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by

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EXTRACTION METALLURGY DIVISION

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Mines Branch Investigation Report IR 63-9

INVESTIGATIONS ON A CARBONIFEROUS GOLD ORE  
FROM KERR-ADDISON GOLD MINES LIMITED

by

W.R. Honeywell\* and H. H. McCreedy\*

SUMMARY

A series of laboratory tests was carried out to study the treatment of Kerr-Addison high-carbon gold ore, with the double object of finding a suitable coating reagent to prevent adsorption of gold by some ore constituents, and establishing a process to obtain maximum extraction of the gold.

Of the coating reagents tried, cresylic acid was found to be the most effective in reducing the adsorption of gold by the ore.

A process was developed by which an overall extraction of 86.9 per cent of the gold was obtained. Carbon was removed and discarded by flotation using cresylic acid as the principal collector. A gold-sulphide flotation concentrate was then produced, roasted and cyanided, and the flotation tailings were discarded.

The recovery of the gold in the sulphide concentrate was about 93.5 per cent and the cyanide extraction was in the order of 93 per cent.

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## INTRODUCTION

For some years Kerr-Addison Gold Mines Limited have known that in some sections of their mine, some of the gold-bearing ore has the ability to adsorb soluble gold from the pregnant cyanide solution. This ore often adsorbs as much as twenty-five dollars worth of gold per ton of solids.

Since 1954 various companies and institutions have worked on the problem and it has been found that the gold-adsorbing ore generally has a high content of a black graphite-like constituent, which is believed, however, to be an amorphous carbon compound. These high-carbon ores are often referred to as "active" ores by the mill staff.

The high-carbon ore is becoming more prevalent in the lower zones of the Kerr-Addison mine and consequently, Mr. George Hawkes, Mill Superintendent, requested in letters of February 11 and March 14, 1961, that the Mines Branch try to develop an economical method for successfully treating this ore.

In 1961, Mr. L. Legall, a summer student at the Mines Branch conducted an investigation to isolate some reagents which would decrease the rate of adsorption of gold by the carbon mineral (1). It was presumed that these reagents coated the carbon particles and thus prevented the adsorption of the gold.

Prior to Mr. Legall's investigation, test work had been done at the American Cyanamid Company laboratories which showed that American Cyanamid reagent S3206, when added to the grind, was effective in reducing gold adsorption on Kerr-Addison "active" ore. Both Mr. Legall's and American Cyanamid's work indicated that precoating the "active" ore was an effective method for reducing the amount of gold adsorbed by the "active" ore. However, early in 1962, samples of "active" ore were obtained from the mine which did not respond to the precoating technique. Consequently Mr. Hawkes, in a letter dated April 5, 1962, requested that work be done at the Mines Branch on this more refractory ore. This report covers the test work done in response to this request.

In the present investigation the approach to the problem was as follows:

- (1) a flotation step to remove carbon, the efficiency of which was assessed by comparing the results of gold adsorption tests on both the flotation tailings and the flotation feed;
- (2) a double flotation step to produce a carbon mineral concentrate for discard and a gold-sulphide concentrate for subsequent treatment for gold recovery;

- (3) cyanidation tests, on roasted and unroasted flotation products produced by the above methods, to determine the extraction of gold.

### PROCEDURE

Investigations were done using two samples of Kerr-Addison "active" ore. One sample (our Ref. No. 6/61-6) was a high-carbon ore with a low gold assay. Most of the tests were carried out on a 100 pound sample (our Ref. No. 2/62-2) of minus 1 in. high-carbon ore. Three flotation and cyanidation tests were done on a sample of normal mill feed ore (our Ref. No. 6/62-6) for comparative purposes.

The samples were crushed at the Mines Branch to minus 10 mesh and split into 1150 gram lots to be used as feed for the individual flotation tests.

#### Flotation Procedure

The 1150 gram charge was ground for 25 minutes at 66 per cent solids, giving a product of 65.7 per cent minus 200 mesh. The charge was then floated in a Fagergren laboratory flotation cell at 30 per cent solids. The carbon was floated off with cresylic acid (or other reagent)\* and pine oil, added in three stages. The gold-sulphide concentrate was then floated using Cyanamid 343 as the collector with copper sulphate and Aerofloat 25 as collector-assisting agents. Pine oil was used as frother. As an example, the detailed procedure used in Test K-26 is given below:

<u>Reagents Added</u>	<u>lb/ton</u>
<u>Carbon Float</u>	
Sodium carbonate	0.2
Cresylic acid	1.0
Pine oil	0.08
Conditioned--3 min (pH=9.2)	
Rougher float--4 min	
Cresylic acid	0.25
Pine oil	0.08
Conditioned--3 min	
1st Scavenger float--5 min	

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\* Other reagents used as collectors for the carbon are given in Table 2, Tests K-2 to K-4, and Tests K-12 to K-19.

	<u>lb/ton</u>
Cresylic acid	0.12
Pine oil	0.04
Conditioned--3 min	
2nd Scavenger float--4 min	

The above three floats were combined as the carbon concentrate.

#### Gold-Sulphide Float

Cyanamid 343	0.22
Copper sulphate	0.1
Pine oil	0.04
Aerofloat 25	0.04
Conditioned--6 min (pH=8.6)	
Rougher float--6 min	
Cyanamid 343	0.05
Pine oil	0.08
Aerofloat 25	0.04
Conditioned--3 min	
1st Scavenger float--3 min	

The first scavenger float was repeated and the three floats were combined as the gold-sulphide concentrate.

#### Adsorption Testing Procedure

Most of the adsorption tests were carried out on flotation products (listed as tailings in Table 2) from which carbon had been removed by flotation. For comparative purposes, several adsorption tests were performed on mill feed samples, some of which had been treated with various coating reagents.

The procedure used in the adsorption tests was to contact 50 grams of ore sample with a standardized gold-cyanide solution in the ratio of 5 liquid to 1 solid. The standardized gold-cyanide solution was made with 10 mg per litre of reagent grade powdered gold dissolved in a cyanide-lime solution at pH 11 which contained 0.5 g/l sodium cyanide. The pulp was mechanically agitated for periods of 1 to 48 hours at a controlled temperature of 28°C. In the experiments which were carried on for more than 6 hours, a 25 ml sample of pulp was taken at 6 and 24 hours. The filtrates from these samples were analysed for gold. After sampling, additional sodium cyanide and lime were added to the remaining pulp to bring the solution back to the original reagent concentrations.

In the tests on the mill feed samples, the test sample was contacted with the coating agent under test for periods of 25 to 50 minutes prior to the adsorption test. This was done by pulping the sample with water at 30 per cent solids by weight, adding the coating agent to the pulp, and filtering after the contact period. The filter cake was then used for the adsorption test. In the tests on flotation tailings, the tailings were not treated with coating agent prior to the adsorption test.

### Roasting

In most tests the gold-sulphide concentrate was roasted ahead of cyanidation. The roasting was done in an oxidizing atmosphere in an electric laboratory muffle furnace. The samples were started at 450°F and the furnace was heated to a final temperature of 1200, 1500 or 1600°F over a period of about one hour. The furnace was kept at the final temperature for 10 minutes and then allowed to cool.

### Cyanidation

The roasted concentrates were ground for 1 hour in an Abbé mill, and then cyanided in open beakers at a liquid to solids ratio of 3 to 1, with 1.0 lb NaCN/ton of solution. The pH was held at either 11 or 12 and the contact time was 48, 72 or 96 hours.

## RESULTS

The three samples of Kerr-Addison ore which were used in this investigation were analysed for gold and carbon with results as shown in Table 1.

Mineralogical studies were made on the high-carbon ore and the normal mine ore, and the results of this mineralogical study are given in detail in separate reports (2) (3). In both samples the gold occurred as native gold, primarily as inclusions in grains of pyrite and to a lesser extent in the non-opaque minerals. In the "active" sample, however, thin, black, sub-parallel seams, containing an amorphous carbon compound were abundant in some specimens of the rock. It will also be noted from Table 1, that the elemental carbon content was 25 times as high in the "active", i. e., high-carbon, samples as in the normal mill feed.

TABLE 1  
Analyses of Samples Tested

Analysed for	High-carbon Ore Ref. No. 6/61-6	High-carbon Ore Ref. No. 2/62-2	Normal Mill Feed Ref. No. 6/62-6
Au, oz/ton	0.031	0.58	0.375
Ag, oz/ton	0.015	0.065	0.05
CO <sub>2</sub> (combustion) %	27.2	22.0	15.0
CO <sub>2</sub> (evolution) %	9.82	7.14	14.4
Elemental C (calc) %	5.54	4.05	0.2
Sulphur, %	4.94	6.74	2.44

The first series of tests were done to determine the ability of several organic reagents to reduce the adsorption of gold from a gold-bearing cyanide solution. The results of these tests are given in Table 2.

Adsorption tests on the high-carbon ore samples, without any added reagents, showed that the high grade gold sample (our Ref. No. 2/62-2) adsorbed almost all the gold from the solution in 24 hours which was almost double the amount adsorbed by the low grade gold sample (our Ref. No. 6/61-6) (tests K-1, K-5 and K-6). Since the high grade gold sample was the most active in adsorbing gold from solution, the majority of the subsequent work was done on this sample. The best result on this high grade gold sample without flotation, was obtained with the addition of 1.5 lb cresylic acid per ton solids. Only 12 per cent of the gold in solution was adsorbed by the solids in 24 hours when this addition was made (test K-7). Increasing the conditioning time of the ore pulp with the coating reagents, in an attempt to block off the gold adsorption sites to a greater degree, gave adverse results (tests K-10 and K-11).

The reagents listed in order of decreasing effectiveness, in reducing gold adsorption when flotation was used, are: cresylic acid, Acintol, fuel oil, oleic acid and kerosene. When part of the carbon was removed from the feed by flotation with cresylic acid, the tailing product did not adsorb any gold from solution (test K-12). When kerosene was used in flotation, 19 per cent of the gold in solution was adsorbed by the tailings in 24 hours (test K-19).

TABLE 2

Gold Adsorption Tests

Test No.	Sample and Reagent Used	Product Tested	Total Contact Time (hr)	Au, oz/ton in Solution at				Au Removed in 24 hr (%)
				0 hr	1 hr	6 hr	24 hr	
	<u>Sample 6/61-6</u> (Low grade gold)							
K-1	None	Feed	24	0.34	0.28	0.19	0.16	53
K-2	0.5 lb/ton Acintol	Flot. Tail.	1	0.34	0.34			
K-3	0.5 lb/ton Acintol	"	24	0.34	--	0.32	0.32	6
K-4	0.8 lb/ton fuel oil	"	24	0.36	0.32	0.32	0.29	19
	<u>Sample 2/62-2</u> (High grade gold)							
K-5	None	Feed	24	0.36	--	0.022	0.011	97
K-6	None	"	24	0.36	--	0.018	0.014	96
K-7	1.5 lb/ton cresylic acid (25 min)	"	24	0.34	--	0.33	0.30	12
K-8	1.0 lb/ton fuel oil (25 min)	"	24	0.34	--	0.26	0.26	24
K-9	0.75 lb/ton oleic acid (25 min)	"	24	0.34	--	0.22	0.24	29
K-10	3.0 lb/ton cresylic acid (50 min)	"	24	0.29	--	0.21	0.19	34
K-11	2.0 lb/ton fuel oil (50 min)	"	24	0.29	--	0.20	0.18	38
K-12	1.5 lb/ton cresylic acid	Flot. Tail.	24	0.31	--	0.32	0.31	0
K-13	3.5 lb/ton cresylic acid	"	24	0.34	--	0.38	0.38	0
K-14	1.25 lb/ton Acintol emulsion	"	24	0.34	--	--	0.33	3
K-15	1.0 lb/ton fuel oil	"	48	0.34	--	0.29	0.32*	6*
K-16	1.25 lb/ton oleic acid	"	24	0.36	--	0.32	0.32	11
K-17	1.5 lb/ton oleic acid emulsion	"	24	0.36	--	0.37	0.32	11
K-18	0.75 lb/ton oleic acid in alcohol	"	24	0.36	--	0.32	0.23	36
K-19	1.25 lb/ton kerosene	"	24	0.31	--	0.26	0.25	19

\* 48 hr contact time.

NOTE: In tests on flotation tailings, the coating reagent shown was used as the collector for carbon minerals in flotation step. The procedure used for the carbon float is that shown on Page 2.



It was established by the adsorption tests that cresylic acid appeared to be the most suitable reagent and accordingly in the extraction tests, cresylic acid was used in most tests for floating and coating the carbon. For this work it was decided to float off as much carbon as possible, with a minimum of gold, followed by a gold-sulphide concentrate for cyanidation, the latter concentrate being roasted in some tests. The results of this work are given in Table 3.

Test K-21 was carried out as a flotation test only and this showed that 91.8 per cent of the gold was recovered in the sulphide concentrate. The loss of gold in the carbon concentrate was only 2.6 per cent.

In Test K-20, the roasted sulphide concentrate was combined with the tailings for cyanidation, but the cyanide extraction was not satisfactory. Accordingly, in Tests K-22 to K-27 inclusive, only the gold-sulphide concentrate was cyanided, preceded by roasting.

In Tests K-24 and K-25, fuel oil was used in the carbon float step and the gold extraction was slightly lower than in Test K-23 in which cresylic acid was used in this step.

The conditions used in Test K-26 gave the best extraction. In this test cresylic acid was used for the carbon float and the roasted gold-sulphide concentrate was ground for 1 hour before cyanidation.

It was noted that a large amount of the carbon was reporting in the gold-sulphide concentrate and in the next four tests, K-28 to K-31 inclusive, the gold-sulphide concentrate was subjected to a cleaning step, using 0.1 lb of Cyanamid 633/ton concentrate as carbon depressant. This, however, was unsuccessful in depressing the carbon and extraction was not improved (compare tests C-28, C-29 with C-26).

The cleaned gold-sulphide concentrates in tests K-28 and K-29 were roasted, ground for 1 hour and cyanided while tests K-30 and K-31 were treated similarly except roasting was not used. The two tests in which roasting was employed gave an average cyanide extraction of 3 per cent more than for the tests using unroasted material.

## DISCUSSION

The test work covered in this report confirms the mill staff's observation that precoating ore, similar to the samples used in this investigation, was not effective in maintaining good gold extraction in cyanidation. This can be seen in Table 2, tests K-7 and K-8, where, although precoating



agents were used, at least some gold was absorbed from the starting solutions. The reduction in the gold analyses of the solution not only indicates adsorption of gold from solution, but that none of the gold in the ore sample was extracted by the cyanide present in the starting solution. Therefore if substantial amounts of highly "active" ore should be delivered to the mill a technique more complex than simple precoating would have to be used.

As shown by the results of this test work, removal of some of the carbon by flotation followed by flotation of the sulphides which are then roasted and cyanided would result in about 85 per cent of the gold being extracted from highly "active" ore. The advantages of this approach are that the carbon is either discarded or roasted before it is contacted with cyanide-gold solution, and the sulphide flotation and roasting operation are already part of the existing treatment. One question which the test work reported does not answer is whether the roasting procedure used in the fluid bed roaster at the Kerr-Addison plant would produce the same results as were obtained in the laboratory muffle furnace. Information on this latter point may be available from the manufacturers of the roaster.

## CONCLUSIONS

- (1) The samples submitted varied greatly in their ability to adsorb gold from solution.
- (2) Cresylic acid was the most effective reagent of those tested for reducing the amount of gold adsorbed by the solids from the solution.
- (3) Removal of part of the carbon from the feed by flotation with cresylic acid was the most effective way of preventing gold adsorption by the solids.
- (4) The flotation recovery of the gold in a sulphide concentrate was as much as 93.5 per cent. The gold extraction from the sulphide concentrate by cyanidation after roasting was in the order of 93 per cent, giving an overall gold extraction of 86.9 per cent. In a two-stage process, such as this, it is unlikely that more than 90 per cent extraction can be attained.
- (5) Roasting of the gold-sulphide concentrate before cyanidation gave an increase in extraction of about 5 per cent.

## ACKNOWLEDGMENTS

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