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)

July to December, 1934

OTTAWA
J. O. PATENAUDE, I.S.O.
PRINTER TO THE KING S MOST EXCELLENT MAJESTY
1936

No. 748

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)

July to December, 1934

OTTAWA
J. O. PATENAUDE, I.S.O.
PRINTER TO THE KING'S MOST EXCELLENT MAJESTY
1936

No. 748

CONTENTS

MINES BRANCH INVESTIGATIONS IN

ORE DRESSING AND METALLURGY, JULY TO DECEMBER, 1934

I

REVIEW OF INVESTIGATIONS

W. B. Timm
Chief of Division

During the half year ending December 31st, 1934, the results of fifty-four investigations were reported. Twenty-seven reports were issued in printed form, which are included in this report of Investigations in Ore Dressing and Metallurgy, and twenty-seven type-written reports were sent to those directly interested in the particular investigation. Of the twenty-seven printed reports, twenty-five were on gold ores and two on non-metallic minerals. Of the twenty-seven unprinted reports, nineteen were on gold ores, one on a special flotation reagent, two on non-metallic minerals, and five on iron and steel products. Of the forty-four investigations of gold ore, seventeen were on ores from British Columbia, three from Manitoba, thirteen from Ontario, eight from Quebec, and three from Nova Scotia. The ores varied in character, being gold, gold-silver, gold-copper, arsenical-gold, gold-silver-lead, and gold-silver-lead-zinc ores.

As the results of the investigations on Canadian gold ores, a 50-ton cyanide plant was built at Island Mountain Mines, Limited, Wells, British Columbia; a 100-ton cyanide plant at the Queen mine of the Sheep Creek Gold Mines, Limited, Salmo, British Columbia; a 50-ton amalgamation-concentration plant at the Big Slide mine of the Grange Mines, Limited, Pavilion, British Columbia; and a 100-ton cyanide-concentration plant is being built at the Hedley-Mascot mine, Hedley, British Columbia. A 150-ton cyanide plant is being built at God's Lake Gold Mines, Limited, God's Lake, Manitoba; a 50-ton amalgamation plant was built at the Fox Lake Gold Mines, Limited, Mongowin township, Sudbury district, Ontario; a 75-ton amalgamation-concentration plant at Tashota Goldfields, Limited, Tashota, Ontario; and a 100-ton amalgamation-cyanide plant is being built at Wendigo Gold Mines, Ltd., Lake of the Woods district, Ontario. A 150-ton cyanide plant is being built at the Arntfield Gold Mines, Limited, Arntfield, Que.; a 150-ton cyanide plant was built at Canadian Malartic Gold Mines, Limited, Malartic township, Abitibi county, Quebec; and a 50-ton amalgamation-concentration plant is being built at the Bluenose Gold Mining Company, Limited, Guysborough county, Nova Scotia. Milling plants are being considered for other mining properties, the ores of which have been investigated. Investigations were carried out on the milling problems of operating and producing mines, such as Reno Gold Mines, Limited, Salmo, British Columbia; Dentonia Mines, Limited, Greenwood, British Columbia; Central Patricia Mines Limited, Patricia district, Ontario, and United Goldfields of Nova Scotia, Ltd., Queen's county, Nova Scotia. A report was also issued on the use of "Crocetol" frothing reagents for flotation purposes from Shawinigan Chemicals, Limited, Shawinigan Falls, Quebec. As the result of this investigation, these reagents are now being manufactured by the company and used by some of the companies operating flotation-concentration plants.

In addition to the reports of investigations which have been published, twenty-seven investigations of ores, non-metallic minerals, and metallurgical products were reported upon as follows:

Gold ore from the Big Slide mine, Grange Mines, Limited, Kelly creek, Pavilion, British Columbia, (Supplementary report).
Gold ore from Pickle Crow Gold Mines, Limited, Patricia district, Ontario.
Gold ore from Thompson-Joannes Syndicate, Joannes and Rouyn townships, Témiscamingue county, Que.
Gold ore from Lardeau Gold and Silver Mines, Limited, Lardeau district, British Columbia.
Gold ore from Birrell Gold Mines, Limited, Duprat township, Abitibi county, Quebec.
Gold-bearing blanket and table concentrates from United Goldfields of Nova Scotia, Limited, Brookfield mines, Queen's county, Nova Scotia.
Gold-copper ore from Nanoose creek, Vancouver island, British Columbia.
Gold-bearing flotation concentrate from Dentonia Mines, Limited, Greenwood, British Columbia.
Gold ore from the Sakoose Gold Mines, Limited, Dyment, Ontario.
Gold ore from the Harwood Lake Mines, Limited, West River area, Sudbury district, Ontario.
Gold-bearing concentrate from Salmon River Gold Syndicate, Dufferin mines, Halifax county, Nova Scotia.
Gold-silver-lead-zinc ore from the J. & L. Mineral Claims, Revelstoke, British Columbia.
Gold-copper ore from the Fox Lake Gold Syndicate, Mongowin township, Sudbury district, Ontario.
Gold ore from the Amca Mines Syndicate, Timmins, Ont.
Gold ore from the Roderick Gold Mines, Limited, Hole River lake, Manitoba.
Gold ore from the Geiler Mineral Claims, Quadra island, British Columbia.
Gold ore from the Avocalon Mining Syndicate, Vauquelin township, Abitibi county, Quebec.
Gold ore from the Gomak mine, Porcupine Crown Mines, Limited, Chester township, Sudbury district, Ontario.
Gold-silver-lead-zinc ore from the Black Bear Claim, Hall creek, Kitsumgallum lake, B.C.
Comparative tests on Shawinigan Chemicals Limited, "Crocetol" frothing reagents.
Sandblasting tests on silica sands from St. Remi, Quebec.
Concentration of garnet rock from Loughlin township, Sudbury district, Ontario.
Heat treatment of two aeroplane axles for Department of National Defence, Ottawa, Ontario.
Impact tests on 21 samples of steel and 2 samples of brass for Dominion Engineering Works, Montreal, Quebec.
The making of four ingots of nickel-molybdenum steel to develop more satisfactory stay-bolt material for Canadian Pacific Railway Company and Canadian Atlas Steels, Limited.
Metallization of high-grade concentrate from Texada Island magnetite.
Relative value of sponge iron and scrap iron as a base for steel-making.

In addition to the above, many small tests were conducted and reported upon.

The investigations were carried out under the direction and supervision of W. B. Timm, Chief, Division of Ore Dressing and Metallurgy.

The microscopic examination and spectrographic analyses of ores and mill products were performed by M. H. Haycock. During 1934, 1,056 polished and 21 thin sections were prepared and 95 reports of microscopic studies were completed; of these 757 polished and the 21 thin sections were prepared for examination and study in the mineragraphic laboratory of this division and 299 polished sections were prepared for outside sources. A list of the polished sections prepared is as follows:

For Mineragraphic Laboratory	757
For Geological Survey of Canada	136
For Mineral Resources Division, Mines Branch	3
For Queen's University	25
For Nova Scotia Technical College	23
For Noranda Mines, Limited	73
For Macassa Mines, Ltd	19
For Lake Shore Mines Ltd	10
For Consolidated Mining & Smelting Company of Canada, Ltd	10
Total	1056

A number of representative polished sections studied are filed as a permanent record. Those which are not filed are available to Canadian universities for instructional purposes. A set has already been presented to the University of Saskatchewan.

Of the 95 microscopic studies reported, 94 were on Canadian ores and one on a Southern Rhodesian gold ore. The following list shows the types of ores studied:

Gold	71
Base metal	3
Radium	2
Silver	2
Chromium	2
Nickel	2
Miscellaneous	13
Total	95

The predominance of gold ores reflects their importance in Canadian mining at the present time and, as the ores came from deposits distributed from Nova Scotia to British Columbia, indicates the wealth of information which has been collected concerning such ores. It may reasonably be expected that when an opportunity is available for studying in detail the results of both microscopic and test work, the microscopic character of gold ores and their behaviour in the mill can be very closely correlated.

Owing to the pressure of other work, much less use was made of the quartz spectrograph than could be done with profit. Thirty-four analyses by the quartz spectrograph were made, mostly in connection with the work of the chemical and assay laboratories.

The increasing use of the microscope for the investigation of ores and the aid which its use has been to the solving of ore dressing problems, have necessitated the installation of additional equipment for the preparation of polished sections and their study. A new grinding machine was constructed for the preparation of the specimens before mounting; an additional Howard polishing machine was installed and a new and modern photomicrographic apparatus is under construction. The grinding, mounting, and polishing equipment for the preparation of the specimens has been installed in a special room apart from the microscopic, spectrographic, and photomicrographic laboratory.

The investigations of metallic ores were performed by C. S. Parsons, R. J. Traill, A. K. Anderson, J. D. Johnston, W. R. McClelland, and W. S. Jenkins. Forty-four investigations of Canadian ores and one on a Southern Rhodesian ore were carried out by the above staff of ore dressing engineers. R. J. Traill was engaged on research problems in connexion with the investigations and investigated certain problems in connexion with the treatment of Great Bear Lake pitchblende in co-operation with the staff of the Port Hope Radium Refinery. W. R. McClelland also carried out six radium measurements on samples of pitchblende ores from the Great Bear Lake district, N. W. T., and twenty-seven measurements for radioactivity with the alpha electroscope, in the radium-measuring laboratory.

The investigations of non-metallic minerals were carried out by R. K. Carnochan and R. A. Rogers. The investigations show that considerable work is being done on Canadian silica sands to extend their use for sandblasting, the manufacture of glass, carborundum, and other purposes. R. A. Rogers, besides conducting the investigation on gypsum and anhydrite and carrying out the plasticity tests on hydrated limes, performed the chemical analyses on non-metallic products. Several shipments of silica sands were prepared from sandstone for experiments being carried out at the Central Experimental Farms and a quantity of clay prepared for the Ottawa Public School Board.

The metallurgical investigations on iron and steel products were conducted by T. W. Hardy and H. H. Bleakney. T. W. Hardy, who was in charge of the investigations in ferrous metallurgy, resigned May 31 to accept a position with Canadian Atlas Steels, Ltd., Welland, Ontario. The work of this section of the Division was, therefore, considerably curtailed during the latter part of the year. The work consisted of special examinations and tests for the Department of National Defence and Public Works, for the two railway companies, for Canadian Atlas Steels Limited, Welland, Ontario, and the Dominion Engineering Works, Montreal, Quebec. In addition, twelve tons of sponge iron briquettes was made from the concentrate produced from a carload shipment of Texada Island magnetite. The sponge iron was made to determine the relative value of its use as a base compared with scrap iron for steel-making. Owing to the high cost of producing sponge iron as compared to the cost of scrap iron its use for the production of ordinary steels is prohibitive, but where muck bar is used for the manufacture of high quality steel, such as tool and drill steel, it may find an extended use. An effort is being made in co-operation with the producers of high quality steels to determine its value in this connexion

The analytical and assay determinations were performed by a staff of chemists and assayers, under the supervision of H. C. Mabee, Chief Chemist. A total of 4,155 samples of ore, non-metallic minerals, metallurgical and test products, resulting from the investigations of the Division were received in the chemical laboratories, on which over 12,000 chemical determinations were made. This is an increase of twelve per cent over the preceding year. In addition, investigations were carried out on the reduction of Quebec chrome ore by hydrogen; on a basic flux method for the determination of gold and silver by furnace assay; and physical and chemical tests on hydrated limes and plasters. New assay furnaces were installed, making a unit of three electric Globar furnaces, each one being temperature-controlled, and a separate inside room adjacent to the assay laboratory was provided for the assay balances, in which a normal and uniform temperature is maintained.

The preparation of the ores for investigation, the sampling of the ores and test products, the performance of the routine work, the operation of the laboratory equipment, its maintenance, etc., were performed by a staff of mechanics, plant operators, labourers, and laboratory assistants under the direction and supervision of Alex Davie, plant foreman.

The fullest co-operation has been maintained with the industry and those engaged in it. Company and consulting engineers have had the fullest use of the laboratory facilities and co-operation of the staff of the Division for the investigation of their problems. They have had the benefit of the knowledge and experience gained by the staff in conducting the investigations, by consultation and by study of the reports issued. The milling plants and concentrators are, therefore, designed for the most economical treatment of the ores.

II

REPORTS OF INVESTIGATIONS

Ore Dressing and Metallurgical Investigation No. 581

GOLD ORE FROM ISLAND MOUNTAIN, WELLS, CARIBOO DISTRICT, B.C.

Shipment. A shipment, consisting of 31 bags weighing 2,587 pounds, was received on May 31, 1934, from the Island Mountain Mines Company, Limited, 744 West Hastings Street, Vancouver, B.C. The shipment was made up of two samples, as follows: Sample No. 1, 1,732 pounds, designated "Quartz Ore;" and Sample No. 2, 855 pounds, designated "Sulphide Ore."

Characteristics of the Ore. Six polished sections were prepared from specimens taken from each sample, and these were examined microscopically.

The *gangue material of Sample No. 1* consists essentially of white vein quartz. It contains occasional small inclusions of fine-textured grey siliceous material, probably silicified country rock.

The *gangue material of Sample No. 2* is fine-textured, grey impure carbonate. Some specimens contain light grey sugary quartz through which fine carbonate is disseminated; this type of gangue is banded and is somewhat schistose.

The *metallic minerals in Sample No. 1* are: pyrite, arsenopyrite, galena, native gold, and chalcopyrite. Pyrite is abundant and occurs as coarse cubes and crystalline masses; it is much fractured, the veinlets containing gangue, galena, and native gold. Arsenopyrite occurs in considerable amount as small irregular grains and fragments resulting from the shattering of larger grains, and it is veined by gangue and galena. A small amount of galena occurs as narrow veinlets and irregular grains along veinlets of gangue in pyrite and, to a less extent, in arsenopyrite. It is sometimes associated with tiny grains of gold.

The native gold is extremely fine-grained, and occurs only within the pyrite. Much of the gold lies along narrow veinlets or around the boundaries of adjacent crystals of pyrite. In some cases it fills fissures of only a few microns in width. The remaining gold occurs as tiny irregular grains wholly enclosed in pyrite the fractures of which, visible in the polished section, do not penetrate to the gold grains.

Table I shows the grain size and the mode of occurrence of the gold in Sample No. 1, as determined through a quantitative microscopic analysis of the six polished sections.

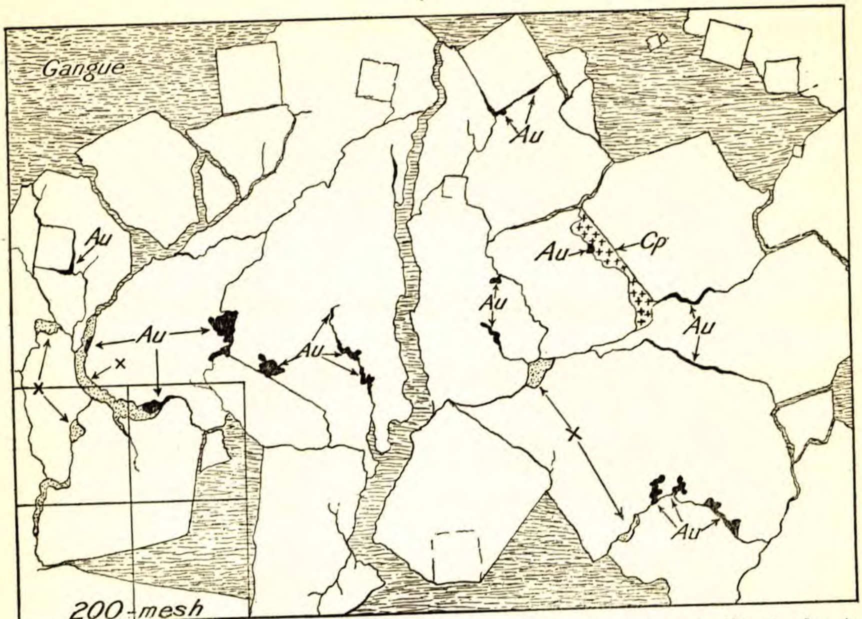


Figure 1. Composite drawing of polished section of specimens, Sample No. 1, showing characteristic occurrence of gold and other minerals. Gold—black (Au); pyrite—white (Py); galena—dotted (X); chalcopyrite—crosses (Cp); gangue—horizontal lines. Magnification, approximately 175 X.

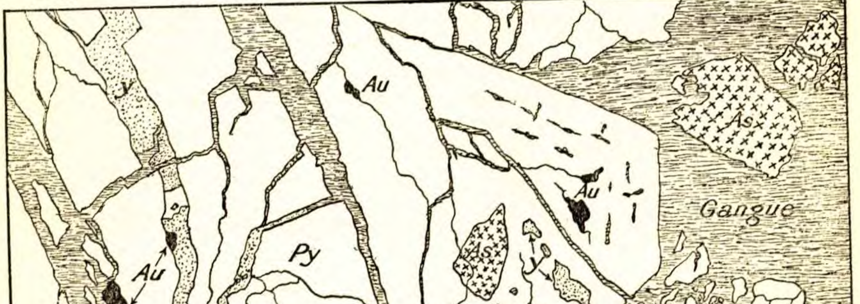


Figure 2. Composite drawing of polished section of specimens, Sample No. 2, showing characteristic occurrence of gold and other minerals. Gold—black (Au); pyrite—white (Py); arsenopyrite—X-pattern (As); galena—dotted (y); chalcopyrite—crosses (Cp); gangue—horizontal lines. Magnification, approximately 125 X.

TABLE I

Grain Size and Mode of Occurrence of Native Gold in Sample No. 1

Mesh	Along fractures	In dense pyrite	Total
	per cent	per cent	per cent
− 200+ 325	6·0	....	6·0
− 325+ 560	12·8	3·4	16·2
− 560+ 800	11·5	8·0	19·5
− 800+1100	8·4	14·6	23·0
−1100+1600	4·4	10·1	14·1
−1600+2300	2·5	6·3	8·8
−2300	4·0	8·0	12·0
Totals	49·6	50·4	100·0

The *metallic minerals present in Sample No. 2* are: pyrite, galena, unknown mineral X, native gold, and chalcopyrite.

The tests for the unknown mineral X are as follows:

Colour: Light grey, like galena.

Hardness: Soft (B).

Crossed nicols: Moderate to strong anisotropism, showing two positions of extinction.

Etch: HNO_3—rapidly turns through brown to black.

HCl—slowly tarnishes grey.

$FeCl_3$—stains brown; rubs grey.

KOH—almost negative; slowly turns differentially grey.

KCN, $HgCl_2$—negative.

Identification: Uncertain. Etch tests are very similar to those for galena, but anisotropism indicates the possibility of its being cosalite ($2PbS.Bi_2S_3$). Sufficient material for a microchemical analysis could not be obtained in the specimens examined.

Pyrite is the only ore mineral abundant in Sample No. 2. Most of it is disseminated, but along certain bands parallel to the indistinct schistosity the pyrite is so abundant as to form fine-grained masses. It is intricately fractured, and the galena, unknown mineral X, and native gold occur along these fractures. Chalcopyrite is extremely rare, as tiny grains in the gangue. Much less native gold was seen than in Sample No. 1, and the grain size is much smaller. All of the gold in this sample, however, occurs along the minute fractures in the pyrite.

Conclusions. Two facts point to the probability that most, if not all, of the gold occurs in the native state: First, no tellurides of gold were seen, and, second, the gold is definitely younger than the pyrite and arsenopyrite, and it is improbable that gold was present in sufficient concentration in the solutions from which they were deposited to cause these sulphides to carry appreciable amounts of the metal in solid solution.

Although the size of the gold particles is extremely small, a large part of the gold in Sample No. 1, and all of that seen in Sample No. 2, occurs along the fractures in the pyrite, and it might reasonably be expected that not only would the pyrite tend to break along these fractures during grinding, but such fractures would be channels for the access of cyanide solution. It is, therefore, probable that the detrimental factor of extremely small grain size would be in part compensated for by the character of the pyrite and the mode of occurrence of the gold in it.

Sampling and Analysis. Each sample was crushed and sampled by standard methods, and was found to assay as follows:

—	Feed—Sample No. 1 (From 1,732-lb. lot)	Feed—Sample No. 2 (From 855-lb. lot)
Gold	0·44 oz/ton	0·85 oz/ton
Silver	0·09 "	0·26 "
Copper	0·03 per cent	0·02 per cent
Iron	8·82 "	16·02 "
Arsenic	0·25 "	0·39 "
Sulphur	8·00 "	14·27 "

Experimental Tests

Series No. 1

Representative portions of Samples Nos. 1 and 2 were taken and mixed in the proportion of 75 per cent of Sample No. 1 (quartz) and 25 per cent of Sample No. 2 (sulphide ore).

A new feed sample was cut from this mixture and found to assay as follows:

Gold................0·55 oz/ton

AMALGAMATION

Five amalgamation tests were made on the above sample.

Test No. 1

A representative sample of −14-mesh ore was crushed dry through a −28-mesh screen and amalgamated on an experimental amalgamation plate. An assay of the amalgamation tailing shows no recovery of gold on the plate.

A screen test on the tailing shows the following:

Mesh	Weight, per cent
− 28+ 35	12·45
− 35+ 48	12·25
− 48+ 65	18·65
− 65+100	14·35
−100+150	9·95
−150+200	8·90
−200	23·45
Total	100·00

Test No. 2

A representative sample of −14-mesh ore was ground in a jar mill, dilution of four parts ore to three parts of water, to give 32 per cent through 200 mesh. The pulp was passed over an experimental amalgamation plate. A small recovery of gold was made in this test.

Assay of feed..Gold, 0·55 oz/ton
Assay of tailing.." 0·53 "

Recovery, $\frac{0 \cdot 02}{0 \cdot 55} \times 100$ ....= 3·64 per cent

A screen test shows the following:

Mesh	Weight, per cent
− 35+ 48	10·45
− 48+ 65	11·75
− 65+100	17·35
−100+150	15·30
−150+200	12·75
−200	32·40
Total	100·00

Test No. 3

A representative sample of −14-mesh ore was ground wet to approximately 43 per cent through 200 mesh in a jar mill charged with iron balls.

The ground pulp was amalgamated by panning in a copper pan that had been coated with mercury and prepared for the test. The pan was agitated by hand until all of the pulp was washed out of the pan. An assay of the amalgamation tailing shows no recovery of gold.

A screen test on the tailing shows the following:

Mesh	Weight, per cent
− 35+ 48	0·50
− 48+ 65	3·80
− 65+100	16·15
−100+150	17·10
−150+200	19·65
−200	42·80
Total	100·00

Test No. 4

The ore used in this test was the same mixture of 75 per cent—25 per cent. It was mixed and re-sampled. The assay of the feed was 0·55 ounce per ton in gold.

The representative sample of ore was ground wet in a jar mill charged with iron balls, to give approximately 50 per cent through 200 mesh. The pulp was amalgamated on an experimental amalgamation plate.

The assay of the tailing showed that there was no recovery of gold.

A screen test shows the following:

Mesh	Weight, per cent
− 35+ 48	0·10
− 48+ 65	0·60
− 65+100	11·25
−100+150	15·60
−150+200	22·15
−200	50·30
Total	100·00

Test No. 5

This test was a repetition of Test No. 4.

The recovery of gold amounted to 1·82 per cent.

A screen test shows the following:

Mesh	Weight, per cent
− 35+ 48	0·05
− 48+ 65	0·75
− 65+100	10·10
−100+150	15·00
−150+200	22·55
−200	51·55
Total	100·00

FLOTATION OF AMALGAMATION TAILING

Test No. 6

The tailing from Test No. 3 was filtered and sampled and charged into a flotation cell where it was conditioned with sodium carbonate, 2·0 pounds per ton, and amyl xanthate, 0·20 pound per ton. Pine oil at the rate of 0·05 pound per ton was added as a frother.

The concentrate assayed 3·08 ounces of gold per ton, with recovery of 88·2 per cent of the gold and a ratio of concentration of 4·2: 1.

The concentrate received further treatment by grinding and cyaniding for 48 hours.

The flotation concentrate was reground and agitated in a solution of sodium cyanide equivalent in strength to 2·0 pounds KCN per ton. Dilution was three parts of solution to one part of concentrate. Lime was added at the rate of 10 pounds per ton of concentrate.

Agitation period was 46 hours.

Results:

Product	Weight, per cent	Assay, gold, oz/ton	Recovery, per cent	Ratio of concentration
Flotation feed	100·00	*0·84	100·00	
Flotation concentrate	24·03	3·08	88·22	4·16 : 1
Flotation tailing	75·97	0·13	11·78	

*Calculated assay for flotation feed.

Product	Assay, gold, oz/ton		Extraction, per cent	Reagents consumed, lb/ton of concentrate	
	Feed	Tailing		KCN	CaO
Flotation concentrate	3·08	0·05	98·38	8·02	12·56

Gold recovered by cyanidation, 98·38 per cent of 88·22 per cent....... 86·79 per cent

CYANIDATION

A series of cyanide tests was made on both dry- and wet-ground samples.

Test No. 7

Representative samples were dry-crushed through 48-, 65-, and 100-mesh screens. The ore was agitated in cyanide solution equivalent in strength to 1·0 pound KCN per ton for periods of 24 and 48 hours. Lime was added at the rate of 5·0 pounds per ton of ore.

The results of the tests are shown in the following table:

Mesh	Period of agitation, hours	Assay, gold, oz/ton		Extraction, per cent	Reagents consumed, lb/ton of ore	
		Feed	Tailing		KCN	CaO
− 48	24	0·56	0·055	90·18	0·21	3·95
− 48	48	0·56	0·055	90·18	0·21	4·10
− 65	24	0·56	0·05	91·07	0·51	4·10
− 65	48	0·56	0·04	92·86	0·51	4·17
−100	24	0·56	0·05	91·07	0·51	6·40

Test No. 8

Representative samples of the mixed ore were ground wet in jar mills charged with iron balls, to give approximately 64 per cent through 200 mesh and 72 per cent through 200 mesh. They were agitated in cyanide solution equivalent in strength to 1·0 pound KCN per ton for periods of 24 and 48 hours.

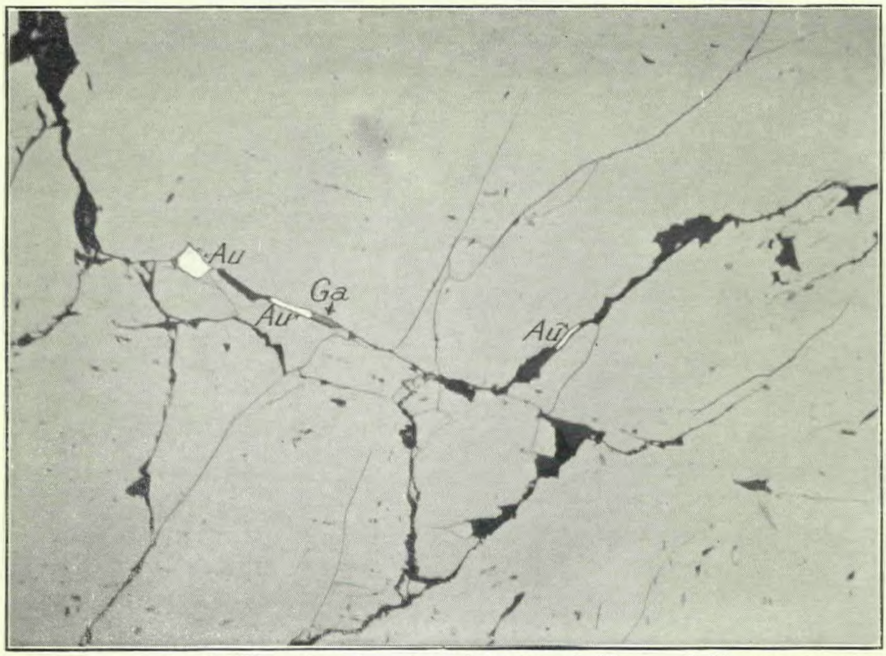
The ratio of dilution was 2·5 : 1. Lime at the rate of 5·0 pounds per ton of ore was used.

The following table shows the results of the tests:

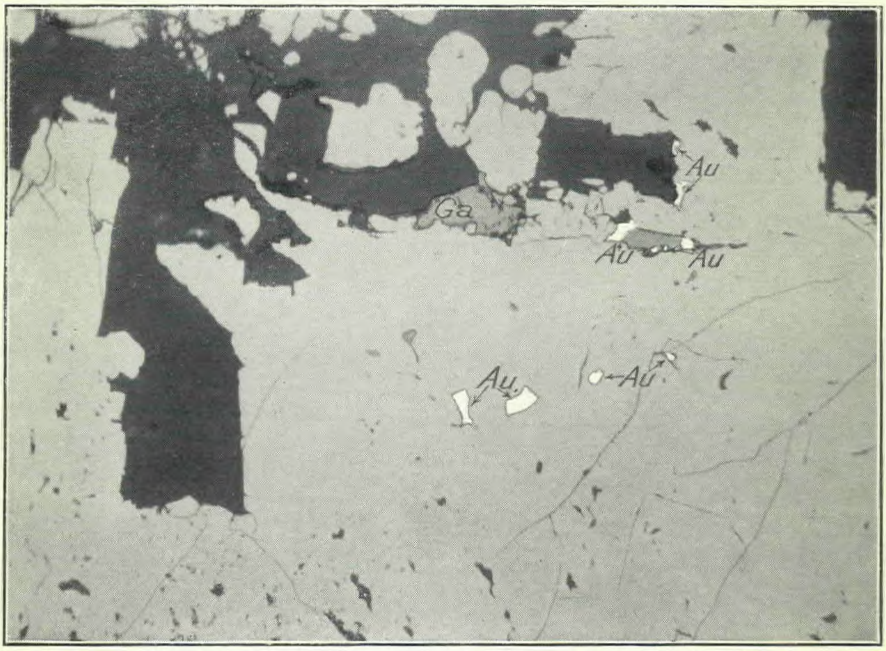
Test No.	Period of agitation, hours	Assay, gold, oz/ton		Extraction, per cent	Reagents consumed, lb/ton of ore	
		Feed	Tailing		KCN	CaO
A	24	0·55	0·03	94·55	0·75	4·19
B	48	0·55	0·03	94·55	0·75	4·26
C	24	0·55	0·02	96·36	0·75	4·12
D	48	0·55	0·02	96·36	0·88	4·57

A screen test shows the following:

Tests A and B		Tests C and D	
Mesh	Weight, per cent	Mesh	Weight, per cent
− 48+ 65	0·25	− 48+ 65	0·30
− 65+100	3·80	− 65+100	1·65
−100+150	9·25	−100+150	5·95
−150+200	22·70	−150+200	20·35
−200	64·00	−200	71·75
Total	100·00	Total	100·00



A. Photograph of polished section of specimen from Sample No. 1. Gold, occurring along fractures in pyrite (white). Galena (grey—Ga) and gangue (dark grey) also form part of the filling of the veinlets. Magnification, approximately 150 X.



B. Photograph of polished section of specimen from Sample No. 2. The gold occurs along fractures and is enclosed by dense pyrite (white). Galena—grey (Ga); gangue—dark grey. Magnification, approximately 150 X.

Series No. 2

A second mixture was made up by taking representative samples from Sample No. 1 (quartz) and Sample No. 2 (sulphide) and mixing them in equal proportions.

A feed sample was cut from this mixture and was found to assay:

Gold.. 0·655 oz./ton

AMALGAMATION

Two duplicate amalgamation tests were made on the new mixture.

Test No. 1

Representative samples were ground wet in jar mills charged with iron balls, to approximately 65 per cent through 200 mesh, and amalgamated on an experimental amalgamation plate.

The results were:

	A	B
Feed............................	0·655 gold oz/ton	0·655 gold oz/ton
Tailing..........................	0·565 "	0·510 "
Recovery........................	$\frac{0 \cdot 09}{0 \cdot 655} \times 100$	$\frac{0 \cdot 145}{0 \cdot 655} \times 100$
	=13·74 per cent	=22·14 per cent

A screen analysis shows the following:

Mesh	Weight, per cent	Weight, per cent
	A	B
− 48+ 65..	0·25	0·15
− 65+100..	3·75	2·80
−100+150..	8·75	8·20
−150+200..	23·40	23·25
−200..	63·85	65·60
Total...	100·00	100·00

CYANIDATION

A series of cyanide tests was made on this mixture.

Test No. 2

Representative samples of −14-mesh ore were ground wet in jar mills to approximately 67 per cent through 200 mesh and 88 per cent through 200 mesh. They were agitated in cyanide solution equivalent in strength to 1·0 pound KCN per ton for 24 hours. The ratio of dilution was 2·5 : 1. Lime at the rate of 5·0 pounds per ton ore was used.

Results:

Test No.	Period of agitation, hours	Assay, gold, oz/ton		Extraction, per cent	Reagents consumed, lb/ton of ore	
		Feed	Tailing		KCN	CaO
A..................	24	0·655	0·02	96·95	0·50	3·87
B..................	24	0·655	0·03	95·42	0·50	4·00
C..................	24	0·655	0·02	96·95	0·80	4·37
D..................	24	0·655	0·03	95·42	0·80	4·37

Screen analysis shows the following:

Tests A and B		Tests C and D	
Mesh	Weight, per cent	Mesh	Weight, per cent
− 48+ 65	0·05	− 65+100	0·25
− 65+100	2·00	−100+150	1·85
−100+150	9·05	−150+200	10·15
−150+200	21·70	−200	87·75
−200	67·20		
Total	100·00	Total	100·00

JIG TESTS

Two jig tests were made on the ore crushed approximately through 14 mesh.

The jig was operated to produce a hutch product. A 20-mesh screen was used on the sieve of the jig, so that the hutch product obtained was finer than 20-mesh size.

The object of these jig tests was to determine, first, whether there was any coarse gold in the sample, and, second, whether any concentration of gold could be obtained.

Results:

Test No.	Product	Weight		Assay, gold, oz/ton	Distribution, gold per cent
		Pounds	Per cent		
1	Ore feed	32·00	100·00	0·655	100·0
	Hutch concentrate	1·83	5·70	3·70	32·2
	Tailing	30·17	94·30	....	67·8
	Total	32·00	100·00	....	100·0
2	Ore feed	35·00	100·00	0·655	100·0
	Hutch concentrate	0·26	0·75	3·04	3·5
	Tailing	34·74	99·25	....	96·5
	Total	35·00	100·00	....	100·0

An examination of the material remaining in the jig bed showed no free gold.

The results of these two tests show that there was no concentration of free gold in the jig concentrate. The increase in the gold assay of the concentrate is entirely due to concentration of the pyrite.

However, in order to prove this point definitely, a barrel-amalgamation test was made on the jig concentrate and on the ore mixture of 50 per cent quartz and 50 per cent sulphide material.

The ore was first ground to 67 per cent through 200 mesh.

The jig concentrate was treated in its natural state without any further grinding.

Samples of both were placed in pebble jars with water and mercury. The amount of mercury used was 10 per cent of the weight of ore. The amalgamation was carried on for one hour by revolving the jars.

Gold amalgamated from jig concentrate........................	39·2 per cent
Gold amalgamated from ore mixture	45·8 "

This shows conclusively that there was no concentration of free gold in the jig concentrate. In fact, some very fine free gold must have washed over into the jig tailing.

Ore Dressing and Metallurgical Investigation No. 582

GOLD-SILVER ORE FROM KOZAK MINE, ALGOMA DISTRICT, ONTARIO

Shipment. Twenty bags containing 1,000 pounds of ore were received May 31, 1934, from Thos. L. Gledhill, Toronto. This consignment was said to have been taken from the Kozak property, Algoma district, Ontario, about mileage 174½, Algoma Central railway.

Characteristics of the Ore. Microscopic examination of polished sections showed the samples to contain pyrite, sphalerite, galena, silver-bearing tetrahedrite (freibergite), native silver, and a small amount of chalcopyrite. The gangue is light in colour, consisting chiefly of quartz with considerable carbonate and sericitic material.

Experimental Tests

Flotation tests were made on material ground to various degrees of fineness. The results show that comparatively fine grinding was necessary to obtain recoveries of 93 per cent of the gold and 95 per cent of the silver. Cyanidation extracts 97·6 per cent of the gold and 51·5 per cent of the silver.

FLOTATION

Test No. 1

A sample of the ore was ground wet, together with 3 pounds soda ash and 0·07 pound Aerofloat No. 25 per ton, until 75 per cent passed 200 mesh. The pulp was then conditioned with 0·10 pound sodium ethyl xanthate per ton; 0·12 pound of pine oil per ton was then added and a flotation concentrate removed.

Results:

Product	Weight, per cent	Assay, oz/ton		Precious metal distribution, per cent	
		Gold	Silver	Gold	Silver
Feed (cal.)	100·0	0·25	9·04	100·0	100·0
Concentrate	11·7	1·86	71·88	86·0	93·0
Tailing	88·3	0·04	0·72	14·0	7·0

The flotation concentrate assayed:

Gold	1·86 oz/ton
Silver	71·88 "
Lead	12·00 per cent
Zinc	20·44 "
Copper	1·03 "

Test No. 2

A test similar to the above was made on a sample ground to pass 86·4 per cent through 200 mesh.

Results:

Product	Weight, per cent	Assay, oz/ton		Precious metal distribution, per cent	
		Gold	Silver	Gold	Silver
Feed (cal.)	100·0	0·17	8·76	100·0	100·0
Concentrate	12·2	1·29	67·64	90·0	94·2
Tailing	87·8	0·02	0·58	10·0	5·8

The concentrate assayed 11·8 per cent lead, 19·5 per cent zinc, and 1·04 per cent copper.

Test No. 3

This test is similar to the preceding two except that the ore was ground to pass 93·6 per cent through 200 mesh.

Results:

Product	Weight, per cent	Assay, oz/ton		Precious metal distribution, per cent	
		Gold	Silver	Gold	Silver
Feed (cal.)	100·0	0·189	8·94	100·0	100·0
Concentrate	13·0	1·360	65·48	93·1	95·2
Tailing	87·0	0·015	0·49	6·9	4·8

The concentrate contained 11·13 per cent lead, 18·69 per cent zinc, and 0·90 per cent copper.

Test No. 4

A sample was floated as in Test No. 3, using Aerofloat No. 31 in place of Aerofloat No. 25 in the grinding mill.

Results:

Product	Weight, per cent	Assay, oz/ton		Precious metal distribution, per cent	
		Gold	Silver	Gold	Silver
Feed (cal.)	100·0	0·186	9·13	100·0	100·0
Concentrate	10·8	1·60	80·06	92·8	94·7
Tailing	89·2	0·015	0·54	7·2	5·3

The concentrate contained 13·41 per cent lead, 21·68 per cent zinc, and 1·06 per cent copper.

Aerofloat No. 31 produces a higher grade concentrate and a lower tailing than the older reagent, Aerofloat No. 25.

Test No. 5

This test was ground 96·8 per cent minus 200 mesh. Other conditions were the same as in Test No. 4.

Results:

Product	Weight, per cent	Assay, oz/ton		Precious metal distribution, per cent	
		Gold	Silver	Gold	Silver
Feed (cal.)	100·0	0·195	8·98	100·0	100·0
Concentrate	10·6	1·67	80·40	90·8	94·9
Tailing	89·4	0·02	0·51	9·2	5·1

The concentrate assayed 13·65 per cent lead, 21·07 per cent zinc, and 1·20 per cent copper.

This test shows a slightly higher gold loss than does Test No. 4, where the grind was 94 per cent minus 200 mesh.

Test No. 6

In this test, copper sulphate was added to the flotation cell. The ore was ground as in Test No. 5, with 3 pounds of soda ash and 0·07 pound Aerofloat No. 31 per ton. It was then conditioned with 1·0 pound copper sulphate per ton and floated with 0·10 pound amyl xanthate and 0·20 pound pine oil per ton. The froth was sluggish and heavy.

Results:

Product	Weight, per cent	Assay, oz/ton		Precious metal distribution, per cent	
		Gold	Silver	Gold	Silver
Feed (cal.)	100·0	0·20	8·91	100·0	100·0
Concentrate	10·3	1·80	82·00	91·2	94·8
Tailing	89·7	0·02	0·52	8·8	5·2

Copper sulphate does not increase extraction but causes a more troublesome froth. The grade of concentrate is higher than in Test No. 5, containing 13·8 per cent lead, 28·2 per cent zinc, and 1·32 per cent copper. Recoveries and tailing losses are about the same.

Test No. 7

In this test, the ore was ground wet with 3 pounds of soda ash and 0·07 pound Barrett No. 4 per ton. After conditioning with 0·10 pound sodium ethyl xanthate and 0·07 pound pine oil per ton, a concentrate was removed. Then 1·0 pound of copper sulphate per ton was added, followed by 0·10 pound sodium xanthate and 0·35 pound pine oil per ton, and a second concentrate removed. This froth was heavy and sluggish.

Results:

Product	Weight, per cent	Assay, oz/ton		Precious metal distribution, per cent	
		Gold	Silver	Gold	Silver
Feed (cal.)	100·0	0·18	9·01	100·0	100·0
Concentrate No. 1	9·3	1·76	90·54	91·1	93·5
Concentrate No. 2	3·1	0·09	4·56	1·6	1·5
Tailing	87·6	0·015	0·51	7·5	5·0

The concentrates had the following analyses:

—	Gold, oz/ton	Silver, oz/ton	Lead, per cent	Zinc, per cent	Copper, per cent
Concentrate No. 1	1·76	90·54	15·45	21·94	1·42
Concentrate No. 2	0·09	4·56	0·39	27·40	0·28

These results indicate that little if any advantage is gained by floating all the zinc in the ore. The same recoveries were obtained as in Test No. 4.

MILL RUN

The ore was fed at the rate of 100 pounds per hour to a rod mill in closed circuit with a classifier. Three pounds soda ash per ton was fed to the mill, together with 0·07 pound Barrett No. 4 per ton. The classifier overflow at 87 per cent minus 200 mesh and 31 per cent solids passed to a conditioning tank where 0·10 pound sodium ethyl xanthate per ton was added. The conditioning tank discharged into the second cell of a 10-cell flotation unit. The concentrate from Cells Nos. 2 and 3 was cleaned in Cell No. 1, producing a finished product. The concentrate from the last seven cells was returned to the second cell together with the cleaner tailing; 0·06 pound of cresylic acid per ton was added to the cells for frothing purposes. The froth was voluminous and hard to control, resulting in a low-grade concentrate.

Assays:

	Gold, oz/ton	Silver, oz/ton
Feed	0·20	7·75
Mill discharge	0·195	7·57
Classifier overflow	0·14	6·95
Flotation concentrate	0·88	57·20
Flotation tailing	0·015	0·54

Distribution of precious metals:

	Gold, per cent	Silver, per cent
Held in mill and classifier	30·0	10·3
Flotation concentrate	63·6	83·5
Loss in tailing	6·4	6·2

Ratio of concentration........................ 7 : 1

Assuming that the precious metals held in the grinding circuit would eventually be recovered in the flotation circuit, a total recovery of 93·6 per cent of the gold and 93·8 per cent of the silver is indicated.

In a full-size machine, the grade of concentrate would be much higher than that produced in this run. The minimum amount of frother added to the unit was too much, resulting in a voluminous froth. In order to determine if returning the cleaner tailing to the circuit would increase tailing losses, sufficient ore for three or four days' continuous run would be required.

After the completion of the run, the ball mill and classifier clean-up was concentrated, and part of the accumulation of silver particles was isolated under a microscope and assayed. The alloy was found to contain 16·87 per cent gold and 83·13 per cent silver.

CYANIDATION

A series of cyanide tests was made on a sample of the ore ground to pass 200 mesh. Portions of the ore were agitated for 24, 48, and 72 hours, 1 : 3 dilution, with a potassium cyanide solution of 2·0 pounds per ton. Lime equal to 6 pounds per ton was added to provide protective alkalinity.

Results:

Time of agitation, hours	Feed, oz/ton		Tailing, oz/ton		Extraction, per cent		Reagent consumption, lb/ton	
	Gold	Silver	Gold	Silver	Gold	Silver	NaCN	CaO
24..........	0·205	9·01	0·015	4·58	92·7	49·2	1·8	4·8
48..........	0·205	9·01	0·005	4·37	97·6	51·5	2·1	4·8
72..........	0·205	9·01	0·005	4·52	97·6	49·8	2·1	4·8

The gold in the ore is readily soluble in cyanide solution, but only about 50 per cent of the silver is recovered under the conditions of the test.

SUMMARY AND CONCLUSIONS

The results of this investigation show that concentration by flotation is the method to adopt for maximum recovery from this ore. Although cyanidation makes a higher recovery of the gold, the silver losses are much higher.

The data on flotation show that fine grinding to about 90 per cent minus 200 mesh is required in order to obtain maximum recovery. Small-scale tests show that a rougher concentrate containing 1·80 ounces per ton in gold and 80·0 ounces per ton in silver can be produced. Cleaning this product will raise the grade. The effect of retaining the cleaner tailing in the main circuit can only be determined after a period of mill operation, when the circuit has become stable.

Ore Dressing and Metallurgical Investigation No. 583

GOLD ORE FROM BOUSQUET GOLD MINES, LIMITED, SUDBURY, ONTARIO

Shipment. A shipment of 20 sacks of ore, net weight 1,360 pounds, was received April 27, 1934. The sample was submitted by Lionel Brooke, 206 Northern Ontario Building, Sudbury, Ontario, on instructions from Ventures, Limited, 100 Adelaide Street West, Toronto.

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

The gangue consists chiefly of milky-white, fine-textured quartz. A small amount of carbonate (probably somewhat dolomitic) is present as small grains and stringers of very irregular shape in the quartz.

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

Pyrite occurs in rather coarse masses and irregular grains, and contains inclusions of gangue, pyrrhotite, and a small amount of chalcopyrite. It is in places intergrown with arsenopyrite, and in age appears to be contemporaneous with it.

Arsenopyrite commonly forms rather coarse crystals disseminated in the quartz, but in places is intergrown with pyrite. It contains inclusions of pyrrhotite and a few grains of native gold.

Chalcopyrite is in considerable amount as small masses associated with pyrite and arsenopyrite, and as fine irregular stringers and tiny grains closely associated with carbonate.

Pyrrhotite occurs as tiny irregular grains in pyrite, its quantity being very small.

Native gold is present mostly in the quartz and carbonate, but a small amount was seen in arsenopyrite.

Mode of Occurrence of the Gold. Native gold occurs chiefly in the gangue, as rather coarse irregular grains. It is generally associated with carbonate and sometimes with chalcopyrite, though it does not occur within this sulphide. The few grains seen were measured and indicate, although very roughly, the size and mode of occurrence of the gold.

Mesh	Per cent in Gangue	Per cent in Arsenopyrite
+100	51	..
−100+200	9	8
−200+325	16	..
−325	12	4
	88	12 Total 100 per cent

No spectrographic analyses were carried out to determine if the arsenopyrite carries invisible gold, because native gold is known to occur in this mineral. It is probable, however, that the gold mineralization may be more closely associated with the chalcopyrite-carbonate mineralization than with the deposition of the pyrite and arsenopyrite, and it follows that there is less probability of the arsenopyrite and pyrite carrying appreciable gold in the form of finely divided particles or in solid solution. Subsequent tests, however, should give some indication of the true condition of the native gold.

Average assays of the ore for the following metals are:

Gold	1·03 oz/ton
Silver	0·07 "
Copper	0·17 per cent
Iron	5·27 "
Arsenic	2·02 "
Sulphur	3·34 "

Experimental Tests

A series of small-scale tests was made on the ore to find how it might be treated in practice. The work consisted of tests by cyanidation, amalgamation, hydraulic classification, blanket concentration, and flotation. By straight cyanidation 95·6 per cent of the gold was extracted in 23 hours when the ore was crushed dry all through 65 mesh. By barrel amalgamation 75 per cent of the gold was extracted, but when plates were used this figure was reduced to 60. In a hydraulic classifier 51·8 per cent of the gold was recovered in a product assaying 11·51 ounces per ton in gold and amounting to 4·6 per cent of the weight of feed used. By straight flotation 82·3 per cent of the gold was recovered in a concentrate amounting to 11·4 per cent of the weight of feed used and assaying 7·18 ounces per ton in gold. By blanketing the flotation tailing an additional 12·3 per cent of the gold was recovered in a blanket concentrate amounting to 4·0 per cent of the weight of feed used and assaying 2·75 ounces per ton in gold. Plate amalgamation of the ore followed by flotation of the amalgamation tailing resulted in 41·6 per cent of the gold being recovered as amalgam and 55·8 per cent of it in a flotation concentrate assaying 4·96 ounces per ton in gold. The flotation tailing assayed 0·03 ounce per ton in gold.

Details of the tests follow:—

CYANIDATION

Tests Nos. 1 to 4

Two samples of the ore were ground in ball mills, approximately 50 per cent through 200 mesh, and agitated in cyanide solution, 1·0 pound potassium cyanide per ton, for 23 hours. Two other samples of the ore, ground dry to pass through a 65-mesh screen, were agitated in cyanide solution, 1·0 pound potassium cyanide per ton, for periods of 23 and 43 hours. The tailings were assayed for gold.

Summary:

Feed sample: gold 1·03 oz./ton

Test No.	Approximate grind	Period of agitation, hours	Tailing assay, gold, oz/ton	Extraction, per cent	Reagents consumed, lb/ton	
					KCN	CaO
1	50 per cent −200 mesh	23	0·05	95·3	1·1	5·4
2	50 per cent −200 mesh	23	0·06	94·2	1·1	5·5
3	−65 mesh	23	0·045	95·6	1·5	6·0
4	−65 mesh	43	0·055	94·6	1·6	6·0

BARREL AMALGAMATION

Tests Nos. 5 and 6

Samples of the ore were ground in ball mills approximately 50 and 70 per cent through 200 mesh and then amalgamated with mercury in jar mills for 30 minutes. The amalgamation tailings were assayed for gold.

Summary:

Feed sample: gold 1·03 oz./ton

Test No.	Grind, per cent −200 mesh	Tailing assay, gold, oz/ton	Recovery, per cent
5	49·1	0·290	71·8
6	72·7	0·255	75·3

PLATE AMALGAMATION

Tests Nos. 10 and 11

Samples of the ore were ground in ball mills approximately 50 and 70 per cent through 200 mesh and then passed over a small amalgamation plate. The tailings were assayed for gold. A sample of the amalgamation tailing from Test No. 10 was agitated in cyanide solution for 24 hours. The cyanide tailing was assayed for gold. These tests were made to see how plate amalgamation compared with barrel amalgamation.

Summary:

Feed sample: gold 1·03 oz./ton

Test No.	Grind, per cent −200 mesh	Tailing assay, gold, oz/ton	Recovery, per cent
10	49·1	0·40	61·2
11	72·7	0·42	59·4

Cyanidation of Amalgamation Tailing:

Feed to amalgamation	1·03 oz/ton gold
Amalgamation tailing	0·40 "
Recovery	61·2 per cent
Feed to cyanidation	0·40 oz/ton gold
Cyanide tailing	0·04 "
Recovery	34·9 per cent
Total recovery	96·1 "

HYDRAULIC CLASSIFICATION

Test No. 7

A sample of the ore ground dry to pass through a 65-mesh screen was put through a hydraulic classifier where the coarse gold and heavy minerals were allowed to settle out against a slowly rising current of water. The classifier oversize and overflow were assayed for gold. This test was intended to give some idea of the results to be expected from the use of a hydraulic trap in practice.

Summary:

Product	Weight, per cent	Assay, gold, oz/ton	Distribution of gold, per cent
Classifier oversize	4·6	11·51	51·8
Classifier overflow	95·4	0·495	48·2
Feed (cal.)	100·0	0·98	100·0

FLOTATION

Test No. 9 B

A sample of the ore was ground approximately 50 per cent through 200 mesh in a ball mill and floated. The products were assayed for gold.

Charge to Ball Mill:

Ore	2,000 grms. −14 mesh
Water	1,500 c.c.
Soda ash	5·0 lb/ton
Water-gas tar	0·14 "

Reagents to Cell:

Potassium amyl xanthate	0·25 lb/ton
Copper sulphate	0·50 "
Pine oil	0·10 "

Summary:

Product	Weight, per cent	Assay, gold, oz/ton	Distribution of gold, per cent
Flotation concentrate	11·4	7·18	82·3
Flotation tailing	88·6	0·20	17·7
Feed (cal.)	100·0	0·996	100·0

Examination of the tailing produced in this test showed the presence of coarse gold. Traps or blankets should be used in combination with flotation on this ore.

Test No. 9A was a duplicate of Test No. 9B and a cyanidation test was made on a sample of a mixture of the two flotation concentrates. The concentrate was agitated in cyanide solution, 5·0 pounds potassium cyanide per ton, for 24 hours at 2·75 : 1 dilution.

Results:

Concentrate	6·68 oz/ton gold
Cyanide tailing	0·96 "
Extraction	85·6 per cent

FLOTATION FOLLOWED BY BLANKETING

Test No. 8

A sample of the ore was ground 50 per cent through 200 mesh in a ball mill and floated. The flotation tailing was passed over a corduroy blanket set at a slope of 2·5 inches per foot. The products were assayed for gold.

Charge to Ball Mill:

Ore	4,000 grms. −14 mesh
Water	3,000 c.c.
Soda ash	5·0 lb/ton
Water-gas tar	0·07 "

Reagents to Cell:

Potassium amyl xanthate	0·20 lb/ton
Copper sulphate	1·00 "
Sodium sulphide	1·00 "
Cresylic acid	0·09 "

Summary:

Product	Weight, per cent	Assay, gold, oz/ton	Distribution of gold, per cent
Flotation concentrate	10·4	7·16	82·9
Blanket concentrate	4·0	2·75	12·3
Blanket tailing	85·6	0·05	4·8
Feed (cal.)	100·0	0·897	100·0

PLATE AMALGAMATION AND FLOTATION

Test No. 12

A sample of the ore was ground 50 per cent through 200 mesh in a ball mill and passed over a small amalgamation plate. The amalgamation tailing was dewatered and conditioned for 5 minutes in a thick pulp with soda ash and copper sulphate and then floated.

Reagents to Conditioner:

Soda ash	5·0 lb/ton
Copper sulphate	0·5 "

Reagents to Cell:

Potassium amyl xanthate	0·20 lb/ton
Aerofloat No. 31	0·12 "
Pine oil	0·05 "

Summary:

Product	Weight, per cent	Assay, gold, oz/ton	Distribution of gold, per cent
Flotation concentrate	11·6	4·96	95·6
Flotation tailing	88·4	0·03	4·4
Amalgamation tailing (cal.)	100·0	0·60	100·0

Recovery by amalgamation	41·6 per cent
Recovery in flotation concentrate	55·8 "
Total recovery	97·4 "

Test No. 13

This was a duplicate of Test No. 12 and the final tailing assayed 0·05 ounce per ton in gold, representing a total recovery of 95 per cent of the gold.

CYCLE CYANIDATION TESTS

Tests Nos. 14 to 21

In this series of tests several batches of ore were treated with one batch of cyanide solution. The ore was ground 50 per cent through 200 mesh in a ball mill and agitated with cyanide solution containing 1·0 pound potassium cyanide per ton for 24 hours at 2·5 : 1 dilution.

The solution was then filtered off, precipitated with zinc dust and used to treat a fresh batch of ore after enough reagents and water were added to bring it back to the original strength and volume.

The cyanide tailing was assayed for gold. This operation was repeated eight times and the final solution assayed to determine its reducing power and harmful ingredients.

Summary:

Feed sample: gold 1·03 oz./ton

Test No.	Tailing assay, oz/ton	Extraction, per cent
14	0·04	96·1
15	0·075	92·7
16	0·055	94·7
17	0·06	94·2
18	0·175	83·0
19	0·07	93·2
20	0·03	97·1
21	0·11	89·3

Owing to the nature of this series of tests the cyanide consumption for each individual test was not determined, but the average amount consumed for the whole series of tests was found to be 1·68 pounds per ton of ore and this appeared to remain fairly uniform throughout the series as judged by the additions of the salt necessary from test to test. The average amount of lime consumed was likewise 3·54 pounds per ton of ore.

High tailing assays were obtained in Tests Nos. 18 and 21, but this is no doubt due to some peculiarity in these particular samples rather than to foul solution as Tests Nos. 19 and 20 show good extractions.

The following determinations were made on the final solution:—

Reducing power	348 c.c.	$\frac{N}{10}$ $KMnO_4$ litre
Potassium thiocyanate	0·55	gramme/litre
Arsenic	0·00496	"
Iron	0·00455	"
Copper	0·18	"

The reducing power as shown above would not be considered high in view of the fact that the gold had been precipitated from the solution with zinc dust before this determination was made.

FLOTATION WITH CYANIDATION OF THE CONCENTRATE

Test No. 22

A sample of the ore was ground 60 per cent through 200 mesh in a ball mill and floated. The concentrate was then reground 99 per cent through 200 mesh, sampled, and assayed for gold and a portion of it agitated in cyanide solution, 5·0 pounds per ton potassium cyanide, for 24 hours. The flotation tailing was also assayed for gold.

Charge to Ball Mill:

Ore.. 4,000 grms. −14 mesh.
Water.. 3,000 c.c.
Sodium carbonate................................. 5·0 lb/ton
Water-gas tar.................................... 0·14 "

Reagents to Cell:

Potassium amyl xanthate.......................... 0·25 lb/ton
Copper sulphate.................................. 0·50 "
Pine oil... 0·10 "

Summary:

Product	Weight, per cent	Assay, gold, oz/ton	Distribution of gold, per cent	Reagents consumed, lb/ton	
				KCN	CaO
Flotation concentrate	13·3	7·42	90·5	....	....
Flotation tailing	86·7	0·12	9·5	....	....
Feed (cal.)	100·0	1·09	100·0	....	....
Concentrate cyanided	13·3	0·30	95·6	20·0	23·2

Net recovery by cyanidation of the flotation concentrate is 95·6 × 90·5 = 86·8 per cent total gold.

AMALGAMATION AND FLOTATION WITH CYANIDATION OF THE CONCENTRATE

Test No. 23

A sample of the ore was ground 50 per cent through 200 mesh in a ball mill and passed over an amalgamation plate. The plate tailing was floated and the concentrate reground practically all through 200 mesh. The flotation tailing and concentrate were then sampled and assayed for gold and a portion of the concentrate agitated in cyanide solution, 5·0 pounds potassium cyanide per ton, for 40 hours.

Charge to Ball Mill:

Ore.. 4,000 grms. −14 mesh
Water.. 3,000 c.c.

Reagents to Cell:

Sodium carbonate................................. 5·0 lb/ton
Copper sulphate.................................. 0·50 "
Aerofloat No. 31................................. 0·12 "
Potassium amyl xanthate.......................... 0·20 "
Pine oil... 0·05 "

Summary:

Feed sample: gold 1·03 oz./ton

Product	Weight, per cent	Assay, gold, oz/ton	Distribution of gold, per cent	Reagents consumed, lb/ton	
				KCN	CaO
Flotation concentrate	7·3	4·75	92·6	....	....
Flotation tailing	92·7	0·03	7·4	....	....
Amalgamation tailing (cal.)	100·0	0·37	100·0	....	....
Concentrate cyanided	7·3	0·12	97·5	29·2	25·3

Recovery by amalgamation........................ 64·1 per cent total gold
Recovery in flotation concentrate............... 33·2 " "
Extracted from concentrate by cyanidation....... 32·4 " "
Total recovery as bullion: 64·1 + 32·4.......... 96·5 " "

CONCLUSIONS

The test work carried out on this ore indicates that a good recovery of the gold can be obtained by any one of a number of standard flow-sheets.

By straight cyanidation of the ore upwards of 95 per cent of the gold can be extracted in 24 hours when the ore is ground 50 per cent through 200 mesh. Plate amalgamation of the ore before agitation in cyanide solution effects a small increase in extraction, but this step would be of doubtful economic value in view of the increased cost it would entail.

Good recoveries were also obtained by flotation with the ore ground 50 per cent through 200 mesh when this step was either followed by blanketing or preceded by plate amalgamation. The flotation or blanket concentrates respond readily to cyanidation, giving good overall recoveries.

The field, therefore, seems to narrow down to a choice between straight cyanidation, on the one hand, and plate amalgamation followed by flotation with cyanidation of the concentrate on the other. No difficulty should be met with solutions fouling in a straight cyanide plant, and as the concentrates are amenable to cyanidation the choice between these two flow-sheets will have to be decided on the basis of costs of installation and operation of each.

Ore Dressing and Metallurgical Investigation No. 584

GOLD ORE FROM BLUENOSE GOLD MINING COMPANY, LIMITED, STORMONT TOWNSHIP, GUYSBOROUGH COUNTY, N.S.

Shipment. A shipment of gold ore, weight 1,600 pounds, was received on June 6, 1934, from the Skunk Den mine, near Goldboro, Guysborough county, Nova Scotia.

Characteristics of the Ore. The gangue consists of light grey to white vein quartz.

The metallic minerals noted in the polished sections are: arsenopyrite, ilmenite (?) or possibly a tungsten mineral, galena, chalcopyrite, pyrrhotite, and native gold.

Arsenopyrite is locally abundant as coarsely crystalline masses and coarse poorly-formed crystals. It contains tiny irregular grains of gangue, galena, chalcopyrite, pyrrhotite, and native gold.

Ilmenite (?) occurs in small imperfect crystals and irregular grains in the gangue. Tests failed to differentiate this mineral, and although it is probably identifiable as ilmenite there remains the possibility that it may be wolframite.

Native gold was seen only as very small irregular grains, both in the arsenopyrite and in the quartz gangue.

Sampling and Analysis. The shipment was crushed and sampled by standard methods and the analysis of the feed sample was as follows:—

Gold	0·395	oz/ton
Silver	0·04	"
Arsenic	0·64	per cent

Experimental Tests

Test work comprised the following:—

1. Plate amalgamation.
2. Table concentration of plate tailing.
3. Cyanidation of raw ore.
4. Flotation of raw ore.
5. Large-scale mill run on 1,353 pounds of ore.
6. Amalgamation and cyanidation of mill run products.

AMALGAMATION AND TABLING

Test No. 1

A 5,000-gramme charge of ore was ground to pass a 35-mesh screen and then pulped and run over an amalgamation plate. The tailing was sampled and assayed for gold.

The remainder of the plate tailing was run over a laboratory Wilfley table.

The results of the test are as follows:—

Plate Amalgamation:

Gold in feed	0·395 oz/ton
Gold in plate tailing	0·205 "
Gold recovery on plate	48·1 per cent

Table Test:

Product	Weight, per cent	Assay		Distribution, per cent	Ratio of concentration
		Gold, oz/ton	Arsenic, per cent		
Feed	100·0	0·205	....	100·00	
Concentrate	4·70	6·69	9·01	67·99	18·32 : 1
Middling	8·86	0·89	....	17·05	
Sand and slime	86·44	0·08	....	14·96	

Screen Test on Products:

Middling		Tailing (sand and slime)	
Mesh	Weight, per cent	Mesh	Weight, per cent
+ 48	1·0	+ 48	1·3
+ 65	18·0	+ 65	17·1
+100	40·0	+100	23·2
+150	24·4	+150	13·5
+200	13·0	+200	13·9
−200	3·6	−200	31·0
	100·0		100·0

To determine the distribution of the gold in the table tailing, a screen analysis was made on this product.

Mesh	Weight, per cent	Assay, gold, oz/ton	Distribution, per cent
+ 65	18·4	0·015	3·71
+100	23·2	0·015	4·67
+200	27·9	0·015	5·62
−200	30·5	0·210	86·00
	100·0		100·00

This discloses the interesting fact that 88 per cent of the gold in the tailing is in the −200-mesh material, i.e. the slime.

CYANIDATION

Tests Nos. 2 and 3

The following consisted of a series of cyanidation tests on different sizes of the ore. Charges of 200 grammes were agitated in bottles using a cyanide solution having a strength equivalent to 1 pound KCN per ton and a protective alkalinity of 5 pounds CaO (lime) per ton. The pulp ratio was 3 : 1.

Test No. 2: (24-hour agitation):

Product	Assay, gold, oz/ton		Extraction of gold, per cent	Reagents consumed, lb/ton	
	Feed	Cyanide tailing		KCN	CaO
− 48 mesh	0·395	0·01	97·47	0·3	5·20
−100 mesh	0·395	0·01	97·47	0·6	5·35
−150 mesh	0·395	0·01	97·47	0·6	5·65
−200 mesh	0·395	0·02	94·94	0·6	5·80

Screen Tests on Cyanide Tailings:

−48 mesh		−100 mesh		−150 mesh	
Mesh	Weight, per cent	Mesh	Weight, per cent	Mesh	Weight, per cent
+ 65	11·6	+150	6·0	+200	19·2
+100	21·4	+200	31·7	−200	80·8
+150	13·1	−200	62·3		
+200	15·1				100·0
−200	38·8		100·0		
	100·0				

Test No. 3: (48-hour agitation):

Product	Assay, gold, oz/ton		Extraction of gold, per cent	Reagents consumed, lb/ton	
	Feed	Cyanide tailing		KCN	CaO
− 48 mesh	0·395	0·01	97·47	0·3	5·05
−100 mesh	0·395	0·015	96·20	0·6	5·80
−150 mesh	0·395	0·01	97·47	0·75	6·10
−200 mesh	0·395	0·015	96·20	0·75	6·25

The tests indicate that the ore cyanides satisfactorily in 24 hours without fine grinding. Ore ground to pass a 48-mesh screen gives a 0·01 ounce per ton tailing with a low cyanide consumption.

FLOTATION

Test No. 4

A 1,000-gramme charge of −14-mesh ore was ground wet for 15 minutes in a pebble jar. The pulp was then floated.

Reagents added to Grinding:

Soda ash	3·0 lb/ton
Potassium amyl xanthate	0·3 "
Aerofloat No. 31	0·14 "

Additions to Cell:

Pine oil	0·10 lb/ton

Product	Weight, per cent	Assay		Distribution, per cent	Ratio of concentration
		Gold, oz/ton	Arsenic, per cent		
Feed	100·00	0·395	....	100·00	
Concentrate	3·89	2·76	14·44	46·22	25·71 : 1
Tailing	96·11	0·13	....	53·78	

Test No. 5

A similar charge to the above was ground for 25 minutes using the same quantities of reagents.

Additions to Cell:

Pine oil	0·05 lb/ton

Product	Weight, per cent	Assay		Distribution, per cent	Ratio of concentration
		Gold, oz/ton	Arsenic, per cent		
Feed	100·00	0·395	....	100·00	
Concentrate	3·04	7·04	21·18	89·83	32·89 : 1
Tailing	96·96	0·025	....	10·17	

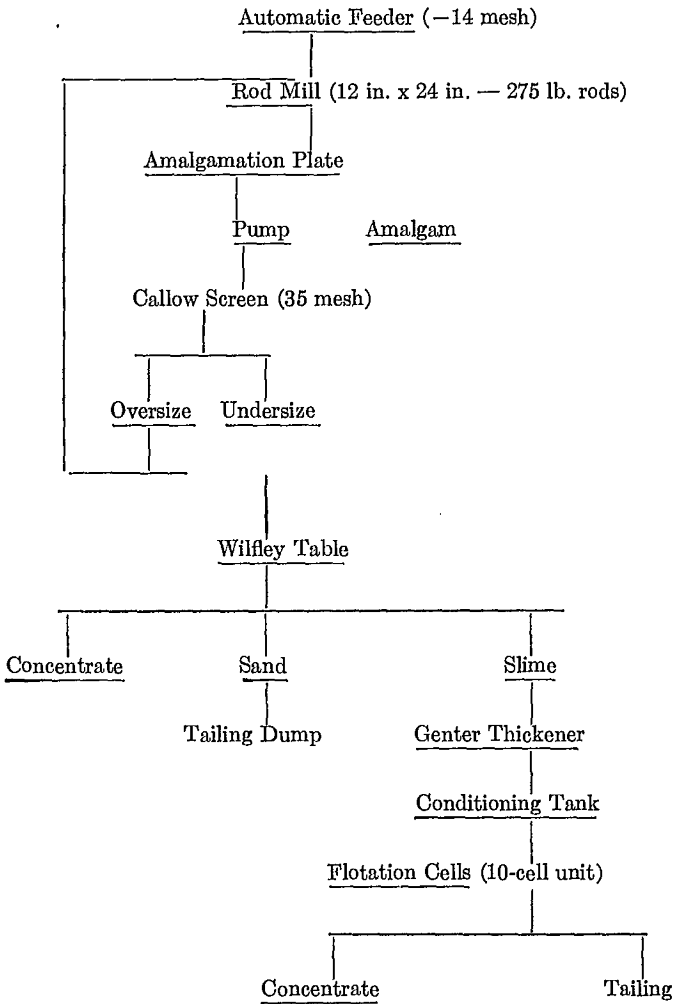
Screen Tests on Flotation Tailings:

Test No. 4		Test No. 5	
Mesh	Weight, per cent	Mesh	Weight, per cent
+ 65	4·2	+ 65	0·2
+100	13·1	+100	2·8
+150	17·1	+150	9·4
+200	22·5	+200	27·7
−200	43·1	−200	59·9
	100·0		100·0

The results of the flotation tests indicate that fine grinding is necessary. Coarse arsenopyrite is difficult to float and must be finely ground for satisfactory separation.

Mill Run No. 1

A sample, 1,353 pounds, of the ore was crushed and treated according to the following flow-sheet:—



The ore crushed to minus 14 mesh was fed to the rod mill from an automatic belt feeder at a rate of 156 pounds per hour. Water was fed to the mill to give a satisfactory pulp for the amalgamation plate.

The undersize from the Callow screen was fed to the Wilfley table. The table middling product was returned to the feed box during the run.

The slime and sand going to the Genter thickener represented about one-half the table discharge.

To the conditioning tank potassium amyl xanthate was fed at the rate of approximately 0·10 pound per ton of cell feed. Cresylic acid was fed to the cells at the rate of 0·155 pound per ton of cell feed.

All products of the run were sampled at approximately five-minute intervals.

Results and Calculations of Mill Run:

Products	Assay	
	Gold, oz/ton	Arsenic, per cent
Feed to rod mill	0·40	0·65
Callow screen	....	....
Undersize	0·115	....
Table concentrate	1·56	27·67
Table sands	0·015	0·10
Flotation concentrate	4·88	18·14
Flotation tailing	0·01	....

Screen Tests on Mill Products:

Callow Screen Undersize		Wilfley Table Sands	
Mesh	Weight, per cent		Weight, per cent
+ 48	1·9	+ 48	2·8
+ 65	7·3	+ 65	10·2
+100	18·2	+100	26·1
+150	17·8	+150	22·9
+200	20·3	+200	23·7
−200	34·5	−200	14·3
	100·0		100·0

Table Slimes		Flotation Tailing	
Mesh	Weight, per cent	Mesh	Weight, per cent
+ 48	10·5	+ 48	1·5
+ 65	1·8	+ 65	3·3
+100	3·7	+100	5·4
+150	4·8	+150	5·2
+200	11·7	+200	11·5
−200	77·5	−200	73·1
Total	100·0	Total	100·0

Gold recovery on amalgamation plate .... 71·25 per cent
Weight of table concentrate recovered .... 35 pounds
Ratio of concentration on table .... 38 : 1 (approx.)

Gold in table concentrate, $\dfrac{100 \times 1{\cdot}56\,(0{\cdot}115 - 0{\cdot}07)}{0{\cdot}115\,(1{\cdot}56 - 0{\cdot}07)}$ .... 40·9 per cent

Total gold in table concentrate, 40·9 per cent of 28·75 per cent ..11·74 per cent

Ratio of concentration in flotation, $\dfrac{4{\cdot}88 - 0{\cdot}01}{0{\cdot}07 - 0{\cdot}01}$ .... 81·16 : 1

Gold in flotation concentrate $\dfrac{100 \times 4{\cdot}88\,(0{\cdot}125 - 0{\cdot}01)}{0{\cdot}125\,(4{\cdot}88 - 0{\cdot}01)}$ ... 92·18 per cent

Total gold in flotation concentrate, 92·18 per cent of 17·01 per cent... 15·68 per cent

Summary of Recoveries and Distribution of Gold from Mill Run

Percentage of gold recovered on amalgamation plate	71·25
Percentage of gold in table concentrate	11·74
Percentage of gold in flotation concentrate	15·68

BARREL AMALGAMATION ON CONCENTRATES

Test No. 6

A charge of table concentrate was barrel-amalgamated in a jar with mercury for 1 hour.

The tailing assayed 0·50 ounce gold per ton, indicating a recovery of 67·9 per cent.

Screen Test on Amalgamation Tailing:

Mesh	Weight, per cent
+ 48	7·4
+ 65	6·4
+100	16·5
+150	22·9
+200	25·5
−200	21·3
Total	100·0

Test No. 7

A charge of table concentrate was given a 10-minute grind and then barrel-amalgamated with mercury for 1 hour as in Test No. 6.

The tailing assayed in gold 0·395 ounce per ton, indicating a recovery of 74·6 per cent.

A screen test on the tailing showed 45·4 per cent −200 mesh.

Test No. 8

A charge of flotation concentrate was ground for 15 minutes and then barrel-amalgamated for 1 hour.

The tailing assayed in gold 3·45 ounces per ton, indicating a recovery of 29·3 per cent.

A screen test on the tailing showed 97·0 per cent −200 mesh.

A summary of these results indicates the possible gold recovery by the foregoing mill method followed by barrel amalgamation of the table and flotation concentrates to be as follows:—

Recovery on amalgamation plates	71·25 per cent
Recovery by amalgamation of table concentrate, 74·6 per cent of 11·74 per cent	8·76 "
Recovery by amalgamation of flotation concentrate, 29·3 per cent of 15·68 per cent	4·59 "
Overall recovery	84·60 per cent

Test No. 9

A 1,000-gramme charge consisting of a mixture of table concentrate and flotation concentrate in the proportion of 4 : 1 was ground wet with 5 pounds lime per ton.

Gold in combined sample	2·285 oz./ton

Two 200-gramme samples were cut from the ground mixed concentrates and agitated for 24 hours in a cyanide solution of strength equivalent to 5 pounds KCN per ton and a protective alkalinity of 5 pounds lime per ton.

Product	Assay, gold, oz/ton		Extraction of gold, per cent	Reagents consumed, lb/ton		Pulp ratio
	Feed	Tailing		KCN	CaO	
Cyanide tailing......	2·285	1·77	22·54	5·02	8·54	3·24 : 1
Cyanide tailing......	2·285	0·25	89·06	4·98	8·64	3·02 : 1

Screen Test on Cyanide Tailing:

Mesh	Weight, per cent
+100	0·6
+150	3·5
+200	16·4
−200	79·5
Total	100·0

Test No. 10

Test No. 9 was repeated because of the erratic results obtained in the duplicate tests.

Particular attention was given to this test, and the cyanide strength was maintained at 5 pounds per ton.

The 200-gramme samples were cut from the ground mixed concentrate and agitated for 24 hours in a cyanide solution of a strength equivalent to 5 pounds KCN per ton of solution.

Product	Assay, gold, oz/ton		Extraction of gold, per cent	Reagents consumed, lb/ton		Pulp ratio
	Feed	Tailing		KCN	CaO	
Cyanide Tailing A	2·280	0·23	90	6·8	9	3 : 1
Cyanide Tailing B	2·280	0·11	95	6·8	9	3 : 1

SUMMARY AND CONCLUSIONS

Two flow-sheets are recommended based on the results of the test work.

For a small mill up to 75 tons, the following flow-sheet is suggested:—

Stamps to crush the ore to 35 mesh and amalgamation plates. The plate tailing to be concentrated on tables. The table sand can be discarded and the slime from the feed end of the table thickened and concentrated by flotation.

For a plant of 100 tons or more capacity, amalgamation followed by cyanidation of the plate tailing is suggested. The ore should be ground in water in ball mills to 60 per cent through 200 mesh, passed over plates, and then thickened and cyanided.

The test work indicates that with the first flow-sheet the following results can be expected:—

Gold recovered by stamp battery amalgamation..................	71·25 per cent
Gold recovered in table concentrate...............................	11·75 "
Gold recovered in flotation concentrate............................	15·7 "

Actual Gold Recovered

At least 74·6 per cent of the gold in the table concentrate can be recovered by barrel amalgamation of this product, therefore 74·6 per cent of 11·75 per cent is 8·76 per cent.

By stamp battery amalgamation plus table concentration and amalgamation of the table concentrate, 71·25 per cent plus 8·76 per cent, or a total of 80 per cent of the gold, can be recovered as bullion.

If flotation be added and the flotation concentrate also barrel-amalgamated, an additional 4·6 per cent can be recovered, or a total of 84·6 per cent.

On the other hand, if the table and flotation concentrates be mixed and treated by cyanidation, the cyanide will extract 90 per cent of their contained gold and a total recovery of 95·7 per cent will be obtained; 71·25 per cent by amalgamation + (90 per cent of 11·75 + 15·7 per cent, or 24·75 per cent).

With the second flow-sheet, the recovery by amalgamation and cyanidation is shown by the test work to be over 96 per cent.

Ore Dressing and Metallurgical Investigation No. 585

GOLD ORE FROM THE CANADIAN MALARTIC MINES, LIMITED, ABITIBI COUNTY, QUEBEC

Shipment. Two shipments of ore were received from the Canadian Malartic Mines, Limited, Quebec, Shipment No. 1 on April 20, 1934, weight 186 pounds, and Shipment No. 2 on May 2, 1934, weight 8,100 pounds.

Sampling and Analysis. Both shipments were crushed and sampled by standard methods. A composite sample of both lots assayed:

Gold	0·22 oz/ton
Silver	0·075 "
Copper	0·02 per cent
Zinc	Trace
Arsenic	Trace
Iron	3·93 per cent
Sulphur	1·98 "

Characteristics of the Ore. The ore is siliceous but contains some carbonate. The metallic minerals noted are disseminated throughout the gangue. The principal sulphide is pyrite, most of which occurs as rather coarse grains, but some occurs as extremely fine grains. The photomicrograph of one of the mill test tailing products shows pyrite grains still locked that are much smaller than 200 mesh.

Experimental Tests

The experimental test work was carried out under the direction of R. C. Mott, who represented the Canadian Malartic Mines, Limited.

Small-scale laboratory tests were first made to investigate several possible methods of treatment, and these were followed by mill tests to check certain of the results obtained.

Outline of Tests

Series I—Straight flotation.
Series II—Flotation followed by blanketing.
Series III—Flotation preceded by traps.
Series IV—Amalgamation and flotation.
Series V—Cyanidation of ore.
Series VI—Cyanidation of concentrate produced.
Series VII—500-lb/hour mill tests.

Series I

FLOTATION

In Tests Nos. 1 to 4, 2,000-gramme lots of −14-mesh ore were ground to various sizes for flotation. The ore was ground with 1,500 c.c. water in a Denver rod mill and the pulp floated in a Denver laboratory machine.

In Tests Nos. 5 and 6, the ore was reduced to flotation size in jar ball mills.

Conditions and results are summarized in Table I.

TABLE I

Test No.	Grind, approximate per cent −200	Concentrate		Tailing		Ratio of concentration	Recovery in concentrate	Reagents consumed, lb/ton
		Weight, per cent	Assay, gold, oz/ton	Weight, per cent	Assay, gold, oz/ton			
1	56·0	6·8	3·27*	93·2	0·075	14·7 : 1	75·9	Soda ash, 1·5; amyl xanthate, 0·1; Aerofloat No. 31, 0·09.
2	45·0	6·1	2·40	93·9	0·085	16·4 : 1	64·6	Soda ash, 1·5; No. 208, 0·1; Aerofloat No. 31, 0·09
3	56·0	7·3	2·34	92·7	0·085	13·7 : 1	68·4	Soda ash, 1·5; amyl xanthate, 0·2; Aerofloat No. 31, 0·06; starch, 1·5.
4	56·0	6·0	2·82	94·0	0·055	16·7 : 1	76·5	Soda ash, 1·5; amyl xanthate, 0·2; Aerofloat, 0·09; copper sulphate, 0·5.
5	92·7	15·9	1·12	84·1	0·04	6·6 : 1	84·2	Soda ash, 2·5; amyl xanthate, 0·2; Aerofloat No. 31, 0·10.
6	91·0	9·9	1·75	90·1	0·05	10·1 : 1	79·4	Soda ash, 2·5; amyl xanthate, 0·50; Aerofloat No. 31, 0·10; copper sulphate, 0·5.

*NOTE.—The concentrate produced in Test No. 1 assayed: Gold, 3·27 oz/ton; copper, 0·14 per cent; zinc, trace; arsenic, trace; iron 26·04 per cent; sulphur, 27·35 per cent.

The highest recovery obtained in Series I, 84·2 per cent, was secured by grinding to 92·7 per cent minus 200 mesh and floating 15·9 per cent of the weight of the ore.

Series II

FLOTATION AND BLANKETING

The same procedure was followed in this series as in Series I. Samples were ground in a Denver rod mill.

Flotation tailings were passed through a mechanical distributor and over a blanket in each test.

Soda ash and Aerofloat were added to the mill in all tests; xanthate and frothing oils to the cell. Copper sulphate was used in Tests Nos. 3, 4, and 5.

Results are summarized in Table II.

TABLE II

Test No.	Grind, per cent −200	Flotation concentrate		Blanket concentrate		Tailing		Total concentrate	
		Weight, per cent	Assay, gold, oz/ton	Weight, per cent	Assay, gold, oz/ton	Weight, per cent	Assay, gold, oz/ton	Ratio	Re-covery, per cent
1	56·0	8·2	1·61	2·7	0·95	89·1	0·07	9·2 : 1	71·8
2	45·0	12·4	1·20	2·9	0·48	84·7	0·075	6·5 : 1	72·2
3	45·0	8·6	1·60*	3·2	0·47	88·2	0·055	8·5 : 1	75·7
4	56·0	7·8	2·07*	2·4	0·73	89·8	0·05	9·8 : 1	79·8
5	80·0	6·6	2·32	1·9	1·16	91·5	0·055	11·8 : 1	76·7

Assays of Flotation Concentrates Produced in Tests Nos. 3 and 4:

—	Gold, oz/ton	Copper, per cent	Zinc, per cent	Arsenic, per cent	Iron, per cent	Sulphur, per cent
Concentrate, Test No. 3	51·60	0·10	0·06	tr.	21·2	20·6
Concentrate, Test No. 4	2·07	0·10	0·05	tr.	23·4	23·7

Test results in Series II closely check Series I. Higher total recoveries were obtained by removing a larger weight of concentrate.

Series III
TRAPS AND FLOTATION

Two samples were tested for the treatment. Each lot was ground in a Denver rod mill, the pulp diluted and passed through a hydraulic classifier (amalgam separator). Trap overflow was floated in each test.

TABLE III

Test No.	Grind, per cent − 200	Trap cleanings		Flotation concentrate		Tailing		Total concentrate	
		Weight, per cent	Assay, gold, oz/ton	Weight, per cent	Assay, gold, oz/ton	Weight, per cent	Assay, gold, oz/ton	Ratio	Re-covery, per cent
1	45·0	0·39	4·92	9·09	1·66	90·52	0·055	10·5 : 1	77·3
2	60·0	0·33	4·22	8·43	2·14	91·24	0·055	11·4 : 1	79·5

Series IV
AMALGAMATION AND FLOTATION

In these tests, the wet-ground pulp was passed over amalgamation plates and the overflow treated by blankets and flotation. Blankets preceded flotation in Test No. 1, but followed flotation in Test No. 2.

TABLE IV

Test No.	Grind, per cent −200	Amalga-mation recovery, (cal.), per cent	Per cent of gold contained in			Total concentrate	
			Blanket concen-trate	Flota-tion concen-trate	Tailing	Ratio of concen-tration	Re-covery, per cent
1	47·2	23·4	8·7	35·4	32·5	14·2 : 1	67·5
2	60·0	24·4	13·1	45·3	19·4	10·8 : 1	80·6

Series V

CYANIDATION

Test No. 1

Wet Grinding. A charge of 2,000 grammes of −14-mesh ore was ground to 45 per cent minus 200 mesh in a Denver rod mill. Three grammes, i.e. 3 pounds per ton, of lime was added to the mill. Pulp was diluted and agitated for 24 hours in a Denver super-agitator in a 0·05 per cent potassium cyanide solution.

Test No. 2

In Test No. 2 the charge was ground as in Test No. 1. The pulp was transferred to a closed Pachuca tank and given a 4-hour pre-liming agitation. Approximately 3 pounds of lime per ton of ore was consumed during this aeration period. The pulp was given a 24-hour agitation with lime and cyanide in a Denver super-agitator.

Tests Nos. 1 and 2 are summarized in Table V (a) following.

TABLE V (a)

Test No.	Grind, approx. per cent −200	Assay, gold, oz/ton		Extraction, per cent	Reagents consumed (lb/ton ore)		Time
		Feed	Tailing		Lime	KCN	
1	45·0	0·22	0·0375	83·0	7·5	0·80	24 hours
2	45·0	0·22	0·03	86·3	12·4	0·76	4 + 24 hours

Tests Nos. 3 and 4

Dry Grinding. Four lots of ore were dry-crushed to pass a 48-mesh screen and four lots to pass 65 mesh. Duplicate samples of each lot were agitated in a 0·05 per cent cyanide solution for 24 hours and 48 hours respectively.

The results of these tests, together with the reagent consumptions, are given in the following table:

TABLE V (b)

Feed sample: gold 0·22 oz/ton

Test No.	Mesh	Period of agitation, hours	Tailing assay, gold, oz/ton	Extraction, per cent	Approximate reagent consumption, lb/ton	
					KCN	CaO
3a	−48	24	0·03	86·3	0·2	8·5
3a	−48	24	0·03	86·3	0·2	8·5
3b	−48	48	0·025	88·7	0·2	8·5
3b	−48	48	0·027	87·7	0·2	8·5
4a	−65	24	0·025	88·7	0·2	8·5
4a	−65	24	0·025	88·7	0·2	8·5
4b	−65	48	0·022	90·0	0·2	8·5
4b	−65	48	0·022	90·0	0·2	8·5

Series VI

CYANIDATION OF CONCENTRATE

Concentrate produced in the laboratory was tested for cyanide extraction with and without regrinding.

In Test No. 1, 200 grammes of concentrate was cyanided for 24 hours in 0·05 per cent KCN solution at 3 : 1 dilution.

In Test No. 2, the concentrate was reground in a pebble mill and cyanided as in Test No. 1.

TABLE VI

Test No.	—	Assay, gold, oz/ton		Extraction, per cent	Reagents consumed, lb/ton		Time
		Feed	Tailing		Lime	KCN	
1	....	2·10	0·81	61·5	10·70	2·45	24 hours
2	Reground..........	2·82	0·22	92·3	16·37	3·40	24 hours

Series VII

MILL TESTS

Two 500-pounds per hour mill tests have been completed on Malartic ore. The shipment received at the Mines Branch for this work, 8,100 pounds, was made up of rejects from mine samples taken during a recent examination. As received, the ore was practically all $-\frac{1}{2}$ inch. It was fed to the continuous unit without further reduction.

In each run, the ore was reduced to approximately 35 per cent minus 200 mesh in a Denver ball mill. The mill discharge was elevated to an amalgamation plate 1·5 feet by 7·0 feet in size. The plate overflow was classified and the sand returned to the mill. The classifier overflow discharged to a small conditioner, which in turn fed a 10-cell bank of Denver flotation machines.

In the flotation plant, maximum recoveries were aimed at; no attempt was made to clean the concentrate.

Grinding, reagent, and assay data are tabulated.

Mill Run No. 1:

Mesh	Mill discharge, i.e. amalgamation feed, per cent	Classifier overflow, i.e. flotation feed, per cent
+ 28	4·9	....
−28+ 35	6·6	....
−35+ 48	9·8	....
−48+ 65	4·7	....
−65+100	16·2	0·8
−100+150	11·2	5·5
−150+200	12·2	17·2
−200	34·4	76·5
	100·0	100·0

Time of Test: 8 a.m. to 4 p.m., May 8, 1934.
Sampling Period: 12.00 noon to 4.00 p.m.
Average Feed Rate: 446 pounds per hour.
Density: Mill discharge, 68 per cent solids
Flotation feed, 29 per cent solids

Reagents:

To Conditioner: Soda ash, 2·7 lb/ton
Copper sulphate, 0·45 lb/ton
Amyl xanthate, 0·10 lb/ton
Aerofloat No. 31, 0·06 lb/ton

To No. 2 Cell: Pine oil, 0·05 lb/ton

To No. 6 Cell: Amyl xanthate, 0·10 lb/ton
Pine oil, 0·03 lb/ton

Mill Feed and Products Assayed:

	Gold, oz/ton
Mill feed	0·225
Mill discharge	0·22
Amalgamation plate feed	0·20
" " overflow	0·145
Flotation feed	0·09
" tailing	0·035
" concentrate	0·029
Table concentrate	0·14
" tailing	0·03

Summary of Results of Mill Run No. 1:

	Distribution of gold, per cent
Recovered on plates	24·5
" in concentrate	27·4
Retained in grinding circuit and flotation equipment	3·5
Flotation tailing loss	12·6
Additional recovery in low-grade table product	2·2

It is difficult to predict mill recoveries from these tests because 35·5 per cent of the total gold in the ore has accumulated in the grinding and flotation equipment and does not show up in the product assays.

It is known, however, that in this case the tied-up gold-bearing minerals are largely rich sulphides, and it is expected that a fair recovery by flotation would be obtained.

In Mill Run No. 1, there is a definite recovery of 24·5 per cent of the total gold by amalgamation and 27·4 per cent in a concentrate. Flotation will recover 85 per cent of that retained in the grinding circuit. The small additional recovery made on a concentrating table (2·2 per cent) would not justify a table installation, hence this figure will be disregarded in the final synopsis.

—	Recovery, per cent	Extraction, per cent
Amalgamation	24·5	24·0
Flotation*	57·1	52·5
Totals	81·6	76·5

*The cyanide extraction on flotation concentrate was 92 per cent. (Series VI, Test No. 2).

Mill Run No. 2

This test was run as a check on Run No. 1. The feed rate was increased to 500 pounds per hour. The same flow-sheet was employed as in Run No. 1. Reagent amounts were cut slightly.

The amalgamation plates, which were given very close attention in Mill Run No. 1, were not dressed during the four-hour sampling period. (Note the lower recovery on plates).

Mill Feed and Products Assayed:	Gold, oz/ton
Mill feed	0·24
Mill discharge	0·22
Amalgamation plate feed	0·195
" " overflow	0·16
Flotation feed	0·10
" tailing	0·035
" concentrate	0·32
Table concentrate	0·12
" tailing	0·03

Summary of Results of Mill Run No. 2:

—	Recovery, per cent	Extraction, per cent
Amalgamation	14·6	14·5
Flotation	67·5	62·1
Total	82·1	76·6

GENERAL SUMMARY OF RESULTS AND CONCLUSIONS

Much test work has been completed on Malartic ore.

Laboratory Report[1] No. 295 of the Mines Branch summarizes work completed on 5,000 pounds of ore received at the Laboratory, April 13, 1928. This shipment assayed 0·90 ounce of gold per ton and contained much free gold. Results reported in this instance are not considered applicable to the run-of-mine ore, which assays about 0·22 ounce per ton in gold.

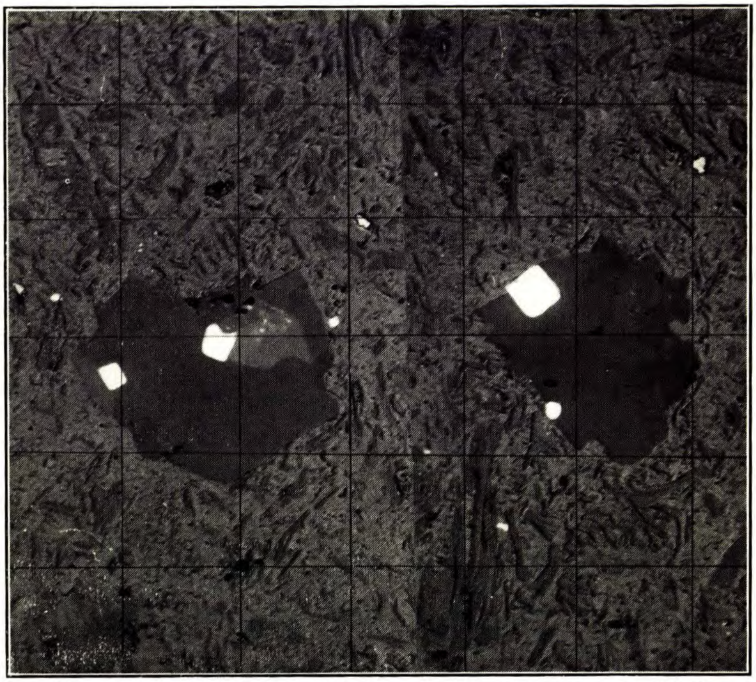
Laboratory Report[2] No. 333 covers the results obtained when testing two lots of ore, 5,470 pounds and 8,720 pounds, received in February and March, 1929. These lots assayed 0·29 and 0·23 ounce per ton respectively and should be representative of mine ore.

The present report covers recent work on ore assaying 0·22 ounce per ton. The results obtained check closely those reported in Report No. 333, except in one particular. In the earlier work recoveries as high as 67 per cent were obtained by barrel amalgamation of the ore. In Test No. 2, Series IV, of recent work, only 24·4 per cent of the contained gold was recovered on plates. This recovery was checked in the 500-pound per hour mill runs, where recoveries of 14·6 per cent and 24·5 per cent were obtained.

Flotation, alone or in combination with traps, blankets, or amalgamation plates, yields low recovery on this ore. By grinding to 90 per cent minus 200 mesh and finer, it is possible to maintain tailing loss at 0·035 ounce per ton when treating 0·22-ounce ore. This results in an immediate loss of 16 to 17 per cent of the total gold in the ore. In addition, concen-

[1] Mines Branch, Dept. of Mines, Canada, Invest. Ore Dressing and Metallurgy, 1928, Rept. 711.
[2] Mines Branch, Dept. of Mines, Canada, Invest. Ore Dressing and Metallurgy, 1929, Rept. 720.

PLATE II



Photomicrograph of a polished section, showing tiny grains of sulphide locked in the gangue. Magnification, 200×. (A 200-mesh grid is superimposed.)

trate produced must be treated further by cyanidation or smelting. Cyanide tailing loss on concentrate will amount to from 5 to 10 per cent of the contained gold, depending on the amount of work expended. Briefly, it is expected that difficulty will be encountered in holding final mill extraction at more than 77 per cent of the gold in the ore.

The reason for the low recovery given by flotation is shown by a microscopical study of the tailing obtained from Mill Runs Nos. 1 and 2. Three polished sections were prepared from a sample of these products and were examined for the presence and also the condition of the sulphides.

The sample consisted chiefly of fragments of gangue with a very small amount of sulphide. By far the greater proportion of the sulphide (pyrite) was found to occur as tiny grains still locked in the gangue.

In general, the average grain size of the table concentrate obtained from tabling the flotation tailing product, as would be expected, is much coarser than that of the flotation tailing. Most of the sulphides present, 89·2 per cent, was found to be locked in the gangue.

The following table gives the results of a microscopical grain analysis carried out on three sections. Percentages are given by volume.

Mesh	Free gangue, per cent	Combined		Free sulphide, per cent
		Gangue	Sulphide	
		per cent	per cent	
+ 48	....	2·5	....	....
− 48+ 65	0·9	3·6	....	....
− 65+ 100	15·7	3·7	....	....
− 100+ 150	30·0	6·8	....	....
− 150+ 200	15·2	2·0	....	....
− 200+ 280	10·9	1·9	0·2	....
− 280+ 400	3·2	....	0·6	....
− 400+ 560	0·7	....	0·4	....
− 560+ 800	0·6	....	0·2	....
− 800+1100	0·07	....	0·1	....
−1100+1600	0·06	....	0·1	0·1
−1600+2300	0·04	....	0·2	0·07
−2300	....	....	0·1	0·06
Total	77·37	20·5	1·9	0·23
	97·87		2·13	
	100·00			

Combined sulphide	89·2 per cent
Free sulphide	10·8 "
Total	100·0 "

On the other hand, a straight cyanide plant working on 50 to 60 per cent minus 200-mesh pulp will extract 88 to 90 per cent of the total gold, with a reasonable reagent consumption. Some doubt exists as to cyanide consumption, but plant operation should be taken care of with not over 0·5 pound per ton. Lime consumption is quite high, 6 to 8 pounds per ton in the laboratory. It is not expected that this figure will exceed 5 pounds per ton in a plant where barren solution is returned to the grinding circuit.

Ore Dressing and Metallurgical Investigation No. 586

GOLD ORE FROM STADACONA ROUYN MINES, LIMITED, ROUYN TOWNSHIP, TÉMISCAMINGUE COUNTY, QUEBEC

Shipment. A shipment consisting of 76 bags of gold ore, weighing 4,600 pounds, was received June 22, 1934, from the Stadacona Rouyn Mines, Limited, Rouyn, Quebec.

Characteristics of the Ore. Microscopic examination of polished sections showed the ore to consist essentially of finely disseminated pyrite with small amounts of chalcopyrite, magnetite, and native gold in a gangue of fine-textured, translucent quartz with patches of chloritic material. The small amount of gold observed occurs both in association with the pyrite and as tiny grains isolated in the quartz.

Experimental Tests

The entire shipment was stage-crushed, ground, and sampled. Analysis showed the shipment to contain 0·20 ounce gold per ton and 0·01 per cent copper.

The investigation including amalgamation, flotation, and cyanidation showed that 55 per cent of the gold is free when the ore is ground 75 per cent minus 200 mesh. When ground minus 150 mesh, 95 per cent of the gold can be extracted by cyanidation. Flotation recovers 93·7 per cent of the gold with a ratio of concentration of 39 : 1; 98 per cent of the gold in the flotation concentrate can be extracted by cyanidation.

AMALGAMATION

Test No. 1

A sample of the ore ground to pass 48 mesh with 48 per cent minus 200 mesh was amalgamated. The amalgamation tailing was then cyanided for 24 hours with a 1·0 pound per ton cyanide solution, 1 : 3 dilution.

Results:

Feed	0·20	oz Au/ton
Amalgamation tailing	0·165	"
Recovery	17·5	per cent
24-hour cyanide tailing	0·02	oz Au/ton
Total recovery amalgamation and cyanidation	90	per cent

Test No. 2

A sample ground to pass 100 mesh with 75 per cent minus 200 mesh was treated similarly.

Results:

Feed	0·20 oz Au/ton
Amalgamation tailing	0·09 "
Recovery	55·0 per cent
24-hour cyanide tailing	0·01 oz Au/ton
Total recovery, amalgamation and cyanidation	95·0 per cent

CYANIDATION

Test No. 3

Samples of the ore ground to pass 48, 100, 150, and 200 mesh were cyanided for 24 and 48 hours, 1 : 3 dilution, with a sodium cyanide solution equivalent in strength to 1·0 pound potassium cyanide. Lime, 7 pounds per ton, was added to supply protective alkalinity.

Results:

Mesh grind	Agitation, hours	Gold, oz/ton		Extraction, per cent	Reagents consumed, lb/ton	
		Feed	Tailing		KCN	CaO
48	24	0·20	0·025	87·5	0·3	5·2
48	48	0·20	0·02	90·0	0·3	5·2
100	24	0·20	0·015	92·5	0·3	5·6
100	48	0·20	0·015	92·5	0·3	5·8
150	24	0·20	0·015	92·5	0·3	6·0
150	48	0·20	0·01	95·0	0·3	6·1
200	24	0·20	0·01	95·0	0·6	6·4
200	48	0·20	0·01	95·0	0·75	6·4

FLOTATION

Test No. 4

A sample of the ore was ground wet together with 4 pounds soda ash and 0·07 pound Barrett No. 4 per ton until 92 per cent passed 200 mesh.

The pulp was then conditioned with 0·10 pound potassium amyl xanthate and 0·09 pound pine oil per ton and a flotation concentrate removed.

Results:

Product	Weight, per cent	Assay, gold, oz/ton	Distribution of gold, per cent
Feed (cal.)	100·0	0·22	100·0
Concentrate	2·2	9·06	91·1
Tailing	97·8	0·02	8·9

Test No. 5

A similar test was made on material ground 98·7 per cent minus 200 mesh.

Results:

Product	Weight, per cent	Assay, gold, oz/ton	Distribution of gold, per cent
Feed (cal.)	100·0	0·21	100·0
Concentrate	2·4	7·94	90·7
Tailing	97·6	0·02	9·3

Test No. 6

The ore was ground wet with 4 pounds soda ash and 0·07 pound Barrett No. 4 per ton. It was then conditioned for 5 minutes with 0·10 pound potassium amyl xanthate and a concentrate removed after adding 0·12 pound pine oil per ton.

The flotation concentrate was cyanided without regrinding. Agitation was continued for 72 hours, 1 : 3 dilution, with a sodium cyanide solution kept at the equivalent of about 5·0 pounds KCN per ton; 10 pounds of lime per ton were added to supply protective alkalinity.

Grind:

Mesh	Per cent
− 65+100	0·3
−100+150	2·5
−150+200	10·7
−200	86·5
Total	100·0

Results:

Product	Weight, per cent	Assay, gold, oz/ton	Distribution of gold, per cent
Feed (cal.)	100·00	0·23	100·0
Concentrate	2·52	8·70	93·7
Tailing	97·48	0·015	6·3

Ratio of concentration: 39·7 : 1

Cyanidation Results:

Feed, flotation concentrate		8·70 oz Au/ton
Cyanide tailing		0·17 "
Extraction		98·0 per cent
Reagent consumption:	Sodium cyanide	11·8 lb/ton
	Lime	8·5 "

Total recovery, flotation and cyanidation.......... 91·8 per cent

SUMMARY AND CONCLUSIONS

The results of this investigation show that comparatively fine grinding to about minus 150 mesh is necessary to liberate the gold. Amalgamation on plates will not yield a high recovery.

Maximum recoveries are obtained by straight cyanidation within 48 hours on ore ground to pass 150 mesh. The time of agitation can be decreased and the maximum recovery obtained by still finer grinding.

Flotation concentration can produce a high-grade product but the tailing from this exceeds that from straight cyanidation of the ore subjected to the same grind.

Cyanidation of the flotation concentrate extracts 98 per cent of the contained gold.

Straight cyanidation extracts 95 per cent of the gold in the raw ore, whereas flotation coupled with cyanidation of the concentrate recovers 91·8 per cent.

An all-cyanide plant is recommended to obtain maximum recoveries.

The choice between a straight cyanide plant and one embodying flotation concentration, and cyanidation of the concentrate will rest on a study of ore reserves, funds available for mill erection, capital outlay, and cost of operation. These factors can only be determined by the management of the company.

Ore Dressing and Metallurgical Investigation No. 587

GOLD ORE FROM RICE LAKE GOLD MINES, LIMITED, MANITOBA

Shipment. A shipment of ore consisting of three boxes, weight 196 pounds, was received on August 7, 1934, from the Rice Lake Gold Mines, Limited. The shipment was submitted by G. B. Tribble, Box 9, Bissett P. O., Manitoba.

Characteristics of the Ore. The gangue was composed of a greenish grey rock through which ran veins of white quartz. Crystals of sulphide minerals were distributed throughout the quartz and greenish grey rock. Mineralization was more abundant in the darker coloured rock.

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

Gold	1·045 oz./ton
Silver	0·10 "

Experimental Tests

Test work comprised cyanidation tests on different sized samples of the ore, plate amalgamation tests, and blanket table concentration.

CYANIDATION

Test No. 1

Charges of 200 grammes of the ore at different sizes were agitated for 24 hours and 48 hours, respectively, in a sodium cyanide solution having a concentration equivalent to 0·05 per cent KCN. Five pounds of lime per ton was added at the start and the pulp ratio was 3:1.

24-Hour Agitation:

Product	Assay, oz./ton		Extraction, per cent	Reagents consumed, lb./ton	
	Feed	Tailing			
− 48 mesh	1·045	0·065	93·78	0·3	3·50
−100 "	1·045	0·05	95·21	0·3	4·10
−150 "	1·045	0·04	96·17	0·3	4·25
−200 "	1·045	0·04	96·17	0·6	4·33

48-Hour Agitation:

Products	Assay, oz./ton		Extraction, per cent	Reagents consumed, lb./ton	
	Feed	Tailing		KCN	CaO
- 48 mesh	1·045	0·05	95·21	0·3	3·65
-100 "	1·045	0·04	96·17	0·3	6·20
-150 "	1·045	0·03	97·12	0·3	6·80
-200 "	1·045	0·03	97·12	0·6	6·65

Cyanidation of the ore as indicated by the tests is very satisfactory. The lime and cyanide consumption is low.

PLATE AMALGAMATION

Test No. 2

Two 1000-gramme charges of −14-mesh ore were ground wet in a pebble mill for 15 minutes and 30 minutes, respectively. The pulp was run over an amalgamation plate.

15-Minute Grinding:

Feed	1·045 oz. Au/ton
Tailing	0·41 " "
Gold recovery	60·76 per cent

Screen Analysis of Plate Tailing:

Mesh	Weight, per cent	Assay, oz./ton	Distribution of gold, per cent
+ 48	6·21	0·34	4·99
+ 65	13·81	0·38	12·41
+100	18·08	0·39	16·67
+150	12·15	0·39	11·20
+200	15·29	0·50	18·07
−200	34·46	0·45	36·66
	100·00		100·00

30-Minute Grinding:

Feed	1·045 oz. Au/ton
Tailing	0·35 " "
Gold recovery	68·42 per cent.

Screen Test of Plate Tailing:

Mesh	Weight, per cent
+ 65	0·3
+100	2·4
+150	8·0
+200	22·7
−200	66·6
	100·0

The results of these tests indicate that finer grinding releases more of the gold, thus increasing the recovery on the plate.

BLANKET CONCENTRATION

Test No. 3

Two tests were run on 1000-gramme samples, one of which was ground for 15 minutes, the other for 30 minutes. The pulp was run over a corduroy blanket set at a slope of $2\frac{1}{2}$ inches to one foot.

15-Minute Grinding:

Product	Weight, per cent	Assay, oz./ton	Distribution of gold, per cent	Ratio of concentration
Concentrate	7·01	9·26	61·34	14·26 : 1
Tailing	92·99	0·44	38·66	

30-Minute Grinding:

Product	Weight, per cent	Assay, oz./ton	Distribution of gold, per cent	Ratio of concentration
Concentrate	8·01	8·66	79·14	12·42 : 1
Tailing	91·99	0·20	20·86	

CONCLUSIONS

The results of the tests indicate that the ore is easily cyanided, a recovery of 97 per cent of the gold being obtained after 48 hours' cyanidation with material ground to pass 150 mesh.

From 60 to 70 per cent of the gold is free and recoverable by amalgamation.

A suggested method of treatment would be to grind the ore to have about 70 per cent pass a 200-mesh screen and pass the mill discharge over a blanket table. The concentrate from the blankets could be amalgamated with mercury in an amalgam barrel, and the tailing thickened and cyanided. By this method the greater part of the coarse free gold would be recovered prior to cyanidation.

Ore Dressing and Metallurgical Investigation No. 588

GOLD ORE FROM THE QUEEN MINE, SHEEP CREEK GOLD MINES, LIMITED, SALMO, B.C.

Shipment. A shipment of gold ore consisting of ten bags, weight 870 pounds, was received on August 28, 1934, from the Queen Mine, Salmo, B.C., and was submitted by the Sheep Creek Gold Mines, Limited.

Characteristics of the Ore. The gangue consists of white and grey quartz with fine grains of metallic sulphides sparsely disseminated through it. No free gold was observed in the ore.

Sampling and Assaying. The sample shipment was crushed and sampled by standard methods. The assay of the feed sample was as follows:

Gold	0·52 oz./ton
Silver	0·20 "
Lead	Nil.
Zinc	0·03 per cent
Copper	0·01 "

Experimental Tests

Test work consisted of cyanidation of raw ore, barrel amalgamation, plate amalgamation, flotation, cyanidation of flotation concentrate, blanket concentration, and combinations of these.

BARREL AMALGAMATION

Test No. 1

A 1,000-gramme charge of minus 14-mesh ore was ground wet in a pebble jar for 20 minutes. The pulp was then barrel-amalgamated with 100 grammes of mercury for 1 hour.

Gold in feed	0·52 oz./ton
Gold in amalgamation tailing	0·08 "
Recovery by amalgamation	84·61 per cent

Screen Test on Tailing:

Mesh	Weight, per cent
+100	1·5
−100+150	5·7
−150+200	17·2
−200	75·6
	100·0

The results of the tests show that at least 84·61 per cent of the gold was free gold.

The following four tests were flotation tests on 1,000-gramme charges of ore. The minus 14-mesh ore was ground wet in a pebble jar.

Test No. 2

Reagents:

To Grinding Mill:

Soda ash.... 4·0 lb./ton

15-minute grind.

To Cell:

Copper sulphate.... 1·0 lb./ton
Potassium amyl xanthate.... 0·4 "
Pine oil.... 0·15 "

Results:

Product	Weight, per cent	Assay			Distribution of gold, per cent	Ratio of concentration
		oz./ton		per cent		
		Au	Ag	Zn		
Feed	100·0	0·52	....	....	100·00	
Concentrate	6·5	5·92	1·44	4·94	80·45	15·38 : 1
Tailing	93·5	0·10	....	....	19·55	

Screen Test on Flotation Tailing:

Mesh	Weight, per cent
+ 65	0·6
− 65+100	6·7
−100+150	12·6
−150+200	23·0
−200	57·1
	100·0

Test No. 3

Reagents:

To Grinding Mill:

Soda ash.. 4·0 lb./ton

30-minute grind.

To Cell:

Copper sulphate.. 1·0 lb./ton
Potassium amyl xanthate................................ 0·4 "
Pine oil.. 0·20 "

Results:

Product	Weight, per cent	Assay, oz./ton		Distribution of gold, per cent	Ratio of concentration
		Au	Ag		
Feed..................................	100·00	0·52	....	100·00	
Concentrate..........................	6·52	5·88	1·50	78·10	15·34 : 1
Tailing..............................	93·48	0·115	....	21·90	

Screen Test on Flotation Tailing:

Mesh	Weight, per cent
+100..	0·3
−100+150..	2·6
−150+200..	12·6
−200..	84·5
	100·0

Test No. 4

Reagents:

To Grinding Mill:

Soda ash.. 4·0 lb./ton
Barrett No. 4... 0·176 "

30-minute grind

To Cell:

Potassium amyl xanthate................................ 0·4 lb./ton
Pine oil.. 0·15 "

Results:

Product	Weight, per cent	Assay, oz./ton		Distribution of gold, per cent	Ratio of concentration
		Au	Ag		
Feed..................................	100·00	0·52	....	100·00	
Concentrate..........................	6·07	7·16	1·62	92·97	16·47 : 1
Tailing..............................	93·93	0·035	....	7·03	

Test No. 5

Reagents:

To Grinding Mill:

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

30-minute grind.

To Cell:

Potassium amyl xanthate.............................. 0·4 lb./ton
Pine oil.. 0·15 "
Cresylic acid... 0·088 "

Results:

Product	Weight, per cent	Assay, Au, oz./ton	Distribution of gold, per cent	Ratio of concentration
Feed..	100·00	0·52	100·00	
Concentrate..................................	8·23	5·40	88·17	12·15 : 1
Tailing.......................................	91·77	0·065	11·83	

Best results by flotation were obtained by grinding with Barrett No. 4.

BLANKET CONCENTRATION

Test No. 6

A 1,000-gramme charge was ground wet for 20 minutes and the pulp run over a corduroy blanket set at a slope of 2½ inches per foot.

Product	Weight, per cent	Assay, Au, oz./ton	Distribution of gold, per cent	Ratio of concentration
Feed..	100·00	0·52	100·00	
Concentrate..................................	5·52	6·65	73·44	18·12 : 1
Tailing.......................................	94·48	0·14	26·56	

CYANIDATION

Test No. 7

Four 200-gramme charges of ore, ground to various sizes, were agitated in bottles in cyanide solution of concentration equivalent to 1 pound KCN per ton and a protective alkalinity of 5 pounds CaO per ton for 24 hours. The pulp ratio was 3 : 1.

Results:

Product	Assay, Au, oz./ton		Extraction of gold, per cent	Reagents consumed, lb./ton	
	Feed	Tailing		KCN	CaO
− 48 mesh..............................	0·52	0·055	89·42	0·60	3·80
−100 "	0·52	0·085	83·65	0·90	4·175
−150 "	0·52	0·025	95·19	0·90	5·95
−200 "	0·52	0·015	97·12	1·05	5·95

Screen Test on Cyanide Tailing:

Mesh	Weight, per cent	Mesh	Weight, per cent	Mesh	Weight, per cent
+ 65	8·7	+150	7·3	+200	23·5
− 65+100	22·6	−150+200	4·7	−200	76·5
−100+150	13·7	−200	88·0		100·0
−150+200	14·6				
−200	40·4		100·0		
	100·0				

Test No. 8

The ore was cyanided for 48 hours.

Results:

Product	Assay, Au, oz./ton		Extraction of gold, per cent	Reagents consumed, lb./ton	
	Feed	Tailing		KCN	CaO
− 48 mesh	0·52	0·04	92·31	0·90	4·025
−100 "	0·52	0·05	90·38	1·29	5·95
−150 "	0·52	0·015	97·12	1·50	6·025
−200 "	0·52	0·01	98·08	1·50	6·175

The cyanidation tests indicate that fine grinding and long contact with cyanide are necessary for good extraction of gold.

AMALGAMATION, CYANIDATION, AND FLOTATION

Test No. 9

A 2,000-gramme sample was given a 20-minute grind in a pebble jar and the pulp then run over an amalgamation plate. A portion of the plate tailing was cyanided and a 1,000-gramme portion was floated. The flotation concentrate was reground and barrel-amalgamated.

Plate Amalgamation:

Gold in feed	0·52 oz./ton
Gold in tailing	0·36 "
Recovery on plate	30·77 per cent

Screen Test on Plate Tailing:

Mesh	Weight, per cent
+ 65	0·1
− 65+100	4·9
−100+150	12·0
−150+200	18·0
−200	65·0
	100·0

Cyanidation of Amalgamation Tailing:

Concentration of cyanide solution equivalent to 0·05 per cent KCN. Protective alkalinity, 5 pounds CaO per ton.

Results:

Product	Assay, Au, oz./ton		Extraction of gold, per cent	Reagents consumed, lb./ton		Pulp ratio
	Feed	Tailing		KCN	CaO	
24-hour cyanide tailing.......	0·36	0·11	69·44	1·15	3·52	3·28 : 1
48-hour cyanide tailing.......	0·36	0·075	79·17	1·45	3·87	3·22 : 1

From results of previous cyanidation tests, Nos. 7 and 8, it follows that amalgamation followed by cyanidation would require fine secondary grinding for the cyanidation of the plate tailing.

Flotation of Amalgamation Tailing:

Reagents:

Soda ash..........	4·0	lb./ton
Barrett No. 4..........	0·176	"
Potassium amyl xanthate..........	0·4	"
Pine oil..........	0·10	"
Cresylic acid..........	0·088	"

Results:

Product	Weight, per cent	Assay, Au, oz./ton	Distribution of gold, per cent	Ratio of concentration
Feed..........	100·00	0·36	100·00	
Concentrate..........	7·02	4·797	93·54	14·25 : 1
Tailing..........	92·98	0·025	6·46	

Barrel Amalgamation of Flotation Concentrate:

Reground for 5 minutes and amalgamated for 1 hour.

Results:

Assay of tailing..........	1·06 oz. Au/ton
Recovery by barrel amalgamation..........	77·90 per cent

Recoveries:

Amalgamation and Cyanidation:

Recovery by amalgamation on plates..........	30·77	per cent
Recovery by cyanidation of amalgamation tailing, 79·17 per cent of (100−30·77)..........	54·81	"
Overall gold recovery..........	85·58	"

Amalgamation and Flotation:

Recovery by amalgamation on plates.......................... 30·77 per cent
Gold in flotation concentrate, 93·54 per cent of (100—30·77)=64·76.
Recovery by amalgamation of flotation concentrate, 77·90 per cent of 64·76 per cent.. 50·45 "

Overall gold recovery.................................. 81·22 "

Test No. 10

In this test, a 2,000-gramme charge was given a 20-minute grind and the pulp run over an amalgamation plate, followed by corduroy blanket.

The blanket concentrate was reground for 5 minutes and barrel-amalgamated for 1 hour.

Gold recovery on plate.. 30·77 per cent

Results of Blanket Concentration:

Product	Weight, per cent	Assay, Au, oz./ton	Distribution of gold, per cent	Ratio of concentration
Concentrate..................................	2·65	8·074	59·44	37·74 : 1
Tailing......................................	97·35	0·15	40·56	

Barrel Amalgamation of Blanket Concentrate:

Feed.. 8·074 oz. Au/ton
Tailing.. 0·915 "
Recovery...88·67 per cent

Summary of Recoveries:

Recovery by amalgamation on plates.................................. 30·77 per cent
Gold in blanket concentrate, 59·44 per cent of (100—30·77)=41·15.
Recovery of gold by amalgamation of reground blanket concentrate (88·67 per cent of 41·15 per cent)................................ 36·49 "

Overall gold recovery.................................... 67·26 "

Concentration on blankets is not satisfactory.

Test No. 11

In this test, a 4,000-gramme charge of ore was ground for 40 minutes in a rod mill with 4 pounds of soda ash per ton and 0·176 pound Barrett No. 4 per ton.

The pulp was then floated, adding 0·4 pound of potassium amyl xanthate per ton and 0·125 pound pine oil per ton to the cell and conditioning for a short time.

The flotation concentrate was reground for 15 minutes and cyanided in a solution equivalent to 0·25 per cent KCN with a protective alkalinity of 5 pounds CaO per ton. Agitation was continued for 48 hours.

Results of Flotation:

Product	Weight, per cent	Assay, Au, oz./ton	Distribution of gold, per cent	Ratio of concentration
Feed...	100·00	0·52	100·00	
Concentrate..................................	5·38	8·82	86·99	18·59 : 1
Tailing......................................	94·62	0·075	13·01	

Results of Cyanidation of Flotation Concentrate:

Product	Assay, Au, oz./ton		Extraction of gold, per cent	Consumption of reagents, lb./ton		Pulp ratio
	Feed	Tailing		KCN	CaO	
Cyanide tailing.............	8·82	0·33	96·26	32·93	12·80	3·43 : 1

Screen Test on Flotation Tailing:

Mesh	Weight, per cent
+150	3·7
−150+200	28·2
−200	68·1
	100·0

Screen Test on Cyanide Tailing:

Mesh	Weight, per cent
+200	0·5
−200	99·5
	100·0

Summary of Recoveries

Gold recovery in flotation concentrate.......................... 86·99 per cent
Gold recovery by cyanidation of flotation concentrate........... 96·26 "

CONCLUSIONS

The barrel-amalgamation test on the raw ore gave a gold recovery of 84·6 per cent, which indicates a high percentage of free gold.

Flotation gave a gold recovery of 92·97 per cent in the concentrate. Grinding with Barrett No. 4 and potassium amyl xanthate added to conditioning gave the best results in the flotation tests.

Cyanidation tests were satisfactory on finely ground ore and after 48 hours of agitation. A tailing of 0·01 ounce of gold per ton, indicating a 98·08 per cent extraction, was made. The KCN consumption was 1·50 pounds per ton and that of lime was 6·175 pounds per ton.

Maximum flotation results gave a gold recovery of 92·97 per cent in the flotation concentrate and a recovery of 96·26 per cent by cyanidation of flotation concentrate. This indicates an overall recovery of 89·5 per cent by flotation followed by cyanidation of the flotation concentrate.

Finer grinding for the flotation would probably result in a higher overall recovery. The cyanide consumption in the treatment of the flotation concentrate is high, being equivalent to 1·77 pounds KCN per ton of ore. This is probably due to the copper sulphide present in the concentrate. There is also the possibility of the copper fouling the solution.

From the results of the test work, straight cyanidation of the ore would appear to be a satisfactory method of treatment. Fine grinding is necessary, however, to free the gold, no matter what treatment is followed.

Ore Dressing and Metallurgical Investigation No. 589

ARSENICAL GOLD ORE FROM MINTO GOLD MINES, LIMITED, BRIDGE RIVER DISTRICT, BRITISH COLUMBIA

Shipment. A shipment of one sack of ore, net weight 100 pounds, was received June 1, 1934. The sample was submitted by Warren A. Davidson, Superintendent, Minto Gold Mines, Limited, Bridge River, British Columbia.

Characteristics of the Ore. Samples showing the more heavily mineralized portions of the ore were selected and examined microscopically to determine the metallic minerals and their modes of occurrence, and for this purpose six polished sections were prepared and examined under the reflecting microscope. In addition, the hand specimens were examined with the binocular microscope.

The gangue consists of fine-textured grey to white quartz and patches and veins of impure grey to white dolomite (or ankerite?), with inclusions of dense, fine-textured, dark grey country rock. A bright green transparent mineral occurs as fine stringers and spots in the dolomitic gangue, and this is probably mariposite.

The distribution of the metallic minerals is very erratic and spotty, and no two polished sections show quite the same mineralogical features. Much of the ore is barren of ore minerals, whereas some portions show marked concentrations of the sulphides, usually in the form of heavily mineralized stringers. In their order of abundance in the sections examined, the ore minerals present are: pyrite, arsenopyrite, pyrrhotite, stibnite, sphalerite, unknown mineral "A", tetrahedrite, chalcopyrite, native bismuth, galena (?), and native gold.

Pyrite, arsenopyrite, and pyrrhotite are locally abundant. The two former sulphides are often much shattered and brecciated, and pyrrhotite commonly invades and replaces pyrite. All three minerals have been seen to contain fine veinlets of dolomitic gangue.

Stibnite is very abundant in one section. It occurs as thick elongated crystals and groups of crystals in a dolomitic gangue, and does not appear to be associated with other ore minerals.

Sphalerite, although present in only a small amount, is rather widespread in association with the other sulphides. It occurs as small irregular grains, and invariably contains numerous tiny dots of chalcopyrite and in some places also of unknown "A" and galena (?).

Unknown "A" occurs as small irregular grains that are often isolated in the dolomitic gangue but are more rarely associated with sphalerite, tetrahedrite, and arsenopyrite. The following tests obtained on the mineral show that it is either jamesonite ($4PbS.FeS.3Sb_2S_3$) or a mineral closely allied in properties and composition.

Colour—galena-white.
Hardness—soft; B.
Crossed nicols—strongly anisotropic.
Etch tests: HNO_3—differentially iridescent to black.
KOH —slowly tarnishes brown—rubs grey.
HCl, KCN, $FeCl_3$, $HgCl_2$—negative.
Microchemical analysis: S—positive—strong.
Sb—positive—strong.
As—trace.
Bi—trace (?).
Fe—positive to trace.
Pb—doubtful—one test positive.
Co, Ni, Cu, Se, Te—nil.

Tetrahedrite occurs in very small amount as small grains associated with sphalerite, unknown "A" and galena (?). Microchemical tests failed to reveal the presence of silver in this mineral.

Chalcopyrite is very small in amount, and its only mode of occurrence is as tiny dots in sphalerite.

A very small amount of native bismuth is present as small irregular grains in pyrrhotite, and more rarely in unknown "A".

A few tiny irregular grains of a mineral closely resembling galena were seen in sphalerite and rarely in pyrite. Their identification is not positive.

Native gold was not seen in any of the polished sections. Examination of the hand specimens under the binocular microscope, however, showed a number of small flakes and grains of native gold occurring in a narrow discontinuous stringer of very dark quartz in light quartz. It is not known to what impurity the dark quartz owes its colour.

Assays show that the ore contains over two ounces of silver to the ton. No silver mineral was identified, but it is possible that such a mineral is present, or that the silver occurs in the tetrahedrite or galena (?).

Assays of the ore showed it to contain the following:

Gold	1·30	oz./ton
Silver	2·43	"
Copper	0·06	per cent
Iron	6·19	"
Arsenic	1·40	"
Lead	0·17	"
Zinc	0·70	"
Antimony	0·10	"
Sulphur	4·76	"
Insoluble	44·14	"

Experimental Tests

A series of small-scale tests was made on the ore to determine how it should be treated to recover the gold from it. The work consisted of tests by concentration, amalgamation, and cyanidation, both alone and in combination. The highest recovery obtained by flotation was 92·9 per cent of the gold in a concentrate amounting to 20·6 per cent of the weight of feed used. The average grade of the concentrate was 5 ounces gold per ton and 9·7 per cent arsenic. By plate amalgamation 26·2 per cent of the gold was recovered. By straight cyanidation of the ore the highest extraction of the gold obtained was 87·3 per cent. This figure could not be raised appreciably by amalgamating the ore before cyanidation, or by tabling out and regrinding and re-cyaniding the sulphides.

Details of the tests follow:

GRINDABILITY TESTS

Samples of the ore, dry-crushed to pass through a 14-mesh screen, were ground in ball mills for periods of 15, 20, 25, and 30 minutes. The pulps were filtered, dried, and passed through a series of screens from 48 to 200 mesh in size. The fractions caught on each of the screens, as well as the one passing through the last screen, were weighed and the reduction in size of the ore particles determined.

The results of these tests are summarized as follows:

Weight, per cent	15-minute grinding	20-minute grinding	25-minute grinding	30-minute grinding
+ 48 mesh	0·3	....	....	....
− 48+ 65 "	1·3	0·1	....	....
− 65+100 "	10·1	2·8	1·6	0·2
−100+150 "	16·1	8·6	6·0	2·8
−150+200 "	23·4	25·1	23·0	17·4
−200 "	48·8	63·4	69·4	79·6
Total	100·0	100·0	100·0	100·0

FLOTATION

Test No. 1

A sample of the ore was ground 69·4 per cent through 200 mesh and floated. An attempt at selective flotation was made, but owing to the small amounts of copper, lead, zinc, and antimony present, this was not practicable and the test was finished as a bulk flotation test.

Charge to Ball Mill:

Ore	2,000 grms. −14 mesh.
Water	1,500 c.c.
Soda ash	4·0 lb./ton.

Reagents to Cell:

Copper-Lead-Antimony

Sodium cyanide	0·10 lb./ton
Cresylic acid	0·07 "

Zinc

Copper sulphate	1·0 lb./ton
Sodium Aerofloat	0·10 "
Pine oil	0·025 "

Pyrite

Potassium amyl xanthate	0·10 lb./ton
Pine oil	0·025 "

Summary:

Product	Weight, per cent	Assay		Distribution of precious metals, per cent	
		Au, oz./ton	Ag, oz./ton	Au	Ag
Concentrate	20·6	5·0	10·85	92·9	97·6
Tailing	79·4	0·10	0·07	7·1	2·4
Feed (cal.)	100·0	1·11	2·29	100·0	100·0

Ratio of concentration—4·85 : 1.

The concentrate assayed 9·7 per cent arsenic.

Test No. 2

A sample of the ore was ground 69·4 per cent through 200 mesh and floated. In this test no attempt at selective flotation was made.

Charge to Ball Mill:

Ore	2,000 grms. −14 mesh.
Soda ash	4·0 lb./ton.
Minerec "A"	0·05 "

Reagents to Cell:

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

Summary:

Product	Weight, per cent	Assay		Distribution of precious metals, per cent	
		Au, oz./ton	Ag, oz./ton	Au	Ag
Concentrate	15·4	7·0	14·50	78·5	93·0
Tailing	84·6	0·35	0·20	21·5	7·0
Feed (cal.)	100·0	1·37	2·40	100·0	100·0

Ratio of concentration—6·49 : 1.

PLATE AMALGAMATION AND FLOTATION

Test No. 14

A sample of the ore was ground 69·4 per cent through 200 mesh in a ball mill and then passed over an amalgamation plate. The amalgamation tailing was conditioned for 5 minutes with copper sulphate and soda ash and then floated with potassium amyl xanthate and pine oil.

Charge to Ball Mill:

Ore	2,000 grms. −14 mesh.
Water	1,500 c.c.

Reagents to Conditioner:

Soda ash	4·0 lb./ton.
Copper sulphate	1·0 "

Reagents to Cell:

Potassium amyl xanthate	0·10 lb./ton.
Pine oil	0·50 "

Summary:

Product	Weight, per cent	Assay		Distribution of precious metals, per cent	
		Au, oz./ton	Ag, oz./ton	Au	Ag
Flotation concentrates..............	15·0	3·46	13·86	54·0	84·5
Flotation tailing.....................	85·0	0·52	0·45	46·0	15·5
Amalgamation tailing (cal.)..........	100·0	0·96	2·46	100·0	100·0

Recovery by amalgamation: (1·30–0·96) ÷ 0·0130 = 26·2 per cent.
Recovery in flotation concentrate: (100·0–26·2) x 54 = 39·9 per cent.

FLOTATION WITH CYANIDATION OF FLOTATION TAILING

Test No. 19

A sample of the ore was ground 69·4 per cent through 200 mesh in a ball mill and floated. The flotation tailing was then agitated in cyanide solution, 2·0 pounds per ton KCN, for 24 hours. All products were assayed for gold.

Charge to Ball Mill:

Ore..	2,000 grms. −14 mesh.
Water..	1,500 c.c.
Soda ash.....................................	1·0 lb./ton.
Aerofloat No. 31	0·07 "

Reagents to Cell:

Potassium amyl xanthate.....................	0·10 lb./ton.
Copper sulphate.............................	1·0 "
Pine oil.....................................	0·10 "

Summary:

Product	Weight, per cent	Assay, Au, oz./ton	Distribution of gold, per cent	Reagents consumed, lb./ton	
				KCN	CaO
Flotation concentrate............	12·4	8·12	83·3	....	....
Flotation tailing.................	87·6	0·23	16·7	....	....
Feed (cal.).......................	100·0	1·21	100·0	....	....
Tailing cyanided.................	87·6	0·12	8·0	1·9	4·25

BLANKETING AND FLOTATION

Test No. 20

A sample of the ore was ground 63·4 per cent through 200 mesh in a ball mill and then passed over a corduroy blanket set at a slope of 2·5 inches per foot. The blanket tailing was floated with the following reagents:

Soda ash...	1·0 lb./ton.
Aerofloat No. 31..	0·07 "
Copper sulphate...	1·0 "
Potassium amyl xanthate..................................	0·10 lb./ton.
Pine oil..	0·25 "

Summary:

Product	Weight, per cent	Assay, Au, oz./ton	Distribution of gold, per cent
Blanket concentrate	9·6	10·79	67·3
Flotation concentrate	8·4	3·56	19·4
Flotation tailing	82·0	0·25	13·3
Feed (cal.)	100·0	1·54	100·0

FLOTATION AND BLANKETING

Test No. 21

A sample of the ore was ground 69·4 per cent through 200 mesh in a ball mill and floated. The flotation tailing was passed over a corduroy blanket set at a slope of 2·5 inches per foot. Samples of the blanket tailing were cyanided for periods of 24 and 48 hours. All products were assayed for gold.

Charge to Ball Mill:

Ore	2,000 grms. −14 mesh.
Water	1,500 c.c.
Soda ash	1·0 lb./ton
Sodium cyanide	0·10 "

Reagents to Cell:

Copper sulphate	1·0 lb./ton.
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	8·3	7·74	42·3
Blanket concentrate	6·4	9·02	38·0
Tailing	85·3	0·35	19·7
Feed (cal.)	100·0	1·52	100·0
Tailing cyanided	85·3	0·17	10·1

Test No. 22.

A sample of the ore was ground 69·4 per cent through 200 mesh in a ball mill and floated. The flotation tailing was then passed over a corduroy blanket set at a slope of 2·5 inches per foot. From this point this test differs from Test No. 21 only in the matter of the reagent combination.

Charge to Ball Mill:

Ore	2,000 grms. −14 mesh.
Water	1,500 c.c.
Soda ash	4·0 lb./ton.
Sodium cyanide	0·10 "

Reagents to Cell:

Copper sulphate	1·0 lb./ton.
Water-gas tar	0·09 "
Potassium ethyl xanthate	0·10 "
Pine oil	0·10 "

Summary:

Product	Weight, per cent	Assay, Au, oz./ton	Distribution of gold, per cent
Flotation concentrate	18·2	5·27	61·1
Blanket concentrate	5·2	10·05	33·3
Blanket tailing	76·6	0·115	5·6
Feed (cal.)	100·0	1·57	100·0

Test No. 26

A sample of the ore was ground approximately 90 per cent through 200 mesh in a ball mill and floated. The flotation tailing was then passed over a corduroy blanket set at a slope of 2·5 inches per foot. All the products were assayed for gold.

Charge to Ball Mill:

Ore	2,000 grms. —14 mesh.
Water	1,500 c.c.
Soda ash	4·0 lb./ton.
Sodium cyanide	0·2 "

Reagents to Cell:

Copper sulphate	1·0 lb./ton.
Water-gas tar	0·09 "
Potassium ethyl xanthate	0·10 "
Pine oil	0·10 "

Summary:

Product	Weight, per cent	Assay, Au, oz./ton	Distribution of gold, per cent
Flotation concentrate	17·2	4·82	68·5
Blanket concentrate	4·9	5·54	22·4
Blanket tailing	77·9	0·14	9·1
Feed (cal.)	100·0	1·21	100·0

A screen test of the blanket tailing showed it to be 87·5 per cent through 200 mesh.

Test No. 27

A sample of the ore was ground approximately 90 per cent through 200 mesh in a ball mill and floated. The flotation tailing was passed over a corduroy blanket set at a slope of 2·5 inches per foot. This test differs from Test No. 26 only in the matter of the reagent combination.

Charge to Ball Mill:

Ore	1,000 grms—14 mesh.
Water	750 c.c.
Soda ash	3·0 lb./ton.
Sodium cyanide	0·10 "

Reagents to Cell:

Barrett No. 4	0·18 lb./ton.
No. 208	0·20 "
Potassium ethyl xanthate	0·20 "
Copper sulphate	1·0 "
Pine oil	0·025 "

Summary:

Product	Weight, per cent	Assay, Au, oz./ton	Distribution of gold, per cent
Flotation concentrate	24·6	4·48	91·5
Blanket concentrate	4·5	1·34	5·0
Blanket tailing	70·9	0·06	3·5
Feed (cal.)	100·0	1·20	100·0

BLANKET CONCENTRATION

Tests Nos. 15, 16, 17, and 18

Samples of the ore were ground 48·8, 63·4, 69·4, and 79·6 per cent through 200 mesh in ball mills and passed over corduroy blankets set at a slope of 2·5 inches per foot. The products were assayed for gold.

Summary of Tests Nos. 15 to 18:

Test No.	Product	Weight, per cent	Assay, Au, oz./ton	Distribution of gold, per cent
15	Concentrate	6·5	13·78	66·9
	Tailing	93·5	0·475	33·1
	Feed (cal.)	100·0	1·34	100·0
16	Concentrate	4·9	17·355	61·9
	Tailing	95·1	0·55	38·1
	Feed (cal.)	100·0	1·37	100·0
17	Concentrate	6·2	12·84	64·4
	Tailing	93·8	0·47	35·6
	Feed (cal.)	100·0	1·24	100·0
18	Concentrate	5·2	19·425	68·7
	Tailing	94·8	0·485	31·3
	Feed (cal.)	100·0	1·47	100·0

HYDRAULIC CLASSIFICATION

Test No. 13

A sample of the ore was ground 63·4 per cent through 200 mesh and passed through a hydraulic classifier where coarse gold and heavy minerals were allowed to settle out against a slowly rising current of water. This test is intended to give some idea of the results to be expected from the use of a hydraulic trap in practice.

Summary:

Product	Weight, per cent	Assay, Au, oz./ton	Distribution of gold, per cent
Classifier oversize	4·6	14·91	54·5
Classifier overflow	95·4	0·60	45·5
Feed (cal.)	100·0	1·26	100·0

CYANIDATION

Tests Nos. 3 to 10

In this series of tests four lots of the ore were dry-crushed to pass through 48-, 100-, 150-, and 200-mesh screens, respectively. Samples of each were agitated in cyanide solution, 2·0 pounds KCN per ton, for periods of 24 and 48 hours. The tailings were assayed for gold.

Summary of Tests Nos. 3 to 10:

Test No.	Grind, mesh	Period of agitation, hours	Tailing assay, Au, oz./ton	Extraction, per cent	Reagents consumed, lb./ton ore	
					KCN	CaO
3	− 48	24	0·21	83·8	1·3	12·3
4	−100	24	0·17	86·9	2·8	13·9
5	−150	24	0·17	86·9	3·1	14·8
6	−200	24	0·165	87·3	4·6	15·5
7	− 48	48	0·215	83·5	2·4	12·5
8	−100	48	0·18	86·2	3·6	14·4
9	−150	48	0·18	86·2	4·2	15·1
10	−200	48	0·175	86·5	5·7	16·3

BARREL AMALGAMATION AND CYANIDATION

Tests Nos. 11 and 12

Samples of the ore, ground dry to pass through 48- and 100-mesh screens, respectively, were barrel-amalgamated for thirty minutes and sampled for assay. Portions of the amalgamation tailings were agitated in cyanide solution, 1·0 pounds KCN per ton, for 24 hours. The cyanide tailings were also assayed for gold.

Summary of Tests Nos. 11 and 12:

Test No.	Amalgamation tailing assay, Au, oz./ton	Cyanide tailing assay, Au, oz./ton	Total extraction, per cent	Reagents consumed, lb./ton ore	
				KCN	CaO
11	0·58	0·22	83·1	1·3	9·6
12	1·08	0·16	87·7	1·9	12·0

CYANIDATION WITH TABLING

Tests Nos. 23 and 24

In each of these tests a sample of the ore was ground approximately 80 per cent through 200 mesh in a ball mill and agitated in cyanide solution, 1·0 pound KCN per ton, for 24 hours without lime. The cyanide tailing was then sampled and assayed and the remainder of it passed over a small concentrating table. The table concentrate was reground and agitated in cyanide solution, 5·0 pounds KCN per ton, for 48 hours. All products were assayed for gold. Assays of the cyanide tailings from the ore were 0·34 and 0·185 ounce per ton in gold, respectively.

Summary of Test No. 23:

Product	Weight, per cent	Assay, Au, oz./ton	Distribution of gold, per cent	Reagents consumed, lb./ton ore	
				KCN	CaO
Table concentrate	21·1	1·04	69·9	4·2	5·25
Table tailing	78·9	0·12	30·1	....	
Table feed (cal.)	100·0	0·31	100·0	....	
Table concentrate cyanided	21·1	0·325	....	....	

Extraction by cyanidation of ore	76·2 per cent
Extraction by cyanidation of table concentrate	11·4 "
Total extraction	87·6 "

Summary of Test No. 24:

Product	Weight, per cent	Assay, Au, oz./ton	Distribution of gold, per cent	Reagents consumed, lb./ton ore	
				KCN	CaO
Table concentrate	24·6	0·46	57·7	5·75	6·25
Table tailing	75·4	0·11	42·3	....	....
Table feed (cal.)	100·0	0·196	100·0	....	....
Table concentrate cyanided	24·6	0·34	....	....	....

Extraction by cyanidation of ore	85·4 per cent
Extraction by cyanidation of table concentrate	2·2 "
Total extraction	87·6 "

CYANIDATION WITH PRE-AERATION

Test No. 25

A sample of ore was ground approximately 80 per cent through 200 mesh in a ball mill and then aerated for 4 hours in a Denver super-agitator. Cyanide and lime were then introduced, and the pulp agitated in a large bottle for 24 hours.

Results:

Feed sample..	Au,	1·30 oz./ton
Cyanide tailing......................................	Au,	0·18 "
Extraction...		86·2 per cent
Reagents consumed....................................	KCN,	2·0 lb./ton ore
	CaO,	1·7 "

It will be observed that pre-aeration reduced the amount of reagents consumed, although it did not improve the extraction.

CONCLUSIONS

Although the results obtained from the tests carried out on this ore have not been particularly satisfactory, they seem to indicate two possible methods of treatment: straight cyanidation, on the one hand, and concentration by flotation and blanketing, the concentrate to be treated at a smelter, on the other.

The best extraction obtained by cyanidation of the ore was 87·6 per cent of the gold. The ore in its natural state is sufficiently alkaline to be cyanided without the addition of lime but, owing to its carbonate content, will consume 15 or more pounds of lime per ton of ore if lime be added to it. In Tests Nos. 23 and 24 the ore, ground approximately 80 per cent through 200 mesh, was agitated without lime and in each case during the ore agitation period 3·2 pounds KCN per ton of ore was consumed. In Test No. 5, with perhaps a little finer grinding, cyanide consumption was about the same but nearly 15 pounds of lime was consumed.

By aerating the pulp before it comes in contact with lime or cyanide, as in Test No. 25, cyanide consumption was reduced to 2·0 pounds per ton and lime consumption to 1·7 pounds per ton of ore with the same grinding as in Tests Nos. 23 and 24. Extraction, however, was not improved by aeration of the pulp.

As for concentration of the ore, good grade concentrates containing 90 per cent or more of the gold were made in Tests Nos. 22, 26, and 27, and if the sample received is representative of the grade of ore in the mine there should be no difficulty in producing concentrates of good shipping grade. The arsenic content of the concentrates will come within the penalty limits of 3 per cent and 15 per cent. This feature, along with a rather low ratio of concentration, detracts somewhat from the feasibility of concentrating.

It appears, therefore, in the light of results so far obtained, that the solution to the problem presented by this ore is to be found in one or other of the above-mentioned processes.

No further work on the ore was possible, because the sample received had all been used, and if any additional information is wanted a new sample will have to be sent in.

Ore Dressing and Metallurgical Investigation No. 590

GOLD ORE FROM GRANDORO MINES, LIMITED, PENTICTON, B.C.

Shipment. A shipment of ore consisting of 6 bags, weight 560 pounds, was received on August 14, 1934, from Grandoro Mines, Limited, Penticton, B.C.

The shipment was submitted by the superintendent, J. M. MacLeod.

Characteristics of the Ore. The ore is composed of white to greyish quartz gangue with sulphide mineralization consisting of masses of small crystals interspersed through the grey quartz. The preponderant sulphide mineral is pyrite.

No free gold was seen by visual examination of the ore.

Sampling and Assaying. The shipment was crushed and sampled by standard methods and the feed sample was assayed giving the following results:

Gold	0·20 oz./ton
Silver	0·05 "
Lead	Nil.
Zinc	0·08 per cent
Copper	0·01 "
Arsenic	Trace.

Experimental Tests

Test work comprised flotation, amalgamation, cyanidation and blanket concentration.

FLOTATION

Test No. 1

A 1,000-gramme charge of minus 14-mesh ore was ground wet for 20 minutes in a pebble jar with 4 pounds soda ash per ton and 0·14 pound Aerofloat No. 31 per ton.

Potassium amyl xanthate, 0·4 pound per ton, and 0·05 pound pine oil per ton were added to the pulp in the cell.

Results:

Product	Weight, per cent	Assay, Au, oz./ton	Distribution of gold, per cent	Ratio of concentration
Feed	100·00	0·20	100·00	
Concentrate	4·78	3·30	94·31	20·92 : 1
Tailing	95·22	0·01	5·69	

Screen Test of Flotation Tailing:

Mesh	Weight, per cent
+ 65	0·4
− 65+100	5·0
−100+150	11·0
−150+200	24·4
−200	59·2
	100·0

Test No. 2

To a 1,000-gramme charge the same reagents were added as in Test No. 1, but the grinding time was increased to 30 minutes.

Results:

Product	Weight, per cent	Assay, Au, oz./ton	Distribution of gold, per cent	Ratio of concentration
Feed	100·0	0·20	100·00	
Concentrate	4·0	4·36	97·32	25 : 1
Tailing	96·0	0·005	2·68	

Screen Test of Flotation Tailing:

Mesh	Weight, per cent
+100	0·7
−100+150	3·7
−150+200	17·0
−200	78·6
	100·0

Test No. 7

Six 1,000-gramme tests were run to obtain sufficient concentrate for a cyanidation test.

Additions to Pebble Jar:

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

Grinding time, 30 minutes.

Additions to Cell:

Potassium amyl xanthate	0·4 lb./ton
Pine oil	0·165 "

Results:

Product	Weight, per cent	Assay, Au, oz./ton	Distribution of gold, per cent	Ratio of concentration
Feed	100·00	....	....	19·37 : 1
Concentrate	5·16	2·94	91·43	
Tailing	94·84	0·015	8·57	

Cyanidation of Flotation Concentrate. A 200-gramme charge of the flotation concentrate was agitated for 24 hours in a solution of sodium cyanide having a concentration equivalent to 5 pounds KCN per ton and a protective alkalinity of 5 pounds CaO per ton in a pulp of 3·17 : 1 density.

Results:

Product	Assay, Au, oz./ton		Extraction of gold, per cent	Reagents consumed, lb./ton	
	Feed	Tailing		KCN	CaO
Cyanide tailing	2·94	0·325	88·95	17·59	3·41

Consumption of cyanide per ton of ore	0·9 pound
Gold recovery in flotation concentrate	91·43 per cent
Gold extraction by cyanidation of flotation concentrate	88·95 "
Overall recovery—88·95 per cent of 91·43 per cent	81·33 "

Test No. 8

Charge to Pebble Jar:

−14 mesh ore	1,000 grammes
Water	750 c.c.
Soda ash	4 lb./ton

Time of grinding—30 minutes.

Additions to Cell:

Copper sulphate	2·0 lb./ton
Potassium amyl xanthate	0·4 "
Pine oil	0·15 "

Results:

Product	Weight, per cent	Assay, Au, oz./ton	Distribution of gold, per cent	Ratio of concentration
Feed	100·00	....	....	21·79 : 1
Concentrate	4·59	2·91	80·0	
Tailing	95·41	0·035	20·0	

The results are not so good as those obtained by grinding with Aerofloat No. 31.

CYANIDATION

Test No. 3

Charges of 200 grammes of sized ore were agitated in solutions of sodium cyanide at a concentration equivalent to 1 pound KCN per ton and a protective alkalinity of 5 pounds CaO per ton. Agitation, 24 hours; pulp ratio, 3 : 1.

Results:

Product	Assay, Au, oz./ton		Extraction of gold, per cent	Reagents consumed, lb./ton	
	Feed	Tailing		KCN	CaO
− 48 mesh	0·20	0·005	97·5	0·10	3·35
−100 "	0·20	0·005	97·5	0·30	3·65
−150 "	0·20	0·01	95·0	0·30	3·95
−200 "	0·20	0·01	95·0	0·60	3·95

Test No. 4

Four 200-gramme charges cyanided as in Test No. 3 for 48 hours.

Results:

Product	Assay, Au, oz./ton		Extraction of gold, per cent	Reagents consumed, lb./ton	
	Feed	Tailing		KCN	CaO
− 48 mesh	0·20	0·02	90·0	0·10	3·65
−100 "	0·20	0·01	95·0	0·60	3·95
−150 "	0·20	0·005	97·5	0·60	3·95
−200 "	0·20	0·01	95·0	0·75	6·25

Screen Tests on Cyanide Tailings:

−48 Mesh		−100 Mesh		−150 Mesh	
Mesh	Weight, per cent	Mesh	Weight, per cent	Mesh	Weight, per cent
+ 65	6·8	+150	7·2	+200	16·1
− 65+100	14·9	+200	21·2	−200	83·9
−100+150	13·1	−200	71·6		100·0
−150+200	19·5		100·0		
−200	45·7				
	100·0				

Fine grinding and long contact with cyanide are not necessary for good extraction and low tailing. Very fine grinding lowers the gold extraction and increases the consumption of both cyanide and lime. The results of the cyanide tests show a 97·5 per cent gold extraction in 24 hours' agitation on material ground to have 45 per cent pass a 200-mesh screen. The cyanide and lime consumptions were 0·10 and 3·35 pounds per ton of ore, respectively.

BARREL AMALGAMATION

Test No. 5

This test was to determine the amount of free gold present in the ore. A 1,000-gramme charge was given a 20-minute grind in a pebble mill and then barrel-amalgamated with 100 grammes of mercury for 1 hour.

Results:

Gold in head	0·20 oz./ton
Gold in amalgamation tailing	0·05 "
Recovery of gold	75 per cent

BLANKET CONCENTRATION

Test No. 6

A 1,000-gramme charge of ore was ground wet for 25 minutes and the pulp run over a corduroy blanket set at a slope of 2·5 inches per foot.

Results:

Product	Weight, per cent	Assay, Au, oz./ton	Distribution of gold, per cent	Ratio of concentration
Feed	100·00	0·20	100·00	
Concentrate	4·86	3·08	79·73	20·58 : 1
Tailing	95·14	0·04	20·27	

CONCLUSIONS

Amalgamation with mercury gave a gold recovery of 75 per cent.

Cyanidation of the raw ore was satisfactory. Fine grinding and long contact with cyanide were not necessary. With ore ground to have 45 per cent pass a 200-mesh screen, 97·5 per cent of the gold was extracted in 24 hours, with a tailing of 0·005 ounce gold per ton. The cyanide and lime consumptions were low, being 0·10 and 3·35 pounds per ton of ore, respectively.

Flotation tests in which Aerofloat No. 31 was added to the grinding circuit gave a 97·32 per cent recovery of gold in the concentrate, with a tailing carrying only 0·005 ounce gold per ton.

The overall recovery of gold by flotation and cyanidation of flotation concentrates as shown in Test No. 7 was 81·33 per cent.

The tests indicate that cyanidation of the ore is the method of treatment to be followed.

Ore Dressing and Metallurgical Investigation No. 591

ORE FROM CENTRAL PATRICIA MINES, LIMITED, AT PICKLE LAKE, ONTARIO

Shipment. A shipment of ore, net weight 59 pounds, was received June 9, 1934. The sample was submitted by A. J. Anderson, Manager, Central Patricia Mines, Limited, Pickle Lake, Ontario.

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 chiefly dark greenish grey rock, which usually possesses a distinct schistosity. It contains stringers of dark smoky quartz and light greenish grey, fine-textured, impure quartz.

Arsenopyrite is the only abundant ore mineral present in the polished sections. It occurs as rather coarse blunt crystals disseminated in the rock, some places in such abundance as to form massive arsenopyrite.

Small amounts of pyrrhotite, chalcopyrite, pyrite, ilmenite, and "limonite" are present. Much of the pyrrhotite is disseminated in the gangue, whereas most of the chalcopyrite is included in arsenopyrite.

Eleven grains of native gold were seen, all within arsenopyrite. Some of these were associated with chalcopyrite. Roughly their occurrence is as follows:—

Gold in arsenopyrite	25 per cent
Gold, associated with chalcopyrite in arsenopyrite	75 " "

A quantitative microscopic analysis of the grain size of the gold shows the following:—

Mesh	Per cent
− 325+ 800	36
− 800+1600	29
−1600+2300	18
−2300	17
	100

As the largest percentage appears in the larger grain sizes, it can be inferred that the data upon which the table is based are inadequate for a true picture, and that the gold is substantially coarser than shown in the table. It does indicate, however, that some of the gold is extremely fine-grained.

The sample assayed:

Gold	0·82 oz./ton
Silver	0·12 "

Experimental Tests

Cyanidation tests were made to determine, if possible, why such low extractions were being obtained by the operators and what could be done to improve this condition. A straight cyanidation test on the ore as received gave an extraction of 78 per cent of the gold. A further test on a sample of ore that had been aerated in water for five hours gave an extraction of 92·7 per cent of the gold. Another sample of ore was passed over a corduroy blanket and the blanket concentrate aerated in water for five hours. The aerated concentrate was then reunited with the untreated blanket tailing and the whole lot cyanided. In this case an extraction of 94·5 per cent of the gold was obtained. Two other samples of ore were aerated for five hours in lime pulp and then cyanided. In these two cases extractions of 95·1 and 96·3 per cent of the gold were obtained.

A cycle cyanidation test was then made on ore aerated in lime pulp in which as much solution as possible was carried forward from test to test. In the first test of the cycle over 95 per cent of the gold was extracted, but tailing assays increased steadily from test to test and in the seventh test of the cycle extraction fell below 80 per cent. This shows the necessity of discarding a large amount of the barren solution at the end of each cycle in order to keep the mill solution as free as possible from fouling matter.

Details of the tests follow.

CYANIDATION

Tests Nos. 1, 2, and 3

Three lots of the ore were ground 90 per cent through 200 mesh in ball mills and treated as follows:

No. 1.—Agitated in cyanide solution, 1·0 pound KCN per ton, for 24 hours.

No. 2.—Aerated in water in a Denver super-agitator for 5 hours and then agitated in cyanide solution, 1·0 pound KCN per ton, for 24 hours.

No. 3.—Passed over a corduroy blanket set at a slope of 2·5 inches per foot. The blanket concentrate was then aerated for 5 hours in a Denver super-agitator, after which it was reunited with the untreated blanket tailing and the whole lot agitated in cyanide solution, 1·0 pound KCN per ton, for 24 hours. The cyanide tailings were all assayed for gold.

Summary:

Feed sample: gold, 0·82 oz./ton.

Test No.	Tailing assay, Au, oz./ton	Extraction, per cent	Reagents consumed, lb./ton	
			KCN	CaO
1	0·18	78·0	2·24	4·50
2	0·06	92·7	1·34	4·25
3	0·045	94·5	1·60	3·60

Tests Nos. 4 and 5

Two samples of the ore were ground 90 per cent through 200 mesh in ball mills and then aerated in lime pulp for 5 hours in Denver super-agitators. The pulp was then transferred to large bottles and enough cyanide added to bring the solution up to 1·0 pound KCN per ton. After 24 hours' agitation the tailings were filtered, washed, and assayed for gold.

Summary:

Feed sample: gold, 0·82 oz./ton.

Test No.	Tailing assay, Au, oz./ton	Extraction, per cent	Reagents consumed, lb./ton	
			KCN	CaO
4	0·04	95·1	1·55	5·5
5	0·03	96·3	1·55	5·5

CYCLE CYANIDE TESTS

Tests Nos. 6 to 12

In this series of tests seven batches of ore were treated with one batch of cyanide solution. The ore was ground 90 per cent through 200 mesh in a ball mill and then aerated in lime pulp for six hours. The aerated pulp was then filtered and repulped in cyanide solution in which it was agitated for 24 hours. At the end of the agitation period the pregnant solution was filtered off, precipitated with zinc dust, and used to treat another batch of pre-aerated ore. The cyanide tailing was assayed for gold. This cycle was repeated seven times and the final solution precipitated with zinc dust and assayed to determine its reducing power and the harmful ingredients present.

These assays showed the final solution to contain the following:

KCNS	0·634 grm./litre
Cu	0·018 " "
Fe	0·0014 " "
SO_3	0·1927 " "
Reducing power	450 c.c. N/10 $KMnO_4$ per litre

Summary:

Feed sample: gold, 0·82 oz./ton.

Test No.	Tailing assay, Au, oz./ton	Extraction, per cent
6	0·035	95·7
7	0·055	93·3
8	0·075	90·9
9	0·10	87·8
10	0·12	85·4
11	0·12	85·4
12	0·175	78·7

It will be observed that at the end of the seventh cycle extraction has fallen off to approximately the same figure as that obtained in Test No. 1, in which raw ore was cyanided directly. This is, no doubt, due to the solution becoming eventually foul. To guard against this happening in mill practice it will be necessary to discard daily a proportion of the barren solution from the mill circuit and replace it with water from the aeration tanks to which fresh cyanide will be added.

Average reagent consumption during the seven tests was as follows:

KCN	0·87 lb./ton
CaO	6·70 "

CONCLUSIONS

A comparison of the results of Tests Nos. 2, 3, 4, and 5 with the result of Test No. 1 will show the value of pre-aerating the ore; and the results of Cycle Tests Nos. 6 to 12 will show the necessity of discarding some barren solution in order to keep the solutions in the dissolving circuit clean and active.

The pyrrhotite in the ore, owing to its reaction with cyanide solution, is responsible for the low extraction of gold that is now being obtained.

The remedy is to grind the ore in water with sufficient lime to maintain an alkaline solution, thicken the ground pulp to approximately 1:1, and agitate with air for about six to eight hours. The cyanide is then added but it will be necessary to control the alkalinity carefully, because if an excess of lime is used the extraction will fall off.

Grinding in water and thickening will automatically take care of the bleeding of barren cyanide solution from the mill, because a volume of solution equal to the volume of water left in the ground pulp after thickening will have to be wasted. It should be found that between 40 and 50 tons of cyanide solution will have to be wasted per 100 tons of ore treated.

The practice recommended is similar to that used at the Dome mill. A solution strength of between ½ pound and ¾ pound per ton may be found more advantageous than the solution strength of one pound per ton used in the experimental tests.

When grinding in water it will, of course, be necessary to use blankets in the grinding circuit between the mills and classifiers in order to prevent accumulation of metallic gold in the grinding circuit. This is very important when an ore contains an appreciable amount of free gold.

The blanket concentrate should be amalgamated for the extraction of the free gold. After amalgamation the concentrate should be added to the aeration tanks.

Ore Dressing and Metallurgical Investigation No. 592

GOLD ORE FROM THE PORCUPINE PENINSULAR GOLD MINES, LIMITED, TIMMINS, ONTARIO

Shipment. A shipment consisting of two bags of gold ore weighing 135 pounds was received July 10, 1934, from the Porcupine Peninsular Gold Mines, Limited, Timmins, Ontario, Robert E. Dye, Agent.

Characteristics of the Ore. The ore consisted of a siliceous gangue carrying a small amount of iron pyrite.

EXPERIMENTAL TESTS

The entire shipment was crushed, ground, and sampled. Analysis showed the lot to contain 0·10 ounce gold, 0·08 ounce silver per ton.

The investigation included amalgamation, flotation, cyanidation, and table concentration. The results obtained showed that 30 per cent of the gold is free when the ore is ground minus 150 mesh; 90 per cent of the gold can be extracted by straight cyanidation. Flotation also recovers 90 per cent with a ratio of concentration of 44·6 : 1. In the flotation concentrate, 88 to 92 per cent of the gold can be extracted by cyanidation. Table concentration of cyanide tailing from coarsely ground feed recovers 45 per cent of the gold.

AMALGAMATION

Test No. 1

A sample of the ore ground to pass 48 mesh with 52·5 per cent minus 200 mesh was amalgamated. The amalgamation tailing was then cyanided for 24 hours with a cyanide solution, 1·0 pound per ton, 1 : 3 dilution.

Results:

Feed	0·10 oz. Au/ton
Amalgamation tailing	0·08 "
Recovery	20·0 per cent
24-hour cyanide tailing	0·03 oz. Au/ton
Total recovery, amalgamation and cyanidation	70·0 per cent

Test No. 2

A sample ground to pass 100 mesh was treated in the same manner.

Results:

Feed	0·10 oz. Au/ton
Amalgamation tailing	0·07 "
Recovery	30·0 per cent
24-hour cyanide tailing	0·015 oz. Au/ton
Total recovery, amalgamation and cyanidation	85·0 per cent

CYANIDATION

Test No. 3

Samples of the ore ground to pass 48, 100, 150, and 200 mesh were cyanided for 24 and 48 hours, 1 : 3 dilution, with a sodium cyanide solution equivalent in strength to 1·0 pound KCN per ton. Lime, 12 pounds per ton, was added to supply protective alkalinity.

Results:

Mesh Grind		Agitation, hours	Au, oz./ton		Extraction, per cent	Reagents consumed, lb./ton	
Through	Per cent −200 mesh		Feed	Tailing		KCN	CaO
48	54·5	24	0·10	0·025	75·0	0·15	7·9
48	54·5	48	0·10	0·02	80·0	0·15	9·4
100	85·6	24	0·10	0·015	85·0	0·3	8·8
100	85·6	48	0·10	0·015	85·0	0·3	10·3
150	92·6	24	0·10	0·0125	87·5	0·3	8·9
150	92·6	48	0·10	0·01	90·0	0·3	10·5
200	....	24	0·10	0·0125	87·5	0·45	9·2
200	....	48	0·10	0·01	90·0	0·45	10·9

FLOTATION

Test No. 4

A sample of the ore was ground in water, neutral circuit, until 85 per cent passed 200 mesh.

The pulp was then conditioned with 0·10 pound potassium amyl xanthate and 0·12 pound pine oil per ton and a flotation concentrate removed.

Results:

Product	Weight, per cent	Assay, Au, oz./ton	Distribution of gold, per cent
Feed (cal.)	100·00	0·11	100·0
Concentrate	2·52	3·70	82·7
Tailing	97·48	0·02	17·3

Test No. 5

A sample of the ore was ground wet together with 8 pounds soda ash per ton until 85 per cent passed 200 mesh. A flotation concentrate was removed after conditioning with 0·10 pound amyl xanthate and 0·12 pound pine oil per ton.

Results:

Product	Weight, per cent	Assay, Au, oz./ton	Distribution of gold, per cent
Feed (cal.)	100·00	0·11	100·0
Concentrate	2·24	4·90	91·8
Tailing	97·76	0·01	8·2

Ratio of concentration—44·6 : 1.

Test No. 6

A test similar to Test No. 5 was made with a grind of 94·8 per cent minus 200 mesh.

Results:

Product	Weight, per cent	Assay, Au, oz./ton	Distribution of gold, per cent
Feed (cal.)	100·00	0·11	100·0
Concentrate	2·25	4·86	91·8
Tailing	97·75	0·01	8·2

Test No. 7

The ore was ground wet with 8 pounds soda ash per ton to pass 85 per cent minus 200 mesh. It was then conditioned for 5 minutes with 0·10 pound potassium amyl xanthate and 0·07 pound pine oil per ton, and a concentrate removed.

The flotation concentrate was cyanided without regrinding. Agitation was continued for 72 hours, 1 : 3 dilution, with a cyanide solution maintained at about 5·0 pounds KCN per ton. Lime, 10 pounds per ton, was added to supply protective alkalinity.

Flotation Results:

Product	Weight, per cent	Assay, Au, oz./ton	Distribution of gold, per cent
Feed (cal.)	100·00	0·095	100·0
Concentrate	2·23	3·62	84·6
Tailing	97·77	0·015	15·4

Ratio of concentration—44·8 : 1.

Cyanidation Results:

Feed = flotation concentrate	3·62 oz. Au/ton
Cyanide tailing	0·425 "
Extraction	88·2 per cent
Reagent consumption—NaCN	8·3 lb./ton
CaO	8·6 "
Total recovery, flotation and cyanidation	74·6 per cent

A series of flotation tests was run to note what recoveries could be obtained from ore ground much more coarsely than in previous tests. The concentrates from four of these were combined, reground in a pebble mill, and cyanided.

Test No. 8

This test is typical of the flotation tests in the series.

Grind:

Mesh	Weight, per cent
+ 65	6·0
− 65+100	18·9
−100+150	14·2
−150+200	14·7
−200	46·2
	100·0

Reagents to Ball Mill:

Soda ash	1·5 lb./ton
Barrett No. 4	0·12 "

Reagents to Flotation Cell:

Amyl xanthate	0·20 lb./ton
Pine oil	0·03 "

Results:

Product	Weight, per cent	Assay, Au, oz./ton	Distribution of gold, per cent
Feed (cal.)	100·00	0·10	100·0
Concentrate	3·00	2·90	90·0
Tailing	97·00	0·01	10·0

Tests Nos. 9, 10, 11, and 12

The following tests are similar to Test No. 8, the grinding being varied to note the shortest grinding time required to obtain satisfactory recoveries.

Results:

Test No.	Mesh grind, per cent					Flotation tailing, Au, oz./ton	Recovery, per cent
	+65	−65 +100	−100 +150	−150 +200	−200		
9	14·5	19·8	12·0	11·2	42·5	0·015	85·0
10	10·5	19·5	13·0	12·6	44·4	0·01	90·0
11	2·1	15·7	16·7	16·0	49·5	0·01	90·0
12	....	4·5	14·4	22·9	58·2	0·01	90·0

It is apparent that no lower tailing will be made from ore ground finer than is shown in Test No. 10. This was practically all through 48 mesh.

The concentrates produced by these four tests were combined, sampled and assayed, and reground. The pulp, at a dilution of 1 : 3 with a 5·0 pound KCN per ton solution, was agitated for 48 hours. Lime was added from time to time to maintain protective alkalinity.

Cyanidation Results:

Feed	1·92 oz. Au/ton
Cyanide tailing	0·15 "
Extraction	92·2 per cent
Reagent consumption: KCN	6·3 lb./ton
CaO	9·2 "
Total recovery, flotation and cyanidation	83·0 per cent

Test No. 13

A sample of the ore was ground coarsely and cyanided. The cyanide tailing was then run over a Wilfley table, removing a concentrate. This product was reground to pass 200 mesh and then re-cyanided.

Cyanidation Results:

Mesh	Weight, per cent
+ 65	2·3
− 65+100	9·2
−100+150	12·0
−150+200	17·7
−200	58·8
	100.0

Strength of solution:	1·0 lb. KCN/ton
	5·0 lb. CaO/ton ore
Dilution	1 : 3
Time of agitation	24 hours.
Feed	0·10 oz. Au/ton
Cyanide tailing	0·025 "
Extraction	75·0 per cent

Results of Table Concentration:

Product	Weight, per cent	Assay, Au, oz./ton	Distribution of gold, per cent
Feed = cyanide tailing	100·00	0·025	100·0
Table concentrate	9·12	0·124	45·3
" tailing	90·88	0·015	54·7

Results of Cyanidation of Table Concentrate:

Strength of solution	3·93 lb. KCN/ton
	13·0 lb. CaO/ton ore
Dilution	1 : 3
Time of agitation	24 hours
Feed	0·124 oz. Au/ton
Cyanide tailing	0·025 "
Extraction	79·9 per cent

Summary of Results of Test No. 13:

Recovery by cyanidation of raw ore	75·0 per cent
Recovery by table concentration of cyanide tailing	11·3 "
Recovery by cyanidation of table concentrate	9·03 "
Total recovery by cyanidation of raw ore and re-cyanidation of table concentrate	84·03 "

SUMMARY AND CONCLUSIONS

Amalgamation will not recover more than 30 per cent of the gold in the raw ore.

Maximum recoveries of metal are obtained by straight cyanidation within 48 hours' treatment of ore ground 93 per cent minus 200 mesh.

Flotation of coarsely ground material, 44 per cent minus 200 mesh, recovers 90 per cent of the gold, the same result as is obtained when the grinding is 95 per cent minus 200 mesh. The grade of concentrate is much higher when the feed is finely ground, being 4·90 ounces gold per ton from the finer grind and 2·90 ounces gold per ton from the coarser. The ratios of concentration were 44·4 : 1 and 33·3 : 1, respectively.

Cyanidation of reground coarse flotation concentrate gives an overall recovery of 83·0 per cent.

Cyanidation of coarsely ground ore, 59 per cent minus 200 mesh, followed by table concentration and cyanidation of the concentrate gives a total recovery of 84·0 per cent of the gold.

The recoveries obtained by the various methods of treatment are as follows:

1. Flotation concentration	90·0 per cent.
2. Cyanidation of ore ground 93 per cent minus 200 mesh	90·0 "
3. Flotation followed by cyanidation of reground concentrate	83·0 "
4. Cyanidation of coarsely ground ore, 59 per cent minus 200 mesh, followed by cyanidation of reground table concentrate	84·0 "

It is apparent that fine grinding followed by straight cyanidation gives the highest metallurgical recovery.

Cyanidation of a coarsely ground feed, followed by regrinding a table concentrate and re-cyaniding, gives a higher recovery than flotation of the same feed followed by cyanidation of the concentrate.

The treatment likely to yield the largest profit can be decided upon only after a study of capital outlay and operating costs of each method.

Ore Dressing and Metallurgical Investigation No. 593

ORE FROM THE WENDIGO MINE, NEAR KENORA, ONTARIO

Shipment. The shipment consisting of 360 pounds of ore was received at the Ore Dressing and Metallurgical Laboratories on August 9, 1934. The ore was submitted by L. G. Cameron, Kenora, Ontario, and was said to be from the Wendigo mine, situated one-half mile north of Witch bay, Lake of the Woods, Ontario.

Purpose of the Experimental Tests. The experimental tests were made to determine the amenability of the ore to various types of milling for the recovery of the contained metals.

Characteristics of the Ore. The ore consists of greenish grey chlorite schist and associated quartz veins through which the ore minerals are distributed as irregular grains, stringers, and small masses. The quartz seen in the polished sections is of two types, greyish white translucent quartz and fine-textured sugary quartz. Pyrite and chalcopyrite are the only abundant ore minerals; the former contains a small amount of pyrrhotite, the latter a small amount of sphalerite.

All of the native gold seen in the polished sections is associated with the greyish white translucent quartz. It occurs as irregular grains and discontinuous stringers, occasionally in contact with pyrite or chalcopyrite, but no gold was seen within any of the sulphides. Most of the gold is quite coarse, several grains approaching 14 mesh in size.

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

Gold	0·29 oz./ton
Silver	0·34 "
Copper	0·82 per cent
Arsenic	0·06 "

Experimental Tests

1. Amalgamation.
2. Straight cyanidation.
3. Flotation.
4. Plate amalgamation followed by blanket concentration.
5. Blanket concentration followed by flotation.
6. Plate amalgamation followed by flotation.

AMALGAMATION

Test No. 1

Representative samples of minus 14-mesh ore were crushed dry to pass 48, 65, and 100 mesh.

From each sample, 1,000-gramme representative portions were amalgamated with mercury in jar mills, dilution 1 : 1. After removing the amalgam, the tailings were dried and sampled. Screen analyses were made on the tailings to note the degree of grinding.

Screen Analysis:

Mesh No.	Weight, per cent		
	−48	−65	−100
− 48+ 65	9·90	....	....
− 65+100	15·95	8·35	....
−100+150	10·00	12·70	7·4
−150+200	9·70	15·85	19·6
−200	54·45	63·10	73·0

The following table shows the assay of each tailing and the recovery by amalgamation:

Mesh No.	Assay, Au, oz./ton		Recovery, per cent
	Feed	Tailings	
− 48	0·29	0·105	63·79
− 65	0·29	0·12	58·62
−100	0·29	0·09	68·97

STRAIGHT CYANIDATION

Test No. 2

Representative samples of minus 14-mesh ore were crushed dry to pass 48, 65, 100, 150 and 200 mesh. Samples from each lot were agitated in cyanide solution, equivalent in strength to 1·0 pound KCN per ton, for periods of 24 and 48 hours. Lime at the rate of 5 pounds per ton was added to give protective alkalinity.' Owing to the large amount of cyanicides present in the ore, frequent additions of reagents were required to keep the solutions up to strength.

Results of 24-Hour Agitation:

Mesh No.	Assay, Au, oz./ton		Extraction, per cent	Reagents consumed, lb./ton ore	
	Feed	Tailing		KCN	CaO
− 48	0·29	0·12	58·62	2·49	8·65
− 65	0·29	0·21	27·59	2·34	8·80
−100	0·29	0·14	51·72	2·49	8·95
−150	0·29	0·11	62·07	4·02	8·65
−200	0·29	0·14	51·72	4·35	8·80

Results of 48-Hour Agitation:

Mesh No.	Assay, Au, oz./ton		Extraction, per cent	Reagents consumed, lb./ton ore	
	Feed	Tailing		KCN	CaO
− 48	0·29	0·05	82·76	4·59	8·65
− 65	0·29	0·08	72·41	4·44	8·80
−100	0·29	0·09	68·97	4·59	8·95
−150	0·29	0·11	62·07	6·75	13·65
−200	0·29	0·10	65·52	7·08	13·80

It will be noted that very irregular results are obtained with high consumption of reagents. The copper-bearing minerals act as cyanicides, making straight cyanidation unsuitable.

FLOTATION

Test No. 3

A representative sample of minus 14-mesh ore was ground in a jar mill, dilution 4 : 3, to give approximately 77 per cent minus 200-mesh product.

The following reagents were added to the mill:

Sodium carbonate	6·0 lb./ton
Sodium cyanide	0·10 "
Minerec "A"	0·10 "

The pulp was floated in a Sub A flotation cell to give a copper concentrate.

The reagents added to the cell were:

Cresylic acid	0·25 lb./ton

The remaining sulphides were activated by:

Copper sulphate	1·0 lb./ton
Potassium amyl xanthate	0·2 "
Pine oil	0·25 "

Two concentrates were obtained. The products were assayed for gold and copper.

Results:

Product	Weight, per cent	Assay		Distribution, per cent		Ratio of concentration
		Au, oz./ton	Cu, per cent	Au	Cu	
Feed	100·00	0·27	0·81	100·00	100·00	
Copper concentrate	3·83	5·84	19·52	82·36	92·06	26 : 1
Pyrite concentrate	8·38	0·10	0·56	3·10	5·78	12 : 1
Tailing	87·79	0·045	0·02	14·54	2·16	

Test No. 3A

A similar test was made using the following reagents in the mill:

Sodium carbonate..	6·0 lb./ton
Sodium cyanide..	0·10 "
Thiocarbanalide..	0·10 "

The reagents to the cell to obtain a copper concentrate:

Cresylic acid..	0·25 lb./ton

To obtain a pyrite concentrate:

Copper sulphate..	1·0 lb./ton
Potassium amyl xanthate..	2·0 "
Cresylic acid..	0·45 "

Results:

Product	Weight, per cent	Assay		Distribution, per cent		Ratio of concentration
		Au, oz./ton	Cu, per cent	Au	Cu	
Feed........................	100·00	0·29	0·84	100·00	100·00	
Copper concentrate..........	4·03	6·32	19·08	86·99	91·13	25 : 1
Pyrite concentrate..........	8·07	0·20	0·60	5·50	5·74	12 : 1
Tailing......................	87·90	0·025	0·03	7·51	3·13	

Grinding.. 78·5 per cent −200 mesh.

Test No. 3B

A representative sample of minus 14-mesh ore was ground in a jar mill with

Sodium carbonate..	6·0 lb./ton.
Aerofloat No. 31..	0·15 "

The pulp was floated with the following reagents to make a bulk concentrate:

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

Results:

Product	Weight, per cent	Assay		Distribution, per cent		Ratio of concentration
		Au, oz./ton	Cu, per cent	Au	Cu	
Feed........................	100·00	0·36	0·84	100·00	100·00	
Flotation concentrate........	12·65	2·74	6·48	97·55	97·91	8 : 1
Tailing......................	87·35	0·01	0·02	2·45	2·09	

Grinding.. 76 per cent −200 mesh.

PLATE AMALGAMATION AND BLANKET CONCENTRATION

Test No. 4

A representative sample of minus 14-mesh ore was ground in jar mills, dilution 4 : 3, to give approximately 61 per cent minus 200 mesh.

The pulp was amalgamated on an amalgamation plate set at a slope of 2½ inches in 12 inches.

The amalgamation tailings were sampled and a representative portion was concentrated on a blanket table set at a slope of 2½ inches in 12 inches.

Results of Amalgamation:

Product	Weight, per cent	Assay, Au, oz./ton	Distribution, per cent	Ratio of concentration
Feed	100·00	0·29	100·00	
Amalgam			44·83	
Tailing		0·16	55·17	

Results of Blanket Concentration:

Product	Weight, per cent	Assay, Au, oz./ton	Distribution, per cent	Ratio of concentration
Blanket feed	100·00	0·12	100·00	
" concentrate	1·48	5·18	66·06	67 : 1
" tailing	98·52	0·04	33·94	

Recovery by amalgamation	44·83 per cent.
Recovery by blanket concentration, 66·06 × 55·17	36·44 "
Overall recovery	81·27 "
Loss in tailing, 33·94 × 55·17	18·73 "
	100·00 "

BLANKET CONCENTRATION AND FLOTATION

Test No. 5

A representative sample of minus 14-mesh ore was ground in jar mills, dilution 4 : 3, to give approximately 60 per cent minus 200 mesh.

The pulp was concentrated on a blanket table set at a slope of 2½ inches in 12 inches.

The blanket tailing was sampled and a representative portion was treated by flotation.

The blanket tailing was reground in a jar mill, dilution 4 : 3, to approximately 80 per cent minus 200 mesh.

The following reagents were used in the mill:

Sodium carbonate	6·0 lb./ton.
Aerofloat No. 31	0·15 "

The reagents added to the flotation cell were:

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

Results of Blanket Concentration:

Products	Weight, per cent	Assay, Au, oz./ton	Distribution, per cent	Ratio of concentration
Feed	100·00	0·35	100·00	
Blanket concentrate	2·21	12·14	77·43	45 : 1
" tailing	97·79	0·08	22·57	

Results of Flotation:

Products	Weight, per cent	Assay, Au, oz./ton	Distribution, per cent	Ratio of concentration
Feed	100·00	0·09	100·00	
Flotation concentrate	11·44	0·68	85·40	9 : 1
" tailing	88·56	0·015	14·60	

Recovery by blanket concentration	77·43 per cent.
Recovery by flotation, 85·4 × 22·57	19·27 "
Overall recovery	96·70 "
Loss in tailing, 14·6 × 22·57	3·30 "
	100·00 "

PLATE AMALGAMATION AND FLOTATION

Test No. 6

A representative sample of minus 14-mesh ore was ground in jar mills, dilution 4 : 3, to give approximately 60 per cent minus 200 mesh.

The pulp was amalgamated on an amalgamation plate set at a slope of 2½ inches to 12 inches.

The amalgamation tailing was treated by flotation to concentrate gold and copper in one concentrate, and the pyrite in a second concentrate.

A representative portion of the tailing was ground in a jar mill, dilution 4 : 3, to give approximately 80 per cent minus 200 mesh. The following reagents were used in the mill:

Sodium carbonate	6·0 lb./ton.
Sodium cyanide	0·1 "
Thiocarbanalide	0·1 "

The following reagent was used in the cell:

Cresylic acid	0·25 lb./ton.

To obtain the pyrite concentrate the following reagents were added to the cell after floating off the first concentrate:

Copper sulphate	1·0 lb./ton.
Potassium amyl xanthate	0·2 "
Pine oil	0·15 "

Results of Amalgamation:

Product	Weight, per cent	Assay, Au, oz./ton	Distribution, per cent	Ratio of concentration
Feed	100·00	0·29	100·0	....
Amalgam	....	....	62·1	....
Amalgamation tailing	....	0·11	37·9	....

Results of Flotation:

Product	Weight, per cent	Assay		Distribution, per cent		Ratio of concentration
		Au, oz./ton	Cu, per cent	Au	Cu	
Flotation feed	100·00	0·11	0·82	100·00	100·00	
Copper concentrate	3·18	2·56	21·72	76·15	85·60	31 : 1
Pyrite concentrate	8·80	0·19	1·12	15·62	12·22	11 : 1
Tailing	88·02	0·01	0·02	8·23	2·18	

Recovery by amalgamation .... 62·1 per cent
Recovery by flotation of copper concentrate, 76·15 × 37·9 .... 28·88 "

Overall recovery .... 90·98 "
Loss in pyrite concentrate, 15·62 × 37·9 .... 5·91 "
Loss in tailing, 8·23 × 37·9 .... 3·11 "

100·00 "

Test No. 6A

A bulk concentrate was made from another portion of the amalgamation tailing, using the following reagents in the jar mill:

Sodium carbonate .... 6·0 lb./ton
Aerofloat No. 31 .... 0·15 "

The following reagents were used in the cell:

Potassion amyl xanthate .... 0·02 lb./ton
Pine oil .... 0·05 "

Results:

Product	Weight, per cent	Assay		Distribution, per cent		Ratio of concentration
		Au, oz./ton	Cu, per cent	Au	Cu	
Flotation feed	100·00	0·13	0·82	100·00	100·00	
" concentrate	13·92	0·83	5·72	89·95	96·86	7 : 1
" tailing	86·08	0·015	0·03	10·05	3·14	

Recovery by amalgamation .... 62·10 per cent
Recovery by flotation, 89·95 × 37·9 .... 34·10 "

Overall recovery .... 96·20 "
Loss in tailing, 10·5 × 37·9 .... 3·80 "

100·00 "

SUMMARY AND CONCLUSIONS

The microscopic study of polished sections of the ore shows the gold to occur chiefly as individual grains of metallic gold in the quartz and attached to chalcopyrite and pyrite crystals. Some of the individual grains of gold are quite coarse. These points are significant, as they explain the high recovery of gold obtained when the bulk of the pyrite is removed in the tailing.

The results of the test work show that when the ore is crushed to 60 per cent through 200 mesh, over 70 per cent of the gold can be caught on special corduroy blankets and that an additional 20 per cent can be recovered in a flotation concentrate assaying between 2 and 2·5 ounces in gold and about 20 per cent copper, which is an excellent grade to ship to a smelter. This gives a total recovery of 90 per cent or more of the gold in the blanket and flotation concentrates.

By using amalgamation plates in place of blankets the test work indicates that over 60 per cent of the gold can be recovered on the plates and that an additional recovery can be obtained by selective flotation, to give an overall recovery of 90 per cent.

A bulk flotation of all the sulphides will raise this recovery to over 96 per cent, but the resulting concentrate, which is shown in Test No. 6A, would probably be lower in grade than is desirable for shipment.

The cyanide tests, as would be expected with an ore having so high a content of copper, did not give satisfactory results, and the process is clearly not suitable for the ore.

If it is decided to build a mill using either blanket concentration or plate amalgamation prior to flotation, it is recommended that the plates or blankets be placed so that they treat the circulating load in the ball mill-classifier grinding-circuit.

It is also probable that finer grinding than 60 per cent through 200 mesh will increase the recovery of gold. Regrinding a pyrite concentrate floated after the copper concentrate is made will undoubtedly increase the recovery of gold, while still maintaining a reasonable shipping grade of concentrate. This step, however, would hardly be practical in a small mill.

The use of a unit flotation cell with a gold trap in the bottom to treat the ball mill discharge is also suggested.

The use of this cell, however, would put most of the gold into the flotation concentrate, but if blankets are used the blanket concentrate can be amalgamated in a clean-up barrel and at least 60 per cent of the gold in the ore recovered as bullion at the mine.

These conclusions are based on the assumption that the sample submitted represents the ore that will be milled.

Ore Dressing and Metallurgical Investigation No. 594

ORE FROM THE KILO MINE, NEAR SLOCAN CITY, B.C.

Shipment. A shipment of ore weighing 182 pounds was received from the C. Q. Mining Company, Limited, 1840 Georgia St. West, Vancouver, B.C., on August 7, 1934. The ore was said to be from the Kilo mine, 10 miles south of Slocan City, B.C.

Purpose of Experimental Tests. The experimental tests were carried out to determine the best method to use for the extraction of the gold.

Characteristics of the Ore. The ore consists of small masses and irregular grains of sulphides and native gold rather sparingly distributed through a gangue composed of medium-textured, somewhat granular, white quartz much of which is stained yellowish brown by iron oxides.

The sulphides identified under the microscope as present in appreciable amounts are pyrite, sphalerite, and galena. The sulphide masses commonly appear as rather coarse pyrite that has been penetrated along fractures and is in places enclosed in sphalerite and galena.

The native gold is varied in its mode of occurrence. The grain size, as shown in polished sections and determined microscopically, is shown in Table I. The modes of occurrence, with approximate percentages of the gold of each mode, are shown in Table II.

TABLE I

Grain Size of the Gold, Determined Microscopically

Mesh	Per cent
+ 48	9·2
− 48+ 65	11·5
− 65+ 100	12·4
− 100+ 150	8·2
− 150+ 200	10·4
− 200+ 325	23·8
− 325+ 560	14·0
− 560+ 800	6·6
− 800+1100	2·2
−1100	1·7
	100·0

TABLE II

Modes of Occurrence of the Gold, Determined Microscopically.

		Per cent
(1)	Enclosed within pyrite, usually as irregular grains, but often as narrow discontinuous veinlets	22·1
(2)	As grains along the boundaries between pyrite and quartz	19·9
(3)	As grains along the boundaries between sphalerite and quartz	19·9
(4)	As grains along the boundaries between pyrite and galena	16·8
(5)	Enclosed within sphalerite, as irregular grains	15·0
(6)	Enclosed within quartz, as irregular grains and occasionally as narrow discontinuous veinlets along the boundaries between the quartz grains	6·3
		100·0

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

Gold	0·81 oz./ton
Silver	0·71 "
Lead	0·27 per cent
Copper	0·02 "
Zinc	0·02 "

EXPERIMENTAL TESTS

1. Amalgamation.
2. Straight cyanidation.
3. Blanket concentration.
4. Blanket concentration followed by flotation.
5. Blanket concentration followed by cyanidation.
6. Plate amalgamation followed by blanket concentration.
7. Plate amalgamation followed by flotation.
8. Amalgamation of blanket concentrate.
9. Straight flotation.
10. Amalgamation of flotation concentrate.

AMALGAMATION

Test No. 1

Representative samples of −14-mesh ore were dry-crushed in a disk pulverizer to pass 48, 65, and 100 mesh.

From each, a portion of ore weighing 1000 grammes was amalgamated with mercury in jar mills, diluted 1:1 with water.

After separating the amalgam, the tailings were sampled and screen tests made.

Screen Tests:

Mesh	Weight, per cent		
	−48	−65	−100
− 48+ 65	1·45		
− 65+100	18·85	2·65	
−100+150	20·75	15·80	
−150+200	21·85	30·45	10·3
−200	37·10	51·10	89·7

Assays made on the sized products of −48-mesh tailing show the following values:—

Mesh	Weight, per cent	Assay, Au, oz./ton
− 65+100	18·85	0·15
−150+200	21·85	0·09
−200	37·10	0·28

Results:

Mesh No.	Assay, Au, oz./ton		Extraction, per cent
	Feed	Tailing	
− 48	0·81	0·19	76·54
− 65	0·81	0·28	65·43
−100	0·81	0·57	29·63

STRAIGHT CYANIDATION

Test No. 2

Representative samples of −14-mesh ore were dry-crushed in a disk pulverizer to pass 48, 65, 100, 150, and 200 mesh.

Samples from each lot were agitated for 24 and 48 hours in cyanide solution, equivalent in strength to 1·0 pound KCN per ton. Lime at the rate of 5·0 pounds per ton of ore was added to give protective alkalinity. The dilution was 3 parts of solution to 1 part of ore.

24-Hour Agitation:

Mesh No.	Assay, Au, oz./ton		Extraction, per cent	Reagents consumed, lb./ton ore	
	Feed	Tailing		KCN	CaO
− 48	0·81	0·38	53·09	0·15	3·65
− 65	0·81	0·22	72·84	0·15	3·71
−100	0·81	0·08	90·12	0·15	3·96
−150	0·81	0·04	95·06	0·30	4·10
−200	0·81	0·07	91·36	0·30	4·16

48-Hour Agitation:

Mesh No.	Assay, Au, oz./ton		Extraction, per cent	Reagents consumed, lb./ton ore	
	Feed	Tailing		KCN	CaO
− 48	0·81	0·28	65·43	0·15	3·5
− 65	0·81	0·16	80·25	0·15	3·65
−100	0·81	0·045	94·44	0·15	3·95
−150	0·81	0·04	95·06	0·15	4·10
−200	0·81	0·06	92·59	0·45	4·10

BLANKET CONCENTRATION

Test No. 3

A representative sample of −14-mesh ore was ground for 10 minutes in a jar mill with steel balls. The dilution was 4 parts of ore to 3 parts of water. The ground ore was passed over an experimental blanket table set at a slope of 2½ inches to 12 inches. A screen test shows the grind. A similar test was made in which the ore was ground for 20 minutes.

Screen Tests:

Mesh	10-minute grinding, weight, per cent	20-minute grinding, weight, per cent
+ 48	2·60	0·05
− 48+ 65	12·75	0·85
− 65+100	20·60	8·05
−100+150	16·60	15·25
−150+200	16·90	24·65
−200	30·55	51·15

The results of the blanket concentration are shown in the table.

10-Minute Grinding:

Products	Weight, per cent	Assay, Au, oz./ton	Distribution of gold, per cent	Ratio of concentration
Feed	100·0	0·81	100·00	
Blanket concentrate	4·0	21·56	76·24	25 : 1
Blanket tailing	96·0	0·28	23·76	

20-Minute Grinding:

Products	Weight, per cent	Assay, Au, oz./ton	Distribution of gold, per cent	Ratio of concentration
Feed	100·0	0·81	100·00	
Blanket concentrate	5·04	18·94	98·24	20 : 1
Blanket tailing	94·96	0·18	1·76	

NOTE:—Panning the blanket concentrates would remove about 2 per cent of the weight as quartz gangue. This would result in higher grade of concentrate and a much greater ratio of concentration with about the same recovery. The feed assay in each test is the average for the whole shipment.

BLANKET CONCENTRATION FOLLOWED BY FLOTATION

Test No. 4

A representative sample of −14-mesh ore was ground in jar mills, dilution 4 : 3 to give a 50 per cent −200-mesh product.

The ground pulp was concentrated on a blanket table set at a slope of 2½ inches to 12 inches. The blanket concentrate was panned to remove as much gangue as possible.

A sample of the blanket tailing was concentrated by flotation, using the following reagents:

Soda ash	4·0 lb./ton
Potassium amyl xanthate	0·2 "
Pine oil	0·2 "

The results show that 85 per cent of the gold was recovered in the blanket concentrate with a ratio of concentration of 149 : 1, and 11·5 per cent of the remaining gold was recovered in the flotation concentrate. The overall recovery was 97 per cent.

The table shows the results of the test.

Blanket Concentration:

Products	Weight, per cent	Assay, Au, oz./ton	Distribution of gold, per cent	Ratio of concentration
Feed	100·00	0·81	100·00	
Blanket concentrate	0·67	130·94	85·48	149 : 1
Blanket tailing	99·33	0·15	14·52	

Flotation Concentration:

Products	Weight, per cent	Assay, Au, oz./ton	Distribution of gold, per cent	Ratio of concentration
Flotation feed	100·00	....	100·00	
Flotation concentrate	†1·72	6·68	79·57	58 : 1
Flotation tailing	98·28	0·03	20·43	

Recovery by blankets	85·48 per cent
Recovery by flotation, 79·57 × 14·52	11·55 "
Total recovery	97·03 "
Loss in tailing, 20·43 × 14·52	2·97 "
	100·00 "

†This product assays 10 per cent lead.

BLANKET CONCENTRATION AND CYANIDATION

Test No. 5

A representative sample of −14-mesh ore was ground in a jar mill, dilution 4 : 3, to give a product 50 per cent −200 mesh.

The ground pulp was concentrated on a blanket table set at a slope of 2½ inches to 12 inches.

The blanket tailing was treated by cyanidation. One sample of tailing was treated direct by agitating in a solution of sodium cyanide equivalent in strength to 1·0 pound KCN per ton. The dilution was 1 part tailing to 2½ parts of solution. Lime at the rate of 5 pounds per ton of tailing was added to give a protective alkalinity. The period of agitation was 24 hours.

A second sample of blanket tailing was reground in a jar mill to 83 per cent −200 mesh and cyanided similarly to the first sample.

The results of the test are shown in the table.

Blanket Concentration:

Products	Weight, per cent	Assay, Au, oz./ton	Distribution of gold, per cent	Ratio of concentration
Feed	100·00	0·81	100·00	
Blanket concentrate	2·89	32·33	89·74	34·6
Blanket tailing	97·11	0·11	10·26	

Cyanidation:

Sample No.	Period of agitation, hours	Assay, Au, oz./ton		Extraction, per cent	Reagents consumed, lb./ton	
		Feed	Tailing		KCN	CaO
1	24	0·11	0·01	90·91	0·19	3·81
Reground	24	0·11	0·005	95·45	0·38	4·11

Recovery on blankets	89·74 per cent
Cyanide Test 1: 90·91 × 10·26	9·33 "
	99·07 "
Cyanide Test 2: 95·45 × 10·26 = 9·79 + 89·74 =	99·53 "

PLATE AMALGAMATION AND BLANKET CONCENTRATION

Test No. 6

A representative sample of −14-mesh ore was ground in a jar mill to give a product 50 per cent −200 mesh.

The ground pulp was amalgamated on an experimental amalgamation plate set at a slope of 2½ inches to 12 inches.

The amalgamation tailing was sampled and a representative portion was concentrated on an experimental blanket table set at a slope of 2½ inches to 12 inches.

The blanket concentrate was panned to remove as much gangue as possible.

The results of the test show an overall recovery of 93 per cent.

The following table shows the results obtained in the test.

Amalgamation:

Products	Weight, per cent	Assay, Au, oz./ton	Distribution of gold, per cent
Feed	100·0	0·81	100·00
Amalgam	....	....	54·32
Amalgamation tailing	....	0·37	45·68

Blanket Concentration:

Products	Weight, per cent	Assay, Au, oz./ton	Distribution of gold, per cent	Ratio of concentration
Blanket feed	100·00	....	100·00	
Blanket concentrate	0·51	84·16	84·36	196 : 1
Blanket tailing	99·49	0·08	15·64	

Recovery by amalgamation	54·32 per cent
Recovery by blanketing, 84·36 × 45·68	38·54 "
Overall recovery	92·86 "
Loss in tailing, 15·64 × 45·68	7·14 "
	100·00 "

PLATE AMALGAMATION AND FLOTATION

Test No. 7

A representative sample of −14-mesh ore was ground in a jar mill to give a product 50 per cent −200 mesh.

The ground pulp was amalgamated similarly to that in Test No. 6.

A representative sample of the tailing was treated by flotation using the following reagents:

Soda ash	4·0 lb./ton
Potassium amyl xanthate	0·2 "
Pine oil	0·2 "

The results of the test are shown in the table.

Amalgamation:

Products	Weight, per cent	Assay, Au, oz./ton	Distribution of gold, per cent
Feed	100·0	0·81	100·00
Amalgam	....	....	53·7
Amalgamation tailing	....	0·375	46·3

Flotation:

Products	Weight, per cent	Assay, Au, oz./ton	Distribution of gold, per cent	Ratio of concentration
Flotation feed	100·0	....	100·00	
Flotation concentrate	2·62	25·4	66·78	38 : 1
Flotation tailing	97·38	0·34	33·22	

Recovery by amalgamation	53·70 per cent
Recovery by flotation, 66·78 × 46·3	30·92 "
Overall recovery	84·62 "
Loss in tailing, 33·22 × 46·3	15·38 "
	100·00 "

AMALGAMATION OF BLANKET CONCENTRATE

Test No. 8

A representative sample of −14-mesh ore, consisting of 8,000 grammes, was ground in jar mills, dilution 4 : 3, to approximately 53 per cent minus 200 mesh.

The pulp was concentrated on a blanket. The concentrate was sampled for assay and the remainder amalgamated with mercury.

The results of the test are shown in the table.

Blanket Concentration:

Products	Weight, per cent	Assay, oz./ton		Distribution of gold, per cent	Ratio of concentration
		Au	Ag		
Feed	100·00	0·81	0·71	100·00	
Blanket concentrate	1·47	60·94	23·26	89·20	68 : 1
" tailing	98·53	0·11	....	10·80	

Amalgamation:

Products	Assay, oz./ton		Distribution, per cent	
	Au	Ag	Au	Ag
Feed (blanket concentrate)	60·94	23·26	100·00	100·0
Tailing	4·04	4·61	6·63	19·8
Amalgam by difference	56·90	18·65	93·37	80·2

Recovery of gold, 93·4 × 89·2 .... 83·3 per cent

Amalgamation recovers 80 per cent of the silver in the concentrate.

FLOTATION

Test No. 9

Several flotation tests were made on the ore. On account of the free gold present the products were erratic. A high tailing was made in each test. The following tests are examples of recoveries made.

In each test 1000-gramme representative samples were used.

Test No. 9a

Reagents to Ball Mill:

Soda ash .... 4·0 lb./ton
Dilution, 4 : 3 with water.
Grind, 48·5 per cent −200 mesh.

Reagents to Flotation Cell:

Potassium amyl xanthate .... 0·2 lb./ton
Pine oil .... 0·15 "

Results:

Products	Weight, per cent	Assay, oz./ton	Distribution of gold, per cent	Ratio of concentration
Feed	100·0	0·81	100·0	
Flotation concentrate	2·0	43·12	84·6	50 : 1
" tailing	98·0	0·16	15·4	

Test No. 9b

Reagents to Ball Mill:

Soda ash.. 6·0 lb./ton
Dilution.. 4 : 3
Grind, 80 per cent—200 mesh.

Reagents to Flotation Cell:

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

Results:

Products	Weight, per cent	Assay, oz./ton	Distribution of gold, per cent	Ratio of concentration
Feed..	100·0	0·81	100·0	
Flotation concentrate........................	2·5	31·20	83·8	40 : 1
" tailing..................................	97·5	0·155	16·2	

Test No. 9c.

Reagents to Ball Mill:

Soda ash.. 6·0 lb./ton
Barrett No. 4... 0·2 "
Dilution.. 4 : 3.
Grind, 78·5 per cent —200 mesh.

Reagents to Flotation Cell:

Sodium ethyl xanthate... 0·2 lb./ton
Pine oil.. 0·05 "

Results:

Products	Weight, per cent	Assay			Distribution, per cent		Ratio of concentration
		Oz./ton		Per cent			
		Au	Ag	Pb	Au	Ag	
Feed................	100·00	0·81	0·71	0·27	100·0	100·0	
Flotation concentrate..	1·48	41·31	34·54	12·44	66·0	65·8	67·6 : 1
" tailing......	98·52	0·32	0·28	....	34·0	34·2	

Test No. 9d

The same reagents were used throughout.

Results:

Products	Weight, per cent	Assay			Distribution, per cent		Ratio of concentration
		Oz./ton		Per cent			
		Au	Ag	Pb	Au	Ag	
Feed................	100·00	0·81	0·71	0·27	100·0	100·0	
Flotation concentrate.	1·36	37·81	27·31	12·84	59·8	53·3	73·5 : 1
" tailing......	98·64	0·35	0·33	....	40·2	46·7	

AMALGAMATION OF FLOTATION CONCENTRATE

Test No. 10

The concentrate from several tests was combined and, after mixing, it was sampled for assay. The remainder was amalgamated with mercury similarly to the blanket concentrate in Test No. 8.

Flotation:

Products	Weight, per cent	Assay			Distribution, per cent		Ratio of concentration
		Oz./ton		Per cent			
		Au	Ag	Pb	Au	Ag	
Feed	100·0	0·81	0·71	0·27	100·00	100·00	
Flotation concentrate	2·0	41·44	33·66	10·52	79·15	76·50	50 : 1
" tailing	98·0	0·22	0·21	....	20·85	23·50	

Amalgamation:

Products	Assay, oz./ton		Distribution, per cent	
	Au	Ag	Au	Ag
Feed (flotation concentrate)	41·44	33·66	100·0	100·0
Tailing	12·02	13·13	29·2	39·0
Amalgam by difference	29·42	20·53	70·8	61·0

Overall Recoveries by Amalgamation:

Recovery of gold, 70·8 × 79·15 .... 56·0 per cent
Recovery of silver, 61·0 × 76·5 .... 46·7 "

SUMMARY OF EXPERIMENTAL TESTS

1. Amalgamation of −48-mesh ore gave a recovery of 76·5 per cent.
2. Straight cyanidation of ore crushed −150 mesh gave a recovery of 95 per cent in 24 hours.
3. Blanket concentration gave a recovery of 98 per cent on ore crushed 51 per cent − 200 mesh.
4. Blanket concentration followed by flotation gave a recovery of 97 per cent.
5. Blanket concentration followed by cyanidation gave a recovery of 99·5 per cent.
6. Plate amalgamation followed by blanket concentration gave a recovery of 93 per cent.
7. Plate amalgamation followed by flotation gave a recovery of 85 per cent.
8. Amalgamation of blanket concentrate gave a recovery of 93 per cent of gold in the concentrate.
9. Straight flotation gave a recovery of 85 per cent.
10. Amalgamation of flotation concentrate gave a recovery of 71 per cent of gold in concentrate.

SUMMARY AND CONCLUSIONS

The microscopic examination of polished sections of the ore showed it to contain a large amount of free gold.

It was, therefore, expected that some method using amalgamation would recover a large percentage of the gold.

The results of the experimental tests show that when the ore is crushed to 50 per cent through 200 mesh and passed over amalgam plates only about 54 per cent of the gold is recovered. However, by passing the ore over special corduroy blankets recoveries of from 85 per cent to as high as 98 per cent were obtained in the blanket concentrate. The blanket concentrate obtained in Test No. 4 is more comparable to mill practice and it shows that blankets will recover at least 85 per cent of the gold. By amalgamating this blanket concentrate in a clean-up barrel 93 per cent of the gold was extracted. This means that a minimum recovery of 79 per cent of the gold can be obtained as bullion by a simple blanket plant.

The test work further shows that if amalgam plates are used in conjunction with the blankets the recovery of bullion will be raised to about 90 per cent. (Refer to Test No. 6). An additional recovery can be made by shipping or further treating the tailing from the amalgamation of the blanket concentrate, as the product will contain, according to the tests, over 4 ounces per ton.

The test work also shows that the blanket tailing can be further concentrated by flotation to yield an additional recovery. The concentrate produced will be of shipping grade and contain over 10 per cent lead and some additional value in silver.

The ore was also found to cyanide readily, giving recoveries up to 95 per cent. In conjunction with a cyanide plant blanket concentration or hydraulic traps in the grinding circuit is recommended; otherwise, metallic gold will accumulate in the ball mill and classifier circuit.

Ore Dressing and Metallurgical Investigation No. 595

ORE FROM THE ARNTFIELD GOLD MINE, AT ARNTFIELD, QUE.

Shipment. A shipment of three lots of ore, aggregate weight approximately one ton, was received August 14, 1934. The shipment consisted of three distinct samples of ore from different parts of the mine. The samples were submitted by V. A. James, Resident Manager, Arntfield Gold Mines, Limited, Arntfield, Quebec.

Assays and Characteristics of the Ore. The samples assayed as follows:

	Gold, oz./ton	Silver, oz./ton
Sample No. 1	0·57	0·08
Sample No. 2	0·23	0·05
Sample No. 3	0·36	0·10
Samples Nos. 1, 2, and 3, mixed	0·42	....

Specimens of the three lots of ore were selected and twelve polished sections were prepared and examined microscopically.

Lot No. 1. The ore of Lot No. 1 is light grey in colour, fine-textured, and is highly siliceous with a considerable amount of light grey quartz and some finely disseminated carbonate. It contains abundant disseminated pyrite, a very small amount of chalcopyrite and rare tiny grains of pyrrhotite. Some portions show finely divided hematite.

Native gold occurs chiefly as very small grains in the quartz, but is also present in the pyrite. An analysis of the occurrence of the native gold gives the following data:

	Per cent
Gold in quartz	50
Gold in cracks in pyrite	37
Gold enclosed within the pyrite	13
	100

Mesh	Per cent Au
− 200+ 325	41·0
− 325+ 560	25·1
− 560+ 800	12·8
− 800+1100	7·7
−1100+1600	5·9
−1600+2300	5·4
−2300	2·1
	100·0

Lot No. 2. The ore of Lot No. 2 is light greenish grey in colour, is highly siliceous, and contains numerous fine stringers and indistinct bands of quartz and a considerable amount of finely disseminated carbonate. It varies somewhat from that of Lot No. 1 in the following points:

(a) Pyrite is rather sparingly disseminated in some parts of the ore, in other parts being so abundant that it forms masses; although of sporadic occurrence, the content of pyrite is probably lower in Lot No. 2 than in Lot No. 1.

(b) Hematite is abundant and occurs as small ragged flakes usually roughly parallel to the structure.

(c) Magnetite is locally abundant and occurs as large to medium-sized crystals, which often contain small grains of chalcopyrite. Chalcopyrite occurs as above and as small disseminated grains in the gangue, usually associated with carbonate.

No native gold was seen in the sections from this lot.

Lot No. 3. The ore of Lot No. 3 is reddish brown to dark grey in colour, is highly siliceous and contains small patches of quartz and fine stringers and disseminated grains of carbonate. Pyrite is disseminated along indistinct stringers in the gangue, and hematite is locally abundant, the latter mineral in extremely finely divided form probably being responsible for the reddish brown colour of much of the ore. Chalcopyrite rarely occurs as tiny grains in pyrite.

A few small grains of native gold were seen within the gangue, usually near or against pyrite. The grain sizes of the gold in this lot, based on the meagre data, are as follows:

Mesh	Per cent Au
− 325+ 560	33
− 560+ 800	25
− 800+1100	18
−1100+1600	12
−1600+2300	8
−2300	4
	100

Summary of Characteristics of the Ore. Three lots of gold ore from Arntfield Gold Mines, Limited were examined microscopically and found to consist of a highly siliceous gangue material that varies considerably as to colour, but which commonly is composed of what is regarded as highly silicified country rock, quartz, and a considerable amount of disseminated carbonate.

The metallic minerals vary considerably in quantity, but pyrite is consistently disseminated through the ore. Locally, hematite and magnetite are prominent. A small amount of chalcopyrite and rare pyrrhotite are present.

Native gold was seen in samples from two of the three lots, and appears to be more abundant in the quartzose portions of the ore that contain abundant pyrite. It occurs chiefly in the gangue and in cracks in the pyrite, but a small proportion is present within pyrite. The native gold is extremely finely divided—a fact which indicates the necessity of grinding comparatively fine.

Experimental Tests

Cyanidation tests at various grindings and pulp dilutions were carried out on the ore and extractions ranging from 83·3 to 97·6 per cent of the gold were obtained, the highest extraction being obtained with the finest grinding and the highest dilution ratio. A few blanket concentration tests were also made and in each case about 25 per cent of the gold was recovered in a concentrate amounting to from one to two per cent of the weight of feed used.

Details of the tests follow:

CYANIDATION

Tests Nos. 1 to 18

In this series of tests, samples of the ore were ground wet in ball mills to 46·2, 69·0, and 94·9 per cent through 200 mesh. Duplicate samples of each of the above sizes were agitated in cyanide solution, 1·0 pound KCN per ton, for 24 hours with three different pulp dilutions, namely, 2 : 1, 1·5 : 1, and 1 : 1 (solution to solids). The tailings were filtered, washed, and assayed for gold.

Summary:

Feed sample: gold, 0·42 oz./ton.

Test No.	Approx. grinding, per cent −200 mesh	Pulp dilution, solution: solids	Tailing assay, Au, oz./ton	Extraction, per cent	Reagents consumed, lb./ton	
					KCN	CaO
1	46·2	2 : 1	0·06	85·7	0·45	1·65
2	46·2	2 : 1	0·07	83·3	....	....
3	46·2	1·5 : 1	0·055	86·9	0·19	1·74
4	46·2	1·5 : 1	0·050	88·1	....	....
5	46·2	1 : 1	0·07	83·3	0·41	2·20
6	46·2	1 : 1	0·07	83·3	....	....
7	69·0	2 : 1	0·03	92·9	0·56	2·40
8	69·0	2 : 1	0·03	92·9	....	....
9	69·0	1·5 : 1	0·04	90·5	0·57	2·23
10	69·0	1·5 : 1	0·03	92·9	....	....
11	69·0	1 : 1	0·04	90·5	0·38	2·25
12	69·0	1 : 1	0·045	89·3	....	....
13	94·9	2 : 1	0·01	97·6	0·82	2·15
14	94·9	2 : 1	0·02	95·2	....	....
15	94·9	1·5 : 1	0·02	95·2	0·80	2·23
16	94·9	1·5 : 1	0·015	96·4	....	....
17	94·9	1 : 1	0·03	92·9	0·38	2·75
18	94·9	1 : 1	0·03	92·9	....	....

PLATE AMALGAMATION AND CYANIDATION

Tests Nos. 19 and 20

In these tests two samples of the ore were ground 46·2 and 69·0 per cent through 200 mesh and passed over amalgamation plates. The plate tailings were sampled and assayed, and portions of each were agitated in cyanide solution, 1·0 pound KCN per ton, for 24 hours. All the products were assayed for gold.

Summary:

Feed sample: gold, 0·42 oz./ton.

Test No.	Approx. grinding, per cent −200 mesh	Extraction, per cent	Cyanide tailing assay, Au, oz./ton	Extraction, per cent	Reagents consumed, lb./ton	
					KCN	CaO
19	0·33	21·4	0·065	63·1	0·20	4·30
20	0·27	35·7	0·04	54·8	0·10	3·90

BLANKET CONCENTRATION

Tests Nos. 21 to 23

Samples of the ore were ground 57·6, 69·0, and 80·2 per cent through 200 mesh and passed over corduroy blankets set at a slope of 2·5 inches per foot. The products were assayed for gold.

Summary:

Test No.	Approx. grinding, per cent −200 mesh	Product	Weight, per cent	Assay, Au, oz./ton	Distribution of gold, per cent
21	57·6	Concentrate	1·92	5·85	25·8
		Tailing	98·08	0·33	74·2
		Feed (cal.)	100·00	0·44	100·0
22	69·0	Concentrate	1·85	6·04	26·2
		Tailing	98·15	0·32	73·8
		Feed (cal.)	100·00	0·43	100·0
23	80·2	Concentrate	1·17	8·92	24·8
		Tailing	98·83	0·32	75·2
		Feed (cal.)	100·00	0·42	100·0

CYANIDATION WITH TABLING

Test No. 24

In this test a sample of the ore was ground 69 per cent through 200 mesh in a ball mill and agitated in cyanide solution, 1·0 pound KCN per ton, for 24 hours. The cyanide tailing was sampled and assayed, and the remainder of it was passed over a small laboratory-size concentrating table. The table concentrate was sampled and assayed and the remainder of it reground and re-cyanided. The table tailing was sampled and assayed, but not further treated.

Summary:

Product	Weight, per cent	Assay, Au, oz./ton	Distribution of gold, per cent	Recovery, per cent of total	Reagents consumed, lb./ton	
					KCN	CaO
Table concentrate	23·3	0·11	62·6	6·1	....	....
" sand tailing	49·6	0·02	24·2	2·4	....	....
" slime "	27·1	0·02	13·2	1·3	....	....
" feed (cal.)	100·0	0·041	100·0	9·8	0·66	2·70
Concentrate cyanided	23·3	0·03	....	....	0·38	1·14

Average tailing..0·022 oz./ton in gold
Extraction by cyanidation of ore.................................. 90·2 per cent
" " table concentrate.................... 4·5 "

Total extraction.. 94·7 "

CONCLUSIONS

The test work carried out indicates that straight cyanidation, with perhaps tabling out and regrinding of the sulphides, is the most practical method for treating this ore. In order to produce a low tailing by straight cyanidation the ore must be ground comparatively fine, 90 or more per cent through 200 mesh. (See Tests Nos. 1 to 18).

In Test No. 24, with the ore ground 69 per cent through 200 mesh, an overall extraction of 94·7 per cent of the gold was obtained with an average tailing of 0·022 ounce per ton in gold. This is a somewhat lower extraction than is obtained in Tests Nos. 12 to 16, although in this case the sulphides were tabled out, reground, and re-cyanided.

It may be possible to determine a point somewhere between these two to which the ore could be ground and, with the assistance of table concentration and regrinding of the sulphides, an extraction obtained that would be equal to that resulting from fine-grinding all of the ore.

Ore Dressing and Metallurgical Investigation No. 596

GOLD ORE FROM PONTIAC-ROUYN GOLD MINES, LIMITED, ROUYN TOWNSHIP, QUEBEC

Shipment. A shipment of gold ore, weighing 2,470 pounds, was received on September 7, 1934, from the Pontiac-Rouyn Gold Mines, Limited, Rouyn township, Quebec. The sample was said to be from the "Quartz Vein" of this company's property.

The sample was submitted by E. K. Fockler, on instructions of J. A. Lindsay, Vice-President of Minefinders, Limited, 100 Adelaide St. West, Toronto.

Characteristics of the Ore. The gangue consists of white quartz and light greenish grey to brown mottled country rock, which contains a considerable amount of carbonate. The quartz is locally much stained by iron oxides.

Pyrite, the most abundant metallic mineral, is rather sparingly disseminated as large irregular grains. A trace of chalcopyrite is present in the pyrite.

In the polished sections examined only one grain of native gold was seen. This occurs within pyrite and is between 200 and 325 mesh in size.

Sampling and Analysis. The shipment was crushed and sampled by standard methods and a representative sample assayed.

Gold	0·160	oz./ton
Silver	0·08	"
Iron	1·73	per cent
Sulphur	0·63	"
Silica	91·30	"
Lime	0·64	"

Experimental Tests

The following experimental tests were conducted:—

1. Amalgamation.
2. Straight cyanidation.
3. Straight flotation.
4. Blanket concentration followed by flotation.
5. Blanket concentration followed by flotation, with finer grinding than used in Test No. 4.

AMALGAMATION

Test No. 1

Representative samples of −14-mesh ore were dry-crushed in a disk pulverizer to pass 48 and 100 mesh.

From each, a portion of ore weighing 1,000 grammes was amalgamated with mercury in jar mills, diluted 1 : 1 with water.

After separating the amalgam, the tailings were sampled for assay and a screen analysis was made to determine the degree of grinding.

Results:

Mesh No.	Assay, Au, oz./ton		Extraction, per cent
	Feed	Tailing	
− 48	0·160	0·10	37·50
−100	0·160	0·08	50·00

Screen Analysis:

Mesh No.	Weight, per cent	
	−48	−100
− 48+ 65	9·10	....
− 65+100	20·95	....
−100+150	17·40	4·85
−150+200	12·40	18·45
−200	40·15	76·70
	100·00	100·00

STRAIGHT CYANIDATION

Test No. 2

Representative samples of −14-mesh ore were crushed dry to pass 48, 100, 150, and 200 mesh. Representative portions from each were agitated for 24 and 48 hours in cyanide solution equivalent in strength to 1·0 pound KCN per ton. The dilution was one part ore to three parts solution. Lime at the rate of 3·0 pounds per ton of ore was added to the solution to give a protective alkalinity.

Results:

Mesh No.	Assay, Au, oz./ton		Extraction, per cent	Reagents consumed, lb./ton ore	
	Feed	Tailing		KCN	CaO
24-Hour Agitation:					
− 48	0·160	0·02	87·50	0·2	2·10
−100	0·160	0·015	90·63	0·3	2·40
−150	0·160	0·015	90·63	0·3	3·80
−200	0·160	0·01	93·75	0·3	3·95
48-Hour Agitation:					
− 48	0·160	0·02	87·50	0·2	1·95
−100	0·160	0·015	90·63	0·3	2·40
−150	0·160	0·015	90·63	0·3	3·80
−200	0·160	0·.01	90·63	0·3	4·10

Note.—Additions of lime were required in the case of the −150-mesh and −200-mesh ore.

The low consumption of cyanide shows that no appreciable amount of cyanicides is present in the sample of ore used in the test.

STRAIGHT FLOTATION

Test No. 3

A representative sample of −14-mesh ore was ground in a jar mill with the following reagent:

Soda ash.. 4·0 lb./ton

Reagents to Cell:

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

A screen analysis was made on the flotation tailing to show the degree of grinding.

Screen Analysis of Flotation Tailing:

Mesh	Weight, per cent
− 48+100	2·40
−100+150	9·50
−150+200	22·25
−200	63·85

Results:

Product	Weight, per cent	Assay, oz./ton		Distribution, per cent		Ratio of concentration
		Au	Ag	Au	Ag	
Feed	100·00	0·16	0·08	100·00	100·00	
Flotation concentrate	1·54	8·60	3·92	82·75	75·5	65 : 1
Flotation tailing	98·46	0·03	0·02	17·25	24·5	

An analysis of the flotation tailing showed:

Sulphur.. 0·03 per cent
Iron... 0·68 "
Silica... 93·50 "
Lime... 0·73 "

BLANKET CONCENTRATION AND FLOTATION

Test No. 4

A representative portion of the feed sample, −14-mesh ore, was ground in a jar mill with steel balls for 20 minutes. The dilution was four parts of ore to three parts of water. The pulp was concentrated on a special corduroy blanket on a table sloping $2\frac{1}{2}$ inches in 12 inches.

The blanket concentrate was panned to remove gangue and give a maximum concentration of gold.

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

Soda ash	2·0 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	100·00	0·16	100·00	
Blanket concentrate	0·31	20·02	40·91	323 : 1
Blanket tailing	99·69	0·09	59·09	

Results of Flotation:

Product	Weight, per cent	Assay, Au, oz./ton	Distribution of gold, per cent	Ratio of concentration
Blanket tailing / Feed to flotation	100·00	0·09	100·00	
Flotation concentrate	1·35	4·54	75·68	74 : 1
Flotation tailing	98·65	0·02	24·32	

An analysis of the flotation concentrate showed:

	Per cent
Sulphur	35·65
Iron	36·96
Silica	15·87
Copper	0·22

Summary of Results of Test No. 4:

	Per cent
Recovery of gold by blanket	40·91
Recovery of gold by flotation, 75·68 × 59·09	44·72
Overall recovery of gold	85·63
Loss in flotation tailing, 24·32 × 59·09	14·37
	100·00

A screen analysis on the flotation tailing shows the degree of grinding.

Screen Analysis:

Mesh	Weight, per cent
− 48+ 65	1·55
− 65+100	9·25
−100+150	15·95
−150+200	24·10
−200	49·15
	100·00

The high ratio of concentration and the coarse grinding should be noted.

The amount of soda ash used in this test was much more than was necessary; less than 1 pound per ton will be required in practice.

Test No. 5

A representative portion of −14-mesh ore was treated similarly to that of Test No. 4, except that the grinding period was increased to 30 minutes.

A screen analysis on the flotation tailing shows the degree of grinding:

Mesh	Weight, per cent
− 65+100	1·50
−100+150	6·50
−150+200	21·20
−200	70·80
	100·00

The same reagents were used in flotation as in Test No. 4.

Results of Blanket Concentration:

Product	Weight, per cent	Assay, Au, oz./ton	Distribution of gold, per cent	Ratio of concentration
Feed	100·00	0·16	100·00	
Blanket concentrate	0·23	31·48	44·64	435 : 1
Blanket tailing	99·77	0·09	55·36	

Results of Flotation:

Product	Weight, per cent	Assay, Au, oz./ton	Distribution of gold, per cent	Ratio of concentration
Blanket tailing / Feed to flotation	100·00	0·09	100·00	
Flotation concentrate	1·67	4·40	88·24	60 : 1
Flotation tailing	98·33	0·01	11·76	

Summary of Results of Test No. 5:

	Per cent
Recovery of gold by blanket	44·64
Recovery of gold by flotation, 88·24 × 55·36	48·85
Overall recovery of gold	93·49
Loss in flotation tailing, 11·76 × 55·36	6·51
	100·00

An analysis of the flotation concentrate gave:

	Per cent
Sulphur	32·80
Iron	35·35
Silica	21·55

SUMMARY AND CONCLUSIONS

Amalgamation of −100-mesh ore gave a recovery of 50 per cent of the gold.

Straight cyanidation gave a maximum recovery of 93 per cent of the gold on −200-mesh ore in 24 hours. The consumption of reagents was low.

Blanket concentration followed by flotation gave a recovery of 93·5 per cent in the combined concentrates.

The treatment methods indicated for this ore are straight cyanidation with the sulphides ground to pass a 200-mesh screen; or flotation after recovering as much free gold as possible by traps, jigs, or blankets prior to flotation. The grade of the flotation concentrate can be varied to give a concentrate that will net the highest smelter return.

Ore Dressing and Metallurgical Investigation No. 597

GOLD ORE FROM GOD'S LAKE GOLD MINES, LIMITED,
GOD'S LAKE, MANITOBA

Shipment. Two shipments of ore were received from God's Lake Gold Mines, Limited, God's Lake, Manitoba, on September 7 and 19, 1934. The first shipment consisted of 5 bags, weight 590 pounds, and the second comprised 17 bags, weight 1,900 pounds.

Characteristics of the Ore. Samples were selected from each shipment, and 8 polished sections were prepared and examined microscopically for the purpose of determining the character of the ore.

First Shipment. An examination of six sections of the first shipment revealed that the ore consists of a gangue of smoky grey quartz and green-to-grey country rock, which is somewhat schistose and banded. Sulphides are rather sparingly disseminated throughout this gangue, and native gold occurs in the quartz.

The sulphides are, in their order of abundance, pyrrhotite, pyrite, arsenopyrite, and chalcopyrite. Pyrrhotite is chiefly confined to the country rock, in which it occurs as finely disseminated grains. Pyrite occurs as sparingly disseminated grains of medium size in both quartz and country rock. Arsenopyrite is locally quite abundant in the schistose portions of the ore, and here it occurs as small elongated crystals oriented parallel to the structure. Chalcopyrite is very rare, traces of this mineral being present in association with the pyrrhotite.

Native gold occurs as irregular grains in the smoky quartz and appears to be of somewhat sporadic occurrence, some portions of the quartz being barren while others contain many small grains of the metal. A quantitative microscopic analysis of the gold gives the following grain size:—

Grain Size, mesh	Gold, per cent
− 100+ 150	12·2
− 150+ 200	18·3
− 200+ 325	29·0
− 325+ 560	20·5
− 560+ 800	7·4
− 800+1100	4·0
−1100+1600	3·5
−1600+2300	2·9
−2300	2·2
	100·0

Second Shipment. The ore of the second shipment is very similar to that of the first. The gangue is chiefly smoky grey quartz and greenish grey country rock, but one section contains a small amount of white quartz, which appears to be barren.

The sulphides are sparsely disseminated in the country rock and are rare in the smoky quartz. In their order of abundance in the sections, they are: pyrite, pyrrhotite, and chalcopyrite, the last being present as a few small grains associated with pyrite or pyrrhotite. Neither native gold nor arsenopyrite was visible in the sections from this shipment.

Sampling and Assaying: The ore was crushed and sampled by standard methods.

Assay of first shipment:	Gold	0·51 oz./ton
	Silver	0·12 "
	Copper	0·01 per cent
Assay of second shipment:	Gold	0·50 oz./ton
	Silver	0·11 "
	Copper	0·05 per cent

Experimental Tests

A number of small-scale tests were carried out on the ore of Shipment No. 1. These comprised classification, cyanidation, flotation, blanket concentration, and amalgamation tests.

A mill run was made on 1,200 pounds of the second shipment of ore.

CLASSIFICATION

Test No. 1

In this test a 1000-gramme sample of the ore was ground wet for 15 minutes and then run through a hydraulic classifier. The purpose of this test was to determine the amount of gold freed in the grinding and possible recovery by traps in the grinding circuit.

Product	Weight, per cent	Assay, Au, oz./ton	Distribution, per cent	Ratio of concentration
Oversize	3·39	3·06	21·16	29·5 : 1
Undersize	96·61	0·40	78·84	

A screen test on the undersize indicated that 44·5 per cent of the ore was minus 200 mesh.

Test No. 2

In this test the ore was ground for 30 minutes, which gave 74·6 per cent through 200 mesh.

Product	Weight, per cent	Assay, Au, oz./ton	Distribution, per cent	Ratio of concentration
Oversize	3·43	6·80	51·22	29·15 : 1
Undersize	96·57	0·23	48·78	

This indicates that at this grinding size slightly over 50 per cent of the gold is present in the oversize.

AMALGAMATION

Test No. 3

A 1000-gramme charge of ore ground to pass a 48-mesh screen was barrel-amalgamated with 100 grammes of mercury for 1 hour.

Gold in feed	0·51	oz./ton
Gold in tailing	0·165	"
Recovery by amalgamation	67·65	per cent

Screen Test on Tailing:

Mesh	Weight, per cent
+ 65	15·2
+100	17·6
+150	10·6
+200	11·5
−200	45·1
	100·0

CYANIDATION

Test No. 4

In this test series of 200-gramme samples at different sizes were cyanided in a solution having a concentration equivalent to 1 pound KCN per ton and a protective alkalinity of 5 pounds lime (CaO) per ton. The pulp dilution was 3 : 1. Time of agitation, 24 hours.

Product	Assay, Au, oz./ton		Extraction, per cent	Reagents consumed, lb./ton	
	Feed	Tailing		KCN	CaO
− 48 mesh	0·51	0·09	82·35	0·3	4·10
−100 mesh	0·51	0·025	95·10	0·6	4·10
−150 mesh	0·51	0·03	94·12	0·6	4·25
−200 mesh	0·51	0·025	93·10	0·9	4·25

Screen Test on Tailings:

−48 Mesh

Mesh	Weight, per cent
+ 65	6·1
+100	15·7
+150	14·2
+200	12·9
−200	51·1
	100·00

−100 Mesh

Mesh	Weight, per cent
+150	7·1
+200	19·0
−200	73·9
	100·0

−150 Mesh

Mesh	Weight, per cent
+200	12·5
−200	87·5
	100·0

Test No. 5

Similar to Test No. 4. Agitation for 48 hours.

Product	Assay, Au, oz./ton		Extraction, per cent	Reagents consumed, lb./ton	
	Feed	Tailing		KCN	CaO
− 48 mesh	0·51	0·05	90·20	0·30	4·25
−100 mesh	0·51	0·03	94·12	1·05	4·25
−150 mesh	0·51	0·02	96·08	1·05	5·80
−200 mesh	0·51	0·015	97·06	1·35	5·95

CYANIDATION AND FLOTATION

Test No. 6

A 3000-gramme charge of ore was ground dry to pass a 65-mesh screen. The ore was run over a corduroy blanket. The concentrate was barrel-amalgamated and cyanidation and flotation tests were carried out on the blanket tailing.

Blanket Test:

Product	Weight, per cent	Assay, Au, oz./ton	Distribution, per cent	Ratio of concentration
Feed	100·00	0·51	100·00	
Concentrate	3·09	9·291	56·30	32·36 : 1
Tailing	96·91	0·23	43·70	

Barrel Amalgamation of Concentrate:

Gold in amalgamation tailing.................................... 0·50 oz./ton
Recovery.. 94·62 per cent

Cyanidation of Blanket Tailing:

Two samples of the tailing were cyanided in a solution of concentration equivalent to 1 pound KCN per ton and a protective alkalinity of 5 pounds CaO per ton.

Time	Assay, Au, oz./ton		Extraction of gold, per cent	Consumption of reagents		Pulp dilution
	Feed	Tailing		KCN	CaO	
24 hours	0·23	0·02	91·30	1·14	4·02	3·27 : 1
48 hours	0·23	0·02	91·30	1·13	4·17	3·23 : 1

Flotation of Blanket Tailing:

A 1000-gramme charge of blanket tailing was reground for 10 minutes with 0·088 pound Barrett No. 4 per ton and 4 pounds soda ash per ton. To the cell were added 0·4 pound potassium amyl xanthate per ton and 0·05 pound pine oil.

Product	Weight, per cent	Assay, Au, oz./ton	Distribution, per cent	Ratio of concentration
Feed	100·00	0·23	100·00	
Concentrate	6·77	3·06	81·63	14·77 : 1
Tailing	93·23	0·05	18·37	

Screen Tests:

Blanket Tailing

Mesh	Weight, per cent
+100	16·0
+150	17·2
+200	18·3
−200	48·5
	100·0

Flotation Tailing

Mesh	Weight, per cent
+100	5·0
+150	9·1
+200	19·5
−200	66·4
	100·0

Summary of Results:

Test No. 6

Blanketing and Cyanidation:

Gold recovered in blanket concentrate	56·30 per cent
Gold recovery by barrel amalgamation of blanket concentrate, 94·62 per cent of 56·30 per cent	53·27 "
Gold in blanket tailing	43·70 "
Gold recovery by cyanidation of blanket tailing, 91·30 per cent of 43·70 per cent	39·90 "
Overall gold recovery, 53·27 + 39·90	93·17 "

Blanketing and Flotation:

Gold recovered in blanket concentrate	56·30 per cent
Gold recovery by barrel amalgamation of blanket concentrate, 94·62 per cent of 56·30 per cent	53·27 "
Gold in blanket tailing	43·70 "
Gold recovered by flotation of blanket tailing, 81·63 per cent of 43·70 per cent	35·67 "

Test No. 7

Additions to Mill:

Ore	1000 grammes
Water	750 c.c.
Soda ash	4·0 lb./ton
Barrett No. 4	0·088 "
Grinding time	30 minutes

Additions to Cell:

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

Product	Weight, per cent	Assay, Au, oz./ton	Distribution, per cent	Ratio of concentration
Concentrate	3·68	11·02	87·53	27·17 : 1
Tailing	96·32	0·06	12·47	

Screen Test Flotation Tailing:

Mesh	Weight, per cent
+100	2·8
+150	8·5
+200	20·8
−200	67·9
	100·0

Test No. 9

A 3000-gramme charge of ore was ground to pass a 48-mesh screen and then run over an amalgamation plate. The tailing was reground and cyanided.

Feed, gold	0·51 oz./ton
Plate tailing, gold	0·32 "
Recovery by amalgamation	37·25 per cent

Screen Test Plate Tailing:

Mesh	Weight, per cent
+ 65	12·5
+100	19·0
+150	12·7
+200	13·2
−200	42·6
	100·0

Cyanidation of Plate Tailing:

Samples of the tailing were given a 10-minute regrind and cyanided in solution having a concentration equivalent to 1 pound KCN per ton, and protective alkalinity of 5 pounds CaO per ton.

Time of agitation	Assay, Au, oz./ton		Extraction of gold, per cent	Consumption of reagents		Pulp dilution
	Feed	Tailing		KCN	CaO	
24 hours	0·32	0·02	93·75	0·98	4·02	3·27 : 1
48 hours	0·32	0·05	84·38	1·96	4·86	3·27 : 1

Screen Test on Cyanide Tailing:

Mesh	Weight, per cent
+100	3·5
+150	7·5
+200	18·1
−200	70·9
	100·0

Summary of Gold Recoveries:

Gold recovery by plate amalgamation	37·25	per cent
Gold recovery by cyanidation of plate tailing, 93·75 per cent of 62·75 per cent	58·83	"
Overall gold recovery	96·08	"

CONCLUSIONS FROM SMALL-SCALE TESTS

The ore can be satisfactorily treated by cyanidation. Grinding to have 74 per cent of the ore pass a 200-mesh screen gave a gold extraction of 95·10 per cent. The cyanide and lime consumption was low.

The use of blankets indicated a recovery of over 56 per cent of the gold. This gold was almost all free, for by barrel amalgamation of the blanket concentrate 94·62 per cent of this gold was recovered in the amalgam. Cyanidation of the blanket tailing gave a 91·3 per cent extraction. The overall recovery, using blankets to remove the greater amount of the free gold prior to cyanidation, was 93·17 per cent.

Mill Run No. 1

A mill run was carried out on the ore of the second shipment.

The ore was crushed to ¼ inch and reduced to −14 mesh in rolls. This size constituted the feed for the test run.

The −14-mesh ore was fed to a 12-inch by 24-inch rod mill. The mill discharge was run over a blanket table, the tailing from which was pumped to an Akins classifier, the classifier operating in closed circuit with the blanket and mill. The classifier overflow was pumped to a small Pachuca tank for cyanidation.

The average rate of feed was 75·5 pounds per hour.

The slope of the blanket was 3½ inches to the foot.

Samples were taken hourly.

Screen Test of Mill Feed:

Mesh	Weight, per cent
+ 20	17·7
+ 28	20·7
+ 35	21·2
+ 48	11·2
+ 65	9·1
+100	6·4
+150	4·5
+200	3·1
−200	6·1
	100·0

Results of Assays, Density of Pulp, and Size:

Time	Mill discharge, Au, oz./ton	Blanket tailing, Au, oz./ton	Classifier overflow, Au, oz./ton	Density of classifier overflow	Classifier overflow, per cent −200 mesh
11.00 a.m.	0·28	0·25	0·09	13 per cent solids	89·5
12.00 noon	0·27	0·35	0·10	....	83·8
1.00 p.m.	0·30	0·28	0·13	....	83·7
2.00 p.m.	0·30	0·33	0·14	....	65·4
3.00 p.m.	0·28	0·24	0·14	....	91·3
4.00 p.m.	0·25	0·23	0·10	8 per cent solids	79·2

Results of the first day's run indicated that the circulating load was heavy. The percentage of solids in the classifier overflow was low.

Mill Run No. 2

In this run the rate of feed was reduced and the circulating load consequently was lowered.

The results of assays, densities, etc., are as follows:

Time	Mill discharge, Au, oz./ton	Blanket tailing, Au, oz./ton	Classifier overflow	
			Au, oz./ton	−200 mesh, per cent
9.40 a.m.	0·19	0·19	0·11	64·7
10.45 a.m.	0·20	0·20	0·12	51·1
11.45 a.m.	0·22	0·20	0·14	62·8
12.45 p.m.	0·25	0·36	0·20	69·0
2.45 p.m.	0·19	0·25	0·11	70·0
3.45 p.m.	0·23	0·22	0·12	62·6

Samples of classifier overflow taken for density show the percentage of solids as follows:

Time	Solids, per cent
9.30 a.m.	20·0
11.40 "	37·0
1.40 p.m.	39·0
1.46 "	28·0
2.05 "	18·0
2.50 "	20·0

Cyanidation of Classifier Overflow:

Sufficient of the classifier overflow was pumped to the required level in a Pachuca tank for a cyanidation test.

Sodium cyanide equivalent to 1·10 pounds KCN per ton of solution was added and 1·1 pounds of lime was added for protective alkalinity.

A sample of pulp gave a pulp density of 22·5 per cent solids. The solids assayed for gold gave 0·10 ounce per ton.

Screen Test on Solids:

Mesh	Weight, per cent
+100	0·2
+150	3·5
+200	20·4
−200	75·9
	100·0

Cyanidation was continued for 42 hours. Samples were taken at different periods of the agitation and the gold assays were as follows:

18 hours	Gold,	0·02 oz./ton
24 "	"	0·015 "
36 "	"	0·02 "
42 "	"	0·02 "

The cyanide consumption was 0·39 pound KCN per ton.

The lime consumption was 3·27 pounds per ton.

Gold extraction in 24 hours = 85 per cent.

Barrel Amalgamation of Blanket Concentrate:

Weight of blanket concentrate	4·51 pounds
Ratio of concentration	270 : 1
Gold in concentrate	25·50 oz./ton

A charge of the blanket concentrate was reground and amalgamated with mercury for 30 minutes.

Gold in amalgamation tailing	4·14 oz./ton
Gold recovered by amalgamation	83·76 per cent

Screen Test Blanket Concentrate:

Mesh	Weight, per cent
+ 48	2·6
+ 65	12·2
+100	13·4
+150	12·3
+200	20·0
−200	39·5
	100·0

Screen Test Amalgamation Tailing:

Mesh	Weight, per cent
+ 65	1·2
+100	4·8
+150	8·4
+200	18·9
−200	66·7
	100·0

Summary of Results on Mill Run:

Gold in mill feed	0·50	oz./ton
Gold in classifier overflow	0·133	"
Gold recovered on blankets or retained in grinding circuit	73·40	per cent
Recovery of gold by amalgamation of blanket concentrate, 83·76 per cent of 73·40 per cent	61·48	"
Recovery by cyanidation (classifier overflow and amalgamation tailing)		
=85 per cent of (100−73·4)	22·61	"
=85 per cent of (73·40−61·48)	10·13	"
Overall recovery of gold = 61·48 + 22·61 + 10·13	94·22	"

CONCLUSIONS

Grinding to have a classifier overflow containing around 75 per cent −200 mesh appears to give satisfactory results.

Although straight cyanidation of the ore is satisfactory, there are certain advantages in using some form of equipment such as blankets, jigs, or traps, in closed circuit with the mill and classifier. There are indications of considerable coarse free gold in the ore and its removal before cyanidation will materially lessen the gold burden in the cyanidation circuit.

Ore Dressing and Metallurgical Investigation No. 598

GOLD-SILVER-LEAD ORE FROM THE MARYSVILLE MINING COMPANY, LIMITED, FORT STEELE MINING DIVISION, B.C.

Shipment. A shipment consisting of four bags of ore, weight 200 pounds, was received on October 13, 1934, from the Marysville Mining Company, Limited, Fort Steele mining division, B.C.

The four bags were designated as follows:

M1—From lower tunnel on Dardanelles group.
M2—From upper tunnel on Dardanelles group.
M3—Wellington group, Hellroaring creek.
M4—Wellington group, Hellroaring creek.

The Dardanelles group is on Wild Horse creek, a few miles from Fort Steele. The Wellington group is a few miles west of the village of Marysville.

The samples were submitted by M. E. Davis, president of the company, 83 Yonge Street, Toronto, Ont.

Characteristics of the Ore. The gangue consists chiefly of white quartz and green-to-grey banded carbonate, which forms veins and narrow stringers in the quartz. Tests indicate that much of this carbonate is cerussite ($PbCO_3$) in compact, granular, massive form. Tests further indicate that anglesite ($PbSO_4$) and malachite are also present in considerable amount.

The metallic minerals in the ore are galena, pyrite, covellite, chalcopyrite, and "limonite" in the form of iron oxides staining the quartz.

Galena is by far the most abundant metallic mineral, occurring in granular masses and irregular stringers through the quartz. It shows attack along borders and fractures, where it has been altered to lead carbonate and lead sulphate. These carbonates contain abundant extremely finely divided covellite.

Pyrite occurs as somewhat corroded grains, usually in galena but rarely in the quartz; the amount is small. A few rare tiny grains of chalcopyrite are present in the pyrite.

"Limonite" stains the quartz in some places.

The ore from the Marysville Mining Company consists of the primary assemblage of quartz, pyrite, galena, and a trace of chalcopyrite; and a group of secondary minerals includes covellite, cerussite, anglesite, malachite, and "limonite." The latter group indicates that the ore has suffered rather intense alteration.

No gold was visible in the polished sections and its mode of occurrence was not determined.

Sampling and Assaying. For experimental test work, sample M1 was mixed with M2, and M3 combined with M4. The ore was crushed, sampled, and assayed with the following results:

	Lot No. 1 (M1—M2)	Lot No. 2 (M3—M4)
Gold	0·52 oz./ton	0·30 oz./ton
Silver	3·48 "	2·26 "
Copper	0·26 per cent	1·01 per cent
Lead	12·89 "	12·69 "
Zinc	Trace	0·20 "

Experimental Tests

Test work consisted of table concentration, and tabling followed by flotation of table tailing.

An examination of the oversize product after concentration in a hydraulic classifier indicated the presence of considerable free gold in the form of rounded nuggets and flakes.

Lot No. 1

Test No. 1

A sample of ore, −14 mesh, was run over a laboratory Wilfley table. The products were retained and assayed. Results indicated that the size of the ore was a little too coarse. Details of the test are as follows:

Product	Weight, per cent	Assay				Distribution, per cent			Ratio of concentration
		Oz./ton		Per cent					
		Au	Ag	Cu	Pb	Au	Ag	Pb	
Feed	100·00	0·52	3·48	0·26	12·89	100·00	100·00	100·00	
Concentrate	5·77	2·56	12·08	0·38	60·19	26·70	26·93	29·47	17·33 : 1
Middling	13·37	1·63	10·68	0·85	41·96	39·40	55·17	47·60	
Sand tailing	65·67	0·20	0·62	......	1·02	23·74	15·73	5·68	
Slime	15·19	0·37	5·10	......	13·38	10·16	2·17	17·25	

Screen Test on Sand Tailing:

Mesh	Weight, per cent
+ 20	17·9
+ 28	19·3
+ 35	19·7
+ 48	12·6
+ 65	9·6
+100	8·0
+150	5·4
+200	4·5
−200	3·0
	100·0

Screen Test on Slime:

Mesh	Weight, per cent
+ 65	0·2
+100	0·6
+150	3·1
+200	13·4
−200	82·7
	100·0

Test No. 2

A sample of ore was ground to pass a 35-mesh screen and run over a Wilfley table. The concentrate and middling products were re-run over the table.

Results of the test are tabulated as follows:

Product	Weight, per cent	Assay				Distribution, per cent			Ratio of concentration
		Oz./ton		Per cent					
		Au	Ag	Cu	Pb	Au	Ag	Pb	
Feed	100·00	0·52	3·48	0·26	12·89	100·00	100·00	100·00	
Concentrate	6·59	4·90	17·46	0·89	73·80	60·31	36·99	41·20	15·17 : 1
Sand tailing	60·67	0·21	1·12	0·12	3·94	23·79	21·85	20·25	
Slime	32·74	0·26	3·91	......	13·90	15·90	41·16	38·55	

Screen Test on Sand Tailing:

Mesh	Weight, per cent
+ 48	5·9
+ 65	28·4
+100	26·9
+150	16·5
+200	13·6
−200	8·7
	100·0

TABLING AND FLOTATION

Test No. 3

A charge of ore was ground to pass a 20-mesh screen and then fed to the small Wilfley table. The middling product was re-run. The sand tailing was reground and mixed with the slime and the combined tailing product was floated.

Table Test:

Product	Weight, per cent	Assay			Distribution, per cent			Ratio of concentration
		Oz./ton		Per cent				
		Au	Ag	Pb	Au	Ag	Pb	
Feed	100·00	0·52	3·48	12·89	100·00	100·00	100·00	
Concentrate	8·85	3·06	15·76	76·74	51·12	41·73	54·42	11·3 : 1
Sand tailing	74·61	0·275	1·565	4·62	38·73	34·94	27·62	
Slime	16·54	0·325	4·715	13·55	10·15	23·33	17·96	

Flotation of Table Tailing:

The sand tailing was ground with 4 pounds soda ash per ton.

Reagents to Cell:

Aerofloat No. 31 .... 0·14 lb./ton
Potassium amyl xanthate .... 0·30 "
Pine oil .... 0·05 "

Product	Weight, per cent	Assay			Distribution, per cent			Ratio of concentration
		Oz./ton		Per cent				
		Au	Ag	Pb	Au	Ag	Pb	
Concentrate	5·95	3·14	13·34	45·06	62·34	43·64	50·81	16·81 : 1
Tailing	94·05	0·12	1·09	2·76	37·66	56·36	49·19	

Summary of Recoveries:

	Recovery, per cent		
	Gold	Silver	Lead
Recovery in table concentrate	51·12	41·73	54·42
Recovery by flotation of tailing	30·47	34·15	23·16
Overall recovery	81·59	75·88	77·58

The overall recoveries are low and the final tailing is high in gold. The grade of the lead concentrate is, however, satisfactory.

Test No. 4

This test was a table test similar to No. 3, with additional reagents used in the flotation of the tailing.

Table Test:

Product	Weight, per cent	Assay			Distribution, per cent			Ratio of concentration
		Oz./ton		Per cent				
		Au	Ag	Pb	Au	Ag	Pb	
Feed	100·00	0·52	3·48	12·89	100·00	100·00	100·00	
Concentrate	10·74	2·48	16·45	69·06	57·56	56·56	66·96	9·31 : 1
Tailing	89·26	0·22	1·52	4·10	42·44	43·44	33·04	

Flotation of Table Tailing:

The table tailing and slimes were mixed and reground.

Reagents to Mill:

Sodium sulphide .... 8·0 lb./ton
Soda ash .... 3·0 "

Reagents to Cell:

Soda ash	4·0 lb./ton
Potassium amyl xanthate	0·6 "
Aerofloat No. 31	0·07 "
Pine oil	0·05 "

Product	Weight, per cent	Assay			Distribution, per cent			Ratio of concentration
		Oz./ton		Per cent				
		Au	Ag	Pb	Au	Ag	Pb	
Concentrate	10·63	2·02	8·74	19·84	78·71	54·16	59·29	9·41 : 1
Tailing	89·37	0·065	0·67	1·62	21·29	45·84	40·71	

Summary of Recoveries:

	Recovery, per cent		
	Gold	Silver	Lead
Recovery in table concentrate	57·56	56·56	66·96
Recovery in flotation concentrate	33·40	23·53	19·59
Overall recovery	90·96	80·09	86·55

Lot No. 2

TABLING

Test No. 5

A charge of ore, mixture of samples M3 and M4, size -14 mesh, was tabled on a laboratory Wilfley table. The concentrate and middling product were re-run.

Results:

Products	Weight, per cent	Assay				Distribution, per cent			Ratio of concentration
		Oz./ton		Per cent					
		Au	Ag	Cu	Pb	Au	Ag	Pb	
Feed	100·00	0·30	2·26	1·01	12·69	100·00	100·00	100·00	
Concentrate	3·92	3·77	6·89	0·88	73·23	35·97	10·95	23·60	25·51 : 1
Middling	4·41	1·02	7·23	1·60	61·01	10·95	12·92	22·13	
Sand tailing	79·34	0·25	1·97	0·89	6·40	48·28	63·34	41·75	
Slime	12·33	0·16	2·56	1·72	12·35	4·80	12·79	12·52	

With this size of material, the tailing and slime contain the larger percentage of the metallic minerals. The tests indicate that approximately half the lead in the ore is present largely as cerussite ($PbCO_3$) and anglesite ($PbSO_4$).

TABLING AND FLOTATION

Test No. 6

This was a table test carried out on a sample of Lot 2 ore ground to pass a 20-mesh screen. The table tailing was reground and floated.

Table Test:

Product	Weight, per cent	Assay				Distribution, per cent				Ratio of concentration
		Oz./ton		Per cent						
		Au	Ag	Cu	Pb	Au	Ag	Cu	Pb	
Feed	100·00	0·30	2·26	1·01	12·69	100·00	100·00	100·00	100·0	
Concentrate	6·37	3·82	6·70	1·86	42·50	49·05	17·16	10·76	27·3	15·7 : 1
Tailing	93·63	0·27	2·20	1·05	7·70	50·95	82·84	89·24	72·7	

This ore of the Wellington group claims shows very poor concentration on tables.

Flotation of Table Tailing:

A sample of table tailing was ground with 6 pounds of sodium sulphide per ton and 10 pounds soda ash per ton.

Reagents to Cell:

Aerofloat No. 31	0·14 lb./ton
Potassium amyl xanthate	0·60 "
Pine oil	0·10 "

Product	Weight, per cent	Assay				Distribution, per cent				Ratio of concentration
		Oz./ton		Per cent						
		Au	Ag	Cu	Pb	Au	Ag	Cu	Pb	
Concentrate	6·00	4·37	21·33	3·25	37·50	88·85	57·9	18·56	29·28	16·67 : 1
Tailing	94·00	0·035	0·99	0·91	5·78	11·15	42·1	81·44	70·72	

Summary of Recoveries:

	Recovery, per cent			
	Gold	Silver	Copper	Lead
Recovery in table concentrate	49·05	17·16	5·68	27·30
Recovery in flotation concentrate	45·27	47·96	17·51	21·29
Overall recovery	94·32	65·12	23·19	48·59

The total gold recovery is good, but the silver and lead recoveries are much lower than the ore represented in Lot No. 1.

Lots Nos. 1 and 2

TABLING AND FLOTATION

Test No. 7

In this test equal quantities of Lots Nos. 1 and 2 were mixed and ground to pass a 20-mesh screen. The ore was run over a small Wilfley table as in the preceding tests and the tailing was reground and floated.

Table Test:

Product	Weight, per cent	Assay Oz./ton Au	Assay Oz./ton Ag	Assay Per cent Pb	Distribution, per cent Au	Distribution, per cent Ag	Distribution, per cent Pb	Ratio of concentration
Feed	100·00	0·41	2·87	12·79	100·00	100·00	100·00	
Concentrate	7·85	2·73	12·28	68·08	51·39	37·15	55·39	12·74 : 1
Tailing	92·15	0·22	1·77	4·67	48·61	62·82	44·61	

Flotation of Table Tailing:

The tailing was reground with 6 pounds sodium sulphide per ton and 10 pounds soda ash per ton.

Reagents to Cell:

Potassium amyl xanthate	0·4 lb./ton
Aerofloat No. 31	0·14 "
Pine oil	0·10 "

Product	Weight, per cent	Assay Oz./ton Au	Assay Oz./ton Ag	Assay Per cent Pb	Distribution, per cent Au	Distribution, per cent Ag	Distribution, per cent Pb	Ratio of concentration
Concentrate	7·85	2·56	13·60	22·60	78·42	59·46	24·42	12·74 : 1
Tailing	92·15	0·06	0·79	5·96	21·58	40·54	75·58	

Summary of Recoveries:

	Recovery, per cent Gold	Recovery, per cent Silver	Recovery, per cent Lead
Recovery in table concentrate	51·39	37·15	55·39
Recovery in flotation concentrate	38·12	37·35	10·89
Overall recovery	89·51	74·50	66·28

CONCLUSIONS

The highly altered nature of the mineral constituents of the ore makes the problem of satisfactory concentration a difficult one.

The lead is present as sulphide (galena), carbonate (cerussite), and sulphate (anglesite); the copper is found largely as malachite; and free gold is found as small rounded nuggets and flakes. These conditions of mineralization make a two-stage concentration necessary.

Despite the similarity, mineralogically, of the samples from the Dardanelles and the Wellington groups, their behaviour differed considerably in the concentration tests. Tests conducted on the ore of the Wellington group, while indicating a higher recovery of gold, show a much lower recovery of silver and lead.

Primary grinding to 20-mesh will give a suitable product for the table concentration. The concentrate will contain the bulk of the free gold and the galena. The table sand requires to be reground and the slime thickened. The table tailing, consisting largely of lead carbonate, requires sulphidizing with sodium sulphide prior to flotation.

The copper minerals in the ore are difficult to concentrate.

The results of the experimental tests indicate that a fair grade of lead concentrate can be made by tabling and flotation. This concentrate will contain over 90 per cent of the gold and around 80 per cent of the silver present in the ore.

Ore Dressing and Metallurgical Investigation No. 599

GOLD-COPPER ORE FROM TASHOTA GOLDFIELDS, LIMITED, TASHOTA, ONTARIO

Shipment. A shipment consisting of three lots of ore marked A-1, A-2, and D-2, total weight 1,960 pounds, was received October 4, 1934, from the Tashota Goldfields, Limited, Tashota, Ontario.

Characteristics of the Ore. All the lots were examined in the mineragraphic laboratory and found so similar that they were grouped under a single description.

The gangue consists of fine-textured, greyish white quartz with a considerable amount of dark greenish grey material that is probably altered country rock. A small amount of carbonate occurs as tiny, disseminated grains and irregular stringers.

The metallic minerals present are, in their order of abundance in the polished sections examined, pyrrhotite, pyrite, chalcopyrite, sphalerite, arsenopyrite, native bismuth, and a grey undetermined mineral. Sufficient of this mineral for microchemical or spectrographic analyses could not be collected.

The sulphides occur in a network of rather coarse, irregular stringers. Pyrrhotite, pyrite, and chalcopyrite are the only abundant sulphides, the pyrrhotite and chalcopyrite forming stringers and often containing many small crystals of pyrite; both of these minerals vein the pyrite in some sections. A small portion of the chalcopyrite also occurs as small, disseminated grains.

Sphalerite is quite common, but the amount is small. It usually occurs within pyrite or chalcopyrite, and some grains contain tiny dots of the latter mineral. Arsenopyrite is rare, a few crystals of this mineral being associated with pyrite. Native bismuth is present in small amount as irregular grains in pyrrhotite or chalcopyrite. No native gold was seen in the sections examined and its mode of occurrence is not known.

Experimental Tests

The three lots were sampled and assayed and were found to contain:

Lot No.	Gold, oz./ton	Silver, oz./ton	Copper, per cent
A-1	0·175	0·25	0·43
A-2	0·66	0·41	0·19
D-2	0·65	0·86	0·95

As all three lots were apparently similar, they were mixed and sampled and found to contain:

Gold	0·39 oz./ton
Silver	0·45 "
Copper	0·52 per cent

The ore is identical physically with that examined in 1930 and reported on in Investigations in Ore Dressing and Metallurgy, Mines Branch publication No. 724, report No. 368, pp. 122-129. The present investigation supplements the work done on the previous shipment.

Mill Run No. 1

The ore, crushed to −14 mesh, was fed at the rate of 97 pounds per hour to a rod mill. The mill discharge, 51 per cent−200 mesh, was diluted to 35 per cent solids and passed over a corduroy blanket. The blanket tailing flowed to a classifier, which returned its oversize to the mill. The classifier overflow, 66 per cent−200 mesh with 26 per cent solids, passed to a conditioning tank and thence to the second cell of a bank of ten flotation cells. Cells Nos. 2 and 3 produced a rougher concentrate, which was cleaned in cell No. 1. The cleaner tailing passed to cell No. 2. The concentrate from cells Nos. 4 to 10 was returned to cell No. 2 with the feed.

Reagents to Conditioning Tank:

Soda ash	4·4 lb./ton
Sodium ethyl xanthate	0·14 "
Pine oil	0·06 "

—	Gold, oz./ton	Copper, per cent
Feed	0·425	0·55
Mill discharge	0·46	0·68
Blanket concentrate	14·08	0·68
Blanket tailing	0·32	0·63
Classifier overflow	0·15	0·53
Flotation concentrate	1·25	7·94
Flotation tailing	0·04	0·01

The classifier overflow contained considerably less gold than the blanket tailing. This indicates that the classifier is operating as a trap. Considerable time would elapse before the grinding circuit would be saturated.

Recoveries of Gold:

On blankets	32·9 per cent
Held in mill and classifier	31·8 "
In flotation concentrate	26·8 "
Total	91·5 "

Ratio of Concentration:

Blankets	98·5 : 1
Flotation	11 : 1

Mill Run No. 2

This run is similar to the preceding one. The soda ash to the flotation conditioner was reduced from 4·4 pounds to 2·2 pounds per ton. The blanket concentrate was united with that of the run following.

—	Gold, oz./ton	Copper, per cent
Feed	0·39	0·41
Mill discharge	0·315	0·44
Blanket concentrate, Mill Runs Nos. 2 and 3	60·93	1·60
Blanket tailing	0·30	0·55
Classifier overflow	0·155	0·43
Flotation concentrate	2·15	7·02
Flotation tailing	0·035	trace

Recoveries of Gold:

Held in mill, classifier, and blankets	60·3 per cent
In flotation concentrate	31·0 "
Total	91·3 "

Ratio of Concentration:

Flotation	17·6 : 1

Ninety-eight per cent of the copper is recovered in the flotation concentrate. This product assays 7·02 per cent copper, and 2·15 ounces gold per ton.

The blanket concentrate was reground and barrel-amalgamated, leaving a residue containing 1·01 ounces gold per ton, a recovery of 98·3 per cent.

Mill Run No. 3

The flow-sheet in this run was the same as that in the two preceding ones. The feed was reduced, in order to obtain a finer grind. The following screen analyses show the sizes of the products:

Mesh	Mill discharge, per cent	Classifier overflow, per cent
+ 65	0·2	.....
− 65+100	3·3	2·0
−100+150	10·7	6·7
−150+200	21·5	21·5
−200	64·3	69·8
	100·0	100·0

Reagents to Conditioning Tank:

Soda ash	3·0 lb./ton
Sodium ethyl xanthate	0·2 "
Pine oil	0·08 "

—	Au, oz./ton	Cu, per cent
Feed	0·39	0·49
Mill discharge	0·31	0·48
Blanket concentrate, Mill Runs Nos. 2 and 3	60·93	1·60
Blanket tailing	0·235	0·50
Classifier overflow	0·17	0·53
Flotation concentrate	1·06	4·66
Flotation tailing	0·035	trace

Recoveries of Gold:

In blanket concentrate	19·2 per cent
Retained in grinding circuit	37·2 "
In flotation concentrate	35·9 "
Total	92·3 "

Ratio of Concentration:

Blankets	796 : 1
Flotation	7·6 : 1

Mill Run No. 4

In this run, the blankets were replaced by amalgamation plates. In all other details, the run was similar to Mill Run No. 3.

—	Gold, oz./ton	Copper, per cent
Feed	0·39	0·53
Mill discharge	0·44	0·57
Amalgam tailing	0·23	0·50
Classifier overflow	0·14	0·43
Flotation concentrate	1·25	4·94
Flotation tailing	0·03	trace

Recoveries of Gold:

Held in mill and classifier	10·3 per cent
Amalgam	53·9 "
In flotation concentrate	28·8 "
Total	93·0 "

Ratio of Concentration:

Flotation	12 : 1

Test No. 5

In the preceding tests, the copper concentrate was bulky and low grade. To obtain a flotation tailing low enough in gold to be discarded, it apparently is necessary to remove most of the sulphides. The large amount of pyrrhotite and pyrite in the copper concentrate reduces the copper content.

To note the effect of producing a high-grade copper concentrate on the gold recovery, a sample of the ore was ground in a ball mill with 6·0 pounds lime per ton ore to pass 63 per cent −200 mesh. The pulp was then passed over a corduroy blanket and the tailing dewatered. It was then conditioned 15 minutes with 2·0 pounds lime per ton, 0·10 pound butyl xanthate and 0·08 pound pine oil per ton, and a flotation concentrate was removed.

Results:

Product	Weight, per cent	Assay		Distribution, per cent	
		Au, oz./ton	Cu, per cent	Au	Cu
Feed (cal.)	100·00	0·54	0·49	100·0	100·0
Blanket concentrate	3·16	12·79	....	74·5	....
Blanket tailing	....	0·145	0·47	....	....
Flotation concentrate	2·50	2·69	19·06	12·4	98·1
Flotation tailing	94·34	0·075	0·01	13·1	1·9

Ratio of Concentration:

Blankets .... 31·6 : 1
Flotation .... 40·0 : 1

Flotation recovers 98·1 per cent of the copper in a concentrate assaying 19·06 per cent copper, and 2·69 ounces gold per ton. The flotation tailing, however, contains 0·075 ounce gold per ton.

Cyanide tests were made on this product without further grinding. The flotation tailing, 1 : 3 dilution, with a 2·0 pound KCN solution, was reduced within 24 hours to 0·01 ounce gold per ton, an extraction of 86·7 per cent of the contained gold. Consumption of reagents was reasonable, 1·2 pounds KCN and 5·2 pounds lime per ton of ore. Longer agitation did not reduce the cyanide tailing below 0·01 ounce gold per ton.

SUMMARY AND CONCLUSIONS

The investigation shows that from 50 to 65 per cent of the gold can be recovered on blankets placed between the grinding mill and the classifier. Barrel amalgamation recovers 98 per cent of the gold in this concentrate. Flotation of the blanket tailing to obtain a maximum recovery of gold gives a tailing containing 0·035 ounce per ton. The concentrate, however, is low grade, containing approximately 7 per cent copper and from 1·25 to 2·0 ounces gold per ton.

To produce a copper concentrate of shipping grade, it is necessary to depress part of the pyrrhotite and pyrite with lime. This results in a flotation concentrate, as shown in Test No. 5, containing 19·06 per cent copper and 2·69 ounces gold per ton with a ratio of concentration of 40 : 1.

The tailing contains 0·075 ounce gold per ton, which is readily reduced to 0·01 ounce by cyanidation.

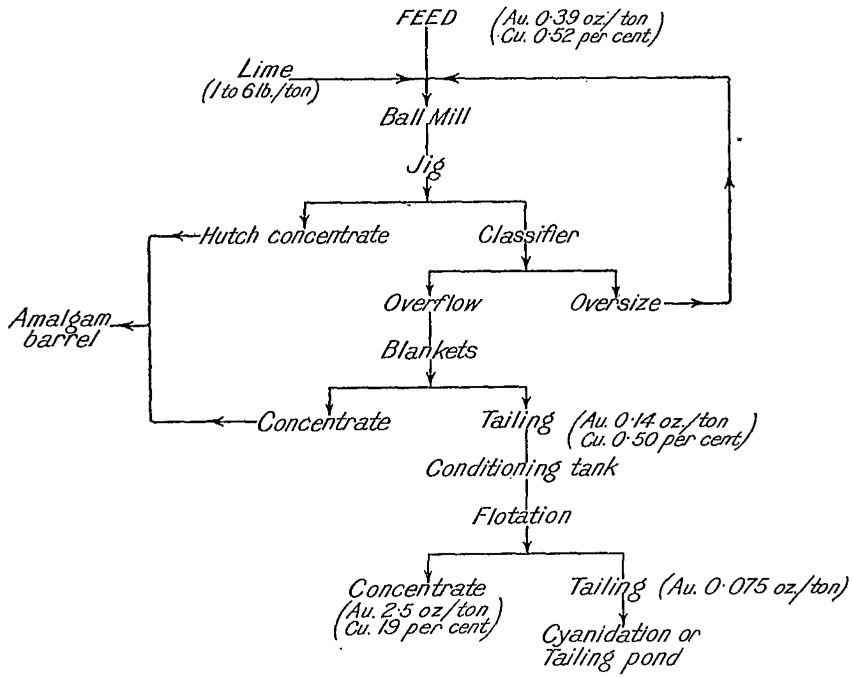


Figure 3. Flow-sheet recommended for treatment of ore from Tashota Goldfields, Ltd.

For a small daily tonnage, the most suitable method of treatment will be blanket and flotation concentration, with removal of coarse gold from the ball mill discharge by a jig of the Harz type. This will remove much of the free gold as a hutch product. The overflow from this jig should pass to a classifier, returning the oversize to the mill for further grinding. The classifier overflow should pass over blankets in order that as much gold as possible be removed from this product before passing to the flotation circuit. The concentrates from the jig and blankets should be barrel-amalgamated. The blanket tailing should be floated to recover a copper concentrate. Particular attention should be paid to obtaining the proper quantity of lime to add to the ball mill, and the most suitable flotation reagent combination to produce a concentrate of shipping grade and a tailing low enough to discard. These factors can only be determined by a study of freight, handling, and smelter costs, and of tailing losses on concentrates of various grades. The small amount of tailing from the amalgamation of jig and blanket concentrates may be mixed with the flotation concentrates for shipment to a reduction plant.

When a larger daily tonnage is treated, a higher grade copper concentrate could be made. This will leave more gold in the flotation tailing, which should be cyanided. This process should be thoroughly investigated. The large proportion of pyrrhotite in the ore, unless rendered more or less inert by some method such as aeration in a high-lime pulp, may give rise to an accumulation of ferrous compounds. These usually result in lower recoveries and loss of cyanide owing to the necessity of periodic wasting of solutions or continuous bleeding.

The above combination, jig, blanket, and flotation concentration followed by cyanidation, should recover 97 per cent of the gold and 98 per cent of the silver.

Ore Dressing and Metallurgical Investigation No. 600

COPPER-GOLD ORE FROM THE SUNSET AND MOTHERLODE MINES, BOUNDARY DISTRICT, B.C.

Shipment. A shipment of 260 pounds of ore was received on October 13, 1934, from the Gold Ridge Mining Syndicate, 626 West Pender Street, Vancouver, B.C. The shipment was said to be from the Sunset and Motherlode mines, in the Boundary district, near Greenwood, B.C. It was in two lots: bag No. 1, Sunset ore; and bag No. 2, Motherlode ore.

Sampling and Assays. Both lots were crushed to 14 mesh and sampled separately, with the following results:

Sunset Ore		*Motherlode Ore*	
Copper	1·11 per cent	Copper	0·84 per cent
Gold	0·06 oz./ton	Gold	0·05 oz./ton
Silver	0·29 "	Silver	0·18 "

Character of the Ore. Four polished sections were prepared from samples of the ore from each lot. These were examined microscopically for the purpose of determining the character of the ore.

Summary of Microscopic Study. The two samples were found to be quite similar in character; abundant massive magnetite, coarse pyrite, chalcopyrite, and a small amount of hematite being common to both samples. In addition to these minerals, the Sunset sample contains rare sphalerite, and an unknown mineral, tentatively identified as electrum (gold-silver alloy).

A comparison of the sections from the two samples indicates that in the Motherlode ore the massive magnetite is somewhat finer and more intimately admixed with gangue than in the Sunset, that the pyrite tends to occur in larger grains and is probably easier to free than in the Sunset, and that the chalcopyrite is probably more intimately admixed with magnetite than in the Sunset. It must be remembered, however, that this comparison is based upon the results of the study of only four polished sections from each sample.

Experimental Tests

The following are the results of the experimental tests made on the ore. The first three tests were made on the separate lots, but all the later tests were made on a mixture of equal amounts of the Motherlode and Sunset materials.

Test No. 1–S (Sunset Ore)

This is a straight flotation test made on 1,000 grammes of the Sunset ore. The sample was ground to the screen sizes given below and then floated in a batch flotation cell of the mechanical type.

Reagents. The following reagents were added and ground with the ore in a ball mill:

Lime.. 1·0 lb./ton ore
Aerofloat No. 25..................................... 0·12 "

The following reagent was added to the flotation cell during flotation:

Pine oil... 0·08 lb./ton ore

The concentrate (rougher) was recleaned, giving a middling product.

Results:

Mesh	Weight, per cent
− 65 + 100	0·3
−100 + 150	3·5
−150 + 200	19·3
−200	76·9
Total	100·0

Product	Weight, per cent	Assay		Distribution of metals, per cent	
		Cu, per cent	Au, oz./ton	Cu	Au
Copper concentrate	4·32	20·90	0·79	78·60	39·29
Middling	5·87	2·66	0·515	13·59	34·79
Tailing	89·81	0·10	0·025	7·81	25·92
Totals	100·00	1·15	0·087	100·00	100·00

Test No. 1–M. (Motherlode Ore)

This is a duplicate of Test No. 1–S, run on the Motherlode ore.

Results:

Screen Test on Ground Ore:

Mesh	Weight, per cent
− 65+100	0·8
−100+150	4·3
−150+200	19·0
−200	75·9
Total	100·0

Product	Weight, per cent	Assay		Distribution of metals, per cent	
		Cu, per cent	Au, oz./ton	Cu	Au
Copper concentrate	4·02	18·24	0·72	80·95	67·21
Middling	8·07	0·94	0·12	8·38	22·56
Tailing	87·91	0·11	0·005	10·67	10·23
Totals	100·00	0·90	0·04	100·00	100·00

Test No. 2–S. (Sunset Ore)

This is a flotation test in which a bulk flotation of all the sulphides was first made. The bulk flotation was then re-treated and a selective flotation of the copper attempted. A 1,000-gramme sample was ground to the screen sizes given below and then floated in a batch flotation cell.

Reagents. The following reagent was added and ground with the ore in a ball mill:

Aerofloat No. 25 .... 0·12 lb./ton

The following reagents were added to the flotation cell for the bulk flotation of the sulphides:

Butyl xanthate .... 0·3 lb./ton
Pine oil .... 0·08 "

Results:

Screen Test on Ground Ore:

Mesh	Weight, per cent
− 65+100	0·3
−100+150	3·5
−150+200	19·3
−200	76·9
Total	100·0

Bulk Flotation of Sulphides:

Product	Weight, per cent	Assay		Distribution of metals, per cent	
		Cu, per cent	Au, oz./ton	Cu	Au
Sulphide concentrate	23·51	4·36	0·035	90·54	95·58
Tailing	76·49	0·14	0·005	9·46	4·42
Totals	100·00	....	....	100·00	100·00

SELECTIVE FLOTATION OF BULK CONCENTRATE

The bulk concentrate was conditioned for 15 minutes with 8 pounds of lime per ton of concentrate and re-floated without the addition of any further reagent. The copper concentrate was recleaned, giving a concentrate, middling, and tailing from the operation.

Summary:

Product	Weight, per cent	Assay		Distribution of metals, per cent	
		Cu, per cent	Au, oz./ton	Cu	Au
Copper concentrate	5·84	13·74	1·07	70·85	72·76
Copper middling	5·40	3·13	0·295	14·92	18·51
Tailing from second operation	12·27	0·44	0·03	4·77	4·31
Primary tailing	76·49	0·14	0·005	9·46	4·42
Totals	100·00	1·13	0·08	100·00	100·00

All the tests following were made on a mixture of the Motherlode and Sunset ores taken in equal portions.

Test No. 3

This test was run under the same conditions as was Test No. 1–S, and with the same quantities and kinds of reagent.

Results:

Product	Weight, per cent	Assay		Distribution of metals, per cent	
		Cu, per cent	Au, oz./ton	Cu	Au
Copper concentrate	5·66	14·90	0·73	87·02	57·04
Copper middling	2·97	2·08	0·28	6·38	11·46
Tailing	91·37	0·07	0·025	6·60	31·50
Totals	100·00	0·97	0·07	100·00	100·00

Test No. 4

This is a flotation test made on 1,000 grammes of the mixed ore.

The sample was ground in a ball mill until 75 per cent of the material would pass a 200-mesh screen.

Reagents: A change was made in the type of reagents. The ore was ground with the following reagents:

Soda ash	1·0 lb./ton
Cyanide	0·10 "
Aerofloat No. 25	0·12 "

Results:

Product	Weight, per cent	Assay		Distribution of metals, per cent	
		Cu, per cent	Au, oz./ton	Cu	Au
Copper concentrate	5·21	14·16	0·46	76·85	54·42
Copper middling	6·03	2·36	0·185	14·82	25·40
Tailing	88·76	0·09	0·01	8·33	20·18
Totals	100·00	0·96	0·04	100·00	100·00

Test No. 5

This is a flotation test made on 2,000 grammes of ore. The ore was ground to the sizes shown in the screen-test table given below. The grinding was done in a larger mill, known hereafter in this report as ball mill No. 2.

Reagents. The following reagents were ground with the ore:

Lime	0·75 lb./ton
Aerofloat No. 25	0·09 "

The following reagent was added direct to the flotation cell:

Aerofloat No. 25	0·06 lb./ton

Results. After flotation, the flotation tailing was run over blankets to catch any free gold not floated.

Screen Test on Ground Ore:

Mesh	Weight, per cent
+ 65	0·05
− 65+100	0·50
−100+150	2·90
−150+200	19·10
−200	77·45
Total	100·00

Product	Weight, per cent	Assay		Distribution of metals, per cent	
		Cu, per cent	Au, oz./ton	Cu	Au
Copper concentrate	5·53	12·94	0·81	71·6	60·5
Blanket concentrate	3·39	....	0·46	....	21·0
Tailing	91·08	0·31	0·015	28·4	18·5
Totals	100·00	0·99	0·07	100·0	100·0

Test No. 6

This flotation test was made on 4,000 grammes of ore ground, 2,000 grammes at a time, in ball mill No. 2. The ore was ground to the same fineness as in Test No. 5.

The tailing from the flotation test was run over a blanket in the hope that additional gold would be recovered.

A change was introduced in this test: the middling obtained from cleaning the copper rougher concentrate was dewatered, reground, and re-floated. The concentrate obtained from this step is shown separately in the table of results. The tailing was mixed with the primary flotation tailing and passed over the blanket.

Reagents. The following reagents were ground in the ball mill with the ore:

Lime	1·2 lb./ton
Aerofloat No. 25	0·12 "
Butyl xanthate	0·04 "

The reground middling was floated with the addition of Aerofloat No. 25 direct to the cell.

Aerofloat No. 25 ....0·02 lb./ton of original ore.

Results:

Product	Weight, per cent	Assay		Distribution of metals, per cent	
		Cu, per cent	Au, oz./ton	Cu	Au
Copper concentrate	9·91	7·56	0·31	78·3	60·2
Concentrate from reground middling	1·53	8·66	0·71	13·9	21·4
Tailing from reground middling	4·20	0·79	0·12	3·4	9·8
Blanket concentrate	1·03	....	0·02	....	....
Tailing	83·33	0·05	0·005	4·4	8·6
Totals	100·00	0·96	0·05	100·0	100·0

Test No. 7

This flotation test was made on 4,000 grammes of ore ground, 2,000 grammes at a time, in a rod mill. The fact of grinding in the rod mill should be noted, as reference will be made to it later in connection with the results of later tests.

The same procedure was followed as in Test No. 6. The primary flotation tailing was mixed with the tailing from the reground middling and assayed and the result reported as one tailing.

Reagents. The reagents were as used in Test No. 6, with the exception that the amount of lime used was increased to 1·5 pounds per ton.

Results:

Product	Weight, per cent	Assay		Distribution of metals, per cent	
		Cu, per cent	Au, oz./ton	Cu	Au
Copper concentrate...............	6·47	11·35	0·42	78·20	58·75
Concentrate from reground middling........................	1·57	6·15	0·46	10·29	15·55
Blanket concentrate.............	1·84	....	0·16	....	6·26
Tailing..........................	90·12	0·12	0·01	11·51	19·44
Totals..............	100·00	0·94	0·05	100·00	100·00
Combined flotation concentrate..	8·04	10·3	0·43	88·49	74·30

Test No. 8

In this test the reagents were changed. Otherwise, the procedure followed was identical with that of Test No. 7. The grinding was done in the rod mill.

Reagents. The following reagents were ground with the ore in the rod mill:

Soda ash...	1·75 lb./ton of ore
Aerofloat No. 25..	0·12 "
Cyanide..	0·12 "

Results:

Product	Weight, per cent	Assay		Distribution of metals, per cent	
		Cu, per cent	Au, oz./ton	Cu	Au
Copper concentrate...............	5·82	15·25	0·55	88·00	74·3
Concentrate from reground middling........................	1·01	3·00	0·55	3·00	13·0
Blanket concentrate..............	2·55	....	0·04	....	2·3
Tailing..........................	90·62	0·10	0·005	9·00	10·4
Totals..............	100·00	1·01	0·04	100·00	100·00
Combined flotation concentrate..	6·83	13·5	0·55	91·00	87·3

Attention is drawn to the improvement in the recoveries obtained with the soda ash-cyanide circuit over those obtained with the lime circuit.

Test No. 9

Lime was used in this test as a reagent and the grinding was done in the rod mill. The ore was ground to the same fineness as in the previous tests.

The procedure in regard to regrinding the middling was the same as in Tests Nos. 6, 7, and 8. The blanket was not used.

Reagents. The following reagents were ground with the ore, in the rod mill:

Lime	2·5 lb./ton (*Note increase.*)
Aerofloat No. 25	0·12 "

The following reagents were added to the mill when regrinding the middling:

Lime	0·25 lb./ton of original ore
Aerofloat No. 25	0·03 " "

Results:

Product	Weight, per cent	Assay		Distribution of metals, per cent	
		Cu, per cent	Au, oz./ton	Cu	Au
Copper concentrate	3·64	20·44	0·60	74·6	48·1
Concentrate from reground middling	1·31	8·72	0·71	11·4	20·5
Tailing from reground middling	3·81	1·23	1·135	4·7	11·3
Tailing	91·24	0·10	0·01	9·2	20·1
Totals	100·00	1·00	0·045	99·9	100·0
Combined flotation concentrate	4·95	17·33	0·63	86·0	68·6

Test No. 10

This test is a return to the bulk flotation principle used in Test No. 2–S. In this test, an attempt was made to float the bulk concentrate containing all the sulphides from a rather coarsely ground product. The bulk concentrate was reground before the flotation of a copper concentrate was attempted.

Screen Test on Ground Ore:

Mesh	Weight, per cent
+ 65	0·5
−65 +100	3·8
−100+150	10·4
−150+200	23·4
−200	61·9
Total	100·0

Reagents. The following reagents were ground with the ore in the rod mill:

Lime	0·5 lb./ton
Aerofloat No. 25	0·12 "
Amyl xanthate	0·04 "

The following reagents were ground with the bulk concentrate:

Lime	1·0 lb./ton of original ore.
Aerofloat No. 25	0·03 " "

Results:

Product	Weight, per cent	Assay		Distribution of metals, per cent	
		Cu, per cent	Au, oz./ton	Cu	Au
Concentrate	3·36	14·76	0·37	51·0	25·6
Tailing from bulk concentrate	10·38	3·08	0·265	33·0	56·7
Primary tailing	86·26	0·18	0·01	16·0	17·7
Totals	100·00	0·97	0·048	100·0	100·0

Tests Nos. 11 to 16

Test No. 11 was made to check the results obtained with the soda-ash-cyanide circuit used in Test No. 7.

In Test No. 7, the ore was ground in a rod mill, but in Test No. 11 ball mill No. 2 was used. The kinds and quantities of the reagents were the same but the pulp, when placed in the flotation machine, could not be floated—a watery, barren froth was obtained with no copper mineral in it. In case some mistake had been made in the reagents, the test was repeated, but the result was the same.

A third test was run, the rod mill being reverted to and used for grinding. The copper was again found to float freely and the results checked with those obtained in Test No. 7.

This condition has been experienced in the milling of heavy sulphide ores at the Eustis, Noranda, and Aldermac mines in the province of Quebec. The laboratory tests on these ores showed no indication of such trouble and it was only when the mill was erected and put into operation that the difficulty was experienced. A careful investigation carried out in the Noranda mill showed that the trouble originated in the grinding mill and that soluble salts having the composition of sulphites were formed which were not found present in the pulp when the ore was ground in the small, laboratory batch mill.

It was found that if oxygen were dissolved in the pulp these sulphites could be oxidized to sulphates and in this more or less stable condition they no longer had a detrimental effect. In other words, the copper would again float freely. The question was how to get the maximum amount of oxygen into solution in the pulp in the shortest possible time. It was found that blowing air through a shallow depth of pulp, such as in passing air up through the pulp in a MacIntosh flotation cell, was not effective. Practically no oxygen was found to be absorbed by the pulp.

Blowing air into the bottom of a deep tank of pulp was then tried, with the idea that more oxygen would be dissolved under the pressure of the high column of pulp. This method was found to be effective, inasmuch as in from 15 to 20 minutes of continuous operation in a 10-foot deep tank the copper again floated freely. This is the system now in operation at Noranda, Eustis, and Aldermac.

The condition described in Test No. 11 is our first experience of its occurrence in laboratory batch testing, and the only explanation that would seem to account for the difference in results obtained in the two types of mills is that in order to grind the same quantity of ore it required only 15 minutes in the ball mill and twice that time, or 30 minutes, in the rod mill. The extra grinding time required in the rod mill allowed time for the replacement of the oxygen consumed in the pulp by oxygen from the air in the mill, so that the sulphites formed were converted into sulphates.

Test No. 17

A sample, 4,000 grammes, of ore was ground for 15 minutes in ball mill No. 2 with the following reagents:

Soda ash	2·0 lb./ton
Cyanide	0·12 "
Aerofloat No. 25	0·08 "

The pulp from the ball mill was placed in a Pachuca tank and agitated with air for 10 minutes. In order to obtain the effect of a deep column of pulp, the tank was operated under a pressure of 20 pounds; 0·03 pound of Aerofloat No. 25 per ton was added to the Pachuca tank.

Results:

Screen Test on Ground Ore:

Mesh	Weight, per cent
+150	3·0
−150+200	31·4
−200	65·6
Total	100·0

Product	Weight, per cent	Assay		Distribution of metals, per cent	
		Cu, per cent	Au, oz./ton	Cu	Au
Copper concentrate	4·01	20·36	0·80	80·6	65·7
Concentrate from reground middling	0·98	7·78	0·76	7·6	15·2
Tailing from reground middling	3·15	1·42	0·15	4·5	9·6
Primary tailing	91·86	0·08	0·005	7·3	9·5
Totals	100·00	1·0	0·049	100·0	100·0
Combined flotation concentrate	4·99	17·7	0·79	88·2	80·9

Particular attention is directed to the greatly increased recovery of the gold. In practice, the tailing from the reground middling would be circulated back to the feed end of the flotation machines and it is conservative to estimate that half of the gold and copper in this product would be recovered in the copper concentrate without lowering its grade.

CONCLUSIONS

A conservative estimate based on the results of the laboratory tests indicates that a copper concentrate assaying 20 per cent copper and 0·80 ounce gold per ton can be obtained from this grade of ore with a recovery of 90·5 per cent of the copper and 85·0 per cent of the gold, provided that the following flow-sheet be used:

Grinding in ball mills to 75 per cent through 200 mesh. Air-conditioning the classifier overflow for 20 minutes in a tank having a minimum depth of 10 feet of pulp. The flow from the conditioner would then go to a bank of mechanical-type flotation machines, where a rougher concentrate of copper would be made. This concentrate should be cleaned and the middling obtained from the cleaning operation should be thickened and reground to have all pass 200 mesh. This reground product should also be air-conditioned and then returned to the head of the flotation circuit with the original feed.

Ore Dressing and Metallurgical Investigation No. 601

GOLD ORE FROM THE RENO GOLD MINES, LIMITED, SALMO, B.C.

Shipment. A shipment of ore consisting of two bags, weight 190 pounds, was received from the Reno Gold Mines, Limited, Salmo, B.C., on November 20, 1934. The sample was submitted by the manager, W. R. Lindsay.

Characteristics of the Ore. The gangue material is principally quartz. The sulphide minerals are mostly galena and sphalerite. Other sulphides occur in minor quantity and pyrrhotite is reported as present in the ore. Free gold is present.

Sampling and Analysis. The shipment was crushed and sampled by standard methods, and a feed sample assayed with the following results:

Gold	0·595 oz./ton
Silver	0·41 "
Lead	0·14 per cent
Zinc	0·50 "

Purpose of Experimental Tests. The object of the tests was to revise the flow-sheet so that the concentrate, after barrel-amalgamation for recovery of free gold, could be turned back into the circuit, if necessary, being subjected to further grinding before cyanidation. The practice provides for the production of a lead table concentrate, which is shipped to a smelter. This concentrate carries 10 per cent of the gold. The table tailing is treated by cyanidation.

Experimental Tests

Test work comprised a table test closely approximating the existing mill practice, with the exception that grinding was carried out in a water circuit and was followed by a number of cyanidation tests on the table products. Pre-aeration of the pulp and direct cyanidation were carried out. The pre-aeration reduced the cyanide consumption appreciably.

Blanket table tests were made and the concentrates were barrel-amalgamated, the combined tailings being cyanided.

The results of the cyanide tests were highly satisfactory, indicating a high recovery and a tailing of from 0·002 to 0·01 ounce per ton. The consumption of reagents was normal.

Test No. 1

A sample of ore (10,000 grammes) ground to minus 20 mesh was fed to a laboratory Wilfley table. The middling product was reground and re-run over the table. Two products were made, viz., a concentrate and a tailing. The latter consisted of both sands and slimes. The concentrate was given a 10-minute grind and barrel-amalgamated with 100 grammes of mercury for 1 hour.

Results of Table Tests:

Product	Weight, per cent	Assay			Distribution, per cent	Ratio of concentration
		Au, oz./ton	Per cent			
			Pb	Zn		
Concentrate.................	7·90	4·91	1·42	3·52	67·8	12·66 : 1
Tailing......................	92·10	0·20	....	....	32·2	

Barrel Amalgamation:

Gold in concentrate.. 4·91 oz./ton
Gold in amalgam tailing.. 1·22 "
Recovery of gold by amalgamation............................... 75·15 per cent
Recovery of total gold by tabling and amalgamation=75·15×67·8=50·95 per cent

CYANIDATION TESTS

Test A

A mixture of amalgamation tailing and table tailing in the proportions resulting from the table test was ground; and the pulp, at a dilution of 3 : 1, was aerated in a Denver agitator with 5 pounds lime per ton of ore for 4 hours.

Screen Test of Product:

Mesh	Weight, per cent
+100..	2·0
−100+150..	8·8
−150+200..	25·9
−200..	63·3
	100·0

Gold in mixed products....................................... 0·325 oz./ton

Two cyanidation tests were carried out on this aerated product, using at the start a solution carrying the equivalent of 1 pound potassium cyanide per ton. Pulp dilution 3 : 1.

Results:

Product	Period of agitation, hours	Assay, Au, oz./ton		Extraction of gold, per cent	Consumption of reagents, lb./ton	
		Feed	Tailing		KCN	Cao
Cyanide tailing.............	24	0·325	0·02	93·85	1·47	3·43
Cyanide tailing..............	48	0·325	0·005	98·46	2·22	3·73

Total consumption of lime:*

24 hours.. 8·43 lb./ton
48 " .... 8·73 "

* These figures are based on the lime used in both the aeration and the cyanidation.

Test B

A mixture similar to that of Test A was used, but the grinding time was increased.

Cyanidation tests were carried out on half of the mixture without any pre-aeration. The remaining half was aerated for 4 hours, as in Test A, prior to cyanidation.

Pre-aeration of the pulp lowers the consumption of cyanide appreciably.

Cyanidation of Raw Ore:

Product	Period of agitation, hours	Assay, Au, oz./ton		Extraction of gold, per cent	Consumption of reagents, lb./ton		Pulp dilution
		Feed	Tailing		KCN	CaO	
Cyanide tailing...	24	0·325	0·005	98·46	2·61	6·95	3 : 1
Cyanide tailing...	48	0·325	0·005	98·46	3·36	7·40	3 : 1

Cyanidation of Aerated Pulp (4-hour aeration):

Cyanide tailing...	24	0·325	0·02	93·85	1·46	4·26*	2·1 : 1
Cyanide tailing...	48	0·325	0·005	98·46	1·55	4·58*	2·1 : 1

* Lime consumed during cyanidation only.

Screen Test on Cyanide Tailings:

Mesh	Weight, per cent
+100..	0·1
−100+150..	2·0
−150+200..	11·9
−200..	86·0
	100·0

A higher tailing was found on the 24-hour agitations on the pre-aerated pulp than in the case of the ore cyanided directly. There is a possibility that aeration may have a slowing-up action on the cyanidation. Agitation for 48 hours, however, gives as low a tailing as does direct cyanidation of the raw ore.

Test C

In this test the mixture of amalgamation and table tailings was ground for a still longer period and the pulp was aerated for 7 hours with 5 pounds lime per ton.

The increased period of aeration apparently removed the retarding influence on the cyanidation observed in the two previous tests for the 24-hour agitation.

Product	Period of agitation, hours	Assay, Au, oz./ton		Extraction of gold, per cent	Reagents consumed, lb./ton		Pulp dilution
		Feed	Tailing		KCN	CaO	
Cyanide tailing.	24	0·325	0·005	98·46	1·57	4·27*	2·6 : 1
Cyanide tailing.	48	0·325	0·002	99·38	1·72	6·25*	2·6 : 1

* Lime consumed during cyanidation only.

Screen Test on Tailings:

Mesh	Weight, per cent
+150	0·6
−150+200	7·3
−200	92·1
	100·0

The total lime consumption would be slightly higher than what is shown in the table, owing to the consumption during aeration.

Test D

In this test a mixture of amalgamation and table tailings in the same proportions as in the previous tests was ground for the same time as in Test C.

Cyanidation tests were made directly on the raw ore. The cyanide strength at the start was equivalent to 1 pound potassium cyanide per ton.

Product	Period of agitation, hours	Assay, Au, oz./ton		Extraction of gold, per cent	Reagents, consumed, lb./ton		Pulp dilution
		Feed	Tailing		KCN	CaO	
Cyanide tailing.	24	0·325	0·01	96·92	2·61	6·90	3 : 1
Cyanide tailing.	48	0·325	0·01	96·92	2·91	6·98	3 : 1

The results of the cyanidation tests indicate that very fine grinding is not essential for a high gold recovery. Pre-aeration of the pulp, in a water circuit, has a definite action in lowering the consumption of cyanide.

Test No. 2

This test was made with the object of comparing blanket concentration with the Wilfley table.

A charge (3,000 grammes) of ore was ground for 30 minutes and the pulp was then run over a corduroy blanket. The results were satisfactory, indicating a possible recovery of over 54 per cent of the gold in a high-grade concentrate.

Blanket Test:

Product	Weight, per cent	Assay, Au, oz./ton	Distribution, per cent	Ratio of concentration
Feed	100·00	....	100·00	
Concentrate	0·23	132·60	54·51	434·7 : 1
Tailing	99·77	0·255	45·49	

Screen Test on Tailing:

Mesh	Weight, per cent
+100	0·1
−100+150	2·2
−150+200	13·6
−200	84·1
	100·0

Test No. 3

This test was a blanket concentration using a larger amount of ore so that sufficient products could be obtained for subsequent cyanidation tests.

A charge (8,000 grammes) of ore was ground for 20 minutes and the pulp then run over a corduroy blanket. The coarser grinding in this test gave a better recovery.

The blanket concentrate was barrel-amalgamated.

The amalgamation tailing and the blanket tailing were mixed and several cyanidation tests were carried out on this product.

Blanket Test:

Product	Weight, per cent	Assay, Au, oz./ton	Distribution, per cent	Ratio of concentration
Feed	100·00	0·595	100·00	
Concentrate	0·78	47·024	61·65	128·2 : 1
Tailing	99·22	0·23	38·35	

Barrel Amalgamation:

Gold in blanket concentrate .... 47·024 oz./ton
Gold in amalgamation tailing .... 6·15 "
Recovery by amalgamation .... 86·92 per cent

Recovery of total gold by blankets and amalgamation:
86·92 × 61·65 .... 53·6 per cent

Screen Test of Blanket Tailing:

Mesh	Weight, per cent
+100	5·1
−100+150	9·8
−150+200	19·7
−200	65·4
	100·0

Test No. 3-A

CYANIDATION TESTS ON TAILINGS OF TEST No. 3

Samples of the amalgamation tailing and the blanket tailing were mixed in the same proportions as the concentrate to tailing in the blanket test. The tailings showed about 65 per cent minus 200 mesh.

These mixed tailings were aerated at a pulp dilution of 3 : 1, with 5 pounds lime per ton, for 7 hours. The gold content of the mixed tailings was 0·276 ounce per ton.

Two cyanidation tests were run on the aerated tailings, one for 24 hours and one for 48 hours. The strength of cyanide solution at the start was equivalent to 1 pound KCN per ton.

Period of agitation	Assay, Au, oz./ton		Extraction of gold, per cent	Reagents consumed, lb./ton		Pulp dilution
	Feed	Tailing		KCN	CaO	
24 hours	0·276	0·03	89·13	0·90	4·25*	3 : 1
48 "	0·276	0·005	98·19	2·13	5·95*	3 : 1

*Lime consumption during cyanidation only.

Recovery of gold by amalgamation .... 53·6 per cent
Recovery of gold by cyanidation:
24-hour agitation: 89·13 × 46·4 .... 41·3 "

Overall recovery .... 94·9 "

Recovery of gold by amalgamation .... 53·6 per cent
Recovery of gold by cyanidation:
48-hour agitation: 98·19 × 46·4 .... 45·5 "

Overall recovery .... 99·1 "

Test No. 3-B

A similar quantity of the tailings was made up as in Test No. 3-A and the material was reground for 10 minutes. A screen test showed 82·7 per cent minus 200 mesh.

One half of the sample was aerated at a pulp dilution of 5 : 1 with 5 pounds lime per ton for 7 hours, following which two cyanidation tests were run.

The other half of the sample was cyanided without any pre-aeration.

Cyanidation Test (Pre-aeration of tailings):

Period of agitation	Assay, Au, oz./ton		Extraction of gold, per cent	Reagents consumed, lb./ton		Pulp dilution
	Feed	Tailing		KCN	CaO	
24 hours	0·276	0·015	94·57	1·41	4·35*	3·27 : 1
48 "	0·276	0·01	96·38	1·91	6·37*	3·24 : 1

*Lime consumption during cyanidation only.

Recovery of gold by amalgamation	53·6 per cent
Recovery of gold by cyanidation:	
24-hour agitation: 94·57 × 46·4	43·88 "
Overall recovery	97·48 "
Recovery of gold by amalgamation	53·6 per cent
Recovery of gold by cyanidation:	
48-hour agitation: 96·38 × 46·4	44·72 "
Overall recovery	98·32 "

Cyanidation Test on Raw Tailings:

Period of agitation	Assay, Au, oz./ton		Extraction of gold, per cent	Reagents consumed, lb./ton		Pulp dilution
	Feed	Tailing		KCN	CaO	
24 hours	0·276	0·04	85·50	2·10	6·55	3 : 1
48 "	0·276	0·01	96·38	3·00	8·25	3 : 1

Recovery of gold by amalgamation	53·6 per cent
Recovery of gold by cyanidation:	
24-hour agitation: 85·5 × 46·4	39·67 "
Overall recovery	93·27 "
Recovery of gold by amalgamation	53·6 per cent
Recovery of gold by cyanidation:	
48-hour agitation: 96·38 × 46·4	44·72 "
Overall recovery	98·32 "

CONCLUSIONS

The results obtained from the test work on the sample of ore submitted indicate that the blanket concentrate, after removal of free gold by amalgamation, could be returned to the circuit and satisfactorily cyanided.

In the tests conducted, 53·6 per cent of the gold in the ore was recovered by amalgamation of the blanket concentrate and from 39·67 to 45·5 per cent was recovered by cyanidation, yielding an overall recovery of 93·27 to 99·1 per cent of the gold in the ore.

Very fine grinding did not appear to be necessary, as 65 per cent minus 200 mesh gave a lower tailing than when the ore was ground to 82 per cent minus 200 mesh.

With grinding carried out in a water circuit, it was found that a pre-aeration of the pulp lowered appreciably the consumption of cyanide. The presence of pyrrhotite in the ore is a contributing factor in the consumption of cyanide, and in a water circuit pre-aeration will overcome or lessen this tendency.

Ore Dressing and Metallurgical Investigation No. 602

GOLD ORE FROM THE POWELL-ROUYN GOLD MINES, LTD.
ROUYN TOWNSHIP, QUEBEC

Shipment. A shipment consisting of 35 bags of gold ore, weighing 2,180 pounds was received November 20, 1934, from Minefinders, Limited, Toronto. This material was said to have come from the quartz vein of the Powell-Rouyn Gold Mines, Ltd., Rouyn township, Quebec.

Characteristics of the Ore. Samples were taken from the shipment and six polished sections prepared and examined microscopically to determine the character of the ore.

The gangue consists chiefly of rusty-brown to greenish grey siliceous rock of fine to medium texture and is obviously chiefly altered country rock. This contains indistinct patches and stringers of light-grey to white quartz. No carbonates were visible.

The metallic minerals present in the ore are: pyrite, "limonite", chalcopyrite, galena, and gold.

Pyrite is present in moderate amount as rather sparingly disseminated, irregular grains and poorly formed cubes. In places it is veined by "limonite", and contains rare grains of chalcopyrite, galena, and gold.

"Limonite" is present chiefly as above, but a small amount occurs in the gangue. It is obviously a product of the weathering of pyrite.

Chalcopyrite and galena are present in very small amounts, especially the latter, of which only a few grains were visible in the sections. The chalcopyrite occurs as small irregular grains in gangue and pyrite, while galena was seen only within pyrite.

Only two grains of native gold were visible in the sections, both of these being present in pyrite. Their grain sizes are 400 and 1100 mesh, respectively.

Since only two grains of gold were seen in six polished surfaces, it may be assumed from experience that the sizes seen do not represent the grain size of the gold in the ore. Further, if the gold were extremely fine, it is probable that a larger number of grains would be visible; therefore, it also may be assumed tentatively that the gold occurs in a grain size mostly coarser than 400 mesh.

Experimental Tests

The entire shipment was crushed to ¼ inch and a sample was cut out by an automatic sampler. This sample was then re-sampled by graded crushing and quartering until a representative portion minus 100 mesh was secured. Analysis showed the shipment to contain 0·23 ounce gold, 0·105 ounce silver per ton, and 80·1 per cent silica.

The investigation included tests by amalgamation, flotation, blanket concentration, and cyanidation. Approximately 45 per cent of the gold is free and can be recovered by amalgamation.

Flotation alone does not recover all the gold, but when the coarser particles are removed by amalgamation or blanket concentration, over 90 per cent recovery is effected. Cyanidation of the ore ground 82 per cent minus 200 mesh extracts 94·8 per cent of the gold.

Test No. 1

A sample was dry-ground to pass 48 mesh with 32·7 per cent minus 200 mesh and amalgamated with mercury in a 1:1 pulp in a porcelain jar mill.

Grind:

Mesh	Per cent
− 48+ 65	6·9
− 65+100	27·7
−100+150	17·6
−150+200	15·1
−200	32·7
	100·0

Results:

Feed	0·23 oz. Au/ton
Amalgamation tailing	0·135 "
Recovery	41·3 per cent

The amalgamation tailing was cyanided for 24 hours with a 1·0 pound KCN per ton solution, 1 : 3 dilution.

Feed	0·135 oz. Au/ton
Cyanide tailing	0·035 "
Extraction	74·1 per cent
Total recovery, amalgamation and cyanidation	84·8 "

Test No. 2

A sample, ground to pass 100 mesh with 56 per cent minus 200 mesh, was treated as in Test No. 1.

Results:

Feed	0·23 oz. Au/ton
Amalgamation tailing	0·115 "
Recovery	50·0 per cent
Cyanide tailing	0·015 oz. Au/ton
Extraction	87·0 per cent
Total recovery, amalgamation and cyanidation	93·5 "

These two tests show that some of the gold is comparatively coarse and is released by coarse grinding. Part of the gold is finer, requiring additional grinding for its liberation.

Test No. 3

Samples of the gold were ground dry to pass different meshes and cyanided, 1 : 3 dilution, with a 1·0 pound per ton cyanide solution. Seven pounds of lime per ton was added for protective alkalinity.

Mesh	Agitation, hours	Assay, Au, oz./ton		Extraction, per cent	Reagents consumed, lb./ton		Grind, per cent				
		Feed	Tailing		KCN	CaO	−48 +65	−65 +100	−100 +150	−150 +200	−200
− 48.....	24	0·23	0·03	87·0	0·3	4·4	6·4	27·4	18·2	14·9	33·1
− 48.....	48	0·23	0·04	82·6	0·3	4·4	......	......	......	......	......
−100.....	24	0·23	0·02	91·4	0·3	4·4	......	......	14·8	28·6	56·6
−100.....	48	0·23	0·022	90·4	0·3	4·9	......	......	......	......	......
−150.....	24	0·23	0·015	93·5	0·3	5·2	......	......	......	17·9	82·1
−150.....	48	0·23	0·012	94·8	0·3	5·3	......	......	......	......	......
−200.....	24	0·23	0·012	94·8	0·3	5·4	......	......	......	......	......
−200.....	48	0·23	0·015	93·5	0·6	6·0	......	......	......	......	......

Test No. 4

A sample ground wet in a jar mill to pass 60 per cent through 200 mesh was passed over a blanket. The concentrate was panned to a small bulk to free it from gangue and the pan tailing was added to the blanket tailing.

Results:

Product	Weight, per cent	Assay, Au, oz./ton	Distribution, per cent
Feed (cal.)...	100·000	0·195	100·0
Blanket concentrate....................................	0·296	28·97	43·9
Blanket tailing..	99·704	0·11	56·1

Ratio of concentration.. 338 : 1

Test No. 5

A sample was ground wet in a porcelain mill containing iron balls until 60·2 per cent passed 200 mesh. It was then floated in a laboratory-size flotation machine.

Reagents:

	To Ball Mill	*To Flotation Cell*
Soda ash..............................	1·5 lb./ton	
Amyl xanthate.........................	0·10 "	
Pine oil..............................		0·08 lb./ton

Results:

Product	Weight, per cent	Assay, Au, oz./ton	Distribution, per cent
Feed (cal.)	100·00	0·207	100·0
Flotation concentrate	2·46	7·21	85·8
Flotation tailing	97·54	0·03	14·2

Test No. 6

The ore, crushed to pass 14 mesh, was fed at the rate of 105 pounds per hour to a rod mill. The mill discharge, diluted to 35 per cent solids, passed over an amalgamation plate and thence into a conditioning tank where 3 pounds soda ash and 0·10 pound amyl xanthate per ton were added. The pulp passed from this tank to the second cell of a 10-cell flotation machine. Cells Nos. 2 and 3 produced a rougher concentrate which was cleaned in Cell No. 1. The cleaner tailing passed to Cell No. 2. Cells Nos. 4 to 10 treated the tailing from Cell No. 3. The concentrate from these seven cells was returned to Cell No. 2 with the feed. Cresylic acid, 0·05 pound per ton, was added to the flotation feed for frothing purposes.

Screen Analysis—Rod Mill Discharge:

Mesh	Per cent
+ 65	4·2
− 65+100	15·1
−100+150	18·9
−150+200	20·3
−200	41·5
	100·0

Assays:

	Au, oz./ton	SiO_2, per cent	As, per cent
Feed	0·26	80·2	....
Amalgamation plate tailing	0·14	....	....
Flotation concentrate	4·11	15·4	Trace
Flotation tailing	0·01	82·3	....

Recoveries:

By amalgamation	46·2 per cent
By flotation	50·1 "
Total	96·3 "

Ratio of flotation concentration .... 31·5 : 1

Test No. 7

This run was made in the same way as was Test No. 6, with the exception that corduroy blankets were substituted for the amalgamation plate.

Screen Analysis of Rod Mill Discharge:

Mesh	Per cent
+ 65	1·1
− 65+100	9·4
−100+150	17·2
−150+200	24·0
−200	48·3
	100·0

Assays:

	Au, oz./ton	Ag, oz./ton	SiO_2, per cent
Feed	0·195	....	80·1
Blanket concentrate	17·135	2·67	74·0
" tailing	0·14	....	....
Flotation concentrate	6·02	5·51	....
" tailing	0·015	....	....

Recoveries:

On blankets	28·5 per cent
In flotation concentrates	63·9 "
Total	92·4 "

Ratio of Concentration:

Blankets	309 : 1
Flotation	48 : 1

A sample of the blanket concentrate was reground 96 per cent minus 200 mesh and barrel-amalgamated.

Results:

Feed	17·135 oz. Au/ton
Tailing	0·74 "
Recovery	96·2 per cent

A sample of the flotation concentrate was reground and cyanided. An extraction of 80 per cent of the gold was obtained.

SUMMARY AND CONCLUSIONS

It is apparent that there is considerable coarse free gold in the ore. When straight cyanidation is used, as in Test No. 3, the grinding must be fine, i.e. 82 per cent minus 200 mesh, to obtain a tailing of 0·015 ounce gold per ton within 24 hours. When the free gold has been removed, as in Test No. 2, cyanidation gives a tailing of 0·015 ounce gold per ton within 24 hours, on material ground 56 per cent minus 200 mesh.

Test No. 5 shows that flotation will not give highest recoveries owing to the coarse free gold. Tests Nos. 6 and 7 show that when this gold has been removed by either amalgamation plates or blankets, flotation will produce a low tailing, 0·01 ounce to 0·015 ounce gold per ton.

Part of the gold in the ore is associated with the pyrite, as only 80 per cent of the gold in the flotation concentrate is recoverable by cyanidation.

The process most suitable for an ore of this nature is cyanidation. It will be found most advantageous to install traps to remove free gold from the ball mill discharge before it enters the agitators. Otherwise, coarse particles of gold that are slow to dissolve will eventually pass into the mill tailing. Blankets may be installed to trap this gold, the concentrate being barrel-amalgamated, and the residues added to the feed to cyanidation.

Removal of this gold prior to agitation will make it feasible to grind somewhat coarsely, approximately 50 to 60 per cent minus 200 mesh, and obtain a high recovery.

Ore Dressing and Metallurgical Investigation No. 603

GOLD ORE FROM THE HUDSON-PATRICIA GOLD MINES, LTD.,
NARROW LAKE, ONTARIO

Shipment. Two shipments of ore were received, Lot A, of 7 bags, on October 26, 1934, and Lot B, of 6 bags, on November 8, 1934. Lot A, weighing 890 pounds, was said to have been taken from an ore-shoot in a quartz vein with basalt wall rock, and Lot B, weighing 590 pounds, came from an ore-shoot in a quartz vein with porphyry walls. Character samples of each ore-shoot also were included for microscopic examination.

Characteristics of the Ore. When received, the bulk samples had been crushed to about $\frac{3}{4}$ inch. The special character samples were examined in the mineragraphic laboratory. Three polished sections from each sample were prepared.

The gangue of *Lot A* consists of very dark green to black, altered country rock with veins of fine-textured, white to transparent quartz. The altered country rock contains considerable finely disseminated carbonate.

The metallic minerals present are: pyrite, pyrrhotite, chalcopyrite, arsenopyrite, ilmenite(?), galena, sphalerite, native gold, and an unknown mineral X.

Pyrite, the most abundant metallic mineral, is disseminated rather sparsely as coarse to fine cubes and irregular grains. A small amount of arsenopyrite is associated with the pyrite. Small amounts of chalcopyrite and sphalerite occur as irregular grains in the quartz, sometimes associated with galena. Galena occurs as small masses and stringers in the quartz and in places veins the pyrite. Ilmenite(?) is present as small grains in the altered country rock, and, in places, has been altered to leucoxene(?). Unknown mineral X occurs only as tiny grains in galena.

Native gold is present in the specimens in considerable amount and is distributed as follows:

In quartz alone	55·5	per cent
In quartz associated with galena	33·4	"
In quartz associated with chalcopyrite	11·1	"
	100·0	"

Lot B is much the same as Lot A, except for the following:

1. There is more country rock and less white quartz in Lot B.

2. The metallic minerals present are: pyrite, sphalerite, galena, chalcopyrite, ilmenite (?), and native gold. No arsenopyrite was observed.

3. The average grain size of the pyrite appears to be somewhat smaller in Lot B.

4. Gold occurs in the pyrite.

5. The grain size of the gold is somewhat smaller in Lot B.

Distribution of Native Gold in Lot B

In quartz alone	34·1 per cent
In pyrite alone, but along fractures	34·4 "
In pyrite, associated with galena along fractures	22·2 "
In sphalerite associated with galena	9·3 "
	100·0 "

Grain Size of the Gold:

Mesh	Lot A, per cent	Lot B, per cent	Average of the two samples, per cent
+ 100	36·4	....	22·0
− 100+ 150	16·7	5·4	12·2
− 150+ 200	8·4	8·1	8·3
− 200+ 280	8·5	9·8	9·0
− 280+ 400	8·1	22·0	13·6
− 400+ 560	8·3	18·0	12·1
− 560+ 800	6·2	15·2	9·8
− 800+1100	3·5	10·4	6·2
−1100+1600	2·6	6·1	4·0
−1600+2300	1·0	4·1	2·3
−2300	0·3	0·9	0·3

Experimental Tests

Both lots were sampled by stage-crushing, grinding, and quartering. Assays showed them to contain:

Lot A

Gold	0·335 oz./ton
Silver	0·13 "

Lot B

Gold	0·13 oz./ton
Silver	0·06 "

Equal weights of each lot were mixed and sampled. This mixture was found to contain 0·28 ounce gold per ton and 0·07 ounce silver per ton. All experimental work was carried out on this lot.

The investigation included tests by amalgamation, flotation, blanket concentration, and cyanidation. The results showed that 70 per cent of the gold is freed at minus 48 mesh grinding, 87 per cent can be recovered by flotation, 56 per cent by blanket concentration, and 98 per cent by cyanidation of 82 per cent minus 200-mesh ore.

Test No. 1

To determine the percentage of free gold in the ore, a sample was ground to pass 48 mesh and amalgamated in a jar mill.

After removing amalgam and mercury, the residue was assayed.

Part of the amalgamation tailing was cyanided, 1: 3 dilution, for 24 hours with a solution of 1·0 pound potassium cyanide per ton.

Grind:

Mesh	Per cent
− 48+ 65	4·0
− 65+100	21·4
−100+150	18·2
−150+200	15·2
−200	41·2
	100·0

Results:

Feed	0·28 oz. Au/ton
Amalgamation tailing	0·085 "
Recovery	69·6 per cent
24-hour cyanide tailing	0·025 oz. Au/ton
Total recovery, amalgamation and cyanidation	91·1 per cent

Test No. 2

A similar test was made on a sample ground to pass 100 mesh with 82 per cent minus 200 mesh.

Results:

Feed	0·28 oz. Au/ton
Amalgamation tailing	0·06 "
Recovery	78·6 per cent
24-hour cyanide tailing	0·005 oz. Au/ton
Total recovery, amalgamation and cyanidation	98·2 per cent

The results of these tests indicate that a large proportion of the gold is free. When the ore is ground 41 per cent minus 200 mesh, part of the gold is still locked up in the gangue, as shown by the cyanide tailing of 0·025 ounce gold per ton. When the ore is ground 82 per cent minus 200 mesh, more gold is released and the cyanide tailing is reduced to 0·005 ounce per ton.

Test No. 3

Samples of the ore were ground dry to pass various meshes and cyanided, 1 : 3 dilution, with a cyanide solution equivalent in strength to 1·0 pound KCN per ton. Eight pounds of lime per ton was added at the commencement to maintain protective alkalinity.

Results of Test No. 3

Mesh	Period of agitation, hours	Assay, Au, oz./ton		Extraction, per cent	Final titration, lb./ton		Reagents consumed, lb./ton		Grind				
		Feed	Tailing		KCN	CaO	KCN	CaO	−48 +65	−65 +100	−100 +150	−150 +200	−200
− 48	24	0·28	0·02	92·8	0·90	0·75	0·3	5·7	4·0	21·4	18·2	15·2	41·2
− 48	48	0·28	0·015	94·6	0·90	0·65	0·3	6·0					
−100	24	0·28	0·01	96·4	0·75	0·4	0·75	6·8			2·5	15·3	82·2
−100	48	0·28	0·005	98·2	0·70	0·3	0·9	7·1					
−150	24	0·28	0·005	98·2	0·75	0·3	0·75	7·1				6·3	93·7
−150	48	0·28	0·005	98·2	0·70	0·2	0·9	7·4					
−200	24	0·28	0·02	92·8	0·75	0·2	0·75	7·4					
−200	48	0·28	0·015	94·6	0·70	0·1	0·9	7·7					

Test No. 4

A sample was ground wet in a porcelain jar mill with 3 pounds soda ash and 0·06 pound Barrett No. 4 per ton until 48·9 per cent passed 200 mesh with 1·8 per cent on 65 mesh. It was then floated with 0·05 pound amyl xanthate and 0·05 pound pine oil per ton.

Results:

Product	Weight, per cent	Assay, Au, oz./ton	Distribution, per cent
Feed (cal.)	100·00	0·26	100·0
Flotation concentrate	3·33	6·74	86·9
Flotation tailing	96·67	0·035	13·1

Test No. 5

A sample was ground to the same fineness as was Test No. 4. The pulp was passed over a corduroy blanket and then conditioned with 3·0 pounds soda ash, 0·05 pound amyl xanthate, and floated with 0·05 pound pine oil per ton.

Results:

Product	Weight, per cent	Assay, Au, oz./ton	Distribution, per cent
Feed (cal.)	100·00	0·26	100·0
Blanket concentrate	2·04	7·24	56·2
Flotation concentrate	2·72	3·18	32·9
Flotation tailing	95·24	0·03	10·9

Test No. 6

A sample was ground wet to pass 83·8 per cent through 200 mesh and was then passed over a corduroy blanket. The tailing was panned until free gold was visible. The tailing from this operation was added to the blanket tailing and the mixture cyanided, 1:3 dilution, with a solution of 1·0 pound potassium cyanide per ton. Seven pounds of lime per ton was added to furnish protective alkalinity.

Results:

Blanket Concentration

Feed	0·28	oz. Au/ton
Blanket tailing	0·13	"
Recovery	53·6	per cent

Cyanidation:

Feed = blanket tailing	0·13	oz. Au/ton
24-hour cyanide tailing	0·005	"
Extraction	96·1	per cen

The gold in the blanket concentrate will be readily recovered by barrel amalgamation. The tailing from this operation should be united with the feed to cyanidation.

SUMMARY AND CONCLUSIONS

1. Over 75 per cent of the gold in the ore is native gold and is freed at ordinary fineness of grinding. Coarse grinding, to approximately minus 48 mesh, liberated 70 per cent.

2. Flotation does not recover all the precious metals owing to the presence of free gold.

3. Cyanidation of the ore ground to pass 80 per cent minus 200 mesh extracts 98 per cent of the gold.

Cyanidation is the method indicated for treatment of this ore. Traps to remove coarse gold from the grinding circuit should be installed, otherwise there is a possibility of free gold lodging in the cyanide agitators or passing out in the tailing. Blankets could be employed for this purpose. This would necessitate handling the concentrate produced, barrel amalgamation, and retorting the amalgam.

No difficulty should be encountered in making a 98 per cent recovery of the gold from ore similar to that sent for test purposes.

Ore Dressing and Metallurgical Investigation No. 604

GOLD-SILVER ORE FROM THE MONASHEE MINES SYNDICATE, LIMITED, VERNON, B.C.

Shipment. The shipment, consisting of two boxes of ore, one high-grade lot weighing 90 pounds, and one low-grade lot weighing 84 pounds, was received on November 23, 1934. The samples were submitted by A. E. Pike, Superintendent, Monashee Mines Syndicate, Limited, Vernon, B.C., on the instructions of Gordon F. Dickson, Managing Director, Pacific Building, Vancouver, B.C. The ore is said to be from the property of the Monashee Mines Syndicate, Limited.

Characteristics of the Ore. Six polished sections were prepared from samples from each lot and these were examined microscopically for the purpose of determining the character of the ore.

The gangue in the *high-grade* ore consists of grey to white fine-textured vein quartz with a moderate amount of siliceous greenish grey material which is regarded as altered country rock. A small amount of carbonate is present as fine veinlets and disseminated grains.

Pyrite is the only *ore mineral* which occurs in relatively large quantity. Small amounts of the following minerals, in order of decreasing abundance, are present in the ore: galena, chalcopyrite, sphalerite, unknown mineral X, pyrrhotite, magnetite, and native gold.

Pyrite occurs as disseminated grains which average above 200 mesh in size. The larger grains are considerably fractured, and contain small grains and veinlets of galena with associated native gold.

Galena is present as irregular grains and stringers in the gangue, and as noted above in pyrite. It contains tiny rounded grains of unknown mineral X, and is closely associated with much of the gold.

Chalcopyrite occurs as irregular masses and stringers usually associated with some sphalerite. The latter mineral contains numerous tiny dots of chalcopyrite, and occurs in the gangue as small masses, irregular grains, and stringers.

Unknown Mineral X occurs only as tiny rounded grains in galena. Its properties indicate the possibility of its being dyscrasite (Ag_3Sb) and, if so, it would account for the silver in the ore. The tests are as follows:

Colour:	Silvery white.
Hardness:	Soft, with appearance of sectility.
Crossed nicols:	Isotropic.
Etch tests:	HNO_3—tarnishes brown without effervescence.
	$FeCl_3$—tarnishes iridescent.
	$HgCl_2$—questionable—tarnishes faint brown (?).
	HCl, KCN, KOH—negative.

Pyrrhotite and magnetite occur as rare, disseminated, irregular grains in the gangue.

Native gold is of rather varied occurrence, and quantitative analyses carried out under the microscope show the following distribution.

			Per cent
A. In pyrite			42·5
1. Alone:		Per cent	
(a) In fractures	12·4		
(b) In dense pyrite	3·0		
		15·4	
2. Associated with galena:			
(a) In fractures	22·2		
(b) In dense pyrite	4·9		
		27·1	
		42·5	
B. In galena			21·7
C. In sphalerite, associated with galena and unknown mineral X			20·0
D. In gangue, associated with galena and pyrite			15·8
			100·0

The associations of the native gold can be summarized as follows:

Total gold associated with pyrite	58·3 per cent
Total gold associated with galena	84·6 "
Total gold along fractures in pyrite	34·6 "
Total gold in dense pyrite	7·9 "

Grain Size of the Gold. The following table shows the grain size of the gold visible in the polished sections:

Mesh	Per cent
− 200+ 280	11·7
− 280+ 400	17·5
− 400+ 560	23·7
− 560+ 800	22·3
− 800+1100	11·8
−1100+1600	7·0
−1600+2300	4·3
−2300	1·7
	100·0

The sample of *low-grade* ore is similar in character to the high grade. However, there was less visible gold and a large proportion of greenish grey country rock, and the grain size of the sulphides, particularly pyrite, appeared to be slightly finer.

Sampling and Analysis. The two lots of ore were sampled separately by standard methods and a representative portion of each was assayed.

Low-grade ore:	Gold	0·06 oz./ton
High-grade ore:	Gold	0·64 oz./ton
	Silver	2·77 "
	Zinc	Nil
	Arsenic	Nil
	Copper	0·16 per cent
	Lead	0·34 "

EXPERIMENTAL TESTS

1. Amalgamation.
2. Straight cyanidation.
3. Blanket concentration followed by flotation.
4. Test No. 3 repeated, using finer grinding.
5. Amalgamation followed by flotation.
6. Amalgamation of blanket concentrate.

The experimental tests were carried out on the high-grade ore only.

AMALGAMATION

Test No. 1

Representative samples of minus 14-mesh ore were dry-crushed minus 48 mesh and minus 100 mesh and amalgamated with mercury in jar mills, dilution 1 : 1 with water. After separating the amalgam and mercury the tailings were assayed.

A screen analysis on each tailing shows the degree of grinding.

Screen Analysis:

Mesh	Minus 48 mesh	Minus 100 mesh
	Weight, per cent	Weight, per cent
− 48+ 65	0·75	....
− 65+100	17·50	....
−100+150	18·75	4·15
−150+200	16·00	15·35
−200	47·00	80·50
	100·00	100·00

Results:

Mesh	Assay, Au, oz./ton		Extraction, per cent
	Feed	Tailing	
− 48	0·64	0·425	33·59
−100	0·64	0·34	46·88

STRAIGHT CYANIDATION

Test No. 2

Representative samples of minus 14-mesh ore were dry-crushed to pass the following screens: 48, 100, 150, and 200 mesh. Representative portions from each were agitated for periods of 24 to 48 hours in a solution of sodium cyanide, equivalent in strength to 1·0 pound of potassium cyanide per ton of solution. The dilution ratio was 3 : 1. Lime was added at the rate of 5·0 pounds of lime per ton of ore to give a protective alkalinity to the solution.

Results:

Mesh No.	Period of agitation, hours	Assay, Au, oz./ton		Extraction, per cent	Reagents consumed, lb./ton	
		Feed	Tailing		KCN	CaO
− 48	24	0·64	0·045	92·97	0·30	3·8
−100	24	0·64	0·02	96·88	0·90	3·7
−150	24	0·64	0·02	96·88	1·20	3·8
−200	24	0·64	0·02	96·88	1·20	4·0
− 48	48	0·64	0·035	94·53	0·30	3·5
−100	48	0·64	0·025	96·09	1·05	4·0
−150	48	0·64	0·015	97·66	1·56	4·1
−200	48	0·64	0·015	97·66	1·56	4·3

Assay of cyanide tailing, for silver, on minus 100 mesh:

24-hour tailing: 0·46 oz./ton.

Recovery of silver: $\frac{(2\cdot77-0\cdot46)}{2\cdot77} \times 100 = 83\cdot39$ per cent

The results of the test show that a good recovery of the gold can be obtained with a moderate grind. No advantage was noted in agitating longer than 24 hours.

A recovery of 83·0 per cent of the silver may be expected.

BLANKET CONCENTRATION FOLLOWED BY FLOTATION

Test No. 3

A representative portion of minus 14-mesh ore was ground in jar mills, dilution 4 : 3, until approximately 60 per cent minus 200-mesh product was obtained.

The pulp was concentrated on a special corduroy blanket on a table sloping 2½ inches in 12 inches. The blanket concentrate was panned to remove gangue and sulphides. Native gold was observed in the pan and also considerable galena and a white metal presumably carrying silver. The blanket tailing was dewatered and treated by flotation, using the following reagents:

Soda ash	3·0 lb./ton
Potassium amyl xanthate	0·1 "
Pine oil	0·05 "

Results:

Blanket Concentration:

Product	Weight, per cent	Assay, oz./ton		Distribution of metals per cent		Ratio of concentration
		Au	Ag	Au	Ag	
Feed	100·00	0·64	2·77	100·00	100·00	
Blanket concentrate	0·13	129·31	161·66	25·76	7·36	769 : 1
Blanket tailing	99·87	0·485	2·65	74·24	92·64	

Flotation:

Feed	100·00	0·47	2·59	100·00	100·00	
Flotation concentrate	3·22	13·40	73·40	91·77	91·39	31 : 1
Flotation tailing	96·78	0·04	0·23	8·23	8·61	

Summary of Results:

	Per cent
Recovery of gold by blankets	25·76
Recovery of gold by flotation, 91·77 × 74·24	68·13
Overall recovery of gold	93·89

The flotation concentrate has, in addition to gold, the following assay values:

Silver	73·4 oz./ton
Copper	3·0 per cent
Lead	10·54 "

BLANKET CONCENTRATION FOLLOWED BY FLOTATION

Test No. 4

The ore was ground to 77·7 per cent minus 200 mesh in this test, which was carried out similarly to Test No. 3. The reagents used to float the blanket tailing were the same.

Results:

Blanket Concentration:

Product	Weight, per cent	Assay, oz./ton		Distribution of metals, per cent		Ratio of concentration
		Au	Ag	Au	Ag	
Feed	100·00	0·64	2·77	100·00	100·00	
Blanket concentrate	0·18	104·3	148·3	29·33	9·64	556 : 1
Blanket tailing	99·82	0·45	2·51	70·67	90·36	

Flotation:

Product	Weight, per cent	Assay Au	Assay Ag	Distribution Au	Distribution Ag	Ratio of concentration
Feed	100·00	0·44	2·53	100·00	100·00	
Flotation concentrates	3·58	11·47	64·73	93·42	91·61	28 : 1
Flotation tailing	96·42	0·03	0·22	6·58	8·39	

Summary of Results:

	Per cent
Recovery of gold by blankets	29·33
Recovery of gold by flotation: 93·42 × 70·67	66·02
Overall recovery of gold	95·35

The flotation concentrate has the following assay values in addition to that for gold:

Silver	64·73 oz./ton
Copper	2·46 per cent
Lead	9·54 "

It will be noted that finer crushing gave a larger amount of concentrates of lower grade than in the previous test. The overall recovery of gold is slightly increased.

AMALGAMATION FOLLOWED BY FLOTATION

Test No. 5

A representative sample of minus 14-mesh ore was ground in jar mills, dilution 4 : 3, to give a product approximately 76 per cent minus 200 mesh.

The ground pulp was amalgamated by passing over an amalgamating table sloping $2\frac{1}{2}$ inches in 12 inches.

The amalgamation tailing was dewatered and treated by flotation, using the following reagents:

Soda ash	3·0 lb./ton
Potassium amyl xanthate	0·1 "
Pine oil	0·05 "

Results:

Amalgamation:

Product	Assay, Au, oz./ton	Distribution of gold, per cent
Feed	0·64	100·00
Amalgamation tailing	0·42	65·63
Amalgam (by difference)	0·22	34·37

Flotation:

Product	Weight, per cent	Assay, oz./ton		Distribution of metals, per cent		Ratio of concentration
		Au	Ag	Au	Ag	
Feed	100·00	0·42	2·76	100·00	100·00	
Flotation concentrate	3·55	10·65	70·08	90·74	90·21	28 : 1
Flotation tailing	96·45	0·04	0·28	9·26	9·79	

Summary of Results:

	Per cent
Recovery of gold by amalgamation	34·37
Recovery of gold by flotation: 90·74 × 65·63	59·55
Overall recovery of gold	93·92

The flotation concentrate gave the following assay values in addition to that for gold:

Silver	70·08 oz./ton
Copper	2·83 per cent
Lead	10·44 "

AMALGAMATION OF BLANKET CONCENTRATE

Test No. 6

A representative sample of minus 14-mesh ore was ground in jar mills to approximately 74 per cent minus 200 mesh and concentrated on special corduroy blankets as in Test No. 3.

The blanket concentrate was treated by grinding in an iron mortar with mercury, at a dilution of 1 : 4 with water. After separating the mercury and amalgam the tailing was assayed.

Results:

Blanket Concentration:

Product	Weight, per cent	Assay, Au, oz./ton	Distribution of gold, per cent	Ratio of concentration
Feed	100·00	0·64	100·00	
Blanket concentrate	0·18	114·33	32·16	556 : 1
Blanket tailing	99·82	0·435	67·84	

Amalgamation:

Product	Assay, Au, oz./ton		Extraction, per cent
	Feed	Tailing	
Blanket concentrate	114·33	9·44	91·74

Overall recovery of gold by amalgamation of the blanket concentrate: 91·74 × 32·16 .... 29·5 per cent.

Treatment of the blanket tailing by flotation, as in Test No. 4, may be expected to give an additional recovery of 66 per cent of the gold.

SUMMARY

1. Recovery of gold by amalgamation was 47 per cent.

2. Cyanidation gave an extraction of 97 per cent of the gold and 83 per cent of the silver, on ore ground to approximately 80 per cent minus 200 mesh. Consumption of reagents was not excessive.

3. Blanket concentration at 60 per cent minus 200 mesh gave a recovery of 26 per cent of the gold. Flotation of blanket tailing gave an overall recovery of 94 per cent of the gold.

4. Grinding to 78 per cent minus 200 mesh, blanketing, and flotation of blanket tailing gave an overall recovery of 95 per cent of the gold.

5. Amalgamation on plates gave a recovery of only 34 per cent of the gold; treatment by flotation of the amalgamation tailing gave an overall recovery of 94 per cent of the gold.

It was observed that from 7 to 9 per cent of the silver was recovered in the blanket concentrates and approximately 90 per cent of the remainder in the flotation concentrates. Copper in the flotation concentrates ranged from 2·5 per cent to 3·0 per cent; lead, from 9·5 to 10·5 per cent; and silver, about 70 ounces per ton.

6. Amalgamation of blanket concentrate shows that from 91 to 92 per cent of the gold can be recovered by barrel amalgamation of the concentrate.

CONCLUSIONS

The ore is amenable to treatment by cyanidation and by flotation.

The results of the investigation show that the ore will cyanide easily to give an extraction of about 96 per cent of the gold and 83·4 per cent of the silver, with an average grind of from 70 to 80 per cent minus 200 mesh. The consumption of reagents is normal—potassium cyanide, 0·9 to 1·2 pounds per ton, and lime, 3 to 4 pounds per ton.

The copper-bearing minerals in the ore will act as cyanicides in a straight cyanidation process.

By the use of blanket concentration a product assaying from 100 to 130 ounces gold per ton was obtained. From this, at least 91 per cent of the gold can be extracted by barrel amalgamation. Flotation of the blanket tailing gives an overall recovery of 94 to 95 per cent of the gold, approximately 90 per cent of the silver, and, in addition, amounts of copper and lead in the flotation concentrate.

The ratio of concentration, 28 to 30 : 1, gives a small bulk of shipping-grade concentrate. The tailing from the barrel amalgamation of the blanket concentrate can be mixed with the flotation concentrate for shipment to the smelter.

The best method of treatment can only be determined after a study of freight, handling, and smelter charges and of tailing losses.

The straight cyanidation process will probably be the best method of treatment, provided that the amount of copper in the ore does not increase more than 0·16 per cent as in the sample submitted for test work.

Ore Dressing and Metallurgical Investigation No. 605

ARSENICAL GOLD ORE FROM THE HEDLEY MASCOT MINE, HEDLEY, BRITISH COLUMBIA

Shipment. A shipment of five sacks of ore, net weight 530 pounds, from the Mascot fraction in the old Nickel Plate mine, Hedley, B.C., was received on October 25, 1934. The sample was submitted by Dr. Victor Dolmage, 1318 Marine Building, Vancouver, B.C., at the request of R. H. Stewart, Consulting Engineer for the Hedley Mascot Gold Mines, Limited, Hedley, B.C.

Characteristics of the Ore. Specimens were selected from the sample shipment and four 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, white carbonate, and light grey quartz.

The metallic minerals visible in polished sections are, in their order of abundance: arsenopyrite, pyrite, pyrrhotite, chalcopyrite, sphalerite, and native gold. Arsenopyrite is abundant as coarse grains and crystalline masses, and is crossed by irregular fractures that contain carbonate, chalcopyrite, and pyrrhotite. Pyrite is present in considerable amount as grains and small masses associated with arsenopyrite, and in rare cases it veins the arsenopyrite; the boundaries between these two minerals appear in many cases to be boundaries of growth of the arsenopyrite, and this, coupled with the former, indicates that pyrite was deposited at a late stage of the arsenopyrite mineralization. Pyrrhotite and chalcopyrite are rare, and are usually found together as irregular grains in gangue and arsenopyrite, and as firm veinlets in the latter. A few tiny grains of sphalerite are present in the chalcopyrite.

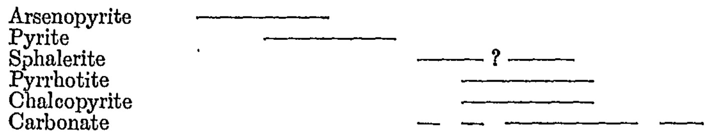
Native gold occurs mostly within dense arsenopyrite, where it is occasionally associated with chalcopyrite. It is extremely fine-grained, and its position appears to be independent of the fracturing of the arsenopyrite. The mode of occurrence of the gold is shown in the table below:

Mode of Occurrence	Gold, per cent	
In arsenopyrite:		
(a) Alone	86·8	
(b) With chalcopyrite	10·5	
		97·3
In gangue		2·7
		100·0

A large number of tiny grains of gold were seen by traversing the four sections with a high-power oil-immersion lens. This indicates that most of the gold is very finely divided, because were coarse gold present in ore of this grade, the probability of the sections cutting so many grains would be very slight. The following table shows the result of a quantitative microscopic grain analysis of the gold:

Size in microns	Theoretical mesh	Gold, per cent
−19 + 13	− 800 + 1,100	3·6
−13 + 9	− 1,100 + 1,600	12·7
− 9 + 6	− 1,600 + 2,300	20·2
− 6 + 4·2	− 2,300 + 3,200	17·2
− 4·2 + 3·0	− 3,200 + 5,000	15·5
− 3·0 + 2·1	− 5,000 + 7,000	14·2
− 2·1 + 1·5	− 7,000 + 10,000	12·1
− 1·5 + 1·0	−10,000 + 14,000	4·9
− 1·0	−14,000	?
		100·0

Although the data are insufficient to determine the *paragenesis*, it nevertheless may be of some value to present in a table what is regarded as the possible succession of deposition. This is shown below:



The important features of the ore from the Hedley Mascot mine are as follows:

(1) Most of the gold occurs in dense arsenopyrite.

(2) A minor proportion of the gold occurs in gangue.

(3) The arsenopyrite is coarse.

(4) The gold is extremely finely divided.

The above facts indicate that:

(*a*) Concentration of the gold by flotation of the arsenopyrite should be relatively easy with comparatively coarse grinding.

(*b*) Recovery of the gold in the arsenopyrite concentrate by means of cyanidation should be comparatively low.

(*c*) Recovery of the gold by cyanidation of the ore as a whole should be comparatively low.

It is probable, also, that the recovery of the finely divided gold in the gangue by cyanidation would be comparatively low.

Sampling and Assaying. Assays of a feed sample of the ore showed it to contain the following:

Gold	0·295 oz./ton
Silver	0·08 "
Copper	0·14 per cent
Lead	Nil
Zinc	0·30 per cent
Arsenic	4·41 "

Experimental Tests

A series of small-scale tests was made on the ore for the purpose of deciding on a suitable method of treatment. The work consisted of concentration and cyanidation tests, both alone and in combination. These tests, and the microscope, show that the gold occurs in an extremely fine state of division and that approximately 87 per cent of it is directly associated with the arsenopyrite.

The highest extraction of gold obtained by straight cyanidation of the ore was 81·7 per cent and this was obtained after grinding the ore 99 per cent through 200 mesh and agitating it in cyanide solution for 48 hours.

Flotation recovered 85 per cent of the gold in an arsenopyrite concentrate assaying 35 to 40 per cent in arsenic and 2·0 ounces or more in gold. This concentrate might be sold to a smelter either before or after cyanidation, or it might be roasted and cyanided on the property. The flotation tailing can be cyanided without further grinding.

The ore may also be cyanided and the cyanide tailing floated, giving a flotation tailing low enough in gold to be discarded. This concentrate also would require roasting and cyaniding unless it were disposed of to a smelter.

CYANIDATION

Tests Nos. 3 to 10

Samples of the ore were ground in ball mills for periods of 20, 30, 40, and 60 minutes, the resulting products being 66·6, 85·5, 92·2, and 99 per cent through 200 mesh, respectively. Samples of each of the above sizes were agitated in cyanide solution, 1·0 pound per ton potassium cyanide, for periods of 24 and 48 hours. The tailings were filtered, washed, and assayed for gold.

Summary of Results:

Test No.	Grinding, per cent −200 mesh	Period of agitation, hours	Tailing assay, Au, oz./ton	Extraction, per cent	Reagents consumed, lb./ton	
					KCN	CaO
3	66·6	24	0·115	61·7	0·8	5·50
4	85·5	24	0·11	63·3	1,34	5·9
5	92·2	24	0·09	70·0	1·2	5·75
6	99·0	24	0·075	75·0	2·0	6·0
7	66·6	48	0·105	65 0	1·50	6·3
8	85·5	48	0·095	68·3	1·60	6·5
9	92·2	48	0·08	73·3	2·10	7·3
10	99·0	48	0·055	81·7	2·50	7·6

Test No. 12

A sample of the ore was ground 99 per cent through 200 mesh in a ball mill and then agitated in a Denver super-agitator without reagents for 6 hours. Lime and cyanide were then added and agitation continued for another 24 hours. The tailing was filtered, washed, and assayed for gold.

Summary—

Feed sample	0·295 Au, oz./ton
Cyanide tailing	0·065 "
Extraction	78·0 per cent
Reagents consumed: KCN	1·07 lb./ton ore
CaO	4·85 "

Test No. 13

A sample of the ore was ground 99 per cent through 200 mesh and aerated in a Denver super-agitator for 16 hours. The pulp was then transferred to bottles, lime and cyanide added and agitation continued for 72 hours. The tailing was filtered, washed, and assayed for gold.

Summary—

Feed sample	0·295 Au, oz./ton
Cyanide tailing	0·065 "
Extraction	78·0 per cent
Reagents consumed: KCN	3·13 lb./ton ore
CaO	10·4 "

Test No. 15

A sample of the ore was ground 99 per cent through 200 mesh with lime added at the rate of 20 pounds per ton of ore. The pulp was then aerated for four hours in Denver super-agitators, filtered, and repulped in fresh cyanide solution, and agitation continued for 48 hours.

Summary—

Feed sample	0·295 Au, oz./ton
Cyanide tailing	0·050 "
Extraction	83·0 per cent
Reagents consumed: KCN	1·86 lb./ton
CaO	11·5 "

FLOTATION

Test No. 1

A sample of the ore was ground 66·6 per cent through 200 mesh and floated. The products were assayed for gold and arsenic.

Charge to Ball Mill:

Ore	2,000 grms. at −14 mesh
Water	1,500 c.c.
Soda ash	1·0 lb./ton
Aerofloat No. 31	0·09 "

Reagents to Cell:

Potassium amyl xanthate	0·20 lb./ton
Barrett No. 4	0·09 "
No. 208	0·20 "
Pine oil	0·05 "

When flotation appeared to be finished, copper sulphate was added at the rate of 1·0 pound per ton of ore and a second concentrate was taken off.

Results:

Product	Weight, per cent	Assay		Distribution, per cent	
		Au, oz./ton	As, per cent	Au	As
Concentrate No. 1	12·3	1·56	19·00	60·4	55·5
Concentrate No. 2	5·6	1·66	31·15	29·3	41·4
Tailing	82·1	0·04	0·16	10·3	3·1
Feed (cal.)	100·0	0·32	4·21	100·0	100·0

Test No. 2

A sample of the ore was ground 85·5 per cent through 200 mesh and floated. The products were assayed for gold and arsenic.

Charge to Ball Mill:

Ore	2,000 grms. at −14 mesh
Water	1,500 c.c.
Soda ash	1·0 lb./ton
Aerofloat No. 31	0·09 "

Reagents to Mill:

Potassium amyl xanthate	0·10 lb./ton
Copper sulphate	1·0 "
No. 208	0·10 "
Pine oil	0·05 "

Results:

Product	Weight, per cent	Assay		Distribution, per cent	
		Au, oz./ton	As, per cent	Au	As
Concentrate	18·2	1·50	23·88	89·3	97·4
Tailing	81·8	0·04	0·14	10·7	2·6
Feed (cal.)	100·0	0·31	4·46	100·0	100·0

FLOTATION WITH CYANIDATION OF CLEANER TAILING AND FLOTATION TAILING

Test No. 17

A sample of the ore was ground 66·6 per cent through 200 mesh and floated in a soda ash circuit. The bulk concentrate thus obtained was filtered and reconditioned with lime and put through a cleaning cell, where a high-grade arsenopyrite concentrate was floated away from other sulphides such as pyrite and chalcopyrite. The cleaner tailing was then reground all through 325 mesh and cyanided. Samples of the flotation tailing were cyanided separately with and without regrinding.

Charge to Ball Mill:

Ore	2,000 grms. at −14 mesh
Water	1,500 c.c.
Aerofloat No. 31	0·09 lb./ton

Reagents to Cell:

Potassium amyl xanthate	0·20 lb./ton ore
No. 208	0·10 "
Copper sulphate	1·0 "
Pine oil	0·05 "
Soda ash	1·0 "

Reagents to Cleaner Cell:

Lime	0·67 lb./ton
Potassium amyl xanthate	0·33 "
Pine oil	0·008 "

Results:

Product	Weight, per cent	Assay		Distribution, per cent	
		Au, oz./ton	As, per cent	Au	As
Arsenopyrite concentrate	10·7	2·18	33·22	82·3	88·4
Cleaner tailing	4·6	0·17	2·02	2·8	2·3
Flotation tailing	84·7	0·05	0·44	14·9	9·3
Feed (cal.)	100·0	0·283	4·02	100·0	100·0

Cyanidation of Products:

Cleaner Tailing, all through 325 Mesh:

Feed sample	0·17 Au, oz./ton
48-hour cyanide tailing	0·02 "
Extraction	88·2 per cent
Extraction, per cent total gold, (0·882 × 2·8)	2·5 per cent

Flotation Tailing, 24-hour Agitation:

Feed sample	0·05 Au, oz./ton
No regrind	0·025 "
92 per cent through 200 mesh	0·015 "
All through 200 mesh	0·015 "
Maximum extraction	70·0 per cent
Maximum extraction, per cent total, 0·700 × 14·9	10·4 per cent

Total Recovery:

In arsenopyrite concentrate	82·3 per cent
As bullion, 2·5 + 10·4	12·9 "
Total	95·2 "

Test No. 18

A sample of the ore was ground 85·5 per cent through 200 mesh and a bulk concentrate floated off in a soda ash circuit. This concentrate was filtered and reconditioned with lime, and a clean arsenopyrite concentrate was removed free from other sulphides such as pyrite and chalcopyrite. Samples of the cleaner tailing and flotation tailing were cyanided with and without regrinding, and the arsenopyrite concentrate was roasted down to 8·1 per cent arsenic and then cyanided with and without regrinding.

Charge to Ball Mill:

Ore	2,000 grms. at −14 mesh
Water	1,500 c.c.
Aerofloat No. 31	0·09 lb./ton

Reagents to Cell:

Potassium amyl xanthate	0·20 lb./ton ore
Copper sulphate	1·0 "
No. 208	0·10 "
Pine oil	0·05 "
Soda ash	1·0 "

Reagents to Cleaning Cell:

Lime	0·75 lb./ton ore
Potassium amyl xanthate	0·25 "
Pine oil	0·006 "

Results:

Product	Weight, per cent	Assay		Distribution, per cent	
		Au, oz./ton	As, per cent	Au	As
Arsenopyrite concentrate	10·8	2·45	39·13	86·6	91·96
Cleaner tailing	7·7	0·16	0·03	4·1	0·06
Flotation tailing	81·5	0·035	0·45	9·3	7·98
Feed (cal.)	100·0	0·305	4·60	100·0	100·00

Cyanidation of Products:

Product	Feed sample assay, Au, oz./ton	Cyanide tailing assay, Au, oz./ton	Extraction, per cent	Extraction, per cent of total gold	Reagents consumed, lb./ton product	
					KCN	CaO
Arsenopyrite concentrate roasted to 7·0 per cent arsenic — All through 150 mesh	3·90	0·28	92·8	80·5	....	....
Roasted arsenopyrite concentrate, reground 30 minutes	3·90	0·24	93·7	81·1	....	....
Cleaner tailing, 97·8 per cent through 325 mesh, agitated 24 hours	0·16	0·04	75·0	3·1	6·1	20·4
Cleaner tailing, 99·6 per cent through 325 mesh, agitated 24 hours	0·16	0·025	84·4	3·5	7·8	21·7
Flotation tailing, 84·0 per cent through 200 mesh, agitated 24 hours	0·035	0·015	57·1	5·3	0·7	6·0
Flotation tailing, 96·0 per cent through 200 mesh, agitated 24 hours	0·035	0·015	57·1	5·3	0·8	6·5

Total maximum recovery as bullion: 81·1 + 3·5 + 5·3............ 89·9 per cent

FLOTATION IN LIME PULP WITH CYANIDATION OF FLOTATION TAILING

Test No. 19

A sample of the ore was ground 85·5 per cent through 200 mesh in a ball mill and floated. The concentrate was cleaned and the cleaner tailing united with the first flotation tailing. Samples of the flotation tailing were cyanided with and without regrinding.

Charge to Ball Mill:

Ore	2,000 grms. at −14 mesh
Water	1,500 c.c.
Lime	3·0 lb./ton ore
Aerofloat No. 31	0·09 "

Reagents to Cell:

Potassium amyl xanthate	0·20 lb./ton ore
No. 208	0·10 "
Copper sulphate	1·0 "
Pine oil	0·05 "

Reagents to Cleaner Cell:

Lime	1·0 lb./ton ore
Potassium amyl xanthate	0·05 "
Pine oil	0·025 "

Results:

Product	Weight, per cent	Assay		Distribution, per cent	
		Au, oz./ton	As, per cent	Au	As
Flotation concentrate	11·9	2·20	30·90	85·6	89·4
Flotation tailing	88·1	0·05	0·51	14·4	10·6
Feed (cal.)	100·0	0·306	4·11	100·0	100·0

Cyanidation of Flotation Tailing:

Product	Flotation tailing assay, Au, oz./ton	Cyanide tailing assay, Au, oz./ton	Extraction, per cent	Extraction, per cent total gold	Reagents consumed, lb./ton tailing	
					KCN	CaO
Flotation tailing, 84 per cent −200 mesh.......	0·05	0·025	50·0	7·2	0·50	6·05
Flotation tailing, 96 per cent −200 mesh.......	0·05	0·01	80·0	11·52	1·90	7·80

Test No. 21

A sample of the ore was ground 85·5 per cent through 200 mesh and floated in lime pulp. The concentrate was not recleaned but was sampled and assayed and a portion of it was ground practically all through 325 mesh and agitated in cyanide solution, 5·0 pounds per ton potassium cyanide, for 48 hours. The cyanide tailing was assayed for gold. The flotation tailing was passed over a small concentrating table to see if the gold in it could be concentrated sufficiently to permit the table tailing to be discarded.

Charge to Ball Mill:

Ore..	2,000 grms. at −14 mesh
Water..	1,500 c.c.
Lime..	3·0 lb./ton ore
Aerofloat No. 31..	0·09 "

Reagents to Cell:

Potassium amyl xanthate..	0·20 lb./ton ore
No. 208..	0·10 "
Copper sulphate..	1·0 "
Pine oil..	0·05 "

Summary:

Table Concentration of Flotation Tailing:

Product	Weight, per cent	Assay		Distribution, per cent	
		Au, oz./ton	As, per cent	Au	As
Table concentrate...............	4·5	0·41	0·98	22·9	12·0
Table sand...............	23·8	0·08	0·19	23·6	12·3
Table slime...............	71·7	0·06	0·39	53·5	75·7
Flotation tailing (cal.)...........	100·0	0·081	0·367	100·0	100·0

Flotation of the Ore:

Product	Weight, per cent	Assay		Distribution, per cent	
		Au, oz./ton	As, per cent	Au	As
Flotation concentrate............	29·0	1·05	14·25	84·2	94·1
Flotation tailing...............	71·0	0·081	0·367	15·8	5·9
Feed (cal.)...............	100·0	0·362	4·41	100·0	100·0

The concentrate reground and cyanided 48 hours produced a tailing assaying 0·135 ounce per ton in gold, representing an extraction of 87·14 per cent of the gold in the concentrate or 73·4 per cent of the total gold in the ore.

Test No. 22

A sample of the ore was ground 85·5 per cent through 200 mesh and floated in a soda ash circuit. The bulk concentrate was sampled and assayed and a portion of it reground practically all through 325 mesh and agitated in cyanide solution, 5·0 pounds per ton potassium cyanide, for 48 hours. The cyanide tailing was assayed for gold. The flotation tailing was passed over a corduroy blanket, set at a slope of 2·5 inches per foot, to see if the gold could be concentrated out of it, permitting the blanket tailing to be discarded. The blanket concentrate and tailing were assayed for gold.

Results:

Product	Weight, per cent	Assay		Distribution, per cent	
		Au, oz./ton	As, per cent	Au	As
Flotation concentrate	18·5	1·34	19·96	79·7	77·0
Blanket concentrate	4·8	0·20	3·50	3·0	3·5
Blanket tailing	76·7	0·07	1·22	17·3	19·5
Feed (cal.)	100·0	0·31	4·79	100·0	100·0

The cyanide tailing from the bulk concentrate, after 48 hours of agitation, assayed 0·145 ounce per ton in gold, representing an extraction of 89·3 per cent of the gold in the concentrate or 71·0 per cent of the total gold in the ore.

CYANIDATION FOLLOWED BY FLOTATION

Test No. 24

A sample of ore was ground 85·5 per cent through 200 mesh and cyanided for 24 hours. The cyanide tailing was floated and the flotation concentrate cleaned to separate the arsenopyrite from the other sulphides. The three products were sampled and assayed and the remainder of the arsenopyrite concentrate was re-united with the remainder of the cleaner tailing. This mixture was roasted down to 12 per cent arsenic and agitated in cyanide solution, 2·0 pounds potassium cyanide per ton, for 24 hours. The cyanide tailing assayed 0·17 ounce per ton in gold, representing an extraction of 82·65 per cent of the gold in the bulk concentrate or 29·8 per cent of the total gold in the ore.

Results:

Product	Weight, per cent	Assay		Distribution, per cent	
		Au, oz./ton	As, per cent	Au	As
Arsenopyrite concentrate	12·8	0·81	39·52	87·4	93·7
Cleaner tailing	3·0	0·075	3·98	1·9	2·4
Flotation tailing	84·2	0·015	0·23	10·7	3·9
Cyanide tailing (cal.)	100·0	0·119	4·98	100·0	100·0

	Per cent total gold
Extraction by cyanidation of ore	59·7
Recovered in bulk concentrate	36·0
Loss in flotation tailing	4·3
Extraction by cyanidation of roasted bulk concentrate	29·8
Loss in cyanide tailing from roasted bulk concentrate	6·2

Total extraction by cyanidation = 59·7 + 29·8 = 89·5 per cent of total gold.

CYANIDATION FOLLOWED BY TABLING

Test No. 11

A sample of the ore was ground 71·0 per cent through 200 mesh and agitated in cyanide solution, 1·0 pound potassium cyanide per ton, for 24 hours. The cyanide tailing was then passed over a small concentrating table and a concentrate was taken off assaying 0·30 ounce per ton in gold and containing 70·7 per cent of the gold in the cyanide tailing. This concentrate was reground practically all through 325 mesh and agitated in cyanide solution, 5·0 pounds potassium cyanide per ton, for 48 hours. Table tailing and cyanide tailing from table concentrate were assayed for gold.

Results:

Product	Weight, per cent	Assay, Au, oz./ton	Extraction, per cent of total gold	Reagents consumed, lb./ton	
				KCN	CaO
Table concentrate cyanided	28·7	0·08			
Table tailing	71·3	0·05			
Average tailing (cal.)	100·0	0·059	80·7	2·20	7·3

ROASTING AND CYANIDATION OF FLOTATION CONCENTRATES

An arsenopyrite concentrate was made which assayed 2·28 ounces per ton in gold and 35·77 per cent arsenic. It contained 85·2 per cent of the gold in the ore and 87·9 per cent of the arsenic. Two tests were made on this concentrate in which it was roasted and then cyanided. In the first test, 400 grammes of the concentrate was roasted down to 283 grammes. This product was sampled and assayed and 250 grammes of it given a second roast with 25 grammes of soda and 25 grammes of charcoal added. The second roasted product weighed 235 grammes and when leached with water the weight was reduced to 223 grammes. The final roasted product contained 8·74 per cent arsenic and cyanided down to 0·19 ounce per ton in gold, representing an extraction of 93·9 per cent of the gold in the concentrate or 80 per cent of the total gold in the ore.

Reagents consumed per ton of raw concentrate were as follows:—

KCN	2·66 pounds
CaO	2·45 "

In the second test, 400 grammes of the concentrate was roasted with 40 grammes of anthracite coal. The roasted product weighed 283 grammes and cyanided down to 0·145 ounce per ton in gold, representing an extraction of 95·5 per cent of the gold in the concentrate or 81·4 per cent of the total gold in the ore.

A sample of a bulk flotation concentrate containing pyrite and chalcopyrite as well as arsenopyrite was roasted at a temperature range of 450° to 530° C. The calcine was then cooled and about 10 per cent of its weight of $Ca(OH)_2$ added to it. After standing overnight, the mixture was diluted, filtered, and washed. It was then ground for one hour in a pebble mill and agitated in cyanide solution, 2·0 pounds per ton potassium cyanide. The cyanide tailing assayed 0·105 ounce per ton in gold, representing an extraction of 93·4 per cent of the gold in the concentrate or 75·4 per cent of the total gold in the ore.

Another lot of bulk concentrate was roasted at 530° to 550° C. with 15 per cent calcium carbonate added. The calcine was ground in a pebble jar for one hour and agitated in cyanide solution, 2·0 pounds per ton potassium cyanide. The cyanide tailing assayed 0·105 ounce per ton in gold, representing an extraction of 92·85 per cent of the gold in the concentrate or 75·1 per cent of the total gold in the ore.

A third sample of bulk concentrate was roasted at 730° to 790° C. The calcine was then reground and cyanided for 24 hours. The calcine assayed 8·00 per cent arsenic and no scheme of roasting has brought the arsenic down below this amount. The cyanide tailing assayed 0·18 ounce per ton in gold, which represents an extraction of 90·0 per cent of the gold in the concentrate or 72·7 per cent of the total gold in the ore.

Reagents consumed were as follows:—

KCN	1·2 lb./ton bulk concentrate
CaO	7·8 " "

Or, in terms of the original ore, the reagents consumed are as follows:—

KCN	0·23 lb./ton ore
CaO	1·5 "

CYANIDATION FOLLOWED BY FLOTATION WITH REGRINDING AND CYANIDATION OF THE BULK CONCENTRATE

Test No. 28

A sample of the ore was ground 85·5 per cent through 200 mesh, agitated in cyanide solution, 1·0 pound per ton potassium cyanide, for 24 hours. The cyanide tailing was filtered and washed and then conditioned with soda ash, 2·0 pounds per ton, for 3 minutes. A bulk concentrate was then floated off with the following reagents:—

Barrett No. 4	0·09 lb./ton
Potassium amyl xanthate	0·10 "
No. 208	0·10 "
Copper sulphate	1·0 "
Pine oil	0·05 "

The concentrate was ground all through 325 mesh and agitated in cyanide solution, 5·0 pounds per ton potassium cyanide, for 48 hours. The tailing was filtered, washed, and assayed for gold, as was also the flotation tailing.

Results:

Product	Weight, per cent	Assay, Au, oz./ton	Extraction, per cent	Reagents consumed, lb./ton ore	
				KCN	CaO
Flotation tailing from cyanide tailing..........................	85·3	0·015			
Cyanide tailing from flotation concentrate....................	14·7	0·27			
Average tailing (cal.)............	100·0	0·052	82·3	5·67	10·0

CONCLUSIONS

Although this ore is not a simple one to treat, comparatively good results were obtained by cyanidation followed by concentration and re-treatment of the concentrate. Flotation of the cyanide tailings is a better method of concentration, so far as small-scale laboratory tests indicate, but a large table, such as would be used in a milling plant, might give better results than the small table used in the test work.

It is possible to float the ore direct and cyanide the products or to cyanide the ore and float the cyanide tailing, in which case the flotation tailing is low enough in gold to be discarded, provided the ore has been ground 85 per cent through 200 mesh.

The treatment of the concentrate, which is high in arsenic, is a matter for further study of three possible methods, namely:—

(1) Concentrate to be sold to a smelter equipped to handle it.

(2) Concentrate to be roasted and cyanided.

(3) Concentrate to be reground all through 325 mesh and cyanided.

The processes for treatment of the concentrate have been named in the order of their efficiency from a purely metallurgical point of view. The one that will provide the greatest net return to the operators will have to be decided upon after a thorough study of costs, freight, and smelter schedules, etc.

Total gold recoveries possible by cyaniding the ore ground 85 per cent through 200 mesh and then concentrating and treating the concentrate by the three methods mentioned, in the order in which they are given, would be approximately 95 per cent, 90 per cent, and 82 per cent.

Ore Dressing and Metallurgical Investigation No. 606

CONCENTRATION OF MICA FROM PRINCE RUPERT, BRITISH COLUMBIA

Shipment. Five bags of mica, shipping weight 300 pounds, were received on August 8, 1934, from Philip M. Ray, Prince Rupert, B.C. The mica had been taken from a deposit on Baker inlet, off Grenville channel, about 25 miles south of Prince Rupert.

Purpose of Experimental Tests. Concentration tests were desired on the mica, and it was requested that the finished products be kept so that they could be submitted to mica users to determine if there might be a demand for them.

H. S. Spence, of the Mineral Resources Division, Mines Branch, co-operated in the test work.

Characteristics of the Shipment. The shipment consisted of mica schist. The mica was in very fine flakes and was white in colour. Magnetite was present, some being embedded in the mica flakes, and there was also a little quartz. Dr. Poitevin, of the Mineralogical Division of the Geological Survey, examined a specimen of the rock and found inclusions even in the finest mica flakes. The mica he identified as altered muscovite.

Experimental Tests

Methods of concentrating the mica included wet tabling, air separation, grinding in different machines and screening, oleic acid and film flotation, and magnetic separation.

The best results were obtained by wet tabling, the next best by air separation. In the grinding and screening tests some gangue remained in the material on top of the screen. Rolls, Raymond pulverizer, Braun pulverizer, and pebble mill were used in these tests. Neither oleic acid nor film flotation gave good results. The magnetic separation tests showed that only in the coarsest size, about −10+28 mesh, could good mica products be made magnetically.

The results of the wet-tabling and air-separation work are given in detail.

WET TABLING

Four wet-tabling tests were made, two small-scale and two large-scale. The best results were obtained by sizing before tabling and the results of only the large-scale test in which this was done are given.

The products from the large-scale table test without sizing were mixed and screened on 26 and 60 mesh by a Hummer vibrating screen. These products had been made from material crushed to −10 mesh by means of a small jaw-crusher and small set of rolls. The screening gave:

−10+26 mesh	66·5 pounds
−26+60 "	87·0 "
−60 "	46·5 "
	200·0 "

Each of the above sizes was tabled on a large Wilfley table, making a concentrate containing most of the magnetite, a middling containing gangue and mica, and a tailing of fairly clean mica. The products, when dried, were as follows:

Product	Lb.	Oz.
−10+26 Table concentrate	12	5
−10+26 " middling	34	10
−10+26 " tailing	18	8
−26+60 " concentrate	5	9
−26+60 " middling	20	13
−26+60 " tailing	59	6
−60 " concentrate	5	11
−60 " middling	10	7
−60 " tailing	25	0
Total	192	5

In the −10+ 26-mesh size the tailing or mica product is 28·3 per cent of the feed, which is not very high. In the −26+60-mesh size the mica product is 69·2 per cent. In the −60-mesh size it is 60·8 per cent. The recoveries for the last two sizes are good and the mica products are fairly free from gangue.

AIR SEPARATION

Eight pounds of −10-mesh material was ground in a Raymond No. 0000 Pulverizer set to give as fine a product as possible. The ground mica was screened on 100 and 200 mesh by means of a No. 7 Rotex screen, giving:

Product	Lb.	Oz.
+100 mesh	1	2
−100+200 "	1	13
−200 "	3	8
Total	6	7

The loss in grinding was 1 pound 9 ounces. In large-scale work there would be very little loss.

The three sizes were run separately through a small 30-inch Gayco air separator, a different setting being used for each size, the coarsest for the +100-mesh, the finest for the −200-mesh, and an intermediate setting for the −100+200-mesh. In the +100-mesh the oversize was re-run three times, giving four fine products. In the −100+200-mesh, the oversize was re-run six times; and in the −200-mesh the oversize was not re-run. After running each size the machine was cleaned, giving a clean-up. These clean-ups were kept separate with the exception of that from the −100+200 which was very small and was put in the oversize.

The products from this work were as follows:

Product	Pounds
+100:	
Run No. 1	0·62
" 2	0·13
" 3	0·08
" 4	0·03
Oversize	0·25
Clean-up	0·01
−100+200:	
Run No. 1	0·97
" 2	0·10
" 3	0·08
" 4	0·07
" 5	0·04
" 6	0·03
" 7	0·02
Oversize	0·33
−200:	
Fines	2·14
Oversize	0·60
Clean-up	0·41

All of the fines are mica products. The first runs in the +100, and −100+200-mesh contain very little gangue. The other fines from these two sizes contain more gangue, the amount increasing from the first run to the last. In the fine from the −200 mesh there is much gangue.

The fine from the +100-mesh is 77·6 per cent of the products from the Gayco, not counting the clean-up, and in the −100+200-mesh size the percentage is 80·1, while in the −200-mesh it is 78·0 per cent.

Another grinding test with the Raymond pulverizer was made, to see whether the mica could be ground to 50 mesh without making so much −200-mesh mica as in the previous test. The regulator was set back 1 inch so that the machine did not grind as fine as possible. The ground mica was screened on a 50-mesh Rotex screen and the oversize returned to the Raymond pulverizer. The Raymond product was screened again and the oversize ground and screened as before, when there remained very little +50 mesh. The −50 mesh was screened on a 200-mesh Rotex screen. This test gave 21·4 per cent of the ground mica −200 mesh. On the previous test the percentage was 54·4. If the mica were ground as in the latter test then more would be recovered in the high-grade form given by the Gayco in the +100 and the −100 +200 sizes, and less in the lower-grade form given by the Gayco in the −200-mesh size.

Mica contains a small amount of water which is driven off when the mica is heated. In order to determine which were the best products from the test work, a number of samples were run for loss on ignition with the following results:

Product	Loss on ignition, per cent
+26 Table tailing	4·22
−26+60 "	4·26
−60 "	4·15
+100 Gayco fines, Run No. 1	4·47
−100+200 " " "	4·51
−200 " " "	3·63

These analyses show the Gayco fines to be better mica products than the table products, except the −200-mesh Gayco fines which are lower in mica than any table product.

Character of the Rock and the Mica. The crude rock contains about 85 to 90 per cent mica. When broken down to natural size with a minimum of crushing it yields various sizes of product ranging from finer than 200 mesh up to 20 mesh. The largest proportion is from 35 to 48 mesh. This shows that the mica in the crude schist is very variable in size. It is easy to crush the rock down to grain size. When the crude rock is crushed in rolls, screened into sizes, and concentrated by tabling, no change is made in shape, colour, or lustre. The various products are all alike in respect to these characteristics.

The mica is hard and tough and it requires as much grinding to reduce it as does ordinary scrap mica. It has ragged outlines, good lustre, and is drab-white in colour with a slight green cast when crushed to grain size.

When the mica is ground in the Raymond pulverizer the edges of the flakes are broken off; the flakes become rounded and lose some of their lustre, which causes them to appear whiter.

When compared with a sample of ground mica used for wall-paper, none of the mica products obtained from the test work appeared so white, but when the wall-paper sample and the finest sizes from both wet and dry concentration were spread on coloured paper and examined so as to reflect light, the appearance of all was about the same.

An inspection under the microscope, made by Mr. Spence, of the products obtained enabled him to draw the following conclusions:

Table tailing, −10+26 mesh " " −26+60 " " " −60 "	Flakes very ragged and irregular in form. Rather thick or fat. Contain some dark inclusions. Medium lustre. Should be satisfactory.
Gayco fine, +100 mesh −100+200 "	Best products. Flakes regular in form—round to oval, with smooth edges. Cream-white colour. Good lustre. Might be suitable for wall-paper trade.
Gayco fine, −200 mesh	Poor drab-grey colour, which seems to be partly due to considerable fine, dirty dust (possibly from machine ?). Would probably be satisfactory for rubber trade.

CONCLUSIONS

The mica could be concentrated by either wet tabling or air separation, as both give good products.

If the wet method were used it would be best to crush to about 26 and size on 60, as the recovery in tabling +26-mesh material was not very high. If this were done about 45 per cent of the feed would be recovered as −26+60-mesh product and about 19 per cent of the feed as −60-mesh product.

If the air separation method were used it would be best to crush with the Raymond pulverizer adjusted so as to give a fair quantity of +50 mesh which would be returned to the grinder. This would give less −200-mesh material, from which the mica product recovered is not so high as from either the −50+100 or the −100+200 mesh. If this method of crushing were used and the air-separator oversizes re-run a few times about 23 per cent of the feed would be recovered as −50+100-mesh product. In the −100+200-mesh size the percentage recovered would be about 39 and in the −200 mesh about 17. If the oversizes were not re-run the percentages would be 17, 29, and 17 for the −50+100, −100+200, and −200 mesh, respectively.

If the dry concentrating method is used the mica will have to be bone dry. A high average humidity of the atmosphere might, also, materially reduce the capacity of air separators.

The objections to wet tabling are that the mica products would have to be dried and that they are not so high in grade as some of those obtained by air separation.

The objections to air separation are the low grade of the −200-mesh product, the fine screening necessary, and the number of times the fines from the air separator must be re-run to get good recoveries.

Everything considered, wet tabling seems to offer the best method of concentrating the mica.

Ore Dressing and Metallurgical Investigation No. 608

SANDBLASTING TESTS MADE WITH CANADIAN SANDS

Purpose of Experimental Tests. During 1933 and 1934 a number of Canadian sands were received for testing as to their suitability for sandblasting. A report on the work done on each sand was sent to the shipper, and the present report summarizes the work up to the end of 1934.[1]

Experimental Tests

The method of testing a sand for use in sandblasting is as follows: Twenty pounds of sand is put into the sand tank of a blasting machine. Air is then admitted and regulated by hand so that a pressure of 80 pounds per square inch is continually registered on a gauge on the air-line that admits air to the top of the sand tank. This gauge shows the pressure in the air-line leading to the blasting nozzle. The cock in the bottom of the sand tank is then opened allowing the sand to flow into a pipe leading to a hose line. In the cock is a small changeable orifice that allows the sand to flow slowly and fairly evenly, and the hose line has a nozzle with a $\frac{1}{4}$-inch opening. The nozzle is held by a clamp at an angle of 45 degrees at a distance of 4 inches from a steel plate resting on a small platform provided with grids. The jet from the nozzle impinges on the plate, which is moved by a hand-operated rod extending outside the cabinet in which the blasting is done; the cabinet catches all the blasted sand except that carried away by the draught from a fan. Most of the dust so carried out is caught by a collector placed before the fan. The time of the run is taken with a stop watch, the plate is weighed before and after blasting, and the sand from the cabinet and collector is screened twice on a 60-mesh Hummer vibrating screen and the sizes weighed. The +60 mesh from the Hummer is made up to 20 pounds and run in the blasting machine again, and the process is continued for several runs. The orifice in the cock is regulated so as to allow the 20 pounds to run out in as near $6\frac{1}{2}$ minutes as possible. Usually no run takes exactly this time, but all runs are plotted and the results for the time desired interpolated.

[1] For previous work on this subject, see "The Suitability of Certain Canadian Sands for Use in Sandblasting," by L. Heber Cole, R. K. Carnochan, and W. E. Brissenden; Investigations of Mineral Resources and the Mining Industry 1931, Mines Branch, Ottawa.

The sands and other products tested were as follows:

1. Sand from Ottawa Silica and Sandstone, Limited, East Templeton, Quebec.
2. Sand from a deposit in Guigues township, Quebec, on the east side of lake Timiskaming.
3. Sand from a deposit near St. Andrews East, Quebec.
4. Sand from the northwest ¼ section 3-26-26 west of the 4th meridian, five miles east of Keoma, on the C.P.R., Alta.
5. Quartz from the Canadian Silica Products, Limited, Chicoutimi, Quebec.
6. Quartz from the Canadian Kaolin Silica Products, Limited, Lac Remi, Quebec.
7. Garnet concentrate, rock, and tailing from the east half of lot 25, range B, Joly township, Labelle county, Quebec, submitted by Eugene McNicoll, 354 St. Catherine Street East, Montreal, Quebec.
8. Garnet concentrate, middling, and tailing from lot 10, range I, Joly township, Labelle county, Quebec, submitted by the International Garnet Syndicate, Reg'd., 2000 McGill College Avenue, Montreal, Que.

Most of the tests were made by moving the nozzle by hand instead of the plate and using a piece of pipe with an opening of $\frac{9}{32}$ of an inch for a nozzle. These tests were not so accurate as those made later with a fixed ¼-inch nozzle and a movable plate. However, the results are given below as after the use of the movable plate was developed, enough material to be tested remained in only four of the shipments.

Sand or product	Steel cut, grammes	Sand consumed, pounds	Grammes cut per pound consumed
East Templeton sand	17·7	9·5	1·86
Témiscamingue sand	17·8	10·4	1·71
St. Andrews sand	19·0	12·0	1·58
Alberta sand	17·6	9·2	1·91
Chicoutimi quartz	22·4	15·4	1·45
Lac Remi quartz	23·8	13·0	1·83
McNicoll garnet rock	20·9	14·0	1·49
" " concentrate	21·9	9·6	2·28
" " tailing	20·3	15·5	1·31

The Alberta sand was tested in five-pound lots and the results multiplied by 4, and the St. Andrews sand in ten-pound lots and results multiplied by 2.

All the above products were sized on a 20-mesh hand screen and 60-mesh Hummer vibrating screen before being used in the tests. This makes possible a fair comparison between any two.

The East Templeton sand has been used extensively for sandblasting and found in actual practice to be very good, so that it can be used as a standard with which to compare the others.

Sandblasters object to dust, and the amount of dust made in blasting seems to be in proportion to the amount of sand consumed. A sand that cuts more, is consumed less, and gives less dust than another sand, is certainly better, but it is difficult to tell which is the better of two sands when one cuts more and is consumed more than the other. A rough method of grading the sand is to divide the grammes cut by the pounds consumed, and this has been done in the above table. Another method is to determine the number of pounds consumed per minute when the number of grammes cut per minute is some definite figure. This method is based on the belief that a fast-cutting sand with a fairly high consumption could be used in practice with a slow feed so as to cut just as fast as a sand with a medium cutting rate and a low consumption. The following table gives the pounds consumed per minute for each sand when cutting 3 grammes per minute.

Sand or product	Pounds consumed per minute
East Templeton sand	1·63
Témiscamingue sand	1·84
St. Andrews sand	1·98
Alberta sand	1·50
Chicoutimi quartz	1·91
Lac Remi quartz	1·60
McNicoll garnet rock	1·99
" " concentrate	1·28
" " tailing	2·26

The consumption per minute is here given to two places of decimals; the last figure is less accurate than the first two, and although of some significance it would be hardly fair to grade a sand above another when there is only a few points difference between them.

The garnet concentrate, owing to its high price, could not be used for sandblasting in general.

The Lac Remi quartz gave a few small white specks on the steel test-piece in one run out of seven. The Témiscamingue sand gave a few small white specks on the test-pieces in all runs.

The results of later tests made with fixed ¼-inch nozzle and movable plate were as follows:

Sand or product	Size	Steel cut, grammes	Sand consumed, pounds	Grammes cut per pound consumed
East Templeton sand—				
No. 4	−10+48	15·8	8·5	1·86
No. 2	−28+65	16·0	10·0	1·60
Témiscamingue sand	−20+60	15·7	10·6	1·48
Lac Remi sand,	−20+60	20·1	12·3	1·63
" " S14A	−10+35	18·9	9·4	2·01
" " S14AG	−10+35	18·6	9·5	1·96
International Garnet Syndicate—				
Garnet concentrate	−10+35	14·4	8·9	1·62
" middling	−10+35	14·8	11·8	1·25
" tailing	−10+35	14·7	14·1	1·04

White specks were found on the test-pieces in some of the runs with Témiscamingue, Lac Remi, and International Garnet Syndicate products.

The following table gives the consumption of sand per minute when each sand is blasted so as to cut 2·75 grammes of steel per minute:

Sand or product	Size	Pounds consumed per minute
East Templeton sand—		
No. 4	−10+48	1·49
No. 2	−28+65	2·02
Témiscamingue sand	−20+60	1·95
Lac Remi sand	−20+60	1·65
" " S14A	−10+35	1·37
" " S14AG	−10+35	1·40
International Garnet Syndicate—		
Garnet concentrate	−10+35	1·87
" middling	−10+35	2·28
" tailing	−10+35	2·61

CONCLUSIONS

The most important properties of a sand that influence its suitability for blasting are those that affect the amount of steel cut and the relative consumption of sand. The cutting of a particular kind of steel in itself is an arbitrary factor, for sandblasting is applied to many materials, but for convenience it is assumed that the behaviour with steel will be similar to that with other materials. The number of pounds of the sand consumed per minute when cutting 2·75 grammes of the steel per minute under uniform pressure and rate of flow, may be termed a measure of the suitability of the sand for sandblasting, and this has been adopted as a provisional standard in the tests described in this report. Uniformity of conditions is attained by using a pressure of 80 pounds per square inch in the air-line, a rate of flow as even as possible, and a set-up described in detail above.

It has been found that by varying the pressure, diverse cutting rates can be obtained from the same sand and that the amount of sand fed per minute is a factor influencing the result largely.

So far as the sands under discussion are concerned, of the two series of tests made the results of the first lend themselves better to direct comparison of the actual sands, because the same size, −20+60 mesh, was used throughout. In the second series the sands are comparable only in regard to the sizes actually tested; these sizes represent commercial products, or products that could be sold in most cases, and comparison can, therefore, be drawn provided price be also taken into consideration.

When cutting 2·75 grammes of steel per minute, East Templeton No. 4 sand is consumed at the rate of 1·49 pounds per minute, No. 2 sand at 2·02 pounds per minute. This difference is due not to quality but solely to the difference in the sizes of the sand. Both these sands are sold for use in blasting; and the Lac Remi sand is also on sale in different sizes, some of which are near to the two sizes tested.

Research on sands used for blasting is still proceeding and has not yet reached the stage when definite standards of quality can be set up. In the present report, results are, therefore, offered rather for general guidance and as illustrating the trend of investigation. Some hold that the cutting power of a sand is more important than its durability, and if this be so more weight should be attached to this property than has been given, but this, as well as other properties, requires further work for confirmation.

INDEX

Canada, mines branch reports.

748, ore dressing investigations, July-Dec., 1934, c. 1.