowing the classifier. It will be recalled that in all previous tests, it was used to air-condition the discharge from the ball mill.

Run No. 11

This run was made to check the results obtained in Run No. 4.

Reagents to Circuit No. 1—Bulk Flotation:

To Ball Mill Discharge:
Sodium silicate.. 2·2 lb./ton
Pine oil.. 0·08 "
Amyl xanthate.. 0·13 "

To Cell No. 4: Amyl xanthate.. 0·08 lb./ton
To Cell No. 7: Amyl xanthate.. 0·08 "
Pine oil.. 0·02 "
To Cell No. 6: Copper sulphate.. 0·26 "
To Cell No. 9: Amyl xanthate.. 0·05 "

Reagents to Circuit No. 2—Copper-iron Separation:

To Discharge of Bulk Concentrate from Circuit No. 1
Lime.. 7·0 lb./ton
Cyanide.. 0·10 "

To Surge Tank No. 2:
Amyl xanthate.. 0·05 lb./ton
To Cell No. 7: Amyl xanthate.. 0·03 "
Classifier overflow.................................... 30 per cent solids

Screen Test:

	Weight, per cent
+ 65	0·6
− 65+100	3·6
−100+150	5·1
−150+200	15·9
−200	74·8
	100·0

Assay	Cu, per cent	Fe, per cent	S, per cent
Classifier overflow	4·08	33·23	36·40
Bulk concentrate	5·36	42·98	48·20
Bulk tailing	0·16	7·36	4·50
Copper concentrate	27·90	32·04	36·40
Iron concentrate	0·15	45·77	50·80

Recoveries:

Product	Copper, per cent	Iron, per cent	Sulphur, per cent	Tons per 100 tons ore
Bulk concentrate	99·0	94·8	97·0	75·4
Tailing	1·0	5·2	3·0	24·6
Totals	100·0	100·0	100·0	100·0
Copper concentrate	96·8	12·8	14·0	14·16
Iron concentrate	2·2	82·0	83·0	61·24
Totals	99·0	94·8	97·0	75·40

It will be noted that this test not only checks Run No. 4 but gives slightly improved results.

Run No. 12

A change in the reagents used in the copper separation from the bulk concentrate was made in this test. It should be noted that no cyanide was used in conjunction with the lime, but that all other reagents were the same as in Runs No. 4 and No. 11.

To Ball Mill Discharge:

Sodium silicate	2·2 lb./ton
Pine oil	0·08 "
Amyl xanthate	0·14 "
To Cell No. 4: Amyl xanthate	0·8 lb./to
To Cell No. 7: Amyl xanthate	0·08 "
Pine oil	0·02 "
To Cell No. 6: Copper sulphate	0·25 "
To Cell No. 9: Amyl xanthate	0·05 "

Reagents to Circuit No. 2—Copper-iron Separation:

To Discharge of Bulk Concentrate from Circuit No. 1:

Lime	7·0 lb./ton

To Surge Tank No. 2:

Amyl xanthate	0·05 lb./ton
To Cell No. 7: Amyl xanthate	0·03 "
Classifier overflow	37 per cent solids

Screen Test:

	Weight, per cent
+48	0·3
−48 +65	0·5
− 65+100	2·5
−100+150	5·8
−150+200	16·4
−200	74·5
	100·0

Assay	Cu, per cent	Fe, per cent	S, per cent
Classifier overflow	3·90	33·63	36·70
Bulk concentrate	5·22	42·78	47·40
Bulk tailing	0·10	5·77	2·70
Copper concentrate	26·86	32·24	36·40
Iron concentrate	0·15	45·57	50·35

Recoveries:

Product	Copper, per cent	Iron, per cent	Sulphur, per cent	Tons per 100 tons ore
Bulk concentrate	99·4	95·6	98·1	74·24
Tailing	0·6	4·4	1·9	25·76
Totals	100·0	100·0	100·0	100·0
Copper concentrate	97·2	13·1	13·7	14·10
Iron concentrate	2·2	82·5	84·4	60·14
Totals	99·4	95·6	98·1	74·24

Run No. 13

In this test a very small amount of cyanide was used in conjunction with the lime, namely 0·03 pound per ton; other reagent as in Run No. 12.

To Ball Mill Discharge:

Sodium silicate	2·2 lb./ton
Amyl xanthate	0·14 "
Pine oil	0·08 "
To Cell No. 4: Amyl xanthate	0·08 lb./ton
To Cell No. 6: Copper sulphate	0·26 "
To Cell No. 7: Amyl xanthate	0·08 "
Pine oil	0·20 "
To Cell No. 9: Amyl xanthate	0·05 "

Reagents to Circuit No. 2—Copper-iron Separation:

To Discharge of Bulk Concentration from Circuit No. 1:

Lime	7·0 lb./ton
Cyanide	0·03 "

To Surge Tank No. 2:

Amyl xanthate	0·05 lb./ton
To Cell No. 7. Amyl xanthate	0·03 "
Classifier overflow	35 per cent solids

Screen Test:

	Weight, per cent
+ 48	0·1
− 48+ 65	0·1
− 65+100	2·3
−100+150	5·0
−150+200	12·8
−200	79·7
	100·0

Assay	Cu, per cent	Fe, per cent	S, per cent
Classifier overflow	3·94	33·43	37·22
Bulk concentrate	5·16	42·39	49·26
Bulk tailing	0·10	5·37	2·37
Copper concentrate	26·00	33·23	38·09
Iron concentrate	0·18	45·57	51·67

No recoveries have been worked out for this test as it can be seen from the assays of the products that the recoveries are practically the same as obtained in Run No. 12.

SUMMARY AND CONCLUSIONS

The results of the experimental runs show conclusively that there will be a decided saving in the cost of reagents by using the bulk flotation method, and that there will also be a marked improvement in the metallurgical recoveries and in the grade of the copper concentrate as compared with those under the present methods of operating the Eustis mill.

The following table shows a summary of the kind and the quantity of reagents used to obtain the results referred to.

Reagents	Quantity in pounds per ton of original feed
Sodium silicate	2·20
Amyl xanthate	0·43
Pine oil	0·10
Copper sulphate	0·26
Lime	

The table below shows the reagents used at present.

Reagents	Quantity in pounds per ton of original feed
Lime	2·5
Black cyanide	0·4
Amyl xanthate	0·17
Butyl xanthate	0·34
Soda ash	3·60
Copper sulphate	0·90
Sodium sulphide	0·50
Pine oil	0·12

There is a very likely possibility that in actual mill operation, the quantities of reagents used in the experimental runs can be reduced.

The test work has not shown definitely whether air-conditioning is necessary or not. Run No. 5 would indicate that it was not necessary, but, as Run No. 5 only covers a short run of half a day, there may have been sufficient effect from the previous day's run accumulated in the circuit to carry through this short period. The lack of air-conditioning is more likely to affect the copper separation than the bulk flotation.

The test work has also shown that it is not necessary to thicken the bulk concentrate before sending it to the copper separation and that in fact it is detrimental to thicken. However, a surge tank of a type which will break down froth should be used to condition the bulk concentrate with the lime reagent before going to the copper separation, and conditioning of at least 15 minutes is required.

The use of a small quantity of copper sulphate in the bulk flotation circuit should be noted. This was found necessary in the test work in order to clean up a streak of chalcopyrite which appeared in the pilot-table over which the tailing, from the bulk flotation, was run. In actual mill operation its use may not be necessary.

Attention is also drawn to the advantage of using a pilot table on the bulk tailing, as an indicator of the efficiency of the operation at any moment.

Ore Dressing and Metallurgical Investigation No. 626

GOLD ORE FROM GUNNAR GOLD MINES, LIMITED AT BERESFORD LAKE, MANITOBA

Shipment. A shipment of 21 sacks of ore, net weight 2,400 pounds, was received March 13, 1935. The shipment was submitted by Jas. Houston, Manager, Gunnar Gold Mines, Limited, Beresford Lake P. O., Manitoba.

Characteristics of the Ore. Thirty-one polished sections were prepared and examined microscopically for determining the character of the ore.

Sample No. 1 (7 sections). The *gangue* is white translucent quartz, which contains large patches of greyish white carbonate and small inclusions of greenish grey chloritic material, probably country rock.

The *metallic minerals* present are pyrite, chalcopyrite, sphalerite, pyrrhotite, and native gold. Pyrite occurs as small crystals and grains, commonly in the chloritic inclusions, rarely in quartz; the amount is not large. A small amount of chalcopyrite occurs as small grains and irregular patches in quartz, in places associated with carbonate. A small quantity of sphalerite is present as small grains in quartz, commonly associated with chalcopyrite. Pyrrhotite is rare as small grains associated with chalcopyrite and sphalerite. Native gold occurs as irregular grains chiefly in the quartz; small amounts of gold are associated with pyrite and sphalerite. (*See* Table II).

The *grain sizes of the sulphides* are given in Table I. Analysis of the chief sulphides shows the following percentages by volume:

Pyrite	67·8 per cent
Sphalerite	23·0 "
Chalcopyrite	9·2 "
	100·0 "

TABLE I

Grain Sizes of Sulphides in Sample No. 1

Mesh	Pyrite, per cent	Sphalerite, per cent	Chalco-pyrite, per cent
+ 65	49·3	51·9	42·0
− 65 + 100	14·7	17·1	12·1
− 100 + 150	10·1	7·2	9·9
− 150 + 200	7·2	6·5	8·2
− 200 + 280	6·4	6·3	11·7
− 280 + 400	5·0	4·5	4·5
− 400 + 560	3·2	3·0	6·3
− 560 + 800	2·3	1·6	1·8
− 800 + 1100	0·8	1·0	1·4
− 1100 + 1600	0·7	0·4	1·1
− 1600 + 2300	0·3	0·3	0·6
− 2300	....	0·2	0·4
	100·0	100·0	100·0

All of the tables are based upon quantitative data obtained by traversing the polished sections very thoroughly under the microscope.

The *grain size of the gold* is given in Table II.

TABLE II

Grain Sizes of the Gold in Sample No. 1

(126 grains of gold measured)

Mesh	Gold in quartz, per cent	Gold associated with pyrite, per cent	Gold associated with sphalerite, per cent	Total gold, per cent
+ 65	....	....	....	....
− 65 + 100	....	....	....	....
− 100 + 150	....	....	....	....
− 150 + 200	7·5	....	2·5	10·0
− 200 + 280	10·6	....	....	10·6
− 280 + 400	14·7	1·7	....	16·4
− 400 + 560	14·1	1·4	1·2	16·7
− 560 + 800	12·2	2·9	1·9	17·0
− 800 + 1100	9·1	1·9	....	11·0
− 1100 + 1600	6·9	0·4	....	7·3
− 1600 + 2300	6·8	0·6	....	7·4
− 2300	3·4	....	0·2	3·6
	85·3	8·9	5·8	100·0

Note.—Of the gold associated with pyrite, 1·1 per cent occurs within it and 7·8 per cent around the borders. Of that associated with sphalerite, 3·7 per cent occurs within it and 2·1 per cent around the borders.

Sample No. 2 (12 sections). The *gangue* is fine-textured, grey translucent quartz.

The *metallic minerals* present in Sample No. 2 are sphalerite, chalcopyrite, pyrite, pyrrhotite, and native gold. The sulphides are sparingly distributed as small irregular masses and grains in the quartz. The gold occurs as irregular grains and very irregular and discontinuous stringers in quartz; small quantities of gold are associated with chalcopyrite, sphalerite, pyrite, and pyrrhotite. (*See* Table IV).

The *grain sizes of the sulphides* in Sample No. 2 are shown in Table III. Their relative percentages by volume are:

Sphalerite	49·0 per cent
Chalcopyrite	35·1 "
Pyrite	9·9 "
Pyrrhotite	6·0 "
	100·0 "

TABLE III

Grain Sizes of the Sulphides in Sample No. 2

Mesh	Sphalerite, per cent	Chalcopyrite, per cent	Pyrite, per cent	Pyrrhotite, per cent
+ 65	73·5	66·3	73·3	74·7
− 65 + 100	10·5	6·1	8·1	10·2
− 100 + 150	5·8	9·4	....	....
− 150 + 200	3·9	6·2	3·3	....
− 200 + 280	2·2	3·5	5·3	4·8
− 280 + 400	1·1	2·1	....	3·4
− 400 + 560	1·1	1·8	2·5	4·7
− 560 + 800	1·0	2·0	2·6	1·7
− 800 + 1100	0·4	1·2	2·8	....
− 1100 + 1600	0·4	1·2	1·8	....
− 1600 + 2300	0·1	0·2	0·3	0·5
− 2300	....	....	....	....
	100·0	100·0	100·0	100·0

The *grain size of the gold* is shown in Table IV.

TABLE IV

Grain Sizes of the Gold in Sample No. 2

(666 grains of gold measured)

Mesh	Gold in quartz, per cent	Gold associated with				Total gold, per cent
		Chalcopyrite, per cent	Sphalerite, per cent	Pyrite, per cent	Pyrrhotite, per cent	
+ 65	4·87	1·11	....	....	....	5·98
− 65 + 100	5·31	2·43	....	....	....	7·74
− 100 + 150	7·08	1·10	....	....	....	8·18
− 150 + 200	13·06	0·40	0·35	....	....	13·81
− 200 + 280	18·79	0·54	....	....	....	19·33
− 280 + 400	12·93	0·44	0·44	....	....	13·81
− 400 + 560	8·77	0·13	0·28	....	....	9·18
− 560 + 800	8·61	0·20	0·22	0·11	....	9·14
− 800 + 1100	5·44	0·06	0·08	0·23	0·09	5·90
− 1100 + 1600	4·07	0·05	0·05	0·15	....	4·32
− 1600 + 2300	1·42	....	0·04	0·13	....	1·59
− 2300	0·93	....	0·03	0·06	....	1·02
	91·28	6·46	1·49	0·68	0·09	100·00

Note: Of the gold associated with chalcopyrite, 0·99 per cent occurs within it, 5·47 per cent around its borders. Of that associated with sphalerite 0·57 per cent occurs within it, 0·92 per cent around its borders. The gold associated with pyrite and pyrrhotite occurs around the borders of these minerals.

Sample No. 3 (6 sections). The *gangue* is chiefly translucent grey quartz, with inclusions of greenish grey chloritic material.

The *metallic minerals* present are pyrite, chalcopyrite, sphalerite, pyrrhotite and native gold. Pyrite is locally abundant as small masses and coarse grains. Chalcopyrite occurs as irregular grains mostly in the gangue, but occasionally in pyrite. A small amount of sphalerite occurs as small masses and grains in quartz. Rare small grains of pyrrhotite are present in pyrite. Native gold occurs as irregular grains in quartz.

The *grain sizes of the sulphides* are given in Table V. It will be noted that the sulphides, particularly pyrite, are considerably coarser than in the preceding samples. Their relative percentages by volume are:

Pyrite	74·7 per cent
Chalcopyrite	13·6 "
Sphalerite	11·7 "

TABLE V

Grain Sizes of the Sulphides in Sample No. 3

Mesh	Pyrite, per cent	Chalcopyrite, per cent	Sphalerite, per cent
+ 65	91·6	64·2	82·1
− 65 + 100	3·4	9·2	14·3
− 100 + 150	2·5	8·9	....
− 150 + 200	0·9	10·4	....
− 200 + 280	0·7	3·7	....
− 280 + 400	0·6	2·4	3·6
− 400 + 560	0·3	....	....
− 560 + 800	....	1·2	....
− 800 + 1100	....	....	....
− 1100 + 1600	....	....	....
− 1600 + 2300	....	....	....
− 2300	....	....	....
	100·0	100·0	100·0

The *grain size of the gold* is given in Table VI.

TABLE VI

Grain Sizes of the Gold in Sample No. 3

(209 grains of gold measured)

Mesh	Gold in quartz, per cent	Gold associated with chalcopyrite, per cent	Total gold, per cent
+ 65	3·93	....	3·93
− 65 + 100	10·23	....	10·23
− 100 + 150	10·54	....	10·54
− 150 + 200	11·17	....	11·17
− 200 + 280	11·80	....	11·80
− 280 + 400	13·38	....	13·38
− 400 + 560	11·01	....	11·01
− 560 + 800	10·39	0·31	10·70
− 800 + 1100	7·25	....	7·25
− 1100 + 1600	6·11	....	6·11
− 1600 + 2300	2·45	....	2·45
− 2300	1·43	....	1·43
	99·69	0·31	100·00

Sample No. 4 (6 sections). The *gangue* is fine-textured grey translucent quartz with inclusions of light green chloritic material.

The *metallic minerals* are pyrite, sphalerite, chalcopyrite, pyrrhotite, and native gold. This sample is very similar to Sample No. 2 in so far as the sulphides are concerned, except that pyrite far predominates over the others. Only five grains of native gold were visible, so the information concerning its mode of occurrence is very meagre. It is known to occur in both quartz and pyrite (*See* Table VIII).

The *grain sizes of the sulphides* are shown in Table VII. Their percentages by volume are as follows:

Pyrite..........	95·5 per cent
Sphalerite..........	3·6 "
Chalcopyrite..........	0·9 "
	100·0 "

TABLE VII

Grain Sizes of the Sulphides in Sample No. 4

Mesh	Pyrite, per cent	Sphalerite, per cent	Chalcopyrite, per cent
+ 65	89·5	50·0	....
− 65 + 100	4·3	21·9	....
− 100 + 150	2·8	....	56·2
− 150 + 200	1·2	10·0	....
− 200 + 280	1·0	7·5	....
− 280 + 400	0·6	6·2	....
− 400 + 560	0·3	4·4	17·7
− 560 + 800	0·3	....	12·9
− 800 + 1100	....	....	7·1
− 1100 + 1600	....	....	6·1
− 1600 + 2300	....	....	....
− 2300	....	....	....
	100·0	100·0	100·0

The *grain size of the gold* is given in Table VIII.

TABLE VIII

Grain Sizes of the Gold in Sample No. 4

(5 grains of gold measured)

Mesh	Gold in quartz, per cent	Gold in pyrite, per cent	Total gold, per cent
+ 280	....	47·2	47·2
− 280 + 400	....	....	....
− 400 + 560	....	....	....
− 560 + 800	19·7	....	19·7
− 800 + 1100	25·2	....	25·2
− 1100	7·9	....	7·9
	52·8	47·2	100·0

Summary. Tables IX and X, giving the grain sizes of the sulphides and native gold, are based upon the data accumulated for all four samples. It must be kept in mind that varying proportions of the different types of ore represented by the samples will vary these figures, and that this table is merely the average of the samples submitted.

TABLE IX

Grain Sizes of the Sulphides in Four Samples

(Based on traverses of 31 sections)

Mesh	Pyrite, per cent	Chalcopyrite, per cent	Sphalerite, per cent	Pyrrhotite, per cent
+ 65	80·9	63·7	69·6	74·7
− 65 + 100	6·4	5·8	12·4	10·2
− 100 + 150	4·1	10·2	5·4	....
− 150 + 200	2·6	6·9	4·3	....
− 200 + 280	2·2	4·3	3·0	4·8
− 280 + 400	1·4	2·3	2·1	3·4
− 400 + 560	1·0	2·3	1·5	4·7
− 560 + 800	0·8	2·0	1·0	1·7
− 800 + 1100	0·3	1·2	0·3	....
− 1100 + 1600	0·2	1·1	0·3	....
− 1600 + 2300	0·1	0·2	0·1	0·5
	100·0	100·0	100·0	100·0

The following shows the percentage of each of the sulphides (percentages given by volume):

Pyrite	57·38	per cent
Sphalerite	24·15	"
Chalcopyrite	16·39	"
Pyrrhotite	2·08	"
	100·00	"

TABLE X

Grain Size and Modes of Occurrence of Gold in Four Samples

(1006 grains of gold measured)

Mesh	Gold in quartz	Gold associated with							Total gold
		Chalcopyrite		Sphalerite		Pyrite		Pyrrhotite	
		With	In	With	In	With	In	With	
	per cent	per cent	per cent	per cent	per cent	per cent	per cent	per cent	per cent
+ 65...	4·29	0·79	....	....	....	....	....	....	5·08
− 65 + 100...	5·88	1·75	....	....	....	....	....	....	7·63
− 100 + 150...	7·21	0·40	0·40	....	....	....	....	....	8·01
− 150 + 200...	12·20	0·29	....	0·25	0·19	....	....	....	12·93
− 200 + 280...	16·68	0·19	0·19	....	....	....	0·19	....	17·25
− 280 + 400...	13·10	0·32	....	0·16	0·16	0·13	....	....	13·87
− 400 + 560...	9·59	0·09	....	0·25	0·19	0·11	....	....	10·23
− 560 + 800...	9·29	0·06	0·08	....	0·16	0·16	0·15	....	9·90
− 800 + 1100...	6·16	0·06	0·04	0·06	....	0·15	0·16	0·06	6·69
− 1100 + 1600...	4·71	0·04	....	0·04	....	0·03	0·11	....	4·93
− 1600 + 2300...	2·03	....	....	0·03	....	0·02	0·11	....	2·19
− 2300 ...	1·22	....	....	0·03	....	....	0·04	....	1·29
	....	3·99	0·71	0·82	0·70	0·60	0·76	....	....
	92·36	4·70		1·52		1·36		0·06	100·00

Table X shows that most of the gold occurs in quartz, with only minor quantities associated with each of chalcopyrite, sphalerite, pyrite, and pyrrhotite. The grain size of the gold ranges from the coarse to the fine meshes, with the largest amount in the −200+280-mesh size. The presence of chalcopyrite and pyrrhotite may affect cyanidation if these minerals are present in sufficient quantities and it may be necessary to remove them. The wide range of size of the gold particles indicates the advisability of using methods for collecting coarse gold in addition to fine grinding and cyanidation to recover the fine gold.

An average sample of the shipment assayed as follows:

Gold..	0·96 oz./ton
Silver..	0·46 "
Copper..	0·02 per cent
Zinc..	Trace

Experimental Tests

The work done on the ore consisted of amalgamation and cyanidation tests both alone and in combination, as well as blanket concentration and hydraulic classification tests. By straight cyanidation of the ore 97·9 per cent of the gold was extracted. This was not increased by combining amalgamation with cyanidation, but by tabling out and regrinding the sulphides extraction can be increased to practically 99·0 per cent of the gold. A recovery was made of 69·8 per cent of the gold in a high-grade blanket concentrate amounting to less than 2 per cent of the weight of feed used.

In a hydraulic classifier 64·6 per cent of the gold was recovered in a product amounting to 5·7 per cent of the weight of feed used.

CYANIDATION

Tests Nos. 1 to 8

Samples of the ore were crushed dry to pass through 48-, –65-, 100- and 150-mesh screens. Portions of each were agitated in cyanide solution, 1·0 pound per ton of potassium cyanide, for periods of 24 and 48 hours. Protective alkalinity was maintained by the addition of lime. The tailings were filtered, washed, and assayed for gold.

Summary:

Feed sample: gold, 0·96 oz./ton.

Test No.	Grinding	Agitation, hours	Tailing assay, Au, oz./ton	Extraction, per cent	Reagents consumed	
					KCN	CaO
1	– 48	24	0·055	94·3	0·3	3·8
2	– 65	24	0·04	95·8	0·3	4·0
3	– 100	24	0·03	96·9	0·3	4·0
4	– 150	24	0·03	96·9	0·3	4·0
5	– 48	48	0·06	93·8	0·3	4·0
6	– 65	48	0·02	97·9	0·3	4·1
7	– 100	48	0·03	96·9	0·3	4·1
8	– 150	48	0·02	97·9	0·3	4·3

AMALGAMATION AND CYANIDATION

Tests Nos. 9 to 12

Samples of the same four lots of dry-crushed ore as used in Tests Nos. 1 to 8 were amalgamated with mercury in jar mills for 30 minutes. The amalgamation tailings were then sampled and assayed, and portions of each were agitated in cyanide solution, 1·0 pound of potassium cyanide, for periods of 24 hours. The cyanide tailings were also assayed for gold.

Summary:

Feed sample: gold, 0·96 oz./ton

Test No.	Grinding	Amalgamation, Au, oz./ton	Extraction by amalgamation, per cent	Cyanide tailing, Au, oz./ton	Extraction by cyanidation, per cent	Total extraction	Reagents consumed, lb./ton	
							KCN	CaO
9	– 48 mesh	0·27	71·9	0·065	21·4	93·3	0·3	2·7
10	– 65 "	0·22	77·1	0·036	19·3	96·4	0·3	3·8
11	–100 "	0·205	78·6	0·030	18·2	96·8	0·3	4·0
12	–150 "	0·20	79·2	0·030	17·7	96·9	0·3	4·1

CYANIDATION WITH TABLING

Test No. 13

A sample of the ore was ground 70 per cent through 200 mesh in a ball mill and then agitated in cyanide solution, 1·0 pound of potassium cyanide per ton, for 24 hours. The cyanide tailing was then passed over a small, laboratory-size concentration table where a sulphide concentrate was taken off. The table concentrate was reground practically all through 200 mesh and agitated in a cyanide solution of the same strength for 24 hours. The table tailing and cyanide tailing from the concentrate were assayed for gold.

Summary:

Feed sample: gold, 0·96 oz./ton

Product	Weight, per cent	Assay, Au, oz./ton	Extraction, per cent	Reagents consumed, lb./ton ore	
				KCN	CaO
Table tailing from primary cyanide tailing	89·0	0·01	....	....	....
Cyanide tailing from table concentrate	11·0	0·01	....	0·09	1·41
Final cyanide tailing (cal.)	100·0	0·01	98·95	0·56	4·2

PLATE AMALGAMATION

Tests Nos. 14 to 17

Samples of the ore were ground wet in jar mills 57, 70, 78, and 85 per cent through 200 mesh and passed over an amalgamation plate. The tailings were filtered, washed, and assayed for gold.

Summary:

Feed sample: gold, 0·96 oz./ton.

Test No.	Grinding, per cent through 200 mesh	Tailing assay, Au, oz./ton	Extraction, per cent
14	57·0	0·295	69·3
15	70·0	0·30	68·8
16	78·0	0·28	70·8
17	85·0	0·38	60·4

BLANKET CONCENTRATION

Test No. 18

A sample of the ore was ground 57 per cent through 200 mesh in a ball mill and passed over a corduroy blanket set at a slope of 2·5 inches per foot. The blanket concentrate and tailing were assayed for gold.

Summary:

Product	Weight, per cent	Assay, Au, oz./ton	Recovery, per cent
Blanket concentrate	1·6	41·87	69·8
Blanket tailing	98·4	0·295	30·2
Feed (cal.)	100·0	0·96	100·0

HYDRAULIC CLASSIFICATION

Test No. 19

A sample of the ore was ground 57 per cent through 200 mesh in a ball mill and passed through a hydraulic classifier where the gold and heavy minerals were allowed to settle out against a slowly rising current of water. This test was intended to give some indication of the results to be expected from the use of a hydraulic trap in practice.

Summary:

Product	Weight, per cent	Assay, Au, oz./ton	Recovery, per cent
Classifier oversize	5·7	10·88	64·6
Classifier overflow	94·3	0·36	35·4
Feed (cal.)	100·0	0·96	100·0

CONCLUSIONS

The tests conducted on the sample of ore submitted indicate that it will be easy to treat. A satisfactory flow-sheet would be cyanidation with concentration and regrinding of the sulphides. In this way about 99 per cent of the gold can be extracted with a very reasonable amount of reagents consumed.

For such a flow-sheet the ore should be ground all through 65 mesh and about 70 per cent through 200 mesh. The sulphide concentrate should be reground practically all through 200 mesh and re-cyanided.

The above is standard practice at the Hollinger mine, Timmins, Ontario, and should be well suited to this ore.

Ore Dressing and Metallurgical Investigation No. 627

GOLD ORE FROM BRADIAN MINES, LIMITED, BRIDGE RIVER AREA, LILLOOET MINING DIVISION, B.C.

Shipment. Shipments of two separate bags of ore, total weight 150 pounds, were received May 1, 1935, from F. E. Grey, Mill Superintendent, Bralorne Mines, Limited, Bralorne, B.C. They were marked Lots Nos. 1 and 2.

Determinations of the value of the two samples, as well as preliminary cyanide tests for the recovery of the gold, were desired.

After crushing, cutting and grinding by standard methods, samples were obtained which showed the lots to contain:—

Lot No.	Gold, oz./ton	Silver, oz./ton	Arsenic, per cent
1	0·19	0·06	0·34
2	1·76	0·42	0·33

Characteristics of the Ore. The gangue of Lot No. 1 is milky-white quartz and greenish grey altered country rock. The latter contains fine stringers and disseminated grains of carbonate.

The metallic minerals consist of sparsely disseminated arsenopyrite and pyrite, a small amount of pyrrhotite, and traces of chalcopyrite. Native gold is present as small, irregular grains in the quartz.

The gangue of Lot No. 2 comprises much more greenish grey country rock and white carbonate than does that of Lot No. 1. Only a small amount of quartz is present.

The metallic minerals are chiefly pyrite and arsenopyrite rather finely disseminated, often as narrow stringers of very fine grains. Very small amounts of pyrrhotite and chalcopyrite are present.

Experimental Tests

The test work included cyanidation and blanket concentration singly and in combination. An overall recovery of 97 per cent of the gold was obtained.

Lot No. 1

Tests Nos. 1 to 8

Samples of the ore were crushed dry to pass through 48-, 100-, 150-, and 200-mesh screens, and portions of each lot were agitated in cyanide solution of 1 pound per ton strength. Ten pounds of lime per ton of ore was added to maintain protective alkalinity. The tailings were assayed for gold.

Results:

Test No.	Mesh grind	Agitation, hours	Feed, Au, oz./ton	Tailing, Au, oz./ton	Extraction, per cent	Reagents consumed, lb./ton	
						KCN	CaO
1.......	48	24	0·19	0·03	84·3	0·3	3·8
2.......	48	48	0·19	0·025	86·8	0·3	3·8
3.......	100	24	0·19	0·025	86·8	0·3	4·1
4.......	100	48	0·19	0·02	89·5	0·3	4·9
5.......	150	24	0·19	0·025	86·8	0·3	5·4
6.......	150	48	0·19	0·02	89·5	0·3	3·9
7.......	200	24	0·19	0·02	89·5	0·3	3·9
8.......	200	48	0·19	0·015	92·1	0·3	4·2

Screen tests were conducted on the cyanide feed, which are summarized as follows:

Mesh	48-mesh, weight, per cent	100-mesh, weight, per cent	150-mesh, weight, per cent
− 48 + 65	4·9	....	....
− 65 + 100	27·1	....	....
− 100 + 150	15·6	14·0	....
− 150 + 200	16·3	18·7	6·2
− 200	35·8	66·9	93·5

Lot No. 2

Tests Nos. 9 to 16

A similar series of cyanidation tests was run on Lot No. 2 which is summarized as follows:

Test No.	Mesh grind	Agitation, hours	Feed, Au, oz./ton	Tailing, Au, oz./ton	Extraction, per cent	Reagents consumed, lb./ton	
						KCN	CaO
9......	48	24	1·76	0·56	68·2	0·3	4·2
10......	48	48	1·76	0·04	97·7	0·3	4·2
11......	100	24	1·76	0·185	89·5	0·3	4·2
12......	100	48	1·76	0·05	97·2	0·3	5·4
13......	150	24	1·76	0·045	97·5	0·3	4·5
14......	150	48	1·76	0·03	98·3	0·3	6·2
15......	200	24	1·76	0·035	98·1	0·3	7·4
16......	200	48	1·76	0·04	98·8	0·5	8·4

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Screen tests of the cyanide feed showed the grinding to be as follows:

Mesh	48-mesh, weight, per cent	100-mesh, weight, per cent	150-mesh, weight, per cent
− 48 + 65	7·1	....	....
− 65 + 100	22·1	....	....
− 100 + 150	7·2	7·4	....
− 150 + 200	11·5	17·8	14·2
− 200	51·7	74·4	85·6

BLANKETING AND CYANIDATION

Test No. 17

In this test 1,000 grammes of Lot No. 2 ore at −14 mesh was ground 20 minutes in a ball mill to 65 mesh with 55·4 per cent through 200 mesh and passed over a corduroy blanket, giving two products, a blanket concentrate and a tailing. The blanket tailing was then agitated in cyanide solution, 1·0 pound of potassium cyanide per ton, for periods of 24 and 48 hours. The cyanide tailing was assayed for gold. A screen test of the blanket tailing showed the grinding to be as follows:—

Mesh	Weight, per cent
+ 100	7·2
− 100 + 150	13·7
− 150 + 200	23·4
− 200	55·4

Blanket Concentration:

Product	Weight, per cent	Assay, Au, oz./ton	Distribution of gold, per cent
Feed (cal.)	100·0	1·79	100·0
Blanket concentrate	0·45	308·88	77·7
Blanket tailing	99·5	0·40	22·3

Cyanidation of Blanket Tailing:

Test No.	Agitation, hours	Feed, Au, oz./ton	Tailing, Au, oz./ton	Extraction, per cent	Reagents consumed, lb./ton	
					KCN	CaO
17	24	0·40	0·02	95·0	0·3	8·0
17	48	0·40	0·025	93·8	0·3	8·4

An overall recovery of 98·7 per cent of the gold is made by blanket concentration followed by cyanidation of the blanket tailing.

Test No. 18

In this test, also on Lot No. 2 ore, the same procedure as in Test No. 17 was followed; the initial grind, however, being somewhat finer.

Screen Test:

Mesh	Weight, per cent
+ 100	1·4
− 100 + 150	7·0
− 150 + 200	20·5
− 200	70·8

Blanket Concentration:

Product	Weight, per cent	Assay, Au, oz./ton	Distribution of gold, per cent
Feed (cal.)	100·0	1·54	
Blanket concentrate	0·35	340·0	77·3
Blanket tailing	99·6	0·35	22·7

Cyanidation of Blanket Tailing:

Test No.	Agitation, hours	Feed, Au, oz./ton	Tailing, Au, oz./ton	Extraction, per cent	Reagents consumed, lb./ton	
					KCN	CaO
18	24	0·35	0·02	94·3	0·3	7·9
18	48	0·35	0·03	91·5	0·3	8·2

An overall recovery of 98·5 per cent of the gold is noted.

Test Nos. 19 to 22

A composite sample of approximately equal quantities of Lots Nos. 1 and 2 was taken and crushed dry to pass through 150- and 200-mesh screens. Portions of each batch were then agitated in cyanide solutions of 1 pound per ton strength, and 10 pounds of lime per ton of ore was added to maintain protective alkalinity. The tailings were assayed for gold.

Results:

Test No.	Mesh grind	Agitation, hours	Feed, Au, oz./ton	Tailing, Au, oz./ton	Extraction, per cent	Reagents consumed, lb./ton	
						KCN	CaO
19	150	24	0·84	0·05	93·9	0·3	9·1
20	150	48	0·84	0·045	94·7	0·3	9·1
21	200	24	0·84	0·045	94·7	0·3	10·2
22	200	48	0·84	0·05	93·9	0·4	9·8

Test No. 23

A composite sample of 500 grammes of Lot No. 1 and 500 grammes of Lot No. 2 at −14 mesh was ground 20 minutes in a ball mill to 65 mesh with 53·9 per cent through 200 mesh and passed over a corduroy blanket, giving two products, a blanket concentrate and a tailing. The blanket tailing was then cyanided for 24 and 48 hours in a solution of 1·0 pound of potassium cyanide per ton. The cyanide tailing was assayed for gold.

A screen test of the blanket tailing showed the grinding to be as follows:

Mesh	Weight, per cent
+ 100	6·0
− 100 + 150	12·5
− 150 + 200	27·5
− 200	53·9

Blanket Concentration:

Product	Weight, per cent	Assay, Au, oz./ton	Distribution of gold, per cent
Feed (cal.)	100·0	1·16	
Blanket concentrate	0·68	132·92	78·5
Blanket tailing	99·3	0·25	21·5

Cyanidation of Blanket Tailing:

Test No.	Agitation, hours	Feed, Au, oz./ton	Tailing, Au, oz./ton	Extraction, per cent	Reagents consumed, lb./ton	
					KCN	CaO
23	24	0·25	0·06	76·0	0·3	7·9
23	48	0·25	0·025	90·0	0·3	7·9

An overall recovery of 97·8 per cent of the gold is noted.

CONCLUSIONS

The ore responds readily to cyanidation, and this is the process to be recommended.

Owing to the comparatively large amount of coarse gold in the ore, both the time of agitation and the fineness of grinding can be cut down if the cyanidation is preceded by blanket concentration or by some other method of concentration, such as jigs.

In Test No. 10, a cyanide tailing of 0·04 ounce of gold per ton was obtained after 48 hours' agitation, preceded by grinding to 51·7 per cent through 200 mesh; whereas blanket concentration followed by only 24 hours' cyanidation of the blanket tailing, on a grind of 55·4 per cent through 200 mesh (Test No. 17), resulted in a cyanide tailing of 0·02 ounce gold per ton.

Ore Dressing and Metallurgical Investigation No. 628

GOLD-COPPER ORE FROM THE ASHLOO GOLD MINING SYNDICATE, SQUAMISH, VANCOUVER MINING DISTRICT, B.C.

Shipment. A shipment of gold-copper ore consisting of 1 bag, weight 115 pounds, was received on March 14, 1935, from the Ashloo Gold Mining Syndicate, Squamish, B.C. The property is 29 miles from tidewater, the first twenty-two miles being a fair road, the final seven miles being a pack-horse trail. The sample was submitted by E. P. Yarwood.

Characteristics of the Ore. The *gangue* consists of fine-textured black siliceous rock and milky-white vein quartz.

The *metallic minerals* identified in the polished sections are pyrite, chalcopyrite, pyrrhotite, arsenopyrite, galena, sphalerite, and native gold. Two additional minerals, both of which occur in very small quantity as small grains in chalcopyrite, were not identified and are classed as undetermined. The tests for these are as follows:—

Undetermined No. 1—

Colour: Grey, like argentite.
Hardness: Soft: B.
Crossed nicols: Isotropic.
Etch tests: HNO_3—quickly blackens.
HCl —slowly grey; some grains negative.
KCN—blackens.
$FeCl_3$ —quickly iridescent.
$HgCl_2$—iridescent.
KOH —negative.

Undetermined No. 2—

Colour: Light grey, with slight pinkish cast.
Hardness: Soft, and sectile (?): A to B.
Crossed nicols: Moderate anisotropism.
Etch tests: HNO_3—tarnishes black to iridescent.
KCN—pitted, and grey.
$FeCl_3$—slowly tarnishes iridescent.
HCl, KOH, $HgCl_2$—negative.

Pyrite, the most abundant metallic mineral, occurs as coarsely crystalline masses and irregular stringers in quartz. It is much fractured, and contains numerous small veinlets and grains of chalcopyrite. The chalcopyrite occurs as above, and as grains and stringers in quartz and black rocky gangue; it contains small, irregular grains of sphalerite, galena, and undetermined minerals Nos. 1 and 2. Pyrrhotite locally forms small masses and stringers in quartz, and is associated with pyrite. Galena, sphalerite, and the two undetermined minerals occur in small amounts as grains in chalcopyrite. A small quantity of arsenopyrite is present as tiny crystals in pyrite.

Only one grain of native gold was visible in the polished sections. This grain is between 65 and 100 mesh in size and is associated with undetermined mineral No. 2 in quartz.

The microscopic examination indicates that the content of sulphide minerals is considerable, the more abundant being pyrite, chalcopyrite, and pyrrhotite. Two undetermined minerals are present in small quantity; it is not known whether these contain valuable elements and their effect on treatment cannot be predicted. Very little is known about the mode of occurrence of the gold since only one grain was seen; it is probable, however, that some of the gold occurs as coarse grains.

Sampling and Assaying. The ore was crushed to −14 mesh and sampled by standard methods. A head sample assayed as follows:—

Gold	0·96 oz./ton
Silver	1·89 "
Copper	0·90 per cent
Iron	6·60 "

Experimental Tests

The object of the test work carried out on the sample of ore submitted was to find a method of treating the ore suitable for the conditions arising from the location of the property. The weight of products shipped out should be kept as low as possible and should contain the maximum amount of gold. Both bulk and selective flotation tests were carried out and the results obtained are the bases on which a suggested flow-sheet for the metallurgical treatment of the ore is submitted at the end of this report. It must be borne in mind that the calculations and suggestions offered are based on the assumption that the sample submitted is representative of the ore.

AMALGAMATION

Test No. 1

In order to determine the amount of free-milling gold present in the ore a sample of ore was ground and barrel-amalgamated with mercury for one hour. The recovery of gold by amalgamation was 17·70 per cent. The result indicates only a small amount of free-milling gold.

The grinding size of the ore for this test is shown by the following screen test:

Mesh	Weight, per cent
+100	0·5
+150	2·8
+200	14·2
−200	82·5
	100·0

FLOTATION

Test No. 2

This was a bulk flotation test in a soda ash circuit. The ore sample (1,000 grammes) was ground in an Abbé jar with 4 pounds of soda ash per ton and 0·07 pound of Aerofloat No. 31 per ton.

Reagents Added to Cell:

Potassium amyl xanthate	0·4 lb./ton
Pine oil	0·1 "

Results:

Product	Weight, per cent	Assay			Distribution, per cent			Ratio of concentration
		Au, oz./ton	Cu, per cent	Fe, per cent	Au	Cu	Fe	
Feed	100·00	0·96	0·90	6·60	100·00	100·00	100·00	
Concentrate	10·96	8·75	7·96	35·82	95·99	97·03	59·4	9·12 : 1
Tailing	89·04	0·045	0·03	3·09	4·01	2·97	40·6	

Test No. 3

In this test the grinding and flotation were carried out in a lime circuit. The tailing was higher in gold than in the previous test.

Reagents:

	Lb./ton
To Grinding—	
Lime	4·0
Aerofloat No. 31	0·07
To Cell—	
Potassium amyl xanthate	0·4

Results:

Product	Weight, per cent	Assay			Distribution, per cent			Ratio of concentration
		Au, oz./ton	Cu, per cent	Fe, per cent	Au	Cu	Fe	
Feed	100·00	0·96	0·90	6·60	100·00	100·00	100·0	
Concentrate	12·31	7·46	6·94	30·24	92·90	97·01	59·0	8·12 : 1
Tailing	87·69	0·08	0·03	2·94	7·10	2·99	41·0	

Test No. 4

This was a bulk flotation test. The ore was ground wet with soda ash and Aerofloat No. 31. At the end of the flotation some copper sulphate solution was added to pull as much pyrite as possible.

Reagents:

	Lb./ton
To Grinding—	
Soda ash	4·0
Aerofloat No. 31	0·07
To Cell—	Lb./ton
Potassium amyl xanthate	0·30
Cresylic acid	0·21
Pine oil	0·15
Copper sulphate	2·0

Results:

Product	Weight, per cent	Assay				Distribution, per cent				Ratio of concentration
		Au, oz./ton	Ag, oz./ton	Cu, per cent	Fe, centper	Au	Ag	Cu	Fe	
Feed	100·00	....	....	....	....	100·00	100·00	100·00	100·00	
Concentrate	12·69	8·09	14·11	7·42	·43 33	96·71	91·52	97·29	62·22	7·88 · 1
Tailing	87·31	0·04	0·19	0·03	·95 2	3·29	8·48	2·71	37·78	

The grinding size was about 82 per cent −200 mesh.

Test No. 5

This was similar to Test No. 4 with the grinding size about 85 per cent −200 mesh.

Reagents:

	Lb./ton
To Grinding—	
Soda ash	4·0
Aerofloat No. 31	0·07
To Cell:—	
Potassium amyl xanthate	0·30
Pine oil	0·20
Copper sulphate	1·0

Results:

Product	Weight, per cent	Assay				Distribution, per cent				Ratio of concentration
		Au, oz./ton	Ag, oz./ton	Cu, per cent	Fe, per cent	Au	Ag	Cu	Fe	
Feed	100·00	....	....	....	....	100·00	100·00	100·00	100·00	
Concentrate	12·65	8·76	12·60	7·22	32·23	97·69	96·82	97·21	60·17	7·91 : 1
Tailing	87·35	0·03	0·06	0·03	3·09	2·31	3·18	2·79	39·83	

Screen Test on Tailing:

Mesh	Weight, per cent
+100	0·2
+150	2·1
+200	12·5
−200	85·2
	100·0

Test No. 6

In this test an attempt was made to obtain a high-grade copper concentrate by selective flotation of the bulk concentrate.

The ore sample was ground with soda ash and Aerofloat No. 31. A bulk float was made and the bulk concentrate was then reground with soda ash. The reground pulp was then conditioned with cyanide and xanthate.

Reagents:

	Lb./ton
To Primary Grinding—	
Soda ash	3·0
Aerofloat No. 31	0·07
To Bulk Flotation—	
Potassium amyl xanthate	0·4
Pine oil	0·1
To Selective Flotation—	
Cyanide	0·10
Amyl xanthate	0·10

Results of Bulk Flotation:

Product	Weight, per cent	Assay			Distribution, per cent			Ratio of concentration
		Au, oz./ton	Ag, oz./ton	Cu, per cent	Au	Ag	Cu	
Feed	100·00	0·96	1·89	0·90	100·00	100·00	100·00	
Bulk concentrate	10·52	8·67	16·44	8·52	94·44	93·24	100·00	9·51 : 1
Bulk tailing	89·48	0·06	0·14	Nil	5·56	6·76	....	

Selective Float of Bulk Concentrate:

Product	Weight, per cent	Assay			Distribution, per cent			Ratio of concentration
		Au, oz./ton	Ag, oz./ton	Cu, per cent	Au	Ag	Cu	
Feed	100·00	8·67	16·44	8·32	100·00	100·00	100·00	
Cu concentrate	54·38	12·06	22·54	8·70	75·64	74·55	56·89	1·84 : 1
Cleaner tailing	45·62	4·63	9·17	7·86	24·36	25·45	43·11	

The results do not indicate a good recovery in the selective float. This is probably due to insufficient grinding of the bulk concentrate and not sufficient time of contact with the cyanide. The two following tests take into account these two factors.

Screen Test of Tailing:

Mesh	Weight, per cent
+100	0·8
+150	4·5
+200	17·0
−200	77·7
	100·0

The bulk tailing was run over a corduroy blanket with the following results:

Product	Weight, per cent	Assay, oz./ton	Distribution, per cent	Ratio of concentration
Concentrate	1·33	4·08	55·0	75·19 : 1
Tailing	98·67	0·045	45·0	

The results indicate that by bulk flotation a fair proportion of free gold will find its way into the tailing.

Test No. 7

The sample of ore was ground in an Abbé pebble jar with 3 pounds of soda ash and 0·07 pound of Aerofloat No. 31 per ton. A bulk float was then made using the following reagents:

	Lb./ton
Potassium amyl xanthate	0·4
Pine oil	0·1

The bulk concentrate was then reground for 20 minutes in an alkaline (soda ash) pulp with 0·20 pound of cyanide per ton of concentrate. A selective float was then made, conditioning with a small amount of amyl xanthate.

The results of these tests follow:

Bulk Flotation:

Product	Weight, per cent	Assay			Distribution, per cent			Ratio of concentration
		Au, oz./ton	Ag, oz./ton	Cu, per cent	Au	Ag	Cu	
Feed	100·00	0·96	1·89	0·90	100·00	100·00	100·00	
Bulk concentrate	11·28	8·68	16·53	7·79	93·64	90·33	100·00	8·87 : 1
Bulk tailing	88·72	0·075	0·225	Trace	6·36	9·67	....	

Selective Flotation of Bulk Concentrate:

Product	Weight, per cent	Assay			Distribution, per cent			Ratio of concentration
		Au, oz./ton	Ag, oz./ton	Cu, per cent	Au	Ag	Cu	
Feed	100·00	8·68	16·53	7·79	100·00	100·00	100·00	
Copper concentrate	63·41	12·64	23·64	11·50	92·29	90·66	93·61	1·58 : 1
Cleaner tailing	36·59	1·83	4·22	1·36	7·71	9·34	6·39	

Test No. 8

In this test the grinding and bulk flotation were carried out as in Test No. 7. The bulk concentrate was ground with 0·20 pound of cyanide and 7·0 pounds of lime per ton of concentrate for 30 minutes, and a selective float made in a fairly dilute pulp. Cresylic acid and pine oil were used as frothers.

Bulk Flotation:

Product	Weight, per cent	Assay			Distribution, per cent			Ratio of concentration
		Au, oz./ton	Ag, oz./ton	Cu, per cent	Au	Ag	Cu	
Feed	100·00	0·96	1·89	0·90	100·00	100·00	100·00	
Bulk concentrate	10·77	9·13	16·21	8·30	95·66	92·45	100·00	9·29 : 1
Bulk tailing	89·23	0·05	0·16	Trace	4·34	7·55	....	

Selective Flotation of Bulk Concentrate:

Product	Weight, per cent	Assay			Distribution, per cent			Ratio of concentration
		Au, oz./ton	Ag, oz./ton	Cu, per cent	Au	Ag	Cu	
Feed	100·00	9·13	16·21	8·30	100·00	100·00	100·00	
Copper concentrate	44·63	16·98	29·50	17·26	83·02	81·21	92·86	2·24 : 1
Cleaner tailing	55·37	2·80	5·50	1·07	16·98	18·79	7·14	

The lime pulp in the selective float of the bulk concentrate raises the grade of the copper concentrate, but tends to lower the gold content.

The cleaner tailing from the selective float was barrel-amalgamated to determine if a further recovery of the gold in this product were possible.

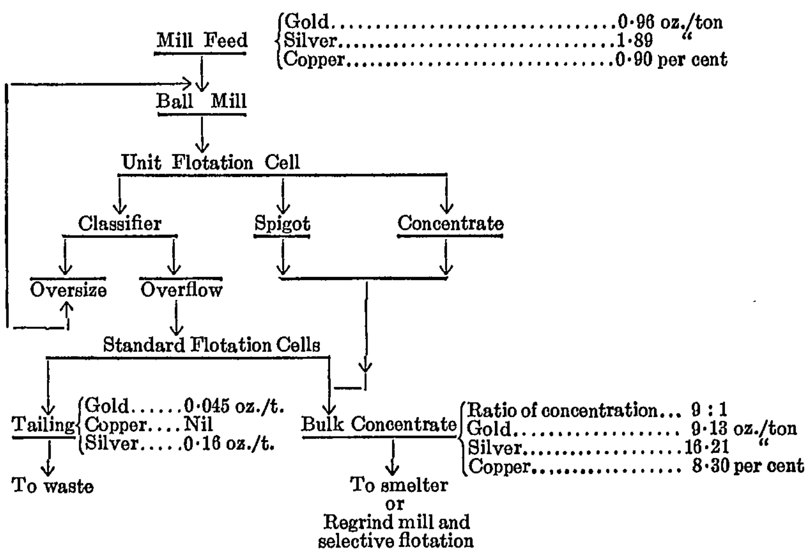
The sample of cleaner tailing assayed 2·48 ounces gold per ton. After amalgamation the tailing assayed 2·23 ounces gold per ton, indicating a recovery of only 10·08 per cent.

The results of this test would indicate that the gold present in the cleaner tailing is associated largely with the pyrite or other sulphides.

CONCLUSIONS

The results of the tests indicate that the use of a unit cell in the classifier circuit followed by standard flotation cells will provide a satisfactory bulk concentrate. This product may be shipped to a smelter, or it may be reground and given a selective float in a secondary flotation unit. The latter method will produce a concentrate in which the grade of copper will be increased and the bulk further reduced for shipping. The tailing from the selective flotation (cleaner tailing) may be barrel-amalgamated.

A suggested flow-sheet is as follows:



The indicated overall recovery of gold by utilizing the above flow-sheet and based on the tests carried out on the ore sample submitted is approximately 98 per cent.

Ore Dressing and Metallurgical Investigation No. 62

GOLD-SILVER ORE FROM THE BAYONNE CONSOLIDATED GOLD MINES, LTD., NELSON, BRITISH COLUMBIA

Shipment. Two bags of ore weighing 120 pounds were received April 23, 1935, from the Bayonne Consolidated Gold Mines, Limited, Nelson, B.C. These were shipped on the advice of P. W. Racey, Consulting Engineer, Vancouver, B.C. One of the bags contained oxidized material, and the other oxidized and sulphide ore. This property is 23 miles from Tye station on the C.P.R., west of Kootenay lake, B.C.

Characteristics of the Ore: The shipment consisted of a siliceous gangue containing much oxidized material. Sulphides of iron, lead, and zinc were present. Gold and silver also were present but owing to the oxidized condition of the ore their relation to other minerals was not determined.

Experimental Tests

For this investigation, the contents of the two bags were mixed together and sampled. Analysis showed the lot to contain:

Gold	0·90 oz./ton	Lead	2·30 per cent
Silver	4·49 "	Zinc	0·80 "
		Copper	0·08 "

The test work included flotation, cyanidation, and amalgamation.

Flotation recovered 87 per cent of the gold, 53 per cent of the silver, and 42 per cent of the lead, with a ratio of concentration of 16·2 : 1. The concentrate contained 12·36 ounces of gold, 38·64 ounces of silver per ton, and 14·6 per cent lead. Cyanidation extracted 97 per cent of the gold and 80 per cent of the silver.

FLOTATION, BLANKETING, CYANIDATION

Test No. 1

A sample of the ore was ground in water to pass 48 per cent through 200 mesh with 2·5 per cent remaining on 65 mesh. The pulp was then passed over a corduroy blanket and the blanket tailing conditioned and a flotation concentrate removed. The flotation tailing was then cyanided for 48 hours.

Results:

Product	Weight, per cent	Assay, oz./ton		Distribution, per cent	
		Au	Ag	Au	Ag
Feed (cal.)	100·00	0·87	4·34	100·0	100·0
Blanket concentrate	7·10	6·89	12·45	56·3	20·4
Blanket tailing	......	0·425	3·815	......	......
Flotation concentrate	2·21	8·18	48·88	20·8	24·9
Flotation tailing	90·69	0·22	2·62	22·9	54·7

Cyanidation of Flotation Tailing:

	Au	Ag
Feed	0·22 oz./ton	2·62 oz./ton
24-hour cyanide tailing	0·08 "	0·97 "
48-hour cyanide tailing	0·045 "	0·895 "
Extraction	80·0 per cent	65·8 per cent

These results show that part of the gold is present as free gold and can be caught on blankets. The blanket concentrate was bulky, containing much gangue and sulphides. Flotation also recovered some of the precious metals. The silver assay of the flotation concentrate indicates that a considerable part of the silver is present as sulphide.

Cyanidation of the flotation tailing indicates the possibility of extracting the gold and silver by this method. The assays of the 24-hour and 48-hour cyanide tailing indicate the need of grinding finer than 48 per cent −200 mesh.

Test No. 2

A sample of the ore was ground wet to pass 100 mesh with 74 per cent −200 mesh. Six pounds of soda ash and 0·10 pound of cyanide were added to the grinding mill; 0·10 pound of butyl xanthate and 0·12 pound of pine oil per ton were added to the flotation cell and a concentrate removed. The flotation tailing was passed over a corduroy blanket to catch any free gold not floated.

Results:

Product	Weight, per cent	Assay, oz./ton		Distribution, per cent	
		Au	Ag	Au	Ag
Feed (cal.)	100·00	0·87	4·76	100·0	100·0
Flotation concentrate	6·17	11·94	39·10	84·6	50·6
Blanket concentrate	4·40	0·81	11·45	4·1	10·6
Blanket tailing	89·43	0·11	2·07	11·3	38·8

Test No. 3

This test is similar to Test No. 2 with the exception that the flotation tailing was not passed over blankets.

Results:

Product	Weight, per cent	Assay, oz./ton		Distribution, per cent	
		Au	Ag	Au	Ag
Feed (cal.)	100·00	0·87	4·56	100·0	100·0
Flotation concentrate	5·98	12·28	40·66	83·9	53·3
Flotation tailing	94·02	0·15	2·27	16·1	46·7

There is a slight advantage to be gained by the use of blankets to trap any free gold not floated. Test No. 2 produces a blanket concentrate containing 0·81 ounce of gold, 11·45 ounces of silver per ton. This is bulky, representing 4·4 per cent of the weight of the feed. If this concentrate were cleaned, most of the bulk would be eliminated and the gold recovered.

Test No. 4

In this test, no cyanide was added to the grinding mill. Amyl xanthate was substituted for butyl xanthate. In all other respects the procedure was the same as in Test No. 3.

Results:

Product	Weight, per cent	Assay, oz./ton		Distribution, per cent	
		Au	Ag	Au	Ag
Feed (cal.)	100·00	0·89	4·51	100·0	100·0
Flotation concentrate	8·87	8·13	30·53	81·5	60·0
Flotation tailing	91·13	0·18	1·93	18·5	40·0

The omission of cyanide from the circuit made the flotation much slower, and the froth was heavy and sluggish. The gold in the tailing was higher and the concentrate more bulky and lower in grade than in Test No. 3.

Test No. 5

A test similar to Test No. 4 was made. The ore was ground with soda ash, conditioned with sodium sulphide and floated. Poorer results were obtained than those of Test No. 4. The concentrate was lower in grade and the tailing loss about the same.

Test No. 6

In this test, finer grinding was adopted. The ore was ground wet with 6 pounds of soda ash and 0·10 pound of cyanide per ton until 89 per cent passed 200 mesh; 0·10 pound of amyl xanthate and 0·12 pound of pine oil per ton were added and a flotation concentrate removed. The flotation tailing was cyanided 1 : 3 dilution with 3·0 pounds of potassium cyanide per ton solution. Ten pounds of lime per ton was added to supply protective alkalinity.

Results:

Product	Weight, per cent	Assay				Distribution, per cent			
		Au, oz./ton	Ag, oz./ton	Pb, per cent	Zn, per cent	Au	Ag	Pb	Zn
Feed (cal.)	100·00	0·92	4·31	2·47	0·76	100·0	100·0	100·0	100·0
Concentrate	8·43	9·30	32·50	13·72	7·95	85·5	46·7	46·7	88·0
Tailing	91·57	0·145	1·715	1·44	0·10	14·5	53·3	53·3	12·0

Cyanidation Results—24 Hours' Agitation:

	Au	Ag
Feed	0·145 oz./ton	1·715 oz./ton
Tailing	0·02 "	0·67 "
Extraction	86·2 per cent	60·9 per cent

Reagents:

KCN....................2·6 lb./ton solution
CaO....................0·3 "

Reagent Consumption:

KCN..1·2 lb./ton ore
CaO..9·1 "

Increasing the time of agitation to 48 hours did not increase the recovery.

These results indicate that the gold left in the flotation tailing is readily soluble in cyanide solution. Flotation recovers 85·5 per cent of the gold in the form of a concentrate. Cyanidation extracts 86·2 per cent of the metal not recovered by flotation. A total recovery of 98 per cent of the gold is, therefore, obtained by the combined processes.

Test No. 7

To note the effect of cleaning the flotation concentrate, a sample was ground wet together with 6·0 pounds of soda ash and 0·10 pound of cyanide per ton until 89 per cent passed 200 mesh; 0·10 pound of amyl xanthate and 0·12 pound of pine oil per ton were added and a flotation concentrate removed. This concentrate was cleaned once, producing a concentrate and a cleaner tailing.

Product	Weight, per cent	Assay				Distribution, per cent			
		Au, oz./ton	Ag, oz./ton	Pb, per cent	Zn, per cent	Au	Ag	Pb	Zn
Feed (cal.).........	100·00	0·87	4·48	2·13	0·93	100·0	100·0	100·0	100·0
Concentrate........	6·16	12·36	38·64	14·65	10·26	87·3	53·1	42·4	67·8
Cleaner tailing.....	1·73	1·62	26·32	4·36	5·08	3·2	10·2	3·5	9·4
Flotation tailing...	92·11	0·09	1·79	1·25	0·23	9·5	36·7	54·1	22·8

Ratio of concentration—16·2 : 1

CYANIDATION

Large samples of the ore were ground dry in a disk pulverizer to pass 48, 100, 150, and 200 mesh. Four series of tests were made on samples from these. They were cyanided with a 4·0 pound of potassium cyanide per ton solution, 1 : 3 dilution for 48 hours.

Grind:

Screen size	−48-mesh grind	−100-mesh grind	−150-mesh grind
− 48 + 65........	....	....	....
− 65 +100........	26·9	....	....
−100 +150........	17·7	8·7	....
−150 +200........	15·2	26·3	15·0
−200........	40·2	65·0	85·0

Test No. 8—Series I

Lime, equivalent to 12 pounds per ton of ore was added to each test.

Results:

Mesh	Agitation, hours	Feed, oz./ton		Tailing, oz./ton		Extraction, per cent		Titration, lb./ton solution		Consumption, lb./ton ore	
		Au	Ag	Au	Ag	Au	Ag	KCN	CaO	KCN	CaO
− 48............	24	0·90	4·49	0·38	1·40	57·8	68·7	3·6	0·22	1·2	11·3
−100............	"	"	"	0·085	1·035	90·6	76·9	3·5	0·2	1·5	11·3
−150............	"	"	"	0·025	0·885	97·2	80·3	3·25	0·15	2·2	11·5
−200............	"	"	"	0·025	0·915	97·2	79·6	3·15	0·17	2·4	11·5
− 48............	48	"	"	0·49	1·40	45·6	68·8	3·4	0·1	1·8	11·7
−100............	"	"	"	0·06	0·92	93·3	79·5	3·2	0·1	2·4	11·7
−150............	"	"	"	0·035	0·785	96·1	82·5	3·1	0·1	2·7	11·7
−200............	"	"	"	0·03	0·82	96·7	81·7	2·95	0·1	3·1	11·7

Test No. 9—Series II

	Lb./ton
CaO added..	12·0
PbO added..	2·0

Results:

Mesh	Agitation, hours	Feed, oz./ton		Tailing, oz./ton		Extraction, per cent		Titration, lb./ton solution		Consumption, lb./ton ore	
		Au	Ag	Au	Ag	Au	Ag	KCN	CaO	KCN	CaO
− 48............	24	0·90	4·49	0·49	1·45	45·6	67·7	3·5	0·25	1·5	11·2
−100............	"	"	"	0·105	1·015	88·3	77·4	3·4	0·25	1·8	11·3
−150............	"	"	"	0·05	0·88	96·7	80·4	3·25	0·15	2·1	11·5
−200............	"	"	"	0·025	0·895	97·2	80·1	3·2	0·15	2·4	11·5
− 48............	48	"	"	0·49	1·35	45·6	69·9	3·5	0·15	1·5	11·5
−100............	"	"	"	0·20	0·98	77·8	78·2	3·35	0·15	1·8	11·5
−150............	"	"	"	0·03	0·79	96·7	82·4	3·2	0·08	2·4	11·7
−200............	"	"	"	0·04	1·04	93·6	76·9	3·1	0·10	2·7	11·7

Test No. 10—Series III

In this series, no lime was added at the commencement. Four pounds per ton was added two hours before the end of the agitation period. The solutions were cloudy and the pulp slow to settle.

Results:

Mesh	Agitation, hours	Feed, oz./ton		Tailing, oz./ton		Extraction, per cent		Titration, lb./ton solution		Consumption, lb./ton ore	
		Au	Ag	Au	Ag	Au	Ag	KCN	CaO	KCN	CaO
− 48............	24	0·90	4·49	0·075	1·085	91·7	75·8	2·9	0·05	3·3	3·8
−100............	"	"	"	0·03	0·86	96·7	80·8	2·65	Nil	4·1	4·0
−150............	"	"	"	0·025	0·735	97·2	88·1	2·35	"	4·9	4·0
−200............	"	"	"	0·02	1·13	97·8	74·8	2·15	"	5·5	4·0
− 48............	48	"	"	0·06	0·66	93·3	85·3	2·9	0·05	3·3	3·8
−100............	"	"	"	0·03	0·69	96·7	84·6	2·6	Nil	4·2	4·0
−150............	"	"	"	0·025	0·625	97·2	86·1	2·3	"	5·1	4·0
−200............	"	"	"	0·02	0·59	97·8	86·9	2·2	"	5·4	4·0

Test No. 11—Series IV

This series is the same as Test No. 10 with 2·0 pounds PbO per ton added.

Mesh	Agitation, hours	Feed, oz./ton		Tailing, oz./ton		Extraction, per cent		Titration, lb./ton solution		Consumption, lb./ton ore	
		Au	Ag	Au	Ag	Au	Ag	KCN	CaO	KCN	CaO
− 48	24	0·90	4·49	0·06	0·99	93·3	75·8	2·9	0·05	3·3	3·8
−100	"	"	"	0·03	0·83	96·7	80·8	2·6	Nil	4·2	4·0
−150	"	"	"	0·02	0·71	97·8	83·6	2·45	"	4·65	4·0
−200	"	"	"	0·02	0·70	97·8	84·4	2·35	"	4·95	4·0
− 48	48	"	"	0·055	0·935	93·9	79·4	2·85	0·05	3·4	3·8
−100	"	"	"	0·025	0·645	97·2	85·6	2·6	Nil	4·2	4·0
−150	"	"	"	0·02	0·69	97·8	84·6	2·45	"	4·65	4·0
−200	"	"	"	0·03	0·68	96·7	84·6	2·4	"	4·8	4·0

These tests indicate that 97 per cent of the gold and 80 per cent of the silver can be extracted within 24 hours from ore ground 85 per cent −200 mesh. When 12 pounds of lime per ton of ore is added at the commencement, a cyanide consumption of approximately 2·4 pounds of potassium cyanide or 1·9 pounds of sodium cyanide per ton is indicated. When the lime is omitted until near the end of the operation, the gold and silver are dissolved more rapidly from the coarser sizes, and a slightly higher recovery is made from the finer sizes. However, there is indicated a consumption of approximately 3·0 pounds of potassium cyanide or 4 pounds of sodium cyanide per ton of ore. The settling rate is very slow.

Test No. 12

A sample of the ore was ground wet in a porcelain mill containing iron balls until 89 per cent passed 200 mesh. The pulp was then diluted to 1 : 2·5 and cyanide added to make a solution strength of 4·37 pounds of potassium cyanide per ton. Lime equivalent to 13 pounds per ton of ore was added and agitation continued for 48 hours.

Results:

Feed	0·90 oz. Au/ton
Tailing	0·42 "
Extraction	53·3 per cent
Reagents—	
KCN	2·9 lb./ton solution
CaO	0·25 "
Consumption—	
KCN	3·7 lb./ton ore
CaO	12·4 "

Test No. 13

To determine why such a low extraction was obtained in the previous test, a sample was ground in the same manner with lime equivalent to 14 pounds per ton of ore and aerated in a Denver super-agitator (Wallace type) for 4 hours. Cyanide sufficient to make a 3·0 pound of potassium cyanide per ton solution and 5·0 pounds of lime per ton were added. Cyanidation was concluded after 48 hours.

Results:

Feed	0·90 oz. Au/ton
Tailing	0·40 "
Extraction	55·5 per cent
Reagents—	
KCN	2·9 lb./ton solution
CaO	0·3 "
Consumption—	
KCN	1·25 lb./ton ore
CaO	18·2 "

The only apparent benefit derived from aeration prior to cyanidation is the reduction in cyanide consumed. This is reduced from 3·7 pounds to 1·25 pounds per ton of ore. During the aeration period, the lime in solution is consumed, the solution titrating only 0·03 pound of lime per ton at the end of the 4-hour aeration period.

Test No. 14

As only 50 to 55 per cent of the gold was extracted by cyanidation when the ore was ground wet in a jar mill as against 97 per cent when ground dry in a disk pulverizer, it was assumed that the small ball mill was not grinding the gold, but merely flattening and hammering the particles so that they were slow to dissolve. To check this point, a sample was ground as in Test No. 12 and amalgamated. After removing amalgam, the tailing was cyanided as in Test No. 12 for a period of 24 hours.

Results:

Feed	0·90 oz. Au/ton
Amalgamation tailing	0·265 "
Recovery	70·6 per cent

Cyanidation:

Feed—Amalgamation tailing	0·265 oz. Au/ton
24-hour cyanide tailing	0·055 "
Extraction	79·2 per cent
Reagent Consumption—	
KCN	2·3 lb./ton ore
CaO	12·2 "

Total recovery, amalgamation plus cyanidation 93·9 per cent. It is apparent that the free gold in the ore which amounts to 70 per cent of the total, is responsible for the low recoveries in Tests No. 12 and 13. To obtain uniform high recoveries, this gold should be removed before the pulp reaches the agitators.

SUMMARY AND CONCLUSIONS

As this property is quite isolated and shipment of concentrate would involve a long truck-haul followed by a rail-haul of 90 miles to the smelter, it is imperative that the gold be recovered as bullion on the property or that a high-grade concentrate of small bulk be produced.

Owing to the presence of sulphides of iron, lead, and zinc in the ore, these minerals will tend to produce a bulky flotation concentrate. By flotation 87 per cent of the gold and from 50 to 60 per cent of the silver can be recovered in a concentrate assaying 12·36 ounces of gold, 38·64 ounces of silver per ton, 14·6 per cent lead, and 10 per cent zinc. From

100 tons of ore 6·16 tons of concentrate can be expected, and 86 per cent of the gold in the flotation tailing is readily extracted by cyanidation, giving an overall recovery of 98 per cent.

When the ore is ground 89 per cent −200 mesh, 70 per cent of the gold is free and can be amalgamated.

The cyanide tests indicate that maximum extraction will be obtained from ore ground approximately 65 per cent −200 mesh. A fairly strong cyanide solution should be used, one containing from 4 to 5 pounds of available potassium cyanide per ton, to obtain good silver recovery.

The presence of lime during the agitation period has a tendency to decrease the rate of solution of the gold and silver. However, when no lime is used, the amount of cyanide consumed becomes prohibitive. The quantity of lime used should be kept at a minimum, only enough being added to obtain a satisfactory settling rate in the thickeners. The amount necessary to add will vary, depending on the degree of oxidation of the feed.

A mill to treat a small daily tonnage must of necessity be of simple design. Single-stage grinding will be used with one classifier in closed circuit with the mill.

The presence of free gold in the ore, unless locked in the grinding circuit by an elaborate system of classification, has been shown to produce high tailing losses. This gold either must be removed prior to agitation, or ground as fine as the gangue and sulphides. This gold could be removed by jigging or caught on corduroy blankets.

The flow-sheet suggested for treatment of a small daily tonnage of this ore is as follows:

Grinding should be done in cyanide solution with lime added to the feed. This should pass to a tube mill capable of fine grinding. The mill discharge should then pass to two or more concentrating tables of the Wilfley type. The concentrates from these tables should be reconcentrated on another table where a narrow bead of gold concentrate could be taken off, also high-grade lead concentrate. The tailing from all these tables should go to a bowl classifier, the oversize from which should be returned to the mill for further grinding. The classifier overflow adjusted to give approximately −200 particles should pass to a thickener and thence through agitators where 24 hours' contact should suffice to give maximum extraction.

The gold concentrate from the table should be barrel-amalgamated and bullion recovered. The lead concentrate, which should not amount to more than 2·6 tons from each 100 tons of feed, should be shipped to the smelter.

The ore on which this investigation was conducted was a mixture of oxidized ore and sulphide ore. Any change in the character of the ore may change the metallurgy. There is the possibility that clean unoxidized sulphides may not respond to the treatment as does this oxidized material. When such ore is obtainable from below the oxidized zone, it would be advisable to have this point checked to govern future mill operation.

Ore Dressing and Metallurgical Investigation No. 630

COPPER-ZINC ORE FROM ABANA MINE, DESMELOIZES TOWNSHIP, ABITIBI COUNTY, QUEBEC.

Shipment. A shipment of 9,835 pounds of ore was received March 16, 1934, and a further shipment of 90 tons was received on January 31, 1935, from the Abana mine of the Normetal Mining Corporation, Limited, in Desmeloizes township, Abitibi county, Quebec.

Arrangements for these shipments were made by M. F. Fairlie, of the Mining Corporation of Canada, Limited.

Character of the Ore. The ore consists of massive sulphides with a minor amount of gangue material. The gangue consists of carbonate (probably dolomite) and silicate, with some quartz; it occurs as small areas and grains included in the sulphide masses. The sulphides are pyrite, sphalerite, chalcopyrite, pyrrhotite, galena and tetrahedrite (or tennantite?). Though the sulphides are commonly intimately admixed, they are usually rather coarse-textured, and even form large masses composed chiefly of one or another of the individual sulphides; these large masses contain small grains of other sulphides. A finer-textured phase of the ore, which forms a lesser percentage of the whole, is fine-grained and the sulphides are intimately admixed, as is shown in Plate IA and B.

Pyrite is the first ore mineral formed, and is disseminated in cubes and irregular grains. It is invaded and veined by pyrrhotite, chalcopyrite, sphalerite, and more rarely galena. Some portions of the ore consist almost entirely of pyrite, and here a rather distinct banding is present, indicating that this mineral has replaced a banded (or schistose) rock.

Sphalerite occurs in large masses and small grains. It often has included or partially surrounded the pyrite grains. Numerous dots of chalcopyrite, and, more rarely, pyrrhotite, occur within the sphalerite.

Chalcopyrite also forms large granular masses. These masses usually contain small corroded remnants of pyrite, pyrrhotite, and sphalerite.

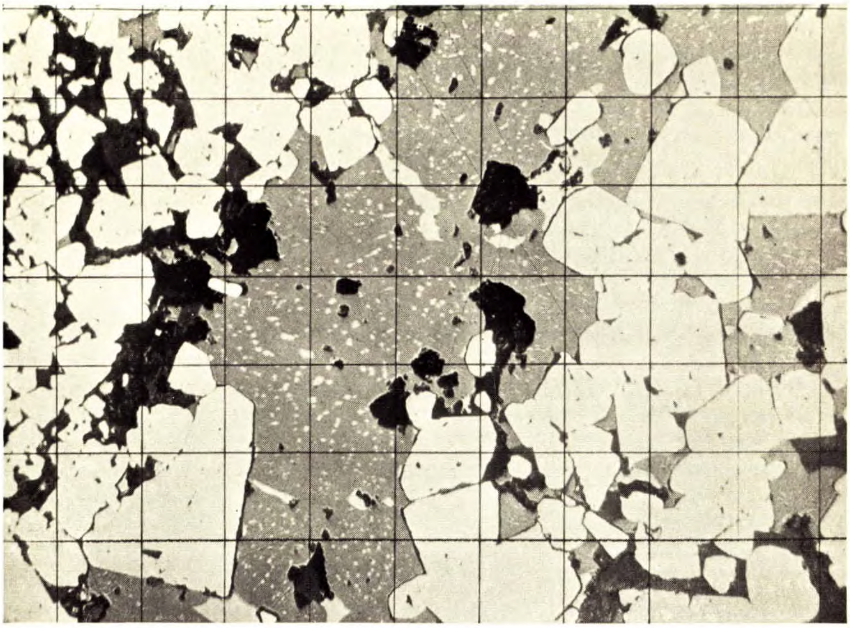
Galena is not common, and occurs as small grains usually associated with chalcopyrite. The galena contains rare small rounded grains of tetrahedrite (or tennantite?).

Pyrrhotite is common and often forms rather large masses in chalcopyrite. It also occurs as small dots in sphalerite.

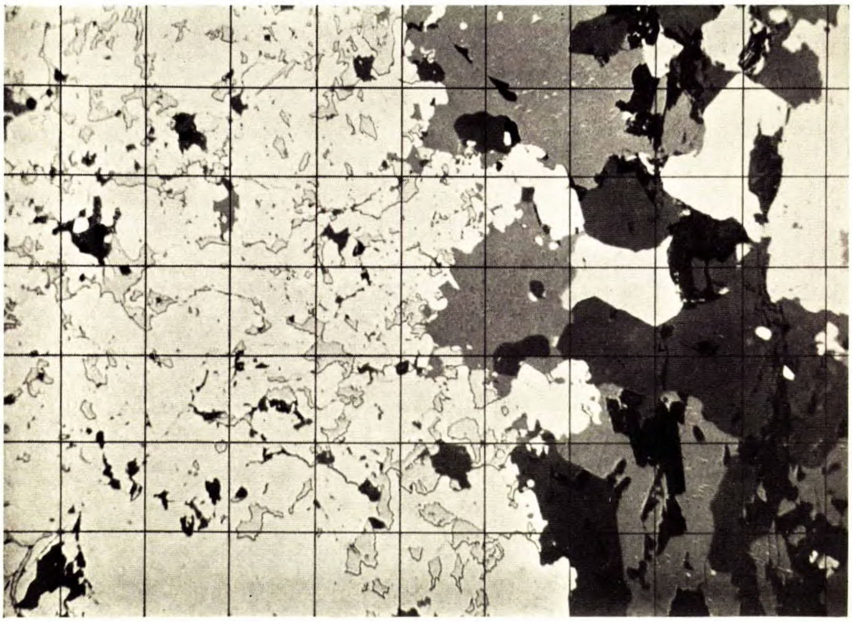
The order of deposition of the minerals is as follows: Silicates (and/or quartz); pyrite; pyrrhotite; sphalerite; chalcopyrite; galena and tetrahedrite (tennantite?); carbonate (dolomitic).

Analysis of Ore:

	Shipment No. 1	Shipment No. 2
Copper	2·80	2·81
Zinc	13·00	15·10
Lead	0·61	0·63
Gold	0·05	0·048
Silver	5·63	5·53
Iron	23·27	24·45
Sulphur	27·32	29·20
Silica	19·23	....
Lime	1·21	....
Magnesia	0·56	....
Alumina	0·10	....



A. Polished section of ore showing the sphalerite and pyrite in the finer phases; ×150, 200-mesh grid. Pyrite—white; chalcopyrite—light grey; sphalerite—medium grey; pits—black; (some very dark grey patches are gangue).



B. Polished section of ore showing intimate admixture of chalcopyrite and pyrite; ×150, 200-mesh grid. Pyrite—white; chalcopyrite—light grey; sphalerite—medium grey; gangue—dark grey; pits—black.

From the above analysis it can be seen that the shipments are very similar. There was, however, a marked difference in the appearance of he two shipments; Shipment No. 1 was clean, fresh ore from underground, whereas Shipment No. 2 was taken from dump ore and was more difficult to treat, owing to a certain degree of oxidation having taken place.

Purpose of Experimental Work. The tests were conducted with the object of obtaining metallurgical data for the purpose of estimating profits. Two main schemes of treatment are under consideration: (1) The production of a high-grade copper concentrate and a high-grade zinc concentrate for shipment to respective smelters, and (2) the production of a bulk concentrate and consideration of the possibility of treating this bulk concentrate by the Waelz process.

The test work on Shipment No. 1 was confined wholly to the production of a bulk concentrate, there being insufficient ore to carry out the selective flotation tests. The work on Shipment No. 2 was for two purposes; primarily, however, it was to produce a quantity of bulk concentrate for shipment to Germany where arrangements had been made for tests to be carried out by the Waelz process. The second purpose was to complete the experimental work in connexion with the selective flotation, in the production of a copper concentrate and zinc concentrate.

Experimental Tests

Reference will first be made to the production of the bulk concentrate for shipment to Germany. The actual results obtained were not so good as those shown by the previous experimental work done on Shipment No. 1. There are probably two reasons which would account for the lower recoveries obtained: first, the ore was slightly oxidized; and, second, the rate of feed was too great for the capacity of the flotation equipment.

The following is a brief summary of the test to produce the bulk concentrate for shipment:

Total amount of ore used	77·0 tons
Weight of concentrate produced	27·75 "

Assays:

—	Average of ore	Average of concentrate	Average of tailing
Copper	2·81 per cent	6·42 per cent	0·43 per cent
Zinc	15·10 "	31·20 "	2·70 "
Lead	0·63 "	1·45 "	0·10 "
Gold	0·045 oz./ton	0·09 oz./ton	0·02 oz./ton
Silver	5·53 "	10·78 "	1·60 "
Iron	....	20·85 per cent	....
Sulphur	....	36·45 "	....
Silica	....	1·10 "	....
Lime	....	0·35 "	....
Magnesia	....	0·02 "	....
Alumina	....	0·75 "	....

The concentrate varied from day to day, the limits being 9·0 per cent copper and 33 per cent zinc to 4·7 per cent copper and 31·7 per cent zinc with tailing as low as 0·2 per cent copper and 1·4 per cent zinc. At times the tailing went to 0·66 per cent copper and 4·85 per cent zinc.

The theoretical recoveries, based on the feed sample of the entire shipment and average concentrate and tailing obtained, are as follows:

	Per cent
Copper	91
Zinc	85
Gold	80
Silver	78

The tonnage of concentrate which theoretically should have been produced is 30·6 tons from 77 tons of ore. Therefore it can be assumed that roughly 3 tons of concentrate was lost in settling, filling, and drying, which is not unreasonable considering the equipment available for that purpose.

It is worthy of note that the tailing from every shift of the run assayed 0·02 ounce per ton in gold. Therefore it is safe to accept the theoretical recovery of 80 per cent for the gold as definitely assured.

The remainder of the report covers the test work in connexion with the production of a bulk concentrate by flotation carried out on Shipment No. 1, and the selective flotation tests made on the rest of Shipment No. 2.

BULK FLOTATION TESTS ON SHIPMENT No. 1

The first series of tests conducted was on small batch lots of ore to obtain data for the large-scale continuous tests. The results of the batch tests are given in the following tables. Table I shows the reagents used; Table II shows the results of the tests; and Table III shows the screen tests made on the feed.

TABLE I

Reagents Used in Batch Tests

Test No.	Reagents	Lb./ton	Added to
1	Soda ash	5·0	Ball mill
	Cyanide	0·1	"
	Copper sulphate	1·0	Flotation cell
	Potassium ethyl xanthate	0·1	"
	Cresylic acid	0·05	"
2	Soda ash	2·5	Ball mill
	Cyanide	0·1	"
	Copper sulphate	1·0	Flotation cell
	Potassium ethyl xanthate	0·1	"
	Cresylic acid	0·05	"
3	Soda ash	2·5	Ball mill
	Cyanide	0·1	"
	Cresylic acid	0·02	Flotation cell for Cu float
	Copper sulphate	1·0	Flotation cell for Zn float
	Potassium ethyl xanthate	0·1	" "
	Cresylic acid	0·02	" "
4	Soda ash	2·5	Ball mill
	Cyanide	0·1	"
	Aerofloat No. 31	0·07	"
	Copper sulphate	1·0	Flotation cell
	Potassium ethyl xanthate	0·1	"
	Cresylic acid	0·03	"

TABLE II

Results of Batch Flotation Tests

Test No.	Product	Weight		Analysis					Units					Distribution, per cent				
		Grammes	Per cent	Per cent			Oz./ton											
				Cu	Zn	Pb	Au	Ag	Cu	Zn	Pb	Au	Ag	Cu	Zn	Pb	Au	Ag
1	Concentrate.........	660·9	32·2	8·58	40·0	1·84	0·03	11·52	276·3	1288	59·2	0·966	370·9	88·3	92·0	76·4	17·7	70·6
	Middling............	199·5	9·7	2·30	7·62	0·87	0·165	8·20	22·3	74	8·4	1·600	79·5	7·1	5·0	10·8	29·3	15·1
	Tailing.............	1191·2	58·1	0·25	0·65	0·17	0·05	1·29	14·5	38	9·9	2·900	75·0	4·6	3·0	12·8	53·0	14·3
	Total.........	2051·6	100·0	3·13	14·0	0·78	0·05	5·25	313·1	1400	77·5	5·466	525·4	100·0	100·0	100·0	100·0	100·0
2	Concentrate.........	556·4	27·9	10·04	30·18	2·14	0·06	14·00	298·2	896	63·6	1·78	415·8	94·0	65·3	87·6	27·9	76·4
	Middling............	282·0	14·2	0·78	12·32	0·43	0·10	4·23	11·1	175	6·1	1·42	60·1	3·5	12·7	8·4	22·3	11·1
	Tailing.............	1153·7	57·9	0·14	4·20	0·05	0·055	1·18	8·1	301	2·9	3·18	68·3	2·5	22·0	4·0	49·8	12·5
	Total.........	1992·1	100·0	3·17	13·7	0·73	0·064	5·44	317·4	1372	72·6	6·38	544·2	100·0	100·0	100·0	100·0	100·0
3	Cu concentrate.......	267·0	13·6	18·40	16·70	3·64	0·04	17·54	250·2	227	49·5	0·54	238·5	87·4	17·0	71·1	9·8	53·6
	Cu middling.........	93·0	4·7	3·14	16·75	1·0	0·13	9·52	14·7	79	4·7	0·61	44·7	5·2	6·0	6·7	11·0	10·0
	Zn concentrate.......	287·5	14·7	0·20	53·8	0·4	0·03	2·34	2·9	791	5·9	0·44	34·4	1·0	59·4	8·5	8·0	7·8
	Zn middling.........	188·7	9·6	0·90	19·5	0·4	0·08	4·01	8·6	187	3·8	0·77	38·5	3·0	14·0	5·5	14·0	8·6
	Tailing.............	1126·5	57·4	0·17	0·83	0·1	0·055	1·55	9·8	48	5·7	3·16	89·0	3·4	3·6	8·2	57·2	20·0
	Total.........	1962·7	100·0	2·86	13·32	0·07	0·055	4·45	286·2	1332	69·6	5·52	445·1	100·0	100·0	100·0	100·0	100·0
4	Concentrate.........	493·0	24·7	9·66	36·3	......	0·12	13·9	238·6	897	......	2·96	343·3	86·5	68·5	......	49·1	64·2
	Middling............	448·4	22·5	1·38	13·56	......	0·09	6·15	31·0	305	......	2·02	138·4	11·2	23·3	......	33·5	25·9
	Tailing.............	1053·7	52·8	0·12	2·05	......	0·02	1·0	6·3	108	......	1·05	52·8	2·3	8·2	......	17·4	9·9
	Total.........	1995·1	100·0	2·76	13·1	......	0·06	5·3	275·9	1310	......	6·03	534·5	100·0	100·0	......	100·0	100·0

TABLE III

Screen Tests

Batch Test No. 1

Mesh	Weight, per cent
+ 65	....
− 65+100	0·4
−100+150	5·9
−150+200	31·5
−200	62·2
Total	100·0

Batch Tests Nos. 2, 3, and 4

Mesh	Weight, per cent
+100	....
+150	1·7
−150+200	23·8
−200	74·5
Total	100·0

Remarks. Attention is drawn to the results obtained in Test No. 4 where 91·8 per cent of the gold reported in the combined concentrate and middling and a tailing assay of 0·02 ounce per ton was obtained. If the reagents used are checked this additional recovery can be credited to the use of Aerofloat No. 31.

LARGE-SCALE CONTINUOUS TESTS

The flow-sheet used in these tests was briefly as follows:

The ore was crushed to ¼-inch size and fed to a 4-foot by 30-inch ball mill operated in closed circuit with a 15-inch classifier of the Dorr type. The feed rate was ¼ ton per hour. The classifier overflow went to a conditioning tank and then to a 10-cell flotation unit. The concentrate was recleaned once.

Table IV gives the reagents used; Table V gives the results; and Table VI gives the screen tests.

TABLE IV

Reagents Used in Continuous Tests

Test	Reagents	Lb./ton	Added to
1	Soda ash	2·5	Ball mill
	Cyanide	0·2	"
	Aerofloat No. 31	0·07	"
	Copper sulphate	1·0	Conditioning tank
	Potassium ethyl xanthate	0·075	"
	Potassium ethyl xanthate	0·035	To Cell No. 7
	Cresylic acid	0·015	"
2	Soda ash	2·5	Ball mill
	Cyanide	0·2	"
	Aerofloat No. 31	0·07	"
	Copper sulphate	1·0	Conditioning tank
	Potassium ethyl xanthate	0·075	"
	Potassium ethyl xanthate	0·015	To Cell No. 7
	Cresylic acid	0·036	"
3	Soda ash	3·1	Ball mill
	Cyanide	0·25	"
	Aerofloat No. 31	0·1	"
	Copper sulphate	1·2	Conditioning tank
	Potassium ethyl xanthate	0·12	"
	Potassium ethyl xanthate	0·044	Cell No. 7
	Cresylic acid	0·02	"
4	Soda ash	3·1	Ball mill
	Cyanide	1·12	"
	Aerofloat No. 31	0·11	"
	Potassium ethyl xanthate	0·15	Conditioning tank
	Copper sulphate	1·22	"
	Potassium ethyl xanthate	0·1	Cell No. 7
	Cresylic acid	0·06	"

TABLE V

Results of Continuous Flotation Tests

(Feed rate = 400 to 500 pounds per hour)

Test No.	Product	Weight, units	Analysis: Per cent Cu	Analysis: Per cent Zn	Analysis: Oz./ton Au	Analysis: Oz./ton Ag	Distribution, per cent Cu	Distribution, per cent Zn	Distribution, per cent Au	Distribution, per cent Ag	Remarks
1	Feed	100·0	3·16	14·55	0·03	5·27	100·0	100·0	100·0	100·0	Note fine grinding used—87·7 per cent —200 mesh.
	Concentrate	28·6	10·95	37·00	0·08	15·96	99·0	93·5	76·4	88·5	
	Tailing	71·4	0·04	1·05	0·01	0·83	1·0	6·5	23·6	11·5	
	Total	100·0	3·16	11·33	0·03	5·16	100·0	100·0	100·0	100·0	
2	Feed	100·0	3·19	14·45	0·03	5·3	100·0	100·0	100·0	100·0	77·7 per cent —200 mesh.
	Concentrate	31·0	9·68	40·10	0·06	11·7	92·8	87·6	57·4	71·8	
	Tailing	69·0	0·34	2·58	0·02	1·36	7·2	12·4	42·6	28·2	
	Total	100·0	3·23	14·21	0·032	4·7	100·0	100·0	100·0	100·0	
3	Feed	100·0	2·8	13·55	0·037	5·12	100·0	100·0	100·0	100·0	80 per cent —200 mesh.
	Concentrate	29·75	8·42	41·80	0·055	12·72	90·7	90·0	53·8	77·6	
	Tailing	70·25	0·37	2·00	0·02	1·56	9·3	10·0	46·2	22·4	
	Total	100·00	2·8	13·8	0·031	4·9	100·0	100·0	100·0	100·0	
4A	Feed	100·0	2·92	13·45	0·035	4·36	100·0	100·0	100·0	100·0	Note effect of reducing amount of cyanide—79·5 per cent —200 mesh.
	Concentrate (A)	45·3	6·28	27·50	0·06	10·50	97·5	98·7	83·5	94·4	
	Tailing (A)	54·7	0·14	0·33	0·01	0·52	2·5	1·3	16·5	5·6	
	Total (A)	100·0	2·92	12·63	0·033	5·0	100·0	100·0	100·0	100·0	
4B	Concentrate (B)	46·4	6·14	29·00	0·07	10·0	97·7	97·3	86·0	93·2	
	Tailing (B)	53·6	0·13	0·52	0·01	0·64	2·3	2·7	14·0	6·8	
	Total (B)	100·0	2·92	13·83	0·04	4·98	100·0	100·0	100·0	100·0	

TABLE VI

Screen Tests

Mesh	Test No. 1	Test No. 2	Test No. 3	Test No. 4
	Weight, per cent	Weight, per cent	Weight, per cent	Weight, per cent
+ 48	....	....	0·5	
− 48+ 65	....	1·2	1·3	1·0
− 65+100	0·2	2·3	3·4	3·6
−100+150	2·6	6·0	4·5	3·9
−150+200	9·5	12·8	10·3	12·0
−200	87·7	77·7	80·0	79·5
Total	100·0	100·0	100·0	100·0

Discussion on Gold Recovery. It can be seen from these results that in order to obtain a high recovery of the gold it was necessary to float considerable pyrite. The conditions maintained in Test No. 4 gave the highest recovery of gold, namely, 83·5 to 86 per cent.

A study of these results will also show that there is evidence which points to the presence of free gold in the ore. It will be observed that the feed sample ran 0·05 ounce in gold and that the classifier overflow or feed to the flotation cells contained only 0·03 ounce, indicating that gold was accumulated in the grinding circuit.

The recoveries shown in the table are calculated on the 0·03-ounce feed, which is the classifier overflow, and if there had been sufficient ore to have continued running, the gold would no doubt have accumulated to a point where the classifier overflow would have gradually increased in gold content and finally reached the assay of the feed to the mill.

SELECTIVE FLOTATION TESTS ON SHIPMENT No. 2

These tests were run with a feed rate of ¼ ton per hour.

The flow-sheet used was briefly as follows:

The ore, crushed to ¼-inch size, was fed to a 4-foot by 30-inch ball mill in closed circuit with a Dorr-type classifier. The classifier overflow went to an air-conditioning tank where the pulp received a 15-minute aeration. Compressed air was used and entered the tank under a head of five feet of pulp. The overflow of the air conditioner went to a second conditioner or surge tank where certain of the reagents were added. The overflow of this tank went to a 10-cell flotation machine. The pulp entered cell No. 2. Cells Nos. 2 and 3 made a concentrate that was recleaned in cell No. 1, which produced finished concentrate. Cells Nos. 4 to 10 made rougher concentrate which was returned and joined the feed entering cell No. 2.

The tailing from the copper circuit went to a second conditioning tank and then to a bank of 13 cells for the zinc flotation. The feed entered cell No. 4, and cells Nos. 4, 5, and 6 made a concentrate that was recleaned in cells Nos. 1, 2, and 3, from all of which there was produced finished concentrate. Cells Nos. 7 to 13 produced rougher concentrate, which was returned with the feed to cell No. 4.

TABLE VII

Results of Continuous Selective Flotation Tests

(Feed rate = 500 pounds per hour)

Test No.	Products	Tons	Assay: Per cent Cu	Assay: Per cent Zn	Assay: Oz./ton Au	Assay: Oz./ton Ag	Distribution, per cent Cu	Distribution, per cent Zn	Distribution, per cent Au	Distribution, per cent Ag	Remarks
3	Feed (class. overflow)...	100·00	2·50	15·30	0·025	3·425	....	....	....	....	Recoveries figured on totals of products.
	Cu concentrate..........	9·9	23·40	9·25	0·14	33·46	93·9	5·9	54·4	71·3	Screen test:
	Zn concentrate..........	25·9	0·48	55·25	0·02	2·98	5·0	91·7	20·3	16·0	+100 = 0·8 per cent
	Tailing..................	64·2	0·04	0·60	0·01	0·87	1·1	2·4	25·3	12·7	−100+150 = 2·8 "
	Total.............	100·0	2·47	15·6	0·025	3·6	100·0	100·0	100·0	100·0	−150+200 = 9·4 "
											−200 = 87·0 "
4	Feed....................	100·0	2·92	15·21	0·02	3·77	....	....	....	....	Recoveries figured as above.
	Cu concentrate..........	10·8	23·80	9·33	0·15	35·91	84·0	6·5	58·7	69·5	Screen test:
	Zn concentrate..........	24·9	0·87	54·25	0·02	3·76	7·0	89·5	18·1	16·7	+100 = 0·7 per cent
	Tailing..................	64·3	0·43	0·93	0·01	1·19	9·0	4·0	23·2	13·8	−100+150 = 2·5 "
	Total.............	100·0	3·06	15·1	0·028	5·6	100·0	100·0	100·0	100·0	−150+200 = 9·9 "
											−200 = 86·9 "
5	Feed....................	100·0	2·50	15·10	0·025	4·05	....	....	....	....	Recoveries figured as above.
	Cu concentrate..........	9·7	23·9	8·90	0·10	35·02	90·7	5·9	39·7	66·7	Screen test:
	Zn concentrate..........	23·8	0·63	54·65	0·02	4·20	5·9	88·4	19·5	19·6	+100 = 0·6 per cent
	Tailing..................	66·5	0·13	1·25	0·015	1·056	3·4	5·7	40·8	13·7	−100+150 = 2·5 "
	Total.............	100·0	2·55	14·7	0·024	5·09	100·0	100·0	100·0	100·0	−150+200 = 8·5 "
											−200 = 88·4 "
6	Feed....................	100·0	2·96	15·0	0·02	4·77	....	....	....	....	Recoveries figured as above.
	Cu concentrate..........	10·7	24·44	8·62	0·15	34·09	88·6	6·1	58·2	68·2	Screen test:
	Zn concentrate..........	25·8	0·78	52·41	0·02	3·18	6·7	89·5	18·7	15·3	+100 = 1·1 per cent
	Tailing..................	63·5	0·22	1·06	0·01	1·39	4·7	4·4	23·1	16·5	−100+150 = 2·5 "
	Total.............	100·0	2·95	15·1	0·028	5·35	100·0	100·0	100·0	100·0	−150+200 = 10·9 "
											−200 = 85·5 "

Six runs were made in all and the results are given in the accompanying tables. Runs Nos. 1 and 2 are not reported, as the results were poor owing to difficulties in obtaining the correct kinds and amounts of reagent.

Summary of the Results of Selective Flotation Tests:

The ore was ground to approximately 85 per cent through 200 mesh. The reagents used in Tests Nos. 3 to 6 inclusive were:

Reagent	Lb./ton	Added to
Soda ash	3·0	Ball mill
Cyanide	0·13	"
Butyl xanthate	0·05	Cu conditioning tank
Pine oil	0·03	" "
Butyl xanthate	0·03	Cu cell No. 5
Pine oil	0·03	" "
Copper sulphate	1·0	Zn conditioning tank
Amyl xanthate	0·21	" "
Pine oil	0·06	" "
Amyl xanthate	0·08	Zn cell No. 5
Pine oil	0·06	" "
Amyl xanthate	0·04	" No. 7

Recoveries:

	Per cent
The copper recovery indicated is approximately	90
The zinc recovery indicated is approximately	90
The gold recovery in the copper concentrate is approximately	55
The silver recovery in the copper concentrate is approximately	68

Grade of Concentrate:

The copper concentrate averaged about 24 per cent copper with 9 per cent zinc and 0·15 ounce in gold and 35 ounces in silver. The zinc concentrate averaged about 54 per cent zinc.

Zinc and Copper Concentrates Combined. If the copper and zinc concentrates from the selective tests are combined to form a bulk concentrate, the following results (calculated) will be obtained:

TABLE VIII

Test No.	Product	Tons	Assay				Distribution, per cent			
			Per cent		Oz./ton					
			Cu	Zn	Au	Ag	Cu	Zn	Au	Ag
3	Feed	100·0	2·5	15·30	0·025	3·425	......	......	......	......
	Bulk concentrate	35·8	6·8	39·8	0·053	11·5	98·9	97·6	74·7	87·9
	Tailing	64·2	0·04	0·60	0·01	0·087	1·1	2·4	25·3	12·1
	Total	100·0	2·47	15·6	0·025	3·6	100·0	100·0	100·0	100·0
4	Feed	100·0	2·92	15·21	0·02	3·77	......	......	......	......
	Bulk concentrate	35·7	7·8	40·6	0·06	13·5	91·0	96·0	76·8	86·2
	Tailing	64·3	0·43	0·93	0·01	1·19	9·0	4·0	23·2	13·8
	Total	100·0	3·06	15·1	0·028	5·6	100·0	100·0	100·0	100·0
5	Feed	100·0	2·5	15·10	0·025	4·05	......	......	......	......
	Bulk concentrate	33·5	7·4	41·4	0·043	13·10	96·6	94·3	59·2	86·3
	Tailing	66·5	0·13	1·25	0·015	1·055	3·4	5·7	40·8	13·7
	Total	100·0	2·55	14·7	0·024	5·09	100·0	100·0	100·0	100·0
6	Feed	100·0	2·96	15·0	0·02	4·77	......	......	......	......
	Bulk concentrate	36·5	7·7	39·5	0·06	12·2	95·3	95·6	76·9	83·5
	Tailing	63·5	0·22	1·06	0·01	1·39	4·7	4·4	23·1	16·5
	Total	100·0	2·95	15·1	0·028	5·35	100·0	100·0	100·0	100·0

CYANIDATION OF TAILING FROM SELECTIVE FLOTATION TESTS

A sample of the flotation tailing was cyanided for 48 to 72 hours at 1 : 3 dilution with a solution strength of 3·0 pounds of potassium cyanide per ton of solution, with 20 pounds of lime per ton of ore.

Results:

Feed assay of flotation tailing	0·02	oz./ton	in gold
	2·18	"	in silver
48- hour tailing	0·006	"	in gold
72-hour "	0·005	"	"
Extraction	75·0	per cent	
Cyanide consumption	12·0	lb./ton of ore	
Lime "	18·2	" "	

CYANIDATION OF A TABLE CONCENTRATE

Some of the tailing from the selective flotation tests on Shipment No. 2 was run over a Wilfley table and a sulphide concentrate made.

A sample of this concentrate was cyanided.

Results:

Assay of concentrate	0·03	oz./ton	in gold
	2·65	"	in silver
Assay of 24-hour cyanide tailing	0·01	"	in gold
" 72-hour " "	0·01	"	"
Extraction	66·7	per cent	
Reagent Consumption—			
Cyanide (KCN)	6·6	lb./ton	
Lime (CaO)	7·8	"	

DISCUSSION OF GOLD RECOVERIES

It is very difficult to draw definite conclusions from the results of these tests, but the evidence indicates that a higher recovery of the gold is obtained when bulk flotation is practised than when selective flotation is practised and the two concentrates are mixed together. Of course, it would in all probability be possible, by making a low-grade zinc concentrate, to increase the gold recovery to a point where it will coincide with the recovery obtained in the bulk flotation.

It is apparent that the gold recovery increases with the amount of pyrite floated, and there is also evidence to support the conclusion that the gold recovery increases with finer grinding for a given grade of concentrate.

The reason why it is difficult to draw definite conclusions is that the gold builds up in the classifier ball mill circuit. Attention already has been drawn to this condition.

Ore Dressing and Metallurgical Investigation No. 631

HIGH-GRADE GOLD ORE FROM BURWASH YELLOWKNIFE MINES, LTD., YELLOWKNIFE RIVER, MACKENZIE DISTRICT, NORTHWEST TERRITORIES

Shipment. A shipment of gold ore, weight 110 pounds, was received on April 27, 1935, from the Burwash Yellowknife Mines, Ltd., Mackenzie district, N.W.T. The sample was submitted by S. Taylor, of the Bear Exploration and Radium, Limited, 85 Richmond St. West, Toronto, Ontario.

It is proposed to operate a small plant handling around 5 tons per day.

Characteristics of the Ore. Twelve polished sections were prepared and examined microscopically for the purpose of determining the character of the ore.

The *gangue* is chiefly impure smoky grey quartz. This contains inclusions of light grey to greenish grey, fine-textured rock.

The *metallic minerals* are present only in very small quantities. Pyrite is most common, occurring as sparsely disseminated grains of medium to small size. Very small amounts of galena, chalcopyrite, arsenopyrite, pyrrhotite, and sphalerite occur as small grains in quartz, and a little "limonite" is present as stains.

Native gold is common. As can be seen from Table I, about half of the gold is free in the quartz and about half is associated with sulphides. The most frequent associates are pyrite and pyrrhotite; the rare associates are galena and a light grey mineral which occurs in such tiny grains that it was not determined.

Table I shows the result of quantitative microscopic analysis entailing the measurement of 479 grains of gold.

TABLE I

Grain Size of Gold

Mesh	Gold free in quartz	Gold associated with sulphides	Total gold
	per cent	per cent	per cent
+ 65	7·5	27·4	34·9
− 65+ 100	5·5	7·6	13·1
− 100+ 150	6·3	2·5	8·8
− 150+ 200	6·2	2·4	8·6
− 200+ 280	3·8	3·0	6·8
− 280+ 400	4·8	1·7	6·5
− 400+ 560	4·7	1·4	6·1
− 560+ 800	4·7	1·2	5·9
− 800+1100	3·0	0·6	3·6
−1100+1600	2·7	0·4	3·1
−1600+2300	1·2	0·2	1·4
−2300	1·1	0·1	1·2
	51·5	48·5	100·0

The microscopic analysis shows that the bulk of the gold is of coarse size and should be amenable to simple treatment with moderate grinding. It is probable, however, that in order to effect high recovery, fine grinding and cyanidation will be necessary at some stage in its treatment, because of the minor portion of gold in a fine state of sub-division.

Sampling and Assaying. The ore was crushed and sampled by standard methods for a high-grade ore. The feed sample assayed as follows:

Gold..16·88 oz./ton
Silver.. 1·97 "

Test work comprised hydraulic classification, blanket concentration and amalgamation tests. The results of the tests indicated that the best grinding size for concentration was around 48 per cent −200 mesh. Over 90 per cent of the gold in the ore is free-milling. Cyanidation by sand percolation was also carried out on the amalgamation tailing.

Experimental Tests

Test No. 1

A sample of ore was ground in an Abbé pebble jar for ten minutes and the pulp then fed to a hydraulic classifier. The object of the test was to determine the amount of free gold that can be separated by gravity methods.

Product	Weight, per cent	Assay, Au, oz./ton	Distribution, per cent	Ratio of concentration
Feed....................................	100·00	16·88	100·00	
Concentrate..............................	0·94	1215·72	67·03	106·3 : 1
Overflow..................................	99·06	5·675	32·97	

Screen Test on Overflow:

Mesh	Weight, per cent
+65	0·5
+100	9·3
+150	16·8
+200	24·8
−200	48·6
	100·0

AMALGAMATION

Test No. 2

A sample of the ore was ground wet in a pebble jar for ten minutes. The pulp was then barrel-amalgamated for one hour with 100 grammes of mercury.

Gold in feed...16·88 oz./ton
Gold in amalgamation tailing.................................. 1·10 "
Gold recovery by barrel amalgamation..........................93·48 per cent

Test No. 3

In this test the sample was given a twenty-minute grind before amalgamation.

Gold in feed	16·88	oz./ton
Gold in amalagmation tailing	0·71	"
Gold recovery by barrel amalgamation	95·79	per cent

Screen Test of Tailing:

Mesh	Weight, per cent
+100	2·1
+150	7·6
+200	24·3
−200	66·0
	100·0

Test No. 4

A sample of ore was ground for ten minutes and the pulp passed over an amalgamated plate.

Gold in feed	16·88	oz./ton
Gold in plate tailing	4·18	"
Gold recovery on plate	75·24	per cent

Test No. 5

In this test the ore was ground for twenty minutes.

Gold in feed	16·88	oz./ton
Gold in plate tailing	6·54	"
Gold recovery on plate	60·66	per cent

The tests indicate that the coarser grind accounts for a higher recovery of the gold.

BLANKET CONCENTRATION

In the three tests the ore samples were ground to approximately the following sizes; 48 per cent −200 mesh, 66 per cent −200 mesh, and 76 per cent −200 mesh. The pulp was passed over a corduroy blanket strake.

Test No. 6 (Ten-minute grind):

Product	Weight, per cent	Assay, Au, oz./ton	Distribution, per cent	Ratio of concentration
Feed	100·00	....	100·0	
Concentrate	0·37	3971·28	88·9	270·2 : 1
Tailing	99·63	1·835	11·1	

Test No. 7 (Twenty-minute grind):

Product	Weight, per cent	Assay, Au, oz./ton	Distribution, per cent	Ratio of concentration
Feed	100·00	....	100·0	
Concentrate	0·26	5114·64	86·2	384·6 : 1
Tailing	99·74	2·13	13·8	

Test No. 8 (Thirty-minute grind):

Product	Weight, per cent	Assay, Au, oz./ton	Distribution, per cent	Ratio of concentration
Feed	100·00		100·0	
Concentrate	0·13	9851·91	81·9	769·2 : 1
Tailing	99·87	2·83	18·1	

The results of the tests on blanket concentration indicate a higher recovery of gold in the case of the coarsest ground ore, and a higher grade concentrate with the finest ground ore.

AMALGAMATION AND CONCENTRATION

Test No. 9

This test was run with the object of approximating on a laboratory scale the results that might be expected with a stamp mill and amalgamation plate.

A sample of ore was ground dry to pass a 28-mesh screen. The ore was then barrel-amalgamated in a 1 : 1 pulp with 5 per cent of mercury (100 grammes) for one hour.

The results are as follows:

Gold in feed	16·88 oz./ton
Gold in tailing	4·14 "
Gold recovery	75·47 per cent

Screen Test on Amalgamation Tailing:

Mesh	Weight, per cent
+ 35	7·1
+ 48	13·8
+ 65	9·7
+100	21·0
+150	11·4
+200	11·3
−200	25·7
	100·0

Test No. 10

In this test the sample of ore was ground dry to pass a 28-mesh screen and barrel-amalgamated as in Test No. 9. The amalgamation tailing was then fed to a laboratory Wilfley table.

Gold recovery by amalgamation was 78·67 per cent.

Results of Table Test on Amalgamation Tailing:

Product	Weight, per cent	Assay, Au, oz./ton	Distribution, per cent	Ratio of concentration
Concentrate	7·23	22·60	45·37	
Middling	10·03	4·27	11·89	13·83 : 1
Tailing	82·74	1·86	42·74	

Recovery of gold in table concentrate: 45·37 per cent of (100 − 78·67) = 9·68 per cent.

Test No. 11

The sample of ore was ground and barrel-amalgamated as in the above test. The tailing was then fed to a corduroy blanket strake.

Gold recovery by amalgamation was 78·44 per cent.

Results of Blanket Test on Amalgamation Tailing:

Product	Weight, per cent	Assay, Au, oz./ton	Distribution, per cent	Ratio of concentration
Concentrate................................	1·94	53·08	28·30	51·55 : 1
Tailing....................................	98·06	2·66	71·70	

Recovery of gold in blanket concentrate: 28·30 per cent of (100 − 78·44) = 6·10 per cent.

A screen test on the blanket tailing indicated a grinding size of 26 per cent −200 mesh.

Test No. 12

In this test the grinding and amalgamation were carried out as in the above tests. The amalgamation tailing was reground, however, before passing over the blanket.

Gold recovery by amalgamation was 80·57 per cent.

Results of Blanket Test on Reground Amalgamation Tailing:

Product	Weight, per cent	Assay, Au, oz./ton	Distribution, per cent	Ratio of concentration
Concentrate................................	1·11	80·54	27·28	90·1 : 1
Tailing....................................	98·89	2·41	72·72	

Recovery of gold in blanket concentrate: 27·26 per cent of (100 − 80·57) = 5·30 per cent.

Screen Test on Tailing:

Mesh	Weight, per cent
+ 65..	0·2
+100..	8·2
+150..	9·2
+200..	29·5
−200..	52·9
	100·0

CYANIDATION

Test No. 13

A sample of ore was ground dry as in the previous tests and barrel-amalgamated with mercury. After separation of the mercury from the pulp, the tailing was fed to a hydraulic classifier to separate the slimes from the sands.

The sand was dewatered and fed to a glass tube, fitted at the bottom with a stop-cock. The height of the column of sand in the tube was 33 inches. A weak solution of lime water was first allowed to percolate through the bed. This was followed by a solution of cyanide of strength equivalent to 5 pounds of potassium cyanide per ton. During the night the solution stood on the bed. The second day a weaker cyanide solution (2·5 pounds of potassium cyanide per ton) was fed to the bed and the solution was allowed to stand on the bed during the second and third nights. The time of contact was approximately 72 hours.

The results of the test are as follows:

Assay of amalgamation tailing—Au.................................. 2·97 oz./ton
Recovery by amalgamation.......................................82·40 per cent

Classification of Amalgamation Tailing:

Product	Weight, per cent	Assay, Au, oz./ton	Distribution, per cent
Feed	100·00	2·97	100·00
Slime	18·88	3·30	20·98
Sand	81·12	2·89	79·02

Sand Percolation:

Ratio of solution to solid—approximately 3·5 : 1.
Consumption of cyanide—approximately 3 pounds per ton of sand.

Screen Test on Sand Tailing:

Mesh	Weight, per cent
+ 35	7·1
+ 48	12·9
+ 65	16·6
+100	24·5
+150	13·2
+200	13·3
−200	12·4
	100·0

Gold in classifier sand...2·89 oz./ton
Gold in percolation tailing.....................................0·35 "
Recovery of gold by cyanide percolation from sand...............87·89 per cent

Summary of Test:

Percentage of amalgamation tailing removed from circuit by de-sliming...18·88 per cent
Gold (not recovered) in slime: 20·98 per cent of (100—82·40)....... 3·69 "
Gold recovered by amalgamation.................................82·40 "
Gold in amalgamation tailing...................................17·60 "
Gold recovered by cyanide percolation of sand: 87·89 per cent of (17·60 − 3·69)...12·22 "
Overall gold recovery by amalgamation and sand percolation 82·40 + 12·22...94·62 "

CONCLUSIONS

The results of test work indicated that at a grinding size of 66 per cent −200 mesh, 95 per cent of the gold was free-milling.

Amalgamation tests carried out to approximate the conditions pertaining in stamp-mill practice indicated gold recoveries from 75 to 82 per cent.

The results obtained by cyanide leaching of the amalgamation tailing after de-sliming are of considerable interest and indicate an overall gold recovery of 94·62 per cent. This treatment of the amalgamation tailing should not offer any serious difficulties in the small operation that is proposed.

The following suggestions are made regarding a simple flow-sheet for a small mill.

A small stamp mill could be used followed by plate amalgamation. A Wilfley table preceded by the usual mercury trap could be used to make a concentrate of the gold-bearing sulphides and in order to catch fine gold not recovered by the table, the table tailing could be passed over blankets. The table and blanket concentrate could then be reground and amalgamated in either a clean-up pan or barrel.

If a ball mill is preferred to stamps, the discharge of the mill can be run through a jig or hydraulic trap and then over blankets. The blanket tailing would go to a drag type classifier in closed circuit with the ball mill. The overflow of the classifier would be passed over a second series of blankets. The blanket and jig concentrate would be ground and amalgamated.

By interpretation of the results of the experimental tests, either of the above described flow-sheets should recover over 85 per cent of the gold.

The cyanide tests indicate that a simple percolation plant to treat the sand portion of the blanket tailing will recover at least 85 per cent of the gold remaining in this product.

The above suggestions are based on the assumption that the sample worked on represents the type of ore which the mill will have to treat.

Ore Dressing and Metallurgical Investigation No. 632

ARSENICAL-GOLD ORE FROM WHITEWATER MINE, ON TULSEQUAH RIVER, SIX MILES NORTH OF TULSEQUAH, TAKU RIVER DISTRICT, ATLIN MINING DIVISION, BRITISH COLUMBIA

Shipment. A shipment of two sacks of ore marked Sample No. 1 and Sample No. 2, weighing 84 pounds and 94 pounds respectively, was received March 8, 1935. The samples were submitted by D. C. Sharpstone, Freeman Hotel, Auburn, California, U.S.A.

Characteristics of the Ore. Samples were taken from the two lots representing the shipment, and twelve polished sections were prepared and examined microscopically for the purpose of determining the character of the ore. The two lots are identical in microscopic character and are described as one.

The *gangue* is a dark to light green, fine-textured carbonate rock, probably dolomitic, which contains stringers of white carbonate and patches of rusty to white quartz.

The *metallic minerals* noted in the polished sections are, in their order of abundance: arsenopyrite, pyrite, undetermined mineral A, pyrrhotite, and magnetite(?). Tests for undetermined mineral A are as follows:

Colour: Grey.
Hardness: Moderately soft—C to D.
Crossed nicols: Isotropic.
Etch tests: HNO_3—quickly tarnishes iridescent.
HCl, KCN, $FeCl_3$, KOH, $HgCl_2$—negative.

Arsenopyrite occurs as small crystals, many of which are needle-like in form. Pyrite grains commonly have irregular shapes, but the smaller grains sometimes show crystal outlines. Undetermined mineral A is rare, occurring as small irregular grains in gangue and pyrite. An extremely small amount of pyrrhotite is present as tiny irregular grains in pyrite, and a few small grains which may be magnetite were seen in the gangue. No native gold was seen.

A quantitative microscopic analysis of the arsenopyrite and pyrite shows that the former is considerably finer than the latter. Table I shows the grain analysis of these two minerals; the percentages are calculated by volume on the basis of 100 per cent of arsenopyrite and pyrite combined.

TABLE I

Grain Analysis of Sulphides

Mesh	Arseno-pyrite, per cent	Pyrite, per cent	Total, per cent
+ 65		10·7	10·7
− 65+100		3·9	3·9
−100+150	1·0	5·1	6·1
−150+200	6·1	4·3	10·4
−200+280	10·2	3·3	13·5
−280+400	10·5	3·2	13·7
−400+560	12·9	2·2	15·1
−560	21·5	5·1	26·6
	62·2	37·8	100·0

Calculating the relative percentages by weight, the amounts are approximately as follows:

	Per cent
Arsenopyrite	65·1
Pyrite	34·9
	100·0

Since no free gold was seen in the polished sections, it is possible that, first, it is chiefly coarse and hence not in the sulphides, or that, second, it occurs chiefly in sub-microscopic form in one or both of the sulphides. The latter is regarded as highly probable, in which case concentration of the sulphides is necessary. As will be seen by the grain analysis, the arsenopyrite is extremely fine, necessitating very fine grinding. The pyrite, on the other hand, is somewhat coarser, and can be liberated more easily.

It is not known whether the gold occurs in arsenopyrite or pyrite, or both.

Sampling and Analysis. The two lots comprising the shipment were sampled individually and assayed for the following:

—	Sample No. 1	Sample No. 2
Gold	0·50 oz./ton	0·41 oz./ton
Arsenic	1·20 per cent	1·72 per cent
Iron	4·33 "	4·88 "
Sulphur	1·26 "	2·79 "
Antimony	Trace	Trace

Experimental Tests

Tests were conducted on Sample No. 1 and on a 1 : 1 mixture of Samples Nos. 1 and 2. From Sample No. 1 about 86 per cent of the gold was recovered in a concentrate amounting to approximately 6 per cent of the weight of feed used, and assaying roughly 6·0 ounces per ton in gold.

From the mixture of Samples Nos. 1 and 2 about 86 per cent of the gold was recovered in a concentrate amounting to about 8 per cent of the weight of feed used. This concentrate will assay roughly 5·0 ounces per ton in gold.

Cyanidation tests on roasted concentrate from the mixed samples showed that from 83 to 87 per cent of the gold in the concentrate could be extracted in this way. This means a net extraction of somewhat less than 75 per cent of the total gold in the ore.

Sample No. 1

FLOTATION, WITH CYANIDATION OF FLOTATION TAILING

Test No. 1

A sample of the ore was ground in a ball mill for 40 minutes and then floated in soda ash pulp. The concentrate was then recleaned in lime pulp. All products were assayed for gold, arsenic, and antimony.

Charge to Ball Mill:

Ore..2,000 grms. −14 mesh
Water..1,500 c.c.
Soda ash..2·0 lb./ton
Aerofloat No. 31..0·09 "

Reagents to Cell:

Potassium amyl xanthate..0·20 lb./ton
No. 208..0·10 "
Pine oil..0·05 "

Copper sulphate, 1·0 pound per ton, was added when flotation appeared to be completed with the above reagents, but it was not effective.

Reagents to Cleaning Cell:

Lime..1·0 lb./ton original ore
Potassium amyl xanthate..0·10 " "
Pine oil..0·025 " "

Summary:

Product	Weight, per cent	Assay			Distribution of metals, per cent	
		Au, oz./ton	As, per cent	Sb, per cent	Au	As
Concentrate........	5·6	6·40	15·54	Trace	69·8	75·5
Cleaner tailing.......	13·5	0·49	0·83	"	12·9	9·7
Flotation tailing.....	80·9	0·11	0·21	"	17·3	14·8
Feed (cal.).........	100·0	0·51	1·15	....	100·0	100·0

A screen test of the flotation tailing showed it to be 89 per cent through 200 mesh and 1·8 per cent on 150 mesh.

Portions of the flotation tailing were agitated in cyanide solution, 1·0 pound of potassium cyanide per ton, for 24 hours. One sample was so treated without further grinding and another one after grinding all through 200 mesh. In both cases the cyanide tailing assayed 0·08 ounce per ton in gold, representing a net extraction of 4·72 per cent of the total gold in the ore.

FLOTATION

Test No. 2

A sample of the ore was ground one hour in a ball mill and then floated. The concentrate was cleaned in another cell and the products assayed for gold and arsenic.

Charge to Ball Mill:

Ore..2,000 grms. −14 mesh
Water......................................1,500 c.c.
Soda ash...................................3·0 lb./ton
Barrett No. 4 oil..........................0·13 "

Reagents to Cell:

Potassium amyl xanthate....................0·40 lb./ton
Pine oil...................................0·10 "

Reagents to Cleaning Cell:

Potassium amyl xanthate....................0·10 lb./ton original ore
Pine oil...................................0·05 " "

Summary:

Product	Weight, per cent	Assay		Distribution of metals, per cent	
		Au, oz./ton	As, per cent	Au	As
Concentrate	6·8	6·66	15·6	86·1	86·9
Cleaner tailing	8·5	0·26	0·49	4·2	3·4
Flotation tailing	84·7	0·06	0·14	9·7	9·7
Feed (cal.)	100·0	0·526	1·22	100·0	100·0

A screen test showed the flotation tailing to be 97 per cent through 200 mesh.

Test No. 3

A sample of the ore was ground in a ball mill for one hour as in Test No. 2 and then conditioned for 5 minutes with sodium silicate in a flotation cell. A concentrate was then taken off and recleaned in another cell without additional reagents.

Charge to Ball Mill:

Ore..2,000 grms. −14 mesh
Water......................................1,500 c.c.
Barrett No. 4 oil..........................0·13 lb./ton

Reagents to Cell:

Sodium silicate............................2·0 lb./ton
Potassium amyl xanthate....................0·40 "
Pine oil...................................0·10 "

Summary

Product	Weight, per cent	Assay		Distribution of metals, per cent	
		Au, oz./ton	As, per cent	Au	As
Concentrate	5·9	5·86	14·11	64·9	69·5
Cleaner tailing	12·9	0·41	0·75	9·9	8·1
Flotation tailing	81·2	0·165	0·33	25·2	22·4
Feed (cal.)	100·0	0·533	1·20	100·0	100·0

Samples Nos. 1 and 2

FLOTATION

Test No. 4

A sample of the two ores, mixed 1 : 1, was ground in a ball mill for one hour and then floated. The concentrate was cleaned in another cell.

Charge to Ball Mill:

Ore...6,000 grms. —14 mesh
Water...4,500 c.c.
Soda ash..3·0 lb./ton
Barrett No. 4 oil...0·13 "

Reagents to Cell:

Potassium amyl xanthate...................................0·40 lb./ton
Pine oil..0·10 "

Reagents to Cleaning Cell:

Potassium amyl xanthate...................................0·10 lb./ton original ore

Summary:

Product	Weight, per cent	Assay		Distribution of metals, per cent	
		Au, oz./ton	As, per cent	Au	As
Concentrate	8·3	4·94	15·68	85·9	86·7
Cleaner tailing	7·9	0·11	0·32	1·8	1·7
Flotation tailing	83·8	0·07	0·21	12·3	11·6
Feed (cal.)	100·0	0·477	1·50	100·0	100·0

Test No. 5

A sample of the two ores, mixed 1 : 1, was ground for one hour in a ball mill and then floated. The concentrate was recleaned in another cell and the products assayed for gold and arsenic.

Charge to Ball Mill:

Ore...2,000 grms. —14 mesh
Water...1,500 c.c.
Soda ash..3·0 lb./ton
Barrett No. 4 oil...0·22 "

Reagents to Cell:

Potassium amyl xanthate...................................0·30 lb./ton
Cresylic acid...0·18 "

Reagents to Cleaning Cell:

Potassium amyl xanthate...................................0·10 lb./ton original ore
Cresylic acid...0·07 " "

Summary:

Product	Weight, per cent	Assay		Distribution of metals, per cent	
		Au, oz./ton	As, per cent	Au	As
Concentrate	6·5	5·86	18·92	80·7	83·0
Cleaner tailing	6·6	0·85	2·63	11·9	11·7
Flotation tailing	86·9	0·06	0·09	7·4	5·3
Feed (cal.)	100·0	0·47	1·48	100·0	100·0

FLOTATION, ROASTING, AND CYANIDATION OF THE CONCENTRATE

Test No. 6

A sample of the two ores, mixed 1 : 1, was ground for one hour in a ball mill and then floated. The concentrate was cleaned in another cell, sampled for assay and the remainder of it roasted at 400° to 750° C. The calcine was sampled for assay and portions of it agitated in cyanide solution, 5·0 pounds of potassium cyanide per ton, for 48 hours with and without regrinding.

Charge to Ball Mill:

Ore.......................................10,000 grms. −14 mesh
Water....................................... 7,500 c.c.
Soda ash.................................... 3·0 lb./ton
Barrett No. 4 oil........................... 0·22 "

Reagents to Cell:

Potassium amyl xanthate..................... 0·30 lb./ton
Cresylic acid............................... 0·18 "

Reagents to Cleaning Cell:

Potassium amyl xanthate..................... 0·10 lb./ton original ore
Cresylic acid............................... 0·07 " "

Summary:

Product	Weight, per cent	Assay		Distribution of metals, per cent	
		Au, oz./ton	As, per cent	Au	As
Concentrate	8·4	4·78	15·48	85·4	85·0
Cleaner tailing	10·3	0·31	0·97	6·8	6·5
Flotation tailing	81·3	0·045	0·16	7·8	8·5
Feed (cal.)	100·0	0·47	1·53	100·0	100·0

Roasting and Cyanidation of Flotation Concentrate:

Loss in weight..............................24·5 per cent
Assay of calcine: Gold...................... 6·40 oz./ton
Arsenic..................................... 3·20 per cent
Cyanide tailing from unground calcine....... 0·83 oz./ton in gold
Extraction..................................87·0 per cent
Reagents consumed: KCN...................... 3·30 lb./ton calcine
CaO...34·4 " "
Cyanide tailing from reground calcine....... 0·825 oz./ton in gold
Extraction..................................87·1 per cent
Reagents consumed: KCN...................... 5·40 lb./ton calcine
CaO...42·1 " "

Test No. 7

This test was the same as Test No. 6 in all respects, but the temperature at which the concentrate was roasted ranged from 400° to 900° C.

Summary of Test No. 7:

Product	Weight, per cent	Assay		Distribution of metals, per cent	
		Au, oz./ton	As, per cent	Au	As
Concentrate	8·7	4·58	14·90	82·7	82·9
Cleaner tailing	10·9	0·32	1·13	7·3	7·9
Flotation tailing	80·4	0·06	0·18	10·0	9·2
Feed (cal.)	100·0	0·48	1·56	100·0	100·0

Roasting and Cyanidation of Flotation Concentrate:

Loss in weight	27·7	per cent
Assay of calcine: Gold	6·14	oz./ton
Arsenic	1·90	per cent
Cyanide tailing from unground calcine	1·04	oz./ton in gold
Extraction	83·1	per cent
Reagents consumed: KCN	2·14	lb./ton calcine
CaO	10·85	" "
Cyanide tailing from reground calcine	1·09	oz./ton in gold
Extraction	82·2	per cent
Reagents consumed: KCN	4·15	lb./ton calcine
CaO	20·6	" "

CONCLUSIONS

The results of tests conducted on this ore indicate that 85 per cent of the gold can be recovered in a flotation concentrate assaying around 5 ounces a ton in gold with a ratio of concentration of approximately 12 : 1. After roasting the concentrate about 87 per cent of the gold contained in it can be extracted by cyanidation. This means that from 70 to 75 per cent of the gold in the ore can be extracted in this way.

In order to obtain the above results the ore should be ground 90 per cent or more through 200 mesh and then floated, the first concentrate being cleaned in another cell and the cleaner tailing returned to the head of the circuit for re-treatment. The clean concentrate should then be roasted, care being taken to keep the temperature down to a dull red heat until fuming ceases and then raise it gradually to a maximum of 750° C.

Comparing the results of cyanidation of roasted concentrates in Tests Nos. 6 and 7, it is worthy of note that of these two, No. 6, the one with the higher arsenic, gave the better extraction. It appears, therefore, that the higher roasting temperature used in Test No. 7 has caused more of the gold to become locked up and immune to attack by cyanide solution. In roasting, therefore, care should be taken to avoid temperatures higher than 750° C.

While these results are far from satisfying, it is difficult to see where any improvement can be made. In plant operation with re-treatment of the cleaner tailing, recovery in the flotation concentrate may be increased to somewhere near 90 per cent with a corresponding increase in net extraction after roasting and cyaniding the concentrate.

Ore Dressing and Metallurgical Investigation No. 633

GOLD ORE FROM THE SHAWKEY GOLD MINING COMPANY, LIMITED, DUBUISSON TOWNSHIP, QUEBEC

Shipment. A shipment of ore comprising 46 bags, weight 2,742 pounds, was received on May 28 from the Shawkey Gold Mining Company, Limited, Siscoe P.O., Dubuisson township, Quebec.

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

The *gangue* is white translucent quartz and fine-textured, dark-grey country rock, which consists largely of carbonate and silicates.

The only *metallic mineral* present in considerable quantity is *pyrite,* which is sparingly disseminated in the dark country rock as coarse to fine crystals and irregular grains. Rare small grains of chalcopyrite occur with the carbonate, and a very small amount of pyrrhotite occurs in both gangue and pyrite.

Native *gold* is very rare in the sections, but a few small grains occur in pyrite, and one in the quartz. The presence of considerable coarse gold is reported as a result of tests recorded in the body of this report.

The information gained by a microscopic examination of ore from this property appears to be of value mainly in indicating the following:—

1. The gangue contains a considerable amount of finely crystalline carbonate.

2. At least some of the gold is present as tiny particles contained in the pyrite; the percentage can not be estimated from this examination.

Sampling and Assaying. The ore was crushed and sampled by standard methods and the results of the assay are as follows:—

Gold	0·54	oz./ton
Silver	0·12	"
Iron	4·59	per cent
Arsenic	0·02	"
Sulphur	0·97	"

Experimental tests included barrel amalgamation, hydraulic classification, standard cyanidation, blanket concentration.

Results indicate that at least 91 per cent of the gold is free-milling.

The tests indicate that the removal of coarse free gold by traps, jigs, or blankets prior to cyanidation will account for from 70 to 87 per cent of the gold present in the ore.

Experimental Tests

AMALGAMATION

Test No. 1

This was a barrel-amalgamation test on the raw ore carried out for the purpose of determining the percentage of free-milling gold in the ore.

The ore was wet ground to a size of 76·9 per cent − 200 mesh and then barrel-amalgamated with 100 grammes of mercury for 1 hour.

The results were as follows:—

Gold in feed	0·54 oz./ton
Gold in amalgamation tailing	0·045 "
Recovery of gold	91·67 per cent

This indicates that a high percentage of the ore is free-milling.

HYDRAULIC CLASSIFICATION

Test No. 2

In view of the fact that the ore contains such a high percentage of free-milling gold, the following test was carried out to determine the results that might be expected from the use of traps or jigs in the grinding—classifier circuit.

A sample of ore was ground to approximately the same size as in Test No. 1, and the pulp was then fed to a hydraulic classifier. The oversize was recovered and further reduced in bulk by panning. A number of colours of gold were observed in the pan.

The results of the test are as follows:—

Product	Weight, per cent	Assay, Au, oz./ton	Distribution of gold, per cent
Feed	100·00	....	....
Oversize	0·09	515·05	70·95
Overflow	99·91	0·19	29·05

CYANIDATION

Test No. 3

Four samples of different grinding sizes were cyanided in solutions of concentration equivalent to 1 pound of potassium cyanide per ton at a pulp dilution of 3 : 1; lime, 5 pounds per ton, was added at the beginning to each test for protective alkalinity.

Product	Assay, Au, oz./ton		Extraction of gold, per cent	Reagents consumed	
	Feed	Tailing		KCN, lb./ton	CaO, lb./ton
− 48 mesh	0·54	0·04	92·59	0·10	3·80
−100 "	0·54	0·025	95·37	0·30	3·95
−150 "	0·54	0·015	97·22	0·30	3·95
−200 "	0·54	0·015	97·22	1·20	7·40

Screen Tests on Cyanidation Tailings:

−48 Mesh

Mesh	Weight, per cent
+ 65	0·5
+100	15·7
+150	16·1
+200	14·0
−200	53·7
	100·0

−100 Mesh

Mesh	Weight, per cent
+150	2·1
+200	15·9
−200	82·0
	100·0

−150 Mesh

Mesh	Weight, per cent
+200	19·2
−200	80·8
	100·0

Fine grinding to −200 mesh has a decided influence on the consumption of both cyanide and lime.

Test No. 4

These tests were carried out similarly to Test No. 3, except that the period of cyanidation was 48 hours.

Product	Assay, Au, oz./ton		Extraction of gold, per cent	Reagents consumed	
	Feed	Tailing		KCN, lb./ton	CaO, lb./ton
− 48 mesh	0·54	0·02	96·3	0·30	3·95
−100 "	0·54	0·015	97·22	0·45	3·95
−150 "	0·54	0·015	97·22	0·30	4·10
−200 "	0·54	0·01	98·15	1·20	9·25

CONCENTRATION, AMALGAMATION, AND CYANIDATION

Test No. 5

This test was a combination of blankets, barrel amalgamation, and cyanidation. A sample of −14-mesh ore, 2,000 grammes in weight, was ground wet for 15 minutes in an Abbé pebble jar. The pulp was then fed to a corduroy blanket strake. The blanket concentrate was barrel-amalgamated with mercury and the blanket tailing reground for 15 minutes and cyanided.

The results of the test are as follows:—

Blanket Concentration:

Product	Weight, per cent	Assay, Au, oz./ton	Distribution of gold, per cent	Ratio of concentration
Feed	100·00	0·54	100·00	
Blanket concentrate	4·03	11·733	87·56	24·81 : 1
Blanket tailing	95·97	0·07	12·44	

Screen Test of Blanket Tailing:

Mesh	Weight, per cent
+ 65	0·2
+100	4·4
+150	9·1
+200	19·0
−200	67·3
	100·0

Barrel Amalgamation of Blanket Concentrate:

Gold in concentrate	11·733 oz./ton
Gold in amalgamation tailing	0·38 "
Recovery by amalgamation	96·78 per cent

Cyanidation of Reground Blanket Tailing:

Strength of cyanide solution was equivalent to 1 pound of potassium cyanide per ton; 5 pounds of lime per ton was added as protective alkalinity. The pulp dilution was 3 : 1.

Time of agitation, hours	Assay, Au, oz./ton		Extraction of gold, per cent	Reagents consumed	
	Feed	Tailing		KCN, lb./ton	CaO, lb./ton
24	0·07	0·010	85·71	0·30	4·10
48	0·07	0·005	92·85	0·30	4·175

Results:

	Per cent
Gold recovered in blanket concentrate	87·56
Gold recovery by barrel amalgamation of blanket concentrate: 96·78 per cent of 87·56 per cent	84·74
Gold recovery by cyanidation of blanket tailing: 92·85 per cent of 12·44 per cent	11·55
Overall recovery of gold: 84·74 + 11·55	96·29

CONCLUSIONS

The results of the tests conducted on the sample of ore submitted indicate no difficulty in its metallurgical treatment.

The presence of free gold and the results obtained from hydraulic classification indicate that a trap or jig should be used in the grinding—classifier circuit in order to remove this coarse gold before cyanidation.

Grinding 80 to 82 per cent −200 mesh appears to be satisfactory. Finer grinding tends to increase the consumption of both cyanide and lime.

The use of blankets, as indicated by Test No. 5, gave a recovery of 84·74 per cent, and an overall recovery after cyanidation of the tailing of 96·29 per cent.

Ore Dressing and Metallurgical Investigation No. 634

GOLD ORE FROM THE BEATTIE GOLD MINE, DUPARQUET TOWNSHIP, ABITIBI COUNTY, QUEBEC.

Shipment. A shipment of 10 sacks of ore was received on April 25, 1935. The shipment was submitted by W. G. Hubler, Mill Superintendent, Beattie Gold Mines, Limited, P.O. Box 101, Noranda, Quebec.

Sampling and Analysis. The ore was crushed and sampled by standard methods, and the assays were as follows:

	Oz./ton
Gold	0·18
Silver	0·05

Experimental Tests

The work done on this sample consisted of cyanidation tests followed by flotation of the cyanide tailings and was done for the purpose of checking the results of similar tests carried out by the owners.

Samples ground to 65, 85, and 98 per cent through 200 mesh were used for this purpose. From 60 to 70 per cent of the gold was extracted by cyanidation, and flotation of the cyanide tailings produced concentrates assaying 0·45 ounce per ton in gold, with a ratio of concentration of about 10 : 1. The flotation tailings assayed 0·02 ounce per ton in gold.

Results of the tests follow:

Test No. 1

A sample of the ore was ground 65 per cent through 200 mesh in a ball mill and then agitated in cyanide solution, 1·0 pound of potassium cyanide per ton, for 24 hours. The cyanide tailing was filtered, washed with water, and floated with the following reagents:

	Lb./ton
Soda ash	3·5
Copper sulphate	1·5
Potassium amyl xanthate	0·10
Pine oil	0·10
Barrett No. 4 oil	0·09

The flotation concentrate and tailing were assayed for gold.

Summary:

Product	Weight, per cent	Assay, Au, oz./ton	Distribution of gold, per cent
Flotation concentrate	8·3	0·46	62·5
Flotation tailing	91·7	0·025	37·5
Cyanide tailing (cal.)	100·0	0·061	100·0

Extraction by cyanidation: 66·1 per cent.

Test No. 2

A sample of the ore was ground 85 per cent through 200 mesh in a ball mill and agitated in cyanide solution, 1·0 pound of potassium cyanide per ton, for 24 hours. The cyanide tailing was filtered, washed with water, and floated with the following reagents:

	Lb./ton
Soda ash	3·0
Copper sulphate	1·0
Potassium amyl xanthate	0·10
Pine oil	0·10

Summary:

Product	Weight, per cent	Assay, Au, oz./ton	Distribution of gold, per cent
Flotation concentrate	5·2	0·455	35·7
Flotation tailing	94·8	0·045	64·3
Cyanide tailing (cal.)	100·0	0·066	100·0

Extraction by cyanidation: 63·3 per cent.

Test No. 3

A sample of the ore was ground 98 per cent through 200 mesh in a ball mill and agitated in cyanide solution, 1·0 pound of potassium cyanide per ton, for 24 hours. The cyanide tailing was filtered, washed with water, and floated with the following reagents:

	Lb/ton
Soda ash	3·0
Copper sulphate	1·0
Potassium amyl xanthate	0·10
Pine oil	0·10
Barrett No. 4 oil	0·09

Summary:

Product	Weight, per cent	Assay, Au, oz./ton	Distribution of gold, per cent
Flotation concentrate	10·2	0·38	68·3
Flotation tailing	89·8	0·02	31·7
Cyanide tailing (cal.)	100·0	0·057	100·0

Extraction by cyanidation: 68·3 per cent.

Test No. 4

A sample of the ore was ground 85 per cent through 200 mesh in a ball mill and then agitated in cyanide solution, 1·0 pound of potassium cyanide per ton, for 24 hours. The cyanide tailing was filtered, washed with water, and floated with the following reagents:

	Lb./ton
Soda ash	3·0
Copper sulphate	1·0
Potassium amyl xanthate	0·10
Barrett No. 4 oil	0·09
Pine oil	0·10

This test was made as a check on Test No. 2 with Barrett No. 4 oil added to the reagent combination.

Summary:

Product	Weight, per cent	Assay, Au, oz./ton	Distribution of gold, per cent
Flotation concentrate	10·0	0·46	71·9
Flotation tailing	90·0	0·02	28·1
Cyanide tailing (cal.)	100·0	0·064	100·0

Extraction by cyanidation: 64·4 per cent.

Test No. 5

A sample of the ore was ground 98 per cent through 200 mesh in a ball mill and agitated in cyanide solution, 1·0 pound of potassium cyanide per ton, for 24 hours. The cyanide tailing was filtered, washed with water, and floated with the following reagents:

	Lb./ton
Soda ash	1·0
Copper sulphate	1·0
Barrett No. 4 oil	0·09
Potassium amyl xanthate	0·20
Pine oil	0·05

This test differed from Test No. 3 in that the soda ash and pine oil were reduced while the xanthate was doubled.

Summary:

Product	Weight, per cent	Assay, Au, oz./ton	Distribution of gold, per cent
Flotation concentrate	7·2	0·455	63·8
Flotation tailing	92·8	0·02	36·2
Cyanide tailing (cal.)	100·0	0·051	100·0

Extraction by cyanidation: 71·7 per cent.

CONCLUSIONS

Although satisfactory tailings were produced in these tests the concentrates were somewhat lower in grade than were those produced in tests carried out at the mine. This may be due to the fact that more of the gold was extracted by cyanidation in the tests carried out in the Ore Dressing Laboratories, and perhaps, also, the sample submitted may have been a little lower in grade than that used for test purposes at the property.

A microscopic examination of the concentrate produced in Test No. 5 showed that it contained 87·2 per cent sulphides and 12·8 per cent gangue. Free gangue material amounted to 5·3 per cent and gangue combined with sulphides amounted to 7·5 per cent.

In Test No. 1 perhaps a better tailing was made than could be made by flotation of the raw ore at that grinding, but at the finer grinding used in Tests Nos. 4 and 5 there does not appear to be any advantage gained by cyaniding the ore before flotation; whereas, on the other hand, if the ore is floated first the concentrate can be handled in a much smaller cyanide plant.

In these latter deductions use has been made of work done on the ore in the Ore Dressing Laboratories at an earlier date.

Ore Dressing and Metallurgical Investigation No. 635

GOLD ORE FROM THE PEARCE MINE, DELORO, ONTARIO

Shipment. A shipment of ore, weight 2,000 pounds, was received on May 27, 1935, from the Pearce mine, Deloro, Ontario. The sample shipment was submitted by John M. Coughlin, Canadian Straub Mining Machinery, 1188 Phillips Place, Montreal, Quebec.

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

The gangue consists of fine-textured, greenish grey chloritic rock with grey translucent quartz and some pinkish white carbonate which appears to be ferruginous dolomite.

The *metallic minerals* present in the sections are arsenopyrite, pyrite, a grey anisotropic mineral which resembles magnetite in colour but which may be one of the spinels (?), chalcopyrite, and pyrrhotite. Arsenopyrite is by far the most abundant ore mineral, is coarse- to medium-grained, and occurs most commonly in the massive form. Disseminated grains are present. It is associated with minor amounts of pyrite and contains small inclusions of chalcopyrite and pyrrhotite. A very small amount of chalcopyrite occurs as above and as small grains in gangue. Pyrrhotite is rare and is present only in the arsenopyrite. The grey anisotropic mineral is disseminated in the chloritic gangue.

No native gold was present in the polished sections and hence its mode of occurrence is not known. However, specks of native gold were observed in a concentrate from an experimental test which indicates its presence in the ore.

Sampling and Assaying. The ore was crushed and sampled by standard methods. The analysis of the feed sample on which test work was carried out was as follows:

Gold	0·785	oz./ton
Silver	0·05	"
Iron	4·65	per cent
Arsenic	2·17	"
Sulphur	2·32	"

EXPERIMENTAL TESTS

A series of small-scale tests was made on the ore to determine a suitable method for its treatment. Blanket and table concentration, amalgamation and cyanidation tests were carried out. The removal of the free gold before cyanidation is necessary as indicated by the results of the tests, which show that 85 per cent is recoverable in a blanket concentrate.

Direct cyanidation of the ore is not satisfactory owing to a high consumption of cyanide and lime and a poor extraction of gold. Pre-aeration of the pulp, however, offsets this tendency as indicated in the tests reported.

Details of the tests are as follows.

AMALGAMATION

Test No. 1

This test was carried out for the purpose of determining the amount of free-milling gold in the ore.

A sample of ore at a grinding size of − 14 mesh was barrel-amalgamated with 100 grammes of mercury for one hour.

Gold in feed	0·785 oz./ton
Gold in amalgamation tailing	0·53 "
Recovery of gold	32·48 per cent

Test No. 2

In this test the ore was ground to 51·2 per cent through 200 mesh. Barrel amalgamation was carried out for one hour.

Gold in feed	0·785 oz./ton
Gold in amalgamation tailing	0·15 "
Recovery of gold	80·88 per cent

The results of these tests indicate a fairly high proportion of free-milling gold.

HYDRAULIC CLASSIFICATION

Test No. 3

The sample of ore was ground wet to a grinding size of 50 per cent through 200 mesh and the pulp fed to a hydraulic classifier.

Native free gold was observed in the oversize. The results of the test follow:

Product	Weight, per cent	Assay, Au, oz./ton	Distribution of gold, per cent
Feed	100·00	0·77	100·00
Oversize	0·55	61·08	43·43
Overflow	99·45	0·44	56·57

BLANKET CONCENTRATION AND CYANIDATION

Test No. 4

In this test a sample of ore was ground to a size of 50 per cent through 200 mesh and the pulp run over a corduroy blanket strake. The blanket concentrate was barrel-amalgamated with mercury for one hour. The blanket tailing was reground and cyanided.

Details of the test follow:

Blanket Concentration:

Product	Weight, per cent	Assay, Au, oz./ton	Distribution of gold, per cent	Ratio of concentration
Feed	100·00	0·785	100·00	
Concentrate	5·73	11·73	85·59	17·45 : 1
Tailing	94·27	0·12	14·41	

Barrel Amalgamation of Blanket Concentrate:

Gold in feed........11·73 oz./ton
Gold in amalgamation tailing........0·82 "
Recovery........93·01 per cent

The blanket tailing was reground and two lots were cyanided, one for 24 hours and one for 48 hours. A solution equivalent to one pound of potassium cyanide per ton was used. Additions of cyanide and lime were added during the tests to maintain the necessary cyanide strength and protective alkalinity.

Agitation, hours	Assay, Au, oz./ton		Extraction of gold, per cent	Reagents consumed		Pulp dilution
	Feed	Tailing		KCN	CaO	
24	0·12	0·015	87·5	1·35	9·32	2·7 : 1
48	0·12	0·01	91·66	2·78	11·20	2·65 : 1

Screen Test on Cyanide Tailing:

Mesh	Weight, per cent
−100+150	1·2
−150+200	8·0
−200	90·8
	100·0

Summary of Results:

	Per cent
Gold recovered in blanket concentrate	85·59
Gold recovery by amalgamation of blanket concentrate: 93·01 per cent of 85·59 per cent	79·61
Gold recovery by cyanidation of blanket tailing: 91·66 per cent of 14·41 per cent	13·21
Overall recovery: 79·61 + 13·21	92·82

TABLE CONCENTRATION

Test No. 5

A sample of ore, grinding size through 14 mesh, was fed to a laboratory Wilfley table.

Details of the test follow:

Product	Weight, per cent	Assay		Distribution of gold, per cent	Ratio of concentration
		Au, oz./ton	As, per cent		
Feed	100·00	0·77	....	100·00	
Table concentrate	5·03	7·60	26·50	49·27	19·88 : 1
Table middling	5·45	3·28	....	23·04	
Sand and slime	89·52	0·24	....	27·69	

PLATE AMALGAMATION AND TABLING

Test No. 6

A sample of ore was ground dry to pass a 28-mesh screen. The ore was pulped and passed over an amalgamated plate. The tailing was then dewatered and fed to a laboratory Wilfley table.

Details of the test are as follows:

Plate Amalgamation:

Gold in feed	0·785 oz./ton
Gold in plate tailing	0·57 "
Recovery of gold on plates	27·39 per cent

Table Concentration of Plate Tailing:

Product	Weight, per cent	Assay		Distribution, per cent		Ratio of concen-tration
		Au, oz./ton	As, per cent	Au	As	
Feed	100·00	0·57	2·34	100·00	100·00	
Table concentrate	9·91	3·24	19·90	66·13	84·31	10·09 : 1
Table middling	2·14	1·11	1·94	4·89	1·77	
Sand and slime	87·95	0·16	0·37	28·98	13·92	

Screen Test of Table Tailing:

Mesh	Weight, per cent
− 28+ 35	16·8
− 35+ 48	24·7
− 48+ 65	19·2
− 65+100	14·4
−100+150	8·7
−150+200	6·6
−200	9·6
	100·0

CYANIDATION

Tests Nos. 7 and 8

Cyanidation tests were carried out on different grinding sizes of raw ore. The initial strength of the solution was equivalent to one pound of potassium cyanide per ton and the pulp dilution 3 : 1. The consumption of reagents was high and numerous additions of cyanide and lime were necessary during the period of the test.

Mesh	Agitation, hours	Assay, Au, oz./ton		Extraction of gold, per cent	Reagents consumed, lb./ton	
		Feed	Tailing		KCN	CaO
− 48	24	0·785	0·385	50·96	3·00	19·10
−100	"	0·785	0·33	57·96	4·83	19·10
−150	"	0·785	0·27	65·61	5·10	20·95
−200	"	0·785	0·14	82·17	6·03	22·20
− 48	48	0·785	0·30	61·78	3·45	19·95
−100	"	0·785	0·19	75·80	5·13	19·25
−150	"	0·785	0·15	80·89	5·40	22·10
−200	"	0·785	0·085	89·17	6·33	28·75

The results of these tests indicate that straight cyanidation of the ore is not satisfactory.

The high tailing is probably due to the presence of coarse gold, and the high consumption of lime and cyanide is due to the presence of arsenopyrite and pyrrhotite combined with a somewhat oxidized condition of the ore.

PRE-AERATION AND CYANIDATION

Test No. 9

In view of the results obtained from Tests No. 7 and 8, a test was run in which a sample of the ore (−150 mesh) was pre-aerated in a lime pulp for 15 hours before cyanidation.

The results indicated a decided improvement. The tailing was lowered and the consumption of cyanide substantially decreased.

Period of agitation, hours	Assay, Au, oz./ton		Extraction of gold, per cent	Reagents consumed, lb./ton		Pulp dilution
	Feed	Tailing		KCN	CaO	
24	0·785	0·09	88·54	1·25	*17·72	3·12 : 1

*Includes lime used in pre-aeration.

SUMMARY AND CONCLUSIONS

The results of the tests carried out on the sample of ore submitted indicate that around 80 per cent of the ore was free-milling at a grinding size of 51 per cent through 200 mesh.

By blanket concentration, amalgamation of blanket concentrate, and cyanidation of blanket tailing, an indicated overall gold recovery of 92·82 per cent was obtained.

Cyanidation of the raw ore gives a low recovery and high consumption of both cyanide and lime. Pre-aeration of the pulp will appreciably lower the cyanide consumption and improve the extraction of gold.

It must be borne in mind that in the metallurgical treatment of this ore, the free-milling gold should be removed by blankets or concentrating tables before cyanidation. From the nature of the ore, pre-aeration before cyanidation will be beneficial, and tests indicate that a low tailing is obtainable by cyaniding the ore after the removal of the free gold as suggested.

III

INVESTIGATIONS THE RESULTS OF WHICH ARE SYNOPSIZED

Gold concentrate from the Casey Summit Gold Mines, Ltd., Summit Lake district, Ont. The concentrate, weighing 6 pounds, was received on December 21, 1934 and consisted of mixed iron sulphides and gangue, some globules of mercury being visible. It assayed 3·56 ounces of gold and 0·43 ounce of silver per ton.

Cyanidation gave an extraction of over 90 per cent of the gold with grinding to about 200 mesh, using 15 pounds of lime per ton of ore and a cyanide solution of 5 pounds of cyanide per ton, 1:3 dilution.

Gold-bearing quartz ore from the Sol d'Or Gold Mines, Limited, Rainbow lake, Patricia district, Ont. The ore, weighing 39 pounds, received on January 3, 1935, was rich in free gold, closely associated with tellurides of mercury and lead, the gold being relatively coarse. It assayed 6·18 ounces of gold and 0·27 ounce of silver per ton and showed a trace of arsenic. Over 70 per cent of the gold was recoverable by amalgamation on plates, and over 90 per cent if blankets were used and the concentrate amalgamated.

Flotation tailing from Dentonia Mines, Limited, Greenwood, B.C. One bag of the tailing was received December 4, 1934, consisting chiefly of quartz and calcite with traces of sulphides; 1·8 per cent remained on 48 mesh, and 37 per cent passed through 200 mesh. It assayed 0·04 ounce of gold and 0·20 ounce of silver per ton.

The object was to learn if the gold were recoverable by cyanidation. Without regrinding a 0·015 tailing, and after grinding to 65 per cent through 200 mesh, a 0·005 tailing, were obtainable.

Mill tailing from the Mikado mill tailing dump, at Cedar Island, Lake-of-the-Woods district, Ont. The tailing consisted of siliceous gangue material and a small amount of sulphides. Twenty pounds of this was received January 10, 1935, and it was found to assay 0·05 ounce of gold and 0·12 ounce of silver per ton, 4·29 per cent of iron and 0·83 per cent of sulphur.

After regrinding 55·4 per cent through 200 mesh, 30 per cent of the gold was extractable by amalgamation; 70 per cent was recoverable in a concentrate amounting to 18·1 per cent of the feed, and assaying 0·21 ounce per ton; by cyanidation 80 to 90 per cent of the gold was extractable in 24 hours.

Mill tailing from the old dumps of the Golden Star Mine, Rainy River district, Ont. A sample weighing 250 pounds was received on January 9, 1935, consisting of quartz sand and a very small amount of sulphides, showing the result of prolonged weathering. It assayed 0·36 ounce of gold and 0·25 ounce of silver per ton and gave traces of lead and arsenic. Poor recoveries were obtained from the raw material by concentration on tables, blankets and by flotation. Cyanidation extracted 75 per cent of the gold in 24 hours. After regrinding to 52 per cent through 200 mesh, an average of 80 per cent was recoverable by the tables and 90 per cent by flotation, the grade of the concentrate being 8 ounces and 2·7 ounces per ton respectively. Cyanidation gave over 95 per cent extraction.

Gold-silver ore from the Paladora Property near the Edgewood-Vernon Highway, Greenwood mining division, B.C. Five small samples, weighing 43 pounds, were received on January 10, 1935. Each sample was assayed and gave:

Sample	Weight, pounds	Assay, oz./ton	
		Gold	Silver
1 Shaft No. 1	9	1·77	7·09
2 " No. 3	8	1·825	9·35
3 Sample W, drift in tunnel	12	0·40	1·76
4	3	2·13	7·96
5	11	0·48	2·65

Nos. 3 and 5 were mixed and the combined sample assayed 0·42 ounce of gold and 2·15 ounces of silver per ton.

By cyanidation 95 per cent of the gold was extractable in 24 hours on ore crushed minus 200 mesh. Recovery by plate amalgamation was low. By cyanidation of the amalgamation tailing an overall recovery of 91 per cent of the gold was obtained and by flotation 84 per cent. Blanket concentration followed by cyanidation gave an overall recovery of 94 per cent of the gold.

Gold ore from Pluto Claim No. 1, High-Rock island, Island lake, Manitoba. The sample, received on January 9, 1935, weighed 29 pounds and assayed 0·37 ounce of gold, 0·46 ounce of silver per ton, 0·03 per cent of copper, 0·02 per cent of arsenic, 0·36 per cent of lead, 0·05 per cent of zinc and 2·24 per cent of iron.

Blanket concentration recovered 63·7 per cent of the gold after grinding to 52 per cent minus 200 mesh, and 65 per cent when 70 per cent was minus 200 mesh. Cyanidation recovered 92 per cent after grinding to 87 per cent minus 200 mesh. In the latter case consumption of cyanide was about 1·5 pounds per ton and of lime about 4·5 pounds. Flotation gave a recovery of 97 per cent at 88 per cent minus 200 mesh, with a ratio of concentration of 20 : 1. About 95 per cent of the silver was in the concentrate.

Gold ore from the Centennial Mine in the Michipicoten area of Algoma district, Ont. Five sacks of quartz with a very small amount of disseminated pyrite and the gold almost all free, weighing 200 pounds, were received April 1, 1935. The ore assayed 0·065 ounce of gold per ton. Amalgamation gave a recovery of 67·6 per cent of the gold.

Gold ore from Lots 9-10, Range 4, Launay township, Abitibi county, Quebec. Eight bags of rusty brown to greyish-white quartz containing pyrite as coarsely-crystalline masses and coarse crystals and irregular grains, with very small quantities of galena, chalcopyrite, and sphalerite, and occasional covellite were received April 1, 1935. The ore assayed 0·31 ounce of gold and 0·10 ounce of silver per ton.

About 98 per cent of the gold was extractable by cyanidation in 24 hours, the ore being crushed dry to pass 150 mesh. About 65 per cent was recoverable by amalgamation and 50 per cent by blanket concentration.

Flotation concentrate from the Northern Empire Mine at Empire, Ontario. This high-grade concentrate, consisting chiefly of pyrite, chalcopyrite, and arsenopyrite, was received on February 23, 1935, and assayed 23·64 ounces of gold and 4·08 ounces of silver per ton, copper 0·60 per cent and arsenic 9·57 per cent. Cyanide tests were desired.

Cyanidation, using local water and a sample of water sent from the mine, gave extraction in both cases in the neighbourhood of 99 per cent of the gold. In the sixth cycle of a cycle cyanidation test the extraction dropped to 96 per cent. This shows the necessity of discarding a quantity of barren solution daily in the mill.

Gold ore from the Murray Algoma Mining Company, Township 28, Range 24, District of Algoma, Ontario. Eight bags, weighing 530 pounds, were received March 25 and March 28, 1935, and assayed 0·43 ounce of gold and 0·13 ounce of silver per ton, no platinum being found. The gangue is white to grey and dark brown to grey mottled rock of fine texture; metallic minerals are pyrrhotite, pyrite, chalcopyrite, marcasite, and native gold, the gold about equally divided between the gangue and the pyrite.

Sixty to seventy per cent of the gold was recoverable on blankets and over 90 per cent of this could be amalgamated by barrel treatment of the concentrate. Blankets and flotation gave a recovery of 97·1 per cent in the respective concentrates. Ninety-seven per cent of the gold was extractable by cyanidation.

Gold ore from the McKenzie-Carscallen Property, Carscallen township, Porcupine district, Ontario. Twenty-one bags of ore, weighing 2,030 pounds, were received April 15, 1935, and found to assay 0·41 ounce of gold and 0·14 ounce of silver per ton. Native gold was seen as coarse, irregular grains in pyrite, near the pyrite, and in quartz.

Over 90 per cent of the gold was recoverable by amalgamation either on plates, or by amalgamating the concentrate from blankets and tables; 98 per cent or more was extractable by cyanidation.

Copper-zinc ore from the old mine dumps of Poulin Gold Mines, Ltd., Sherbrooke county, Quebec. A shipment of 550 pounds was received May 9, 1935, from the dumps of the Suffield, Silver Star, and King mines, and 180 pounds from the Merrington mine. The ore was siliceous, heavily mineralized with sulphides of iron, zinc, copper and lead and bore evidence of long exposure to the weather. Lot No. 1 assayed 0·05 ounce of gold and 4·77 ounces of silver per ton, 1·88 per cent of copper, 20·72 per cent of zinc, and 1·92 per cent of lead. Lot No. 2 assayed 0·12 ounce of silver, 2·74 per cent of copper, and 0·30 per cent of zinc.

Only Lot No. 1 was tested by flotation. Its oxidized character made the ore difficult to treat, the zinc being particularly troublesome and to keep this out of the copper concentrate much cyanide was needed, depressing also the gold-bearing pyrite. Selective flotation cannot, therefore, give high recovery to this dump ore, but the freshly mined ore is amenable.

Concentrate from North Shore Gold Mines, Limited, Thunder Bay district, Schreiber, Ont. One bag, weighing 47 pounds, was received on May 27, 1935. The concentrate assayed 5·9 ounces of gold, 0·9 ounce of silver per ton, 10·6 per cent of sulphur, 53·1 per cent of silica, 0·4 per cent of copper, 5·12 per cent of lime, 12·7 per cent of iron, and no arsenic. Only 10 per cent of the total gold visible under the microscope was free, the rest being enclosed in gangue, the size of the grains ranging from minus 200 mesh to 2300 mesh.

Without grinding, only 6 per cent of the gold was extractable by amalgamation; by grinding to minus 200 mesh, 50 per cent; 97 per cent of this ground material was extractable by cyanidation.

Zinc ore from Mining Claims 19319 to 19330—two to three miles east of Ozone Siding—of the McLean-McNicoll, Limited, Nipigon, Ontario. A shipment of 110 pounds of the ore consisting of massive sulphide of zinc in a gangue of quartz, pink granite, and calcite, was received on June 7, 1935. It assayed only a trace of gold, 0·46 ounce of silver per ton, 15·59 per cent of zinc and a trace of lead.

Over 95 per cent of the zinc was recoverable by flotation in a concentrate containing 60 per cent of zinc, after the ore was ground to 75 per cent through 200 mesh.

Crocetol Frothers "A", "B", "C" and "X", furnished by Shawinigan Chemicals, Limited, Shawinigan Falls, Quebec. A sample of "X" was received on April 4, 1935, for comparative tests with "A", "B", and "C", previously examined. An ore assaying 0·22 ounce of gold per ton and containing 2 to 3 per cent of pyrite was ground to pass 80 per cent minus 200 mesh with 3·0 pounds of soda ash and 0·10 pound of sodium xanthate per ton, and concentrates were removed by adding the "Crocetol" reagents.

All four reagents produced thin and fast-running froths, "X" having the same effect as the others.

Radium ore from Tatee and Bee claims, Great Bear Development Co., Ltd., (Hottah Lake Gold & Radium Mines, Ltd.), east arm of Beaverlodge lake, Hottah Lake area, Mackenzie district, N.W.T. Five lots of ore were received and examined microscopically.

The ore consisted of quartz, pitchblende, and hematite, all intimately mixed, many tiny grains of hematite occurring in the pitchblende. Extremely small amounts of chalcopyrite, pyrite, covellite, galena, and an undetermined light grey mineral were noted.

Radium ore from the WLO and WK Claims, Stairs bay, south arm of Hottah lake, Hottah Lake area, Mackenzie district, N.W.T. Two lots of ore were received and examined microscopically.

Lot No. 1 (Vein No. 6) assayed uranium oxide 13·70 per cent, ferric oxide 43·31, insoluble 37·53, lead 0·68, copper 0·01 per cent, and silver 0·08 ounce per ton. Lot No. 2 (Vein No. 7) gave uranium oxide 13·45, ferric oxide 54·88, insoluble 19·30, lead 0·52, and only traces of copper and silver.

The ore consisted of quartz, pitchblende, and hematite intimately mixed; rare tiny grains of pyrite and a hard white undetermined mineral.

Nickel-copper ore and tailing from B.C. Nickel Mines, Limited, Choate, B.C. Eighteen samples of ore were received in October 1934. The ore contained much pyrrhotite, some chalcopyrite, pentlandite, violarite, and pyrite, very little sphalerite, and a hard white unidentified mineral. Assay showed cobalt to be present but no cobalt-bearing minerals nor any of the platinum groups were recognized.

Three samples of tailing were received on June 6, 1935. The coarser material showed a high degree of combination of pentlandite and pyrrhotite. Assay gave Sample No. 1, 0·01 per cent of copper and 0·27 per cent of nickel; Sample No. 2, 0·02 and 0·43 per cent respectively; and Sample No. 3, 0·03 and 0·64 per cent.

Arsenical Gold ore from Flin Flon Mining Syndicate, Amisk Lake Area, Saskatchewan. Selected specimens of gold ore were submitted for microscopic study. They consisted of white quartz with inclusions of green chloritic material showing much surface alteration; coarse-textured, often massive, arsenopyrite forming from one- to three-quarters of the ore by volume and traversed by a network of fine fractures containing small amounts of chalcopyrite, sphalerite, and pyrrhotite. Much pyrite is associated with the arsenopyrite. Small amounts of chalcopyrite, sphalerite, and "limonite" were noted, and rarely pyrrhotite, magnetite, and covellite.

Approximately 9·6 per cent of the native gold formed tiny irregular grains within the dense pyrrhotite, the rest being in tiny grains in veinlets of gangue cutting across the arsenopyrite. For its recovery concentration by flotation without fine grinding was recommended.

Gold-bearing jig concentrate from Pioneer Gold Mines of B.C., Limited, Pioneer, B.C. The concentrate, the sample of which was received March 15, 1935, consisted of much pyrite and arsenopyrite and little chalcopyrite, pyrrhotite, sphalerite, and galena. Native gold occurred as fine grains, attached to arsenopyrite, attached to gangue, and in dense pyrite; 2·4 per cent of the gold was in the dense pyrite, the rest being wholly, or partly, exposed at the existing fineness of grinding. Most of it should be exposed if the concentrate were ground to pass 200 mesh.

Gold ore from La Forma Claims, near Carmacks, Y.T., for N. A. Timmins Corporation, Ltd., Montreal, Quebec. Three small samples were received on March 27, 1935, designated "Blue Vein", "White Vein", and "Sulphide". The "Blue Vein" consisted of quartz containing pyrite, "limonite", pyrrhotite, and native gold and owed its name to a blue mineral resembling azurite. Moderately coarse grinding should liberate most of the gold as 70·6 per cent of the gold, which is largely coarse, was free in the quartz. The "White Vein" carried well below 1 per cent of metallic minerals, finely disseminated in quartz. These were pyrite, "limonite", chalcopyrite, arsenopyrite, covellite, sphalerite, native copper, native gold, and pyrrhotite. The gold was largely coarse and should be recoverable the same way. The "Sulphide" was soft grey clay, with highly fractured pyrite fragments in abundance and with it a little chalcopyrite. The gold was fine and probably some concentration of the sulphides would be needed.

Gold ore from Pan-Canadian Gold Mines, Ltd., Cadillac township, Abitibi county, Quebec. A sample was received May 14, 1935, consisting of greenish-grey chlorite schist containing numerous small stringers and lenses of quartz. Much pyrite, ilmenite, and magnetite, and very little chalcopyrite, pyrrhotite and arsenopyrite were disseminated throughout the schist, with rare tiny grains of graphite (or molybdenite?). Three tiny grains of gold were seen, two in quartz and one in a fissure in pyrite, but some is probably in the pyrite.

Silver-copper flotation concentrate from Eldorado Gold Mines, Limited, Labine Point, Great Bear Lake, N.W.T. Eighty pounds of concentrate was received January 28, 1935, being a flotation product of table tailing from the pitchblende concentrating tables. It assayed 1,068·4 ounces of silver per ton, 15·85 per cent of iron, 14·10 of sulphur, 11·90 of copper, and 22·50 of insoluble; 48 per cent passed 200 mesh.

Amalgamation recovered 33 per cent of the silver, and other mechanical methods proved unsuitable. Oxidizing, or sulphating roasting with water leaching and precipitation of the silver gave 80 per cent, the manganese in the ore being prejudicial. Chloridizing roasting at 630° C., with addition of 10 per cent of common salt, water leaching to remove soluble salts of copper, iron, etc., and leaching with 5 per cent of hypo gave 94 to 95 per cent, the silver being precipitated by sodium sulphide.

Recovery of Gold and Silver in Zinc Plant residue from Hudson Bay Mining & Smelting Company, Limited, Flinflon, Manitoba. A shipment of 220 pounds of residue was received February 19, 1935. It contained 0·2 ounce of gold and 5·0 ounces of silver per ton.

The residue is not amenable to the usual hydrometallurgical treatment. Chloride volatilization gave encouraging results. Mixed with 5 per cent of its weight in common salt and subjected to temperatures from 880° C. to 1090° C. in trays in a muffle furnace, over 90 per cent of the gold and 70 to 80 per cent of the silver were volatilized. Brine leaching increased the recovery.

Radium ore from the Tatee and Bee Claims, Great Bear Development Co. Ltd., (Hottah Lake Gold & Radium Mines, Ltd.), east arm of Beaverlodge lake, Hottah Lake area, Mackenzie district, N.W.T. A shipment of 3,050 pounds of the ore was received July 23, 1934, in five lots, the lowest grade of which only, weighing 1,125 pounds, was treated. This consisted of pitchblende and hematite intimately mixed, with a little quartz. Upon assay it gave 22·10 per cent of U_3O_8.

The hematite and pitchblende cannot be separated by ordinary means. By crushing it to about 10 mesh, sizing into $-10+30$, $-30+60$, and -60 mesh and tabling each size about 75 per cent could be recovered, of which the grade would be about 30 per cent of U_3O_8.

Grinding Tests on Pebbles from Ceramic, Quebec, 6 miles north of Mattawa, Ontario. Five bags, weighing 505 pounds, were received on December 7, 1934, together with 4 bags of Danish pebbles, weighing 500 pounds. The Ceramic pebbles were mostly greenstone 2 to 4 inches, the Danish were flint, 4 inches in size.

The Ceramic pebbles ground away 1·95 times as fast as the Danish: apparently both kinds do the same amount of grinding. The cost of the Ceramic being about one-half that of the Danish, a commercial test at a mine might justify the use of the former.

Plasticity and fineness tests on hydrated lime from St. John Lime Co., Ltd., Brookfield, N.B. Three samples, each of 4½ pounds, were received January 4, 1935. The plasticity figures ranged from 122 to 180 (many finishing limes are over 300). Not more than 0·5 per cent was left of any on a No. 30 sieve and not more than 15 per cent on a No. 200; thus showing they conform to the standard of fineness for finishing lime.

Because of their low degree of plasticity they cannot be classed higher than mason's hydrated limes.

Gypsum from H. B. McCurdy, Sydney, Nova Scotia. Six small bags were received January 23, 1935, for calcining and tests on suitability for plaster. The weight of each was between 2,000 and 3,000 grammes. They all consisted of crude rock and came respectively from Red Head, Victoria county; Long Hill, Victoria county; near Baddeck bay, N.W. section of Sarah McRae property; 1,000 feet north of boundary line of McRae-McKillop properties, Victoria county; 300 feet north of same line; north side of Plaster Mines road, Victoria county.

All would make good plasters suitable for structural materials having a gypsum base; they should make excellent wallboard; and, having good colour, are suitable for finishing plasters.

Metallization of high-grade concentrate of Texada Island, B.C., magnetite. The -20-mesh concentrate was derived from the ore described in Investigation No. 515 (Report No. 744). It was sintered on a 12 × 48-inch Dwight Lloyd continuous sintering machine, ground to minus ¼ mesh, mixed with charcoal and metallized in the electrically heated rotary retort.

The sponge assayed 92·50 per cent of total iron, 91·48 per cent of metallic iron, 0·011 per cent of phosphorus, 0·013 per cent of sulphur, 3·10 per cent of insoluble, and 0·27 per cent of carbon. For steel-making satisfactory briquettes 2 inches in diameter and 1¼ inches long were produced.

The relative merits of sponge iron and steel scrap as a base for making steel. Ingots of each material were made of S.A.E. grades 1035 and 1065 in a 50-pound induction furnace. In each class the steels were chemically similar.

The tests showed that the steel made from sponge iron was inferior, but this may be due to the difficulty of properly deoxidizing the melt because of its high content of unreduced oxide. For a proper test it should be melted in an electric furnace under careful control of the deoxidation.

The suitability of Quebec chromite for the production of ferrochromium. Four samples of ore were received: No. 1, 93 pounds from Thetford Mines, No. 2, 100 pounds from N.E. part of Lot 17, Con. A, Coleraine township, Wolf county; No. 3, 100 pounds from Lot 19, range 10, Coleraine township, Wolf county; and No. 4, 100 pounds from Lot 10, range IV, Coleraine township, Wolf county.

The iron content of all was found to be too high, although No. 3 approached very nearly to the requisite standard.

Investigation of pinholes in the enamel of an enamelled cast iron product for Ferro-Enamelling Co., Ltd., Ottawa. Pinholes are caused by physical defects on the surface of the casting or by the carbon gases evolved in the decomposition of the carbides of a very thin surface skin or "microchill". Removal of the surface layer by deep sand-blasting usually cures this condition.

The iron and the enamel were found to be sound and the cause was attributed to the "microchill" not having been completely removed by sand-blasting, although the use of an iron of higher silica and lower manganese content would be preferable, the casting being poured from as low a temperature as possible.

Examination of stainless steel tubing used in lighthouse vapour burners for Department of Marine, Ottawa. A 3·5 per cent nickel steel had been found unsatisfactory, and an 18 per cent chromium—8 per cent nickel steel although satisfactory in use was very difficult to machine.

Upon analysis the 18-8 steel showed high silica content, which may have given extra hardness. Two steels were recommended: (a) steel with at least 14 per cent of chromium and no nickel, with one or two per cent of silica; (b) 18-8 steel with small additions of sulphur, selenium, or zirconium. The first was tried and gave good service.

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