



Size dependent gold deportment in the products of copper flotation and methods to increase gold recovery

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Synopsis

Plant survey data has shown that gold recovery through a specific copper concentrator was significantly lower than copper recovery. Size-by-size analysis revealed that this was due to poor recovery of +75 μm and -23 μm gold containing particles. In order to further investigate the nature of the gold losses, experiments were conducted at laboratory scale. Gold deportment studies on the laboratory flotation products revealed that coarse gold (+75 μm) reporting to the rougher tailing was predominantly associated with non-sulphide gangue. Further grinding of the plant rougher tailing improved recovery of gold and copper, while not affecting iron recovery, due to improved liberation of gold from non-sulphide gangue in coarse size fractions. EDTA extraction to remove surface contaminants showed a similar improvement for fine, liberated gold flotation.

Introduction

Commercial porphyry copper ores usually contain copper grades between 0.5% and 2%¹. Minor amounts of gold are often present in these orebodies². The concentration of gold in the majority of large-scale copper/gold ores is low, typically around 1-2 g/t^{3,4}. Flotation is the principal method of pre-concentration for copper and gold^{5,6}. Thus, porphyry copper ore concentrators are designed with the goal of maximizing copper recovery and grade; however, gold recovery as a by-product is also economically important⁷.

The mineralogy of gold particles is usually quite different from the copper rich particles⁸, affecting their floatability in relation to the copper minerals⁹. Gold-chalcopyrite and gold-chalcocite associations do occur but are not very common. Pyrite is the most prevalent host mineral for gold; however, association with other sulphides such as covellite and pyrrhotite may also occur¹⁰. Associations with pyrite and other iron-bearing sulphides are obviously problematic, due to the requirement to reduce the sulphur content of the final copper concentrate¹¹. The addition of depressants to reject iron sulphides and gangue from the

concentrate inevitably leads to a reduction in gold recovery. Associations with hydrophilic iron oxides and silicates are also widespread. Introduction of iron oxide layers on free gold often occurs during primary grinding and regrinding of concentrates, which may also contribute to poor flotation performance with respect to gold¹².

Thus, gold recovery is less than copper recovery in typical copper concentrator operations. Copper recoveries of 90% are representative throughout the world; however, gold recovery is usually at least 10%–15% below this value¹. The purpose of this study is to investigate reasons for reduced gold recovery, with respect to copper recovery, through a copper concentrator and to identify possible avenues for increasing gold recovery, while not affecting copper recovery or grade.

In this study, a plant survey of a commercial copper concentrator was conducted to determine in which streams and in which size fractions the major losses of gold occurred. The flotation performance of the plant rougher block was then simulated in the laboratory, using a sample of the plant rougher feed, and deportment studies performed on these products. It is recognized that the laboratory simulation is only an approximate representation of the plant. Specifically, it is difficult to exactly replicate the particle and mineral size distributions of the plant at laboratory scale. Once the deportment of gold across the rougher separation was understood, and reasons for poor gold recovery identified, strategies to increase gold recovery were tested.

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Methods and materials

Materials

C-7249 collector was supplied by Cytec and is a mixture of mono- and di-thiophosphate. This specific collector is used in the plant. Potassium amyl xanthate (PAX) collector was supplied by Sigma. Ethylene diaminetetraacetic acid (EDTA) was obtained from BDH Laboratory supplies. All reagents were used as supplied without further purification.

Plant survey

A plant survey was performed including the grinding, rougher and cleaner circuits. Selected samples from the rougher and cleaner circuits were analysed for quantitative mineralogical analysis. Mass balances were performed and there was good agreement between the sampled and calculated head grades for both copper and gold. The samples were then classified into size fractions (-8 µm, +8-23 µm, +23-48 µm, +48-75 µm, +75-150 µm and +150 µm) and separate assays and mass balances performed. The recovery values for each size range were plotted against 7 µm, 14 µm, 33 µm, 60 µm, 106 µm and 212 µm, respectively. A bulk sample of SAG feed was collected during the plant survey and was used in the laboratory scale experiments. The SAG feed sample was approximately 2 tonnes, taken as a complete cross-sectional cut of the material on the SAG feed conveyor belt. The total SAG feed sample was then crushed through a jaw and a cone crusher to -1.7 mm. The sample was then rotary riffled into sub-samples suitable for flotation testing. This procedure ensured that the head grade composition of the plant feed during the survey was very similar to that in the laboratory study (Table I).

Laboratory flotation circuit

The plant rougher flotation stage was approximated in the laboratory to enable a gold deportment study on the products

Table I
Head grades of the plant rougher feed during the survey and laboratory flotation tests on SAG feed

Sample	Cu/%	Fe/%	S/%	Au (g/t)
Plant rougher feed	0.70	10.8	3.2	1.2
Laboratory tests on SAG feed	0.74	8.8	2.7	1.2

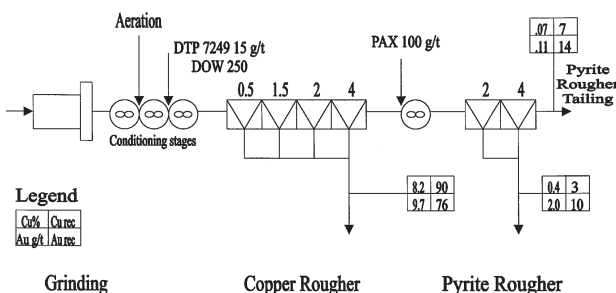


Figure 1—Schematic of the laboratory flotation procedure, showing copper and gold grades and recoveries into the flotation products (copper rougher concentrate, pyrite rougher concentrate, pyrite rougher tailing)

to further investigate reasons for poor flotation of gold. The procedure is shown schematically in Figure 1. A Cominco stainless steel mill was used with 14.4 kg stainless steel rods. The ore charge was 2 kg at pH 11.2 controlled by lime addition to the mill. The feed was ground to a d_{80} of 150 µm, the nominal particle size distribution used in the plant. The ground ore was then transferred to a 2.5 dm³ Denver float cell at 30% solids and conditioned with aeration and 15 g/t C-7249 collector addition for 4 minutes. A copper rougher float was then performed. Four concentrates were collected after 0.5, 2, 4 and 8 minutes respectively, and the products filtered and stored for subsequent analysis. To remove remaining sulphides from the copper rougher tailing, the tailing was then re-conditioned with 100 g/t PAX for a further 2 minutes before flotation to produce a pyrite concentrate. This was performed to improve discrimination and precision in the subsequent gold deportment analysis. Concentrates from the pyrite scavenger stage were collected after 2 and 6 minutes. The pyrite scavenger concentrates and tailing were then filtered and stored prior to analysis.

Gold deportment study

The technique described below was used to determine the deportment of gold across the simulated copper rougher and pyrite rougher stages in the laboratory. This method allows the differentiation of native (free) gold from gold locked with sulphides, gold locked with oxides and gold locked with silicates (non-sulphide gangue). The gold that is not dissolved during the mercury amalgamation stage is designated as locked gold.

The flotation products were first classified into -38, +38-75, +75-150 and +150 µm size fractions. Riffled portions of these size fractions were then analysed for mercury soluble gold by contacting 100 gm of sample with 100 gm of mercury in a sample vial placed in a rotary mixer for 24 hours. The gold content of the mercury was then determined (Table II shows data for the +38-75 µm size range for each flotation product).

Riffled portions of the mercury-insoluble residues were then separated in a heavy liquid of specific gravity (sg) 3.3 (methylene iodide). Riffled portions of the > 3.3 sg products were then separated magnetically, in a dry state, using a Frantz Isodynamic Magnetic separator, set at 0.5 A current and 15° side slope for 20 minutes. Riffled portions of the size fraction head samples, mercury-insoluble residues and all separation products were analysed for gold and the gold distribution calculated (Table II). There was close agreement between the recalculated and the sample head grades for the mercury insoluble fractions, as well as for the total size fraction head samples (Table II).

Polished sections were made of the > 3.3 sg 0.5 A magnetic and > 3.3 sg 0.5 A non-magnetic products. The polished sections were examined mineralogically and the whole surface of each section scanned at a magnification of 100x. Selected mineral separation products were examined in temporary oil mounts by transmitted light microscopy, to identify the major non-opaque minerals. The objective of the mineralogical examination was to identify the principal minerals in each of the > 3.3 sg fractions. Based on this analysis, the association of each separated fraction to a gold bearing phase was as follows : (1) Mercury soluble gold as

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Table II
Gold assay and distribution in the -75+38 µm size fraction of the copper rougher concentrate, pyrite rougher concentrate and pyrite rougher tailing samples produced in the laboratory flotation experiments

-75 + 38 µm size fraction			Copper rougher concentrate			Pyrite rougher concentrate			Pyrite rougher tailing		
			Wt /%	Au (g/t)	Au dist/ %	Wt/ %	Au (g/t)	Au dist/ %	Wt/ %	Au (g/t)	Au dist/ %
Mercury soluble gold				20.5	66.1		1.05	30.1		0.07	28.8
Mercury insoluble gold	<3.3 sg fraction		16.99	8.78	4.8	3.73	2.47	2.6	87.8	0.16	62.2
	>3.3 sg Fraction	Magnetic non-magnetic	11.11	14.94	5.3	8.25	2.23	5.3	12.03	0.13	6.9
			71.90	10.27	23.8	88.02	2.45	61.9	0.17	2.83	2.1
Head assay of mercury insoluble residue		Back calculated sample assay		10.54			2.43			0.16	
				9.15			2.41			0.15	
Head assay of total size fraction sample		Back calculated sample assay		31.0			3.48			0.23	
				29.7			3.60			0.18	

free gold, (2) mercury insoluble gold in the <3.3 sg fraction as gold locked with non-sulphide gangue, (3) mercury insoluble gold in the >3.3 sg fraction and magnetic as gold locked with iron oxide (e.g., limonite), (4) mercury insoluble gold in the >3.3 sg fraction and non-magnetic as gold locked with sulphides.

Laboratory tests on plant streams

Flotation tests with EDTA addition were performed to determine the effect of surface cleaning agents on the recovery of gold from the plant rougher feed. The adopted procedure was the same as the copper rougher stage shown in Figure 1, but with the required amount of EDTA being added at the conditioning stage. Other tests focused on regrinding of the plant copper rougher tailing to different particle sizes (no regrind d_{80} was 150 µm, and regrind to 120 µm and 100 µm). In these tests, 30 g/t of 7249 collector was added after regrinding in a stainless steel mill with stainless steel rods.

Results

Gold department studies

Plant survey

A plant survey was undertaken to identify where the major losses of copper and gold occurred. The results are presented in a simplified block flowsheet in Figure 2. The copper grade in the feed was 0.7%, while the gold grade was 1.2 g/t. The d_{80} of the feed was 140 µm. Copper was predominantly in the form of chalcopyrite (97%), with the remainder as chalcocite and minor covellite. Of the major diluents, the pyrite concentration in the feed was 5.5%, with 92% non-sulphide gangue minerals.

Through the rougher block, the copper and gold grades increased to 9.9% and 10.4 g/t (at recoveries of 97.6% and 75%) respectively. The rougher concentrate was then reground to a d_{80} of 45 µm and treated through the cleaner block. The final concentrate copper grade was 31.5% at 89.8% recovery. The gold recovery was much lower at 55.9% at a grade of 26.8 g/t in the final concentrate.

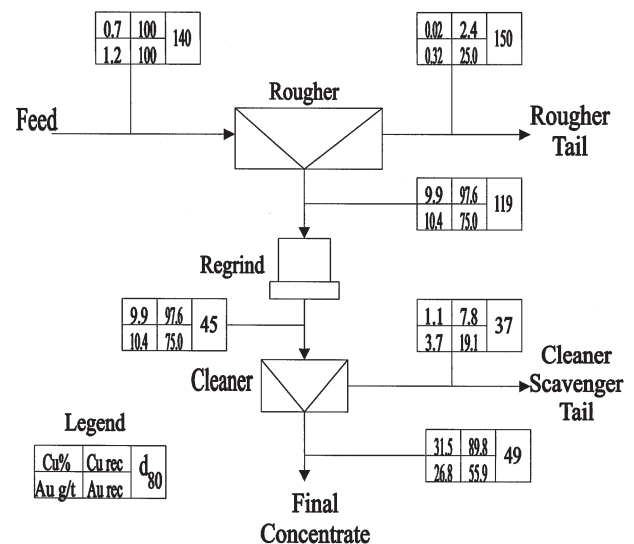


Figure 2—Simplified flowchart of the flotation process in the plant, showing the copper and gold grades and recoveries across the copper rougher and cleaner blocks during the plant survey. Also shown are the d_{80} values of the process streams

The major loss of copper through the circuit is via the cleaner tail where 7.8% of the copper is lost. A significant amount of gold is lost through both the rougher tailing and the cleaner tailing, which account for 25.0% and 19.1% of the gold in the feed, respectively. To ascertain reasons for these losses of gold compared to copper, size-by-recovery data was obtained across the rougher and cleaner blocks. The results in Figure 3a show that gold recovery across the rougher block in the +48-75 µm size fraction is nearly equal to the copper recovery at over 90%. However, for the fine and coarse fractions, the gold recovery is significantly lower than copper recovery, particularly for the +75 µm fraction. As can be seen from the rougher feed size distribution of gold, the +75 µm and -23 µm size ranges contribute a significant proportion of the total gold in the feed.

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Table III
Solids, copper and gold assay and distribution by particle size range for the plant rougher feed during the survey and the laboratory rougher feed of the ground SAG mill feed sample

Size range / μm	Plant rougher feed from survey					Laboratory rougher feed				
	Mass Dist/ %	Cu		Au		Mass Dist/ %	Cu		Au	
		Assay/ %	Dist./ %	Assay (g/t)	Dist./ %		Assay/ %	Dist./ %	Assay (g/t)	Dist./ %
+150	11.00	0.22	3.5	0.65	5.8	17.90	0.30	7.2	0.63	9.4
+75-150	22.00	0.64	20.0	1.01	18.1	27.20	0.54	19.9	1.03	23.4
+38-75	12.70	1.04	18.7	1.35	24.9	18.30	0.84	20.8	1.40	21.4
-38	54.30	0.75	57.8	1.42	51.2	36.60	1.05	52.1	1.50	45.8
Head	100.0	0.70	100.0	1.23	100.0	100.0	0.74	100.0	1.20	100.0

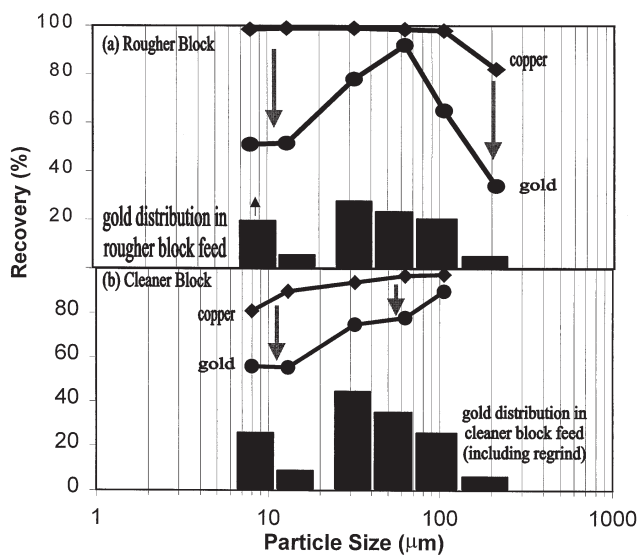


Figure 3—Size-by-size recovery of copper (◆) and gold (●) across the (a) rougher and (b) cleaner blocks during the plant survey. The gold size distribution in the rougher feed (a) and cleaner block feed, including regrind (b), are also shown

For the cleaner block, the gold recovery is below that of copper across all size ranges, but the difference increases with decreasing particle size. The gold size distribution shown in the cleaner block feed is calculated from the combination of the final concentrate and cleaner tailing, and thus includes the size reduction introduced by regrinding on the gold distribution in the rougher concentrate. Thus, most of the gold lost to the cleaner tailing is fine ($\sim 25 \mu\text{m}$), while in the rougher tailing gold is distributed in both fine and coarse ($+75 \mu\text{m}$) size fractions.

Laboratory scale simulation

To determine the mineralogical deportment of gold particles through the products of flotation, a sample of the plant feed, collected during the plant survey, was treated in the laboratory using the procedure shown in Figure 1. The copper and gold recoveries over the rougher stage were 90% and 76% respectively. This compares with 97.6% and 75% for the plant survey. Particularly for the case of gold recovery and

grade, the adopted laboratory scale rougher flotation procedure emulated the plant, allowing a qualitative comparison to be made between the gold distribution in the plant and laboratory streams. Moreover, the head grade of the plant SAG feed sample was very similar to the survey feed assays for the major elements, adding significance to the laboratory study (Table I). The mass, copper and gold size distributions of the plant rougher feed during the survey and that of the laboratory ground SAG are compared in Table III. In the plant survey the d_{80} of rougher flotation feed was $140 \mu\text{m}$, which was finer than the normal target grind for this plant ($150 \mu\text{m}$). Based on the plant target grind, the laboratory flotation tests targeted a d_{80} of $150 \mu\text{m}$. This led to some discrepancies in the mass and gold size distributions, particularly for the $\sim 38 \mu\text{m}$ size range. However, the similar copper and gold grades of each size range from the plant to the laboratory suggests that similar gold deportment characteristics will be obtained for each equivalent size range. As the gold deportment analysis is made on a size-by-size basis, differences in size distributions are not significant to the conclusions related to the laboratory study alone.

Gold in the rougher concentrate, pyrite rougher concentrate and final tail were classified by size and then examined using the gold deportment method. The results in Figures 4 and 5 show the deportment of gold through the flotation procedure. The majority of the gold in the rougher concentrate was free gold (50%) and gold locked with sulphides (30%), mainly chalcopyrite. Gold locked with non-sulphide gangue and iron oxide predominantly reported to the copper rougher tailing. Of interest was the free gold in the copper rougher tailing, which represents 4.4% of the gold in the feed. Free gold in the copper rougher tailing was predominantly in the $\sim 75 \mu\text{m}$ size range.

The gold in the pyrite scavenger concentrate was equal to 10% of the gold in the feed, with 15% being free gold and 75% being locked with sulphides, principally pyrite based on the mineralogical analysis. The pyrite scavenger tailing comprised 14% of the gold in the feed, of which 20% was free gold and 75% was locked with silicates.

Thus, it can be seen that there was a significant loss of gold from the copper roughers due to insufficient liberation, with large losses in the $+75 \mu\text{m}$ size range due to gold being locked with silicates and other non-sulphide gangue ($\sim 10\%$).

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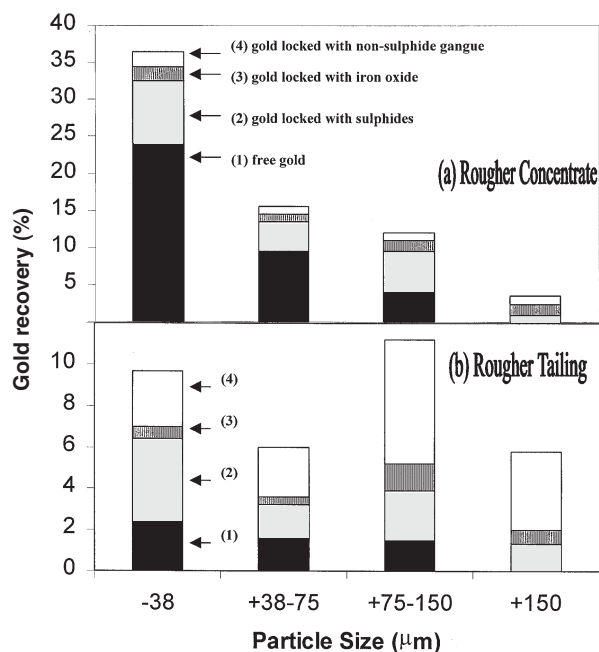


Figure 4—Department of gold across the laboratory simulated copper rougher stage, (a) recovery to the rougher concentrate and (b) recovery to the copper rougher tailing, for (1) free gold, (2) gold locked with sulphides, (3) gold locked with iron oxide, and (4) gold locked with non-sulphide gangue. Recovery with respect to copper rougher feed. The addition of gold recovery into the products represents the gold size distribution in the laboratory rougher feed, shown in Table III

Across the copper rougher block, the loss of fine free gold was surprisingly high, and from the plant survey recovery-by-size data, this problem apparently increases across the cleaner block. It has been suggested the loss of fine free gold may be due to thin surface layers of hydrophilic iron species, which may be introduced during grinding through a number of mechanisms^{12,13}.

Strategies for improving gold recovery

Regrind of plant rougher tail

As the laboratory scale experiments identified mineral liberation as a cause for the low gold recovery in the +75 µm size range, a sample of the plant copper rougher tailing was tested in laboratory flotation after regrinding. The plant rougher tail sample tested had a gold assay of 0.2 g/t. Initial tests, with no regrind and at copper rougher feed d_{80} of 150 µm, gave a concentrate with 32% gold recovery and 36% copper recovery (Figure 6). With regrind to a d_{80} of 120 and 100 µm, the recovery of both gold and copper increased. In the best case at a d_{80} of 100 µm, the gold and copper recoveries were 58% and 77% respectively. The iron recovery was not significantly affected by the decreased grind size, remaining constant at approximately 14%. The total mass pull of the concentrate was also not significantly affected and remained at approximately 8%. This is reflected in the fact that the gold and copper rougher concentrate grades increased with decreasing grind d_{80} from 0.91 g/t and 0.19% respectively at 150 µm, to 1.25 g/t and 0.35% at 100 µm.

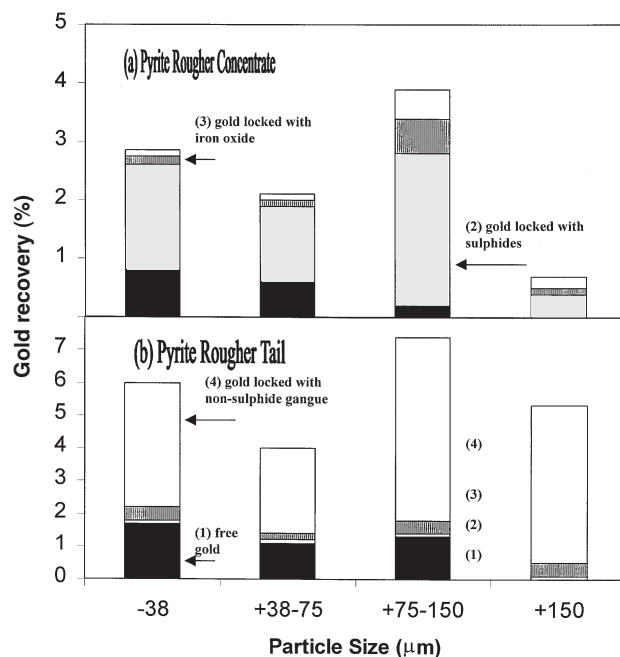


Figure 5—Department of gold across the laboratory simulated pyrite scavenger stage, (a) recovery to the pyrite concentrate and (b) recovery to the pyrite tailing, for (1) free gold, (2) gold locked with sulphides, (3) gold locked with iron oxide, and (4) gold locked with non-sulphide gangue. Recovery with respect to copper rougher feed

It may be suggested that at the initial d_{80} of 150 µm, some of the free gold and gold associated with pyrite floats without regrinding the plant rougher tailing. From the laboratory department work, free gold and gold associated with sulphides account for 27% of the gold in the copper rougher tailing (Figure 4). With the addition of collector most of the gold in pyrite and some of the free gold is recovered (Figure 5). It is suggested that gold that is recovered from the plant copper rougher tailing, at the normal grind size (150 µm) and with additional collector only (Figure 6), is principally gold associated with pyrite and some free gold.

The increase in gold recovery at decreased grind size is probably due to increased liberation of gold locked with silicates, which account for 46% of the gold in the copper rougher tailing based on the laboratory department work. Unfortunately, no department studies on the plant flotation products were performed. Further department work in this area would shed light on the exact reason for these findings.

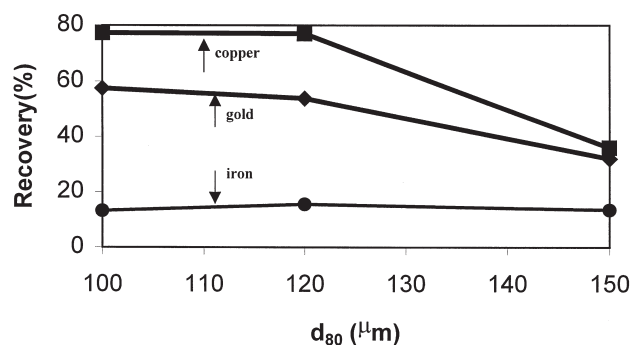


Figure 6—Effect of laboratory regrinding on the recovery of copper (■) and gold (◆) from the plant rougher tailing across a laboratory copper rougher flotation stage. Also shown is the recovery of iron (●)

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EDTA extraction

Previous workers have shown that hydrophilic iron species may be impressed on the surface of gold particles during grinding due to the metals high malleability, or may occur due to surface precipitation. The presence of an iron oxide coating on free gold particles was shown in the case of the plant cleaner tailing in a related study¹³. It was suggested that the low recovery of -23 µm liberated gold observed in this study was also due to this phenomena¹³. EDTA treatment was used in the current study in an attempt to remove these surface layers and increase gold recovery in flotation.

Solution samples of EDTA added to the plant rougher feed were collected and tested for metal ions in solution by ICP. In Table IV, the effect of EDTA addition can clearly be seen, with the concentration of iron and magnesium in

Table IV
Effect of EDTA addition to the plant copper rougher feed on the metal ion concentration in solution. Concentration values shown are in mg/l

EDTA addition (g/t)	Cu	Fe	Mg
0	<0.05	<0.05	5.5
500	0.05	0.16	6.3
1000	0.23	0.88	9.2
2000	0.41	8.02	12.2
4000	0.63	21.09	16.5

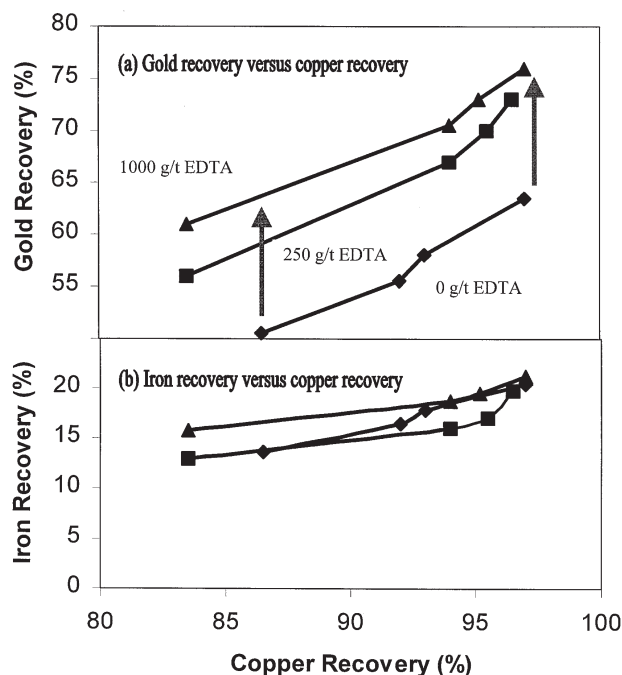


Figure 7—Effect of EDTA extraction on the selectivity of copper with respect to (a) gold and (b) iron for the flotation of plant rougher feed in a laboratory copper rougher flotation test, for (◆) 0 g/t EDTA, (■) 250 g/t EDTA and (▲) 1000 g/t EDTA

solution increasing sharply with EDTA addition. The concentration of calcium and sulphur also increased, but the relative increase was much lower. The copper concentration is also shown, which only increased marginally up to an EDTA addition of 4000 g/t.

The effect of EDTA addition on the flotation of plant rougher feed was investigated in the laboratory in parallel with the solution analysis. In Figure 7, the gold/copper selectivity is shown for EDTA additions up to 1000 g/t. The copper recovery was not altered for additions up to 1000 g/t, remaining at around 97%. The gold recovery, however, was increased from 62% to 76% with the addition of 1000 g/t EDTA. Above this addition rate, the copper recovery decreased slightly. Similarly, the copper/iron selectivity is also shown. Addition of 1000 g/t EDTA had little effect on iron recovery, but significantly increased gold recovery. At higher addition rates, the iron recovery increased slightly. This suggests that the increase in gold recovery with EDTA was not due to an increase in recovery of gold associated with either iron or copper bearing minerals. While no recovery-by-size deportment data were collected for these tests, it is suggested that this increase in gold recovery occurs as fine free gold of the type that reports to the copper rougher tailing in the laboratory gold deportment studies.

Discussion

From the results in Figure 3, it can be seen that there are two size fractions where a significant amount of gold is lost to the tailing streams. In rougher flotation, coarse gold particles (+75 µm) show low recovery. This was mainly due to insufficient liberation of gold from non-sulphide gangue, such as silicates. As silicates are low sg gangue material, recovering these particles from the rougher tailing by gravity separation is also extremely difficult¹³. Gold particles in the +50–75 µm size range were easily recovered in copper rougher flotation, as they were fully liberated. Fine, free gold particles, particularly the -23 µm fraction, were more difficult to recover due to surface contamination, probably introduced by excessive grinding of already liberated gold particles. As shown by Brook *et al.*¹³, fine free gold particles were also difficult to recover from tailing streams by gravity separation, with only approximately 10% of these particles being gravity recoverable. Coarse gold containing particles were also shown to be difficult to recover by gravity separation when locked with low specific gravity gangue minerals. Gold bearing particles in the +75 and -23 µm fractions collectively represent approximately 45% of the gold in the rougher feed. Therefore, poor flotation in these size fractions represents a significant loss of gold.

It has been shown in this study that increased grinding of the tailing resulted in liberation of gold in coarse size fractions, and consequently the recovery improved. Economically this is not often feasible as finer grinding at this (high mass throughput) stage of the circuit may be extremely expensive in terms of energy input and infrastructure required. Fine particle recovery, however, is relatively more easily attainable. From Figure 4, -75 µm gold

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particles, which report to the copper rougher tailing, and which are either free or locked with sulphides, account for approximately 10% of the gold in the feed. In addition, further losses of fine, probably free¹³, gold were observed across the cleaner block. Particularly for the cleaner block, recovery of fine gold particles should be a focus, as these particles have already been recovered across the rougher block, while it is their surface alteration during regrinding which appears to account for their low recovery in cleaning¹³. Both in this current study and a related study¹³, it was shown that removal of these surface contaminants dramatically improved recovery of fine free gold.

Thus, if major improvements in gold recovery are sought, there are two avenues open for investigation. Recovery of coarse gold locked with non-sulphide gangue could be improved by screening coarse particles (+75 μm) from the copper rougher tailing and then regrinding to a d_{80} of 60 μm , where gold recovery was shown to be very high. As discussed above, regrinding of the coarse size fractions has also been shown to increase copper recovery from the copper rougher tailing. This would reduce the mass flowrate through the regrind mill, as the +75 μm size fraction represents approximately 25% of the mass in the rougher tailing. This would also ensure regrinding of particles that require further liberation, and minimize the detrimental effects of over-grinding gold, which is already liberated. Surface cleaning reagents could then be added to the finer size fractions to remove surface contaminants. These two streams could then be combined and fed to a scavenger float to recover the gold being lost at this stage. As mentioned above, gold in the +75 μm and -23 μm size fractions represent 45% of the gold in the feed, and in this plant survey, only showed a recovery of approximately 50%. Thus, improving recovery in these size ranges by even 20% would dramatically increase gold recovery across the plant.

Conclusions

The deportment of gold particles through a copper concentrator has been studied. It was shown that the recovery of gold in the +75 μm and -23 μm size ranges is significantly lower than copper recovery. The performance of the plant scale concentrator was emulated in laboratory scale experiments. Through laboratory scale simulations, it was shown that the lack of gold liberation from non-sulphide gangue is the cause of the low gold recovery in the +75 μm size fraction. The recovery of free gold and gold locked with

sulphides was high. It has been demonstrated in a parallel study¹³ that the low gold recovery for fine particles is due to surface layers of hydrophilic iron species.

Regrind of the plant rougher tail to increase mineral liberation resulted in an increase in the recovery of both gold and copper. The gold and copper concentrate grades were also increased as recovery of iron was unaffected. EDTA extraction was tested to remove hydrophilic surface layers from fine, apparently free, gold particles. Addition of up to 1000 g/t of EDTA increased gold recovery, while not adversely affecting copper recovery. The addition of 1000 g/t EDTA did not increase the recovery of iron to the concentrate. The action of EDTA is apparently directed towards fine, apparently free, gold particles.

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