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Gold recovery from placer concentrates by cyanidation

After you recovered what you thought was all the gold from your sluice-box concentrate, you probably left flakes of gold that were not separated or gold that was not liberated from the quartz. This hard-to-recover gold might be dissolved in a weak cyanide solution, adding to the overall profit of your operation. This gold is then precipitated by zinc dust or absorbed by an ion-exchange resin or activated carbon (charcoal). Recovery by absorption and subsequent oxidation of the charcoal appears to be the preferred method.

Introduction. In a recent study initiated at the request of three placer-mine operators in the Circle mining district, DGGS experimented with recovering gold from cleaned placer concentrates. The operators, from different subdistricts, provided the samples. Each miner first screened the concentrate and recovered gold by gravity methods, and one operator went a step further and used mercury to amalgamate the gold.

In the gravity separation of gold from the gravels and gold from the concentrate, two principles — specific gravity and particle size and shape — oppose each other. This makes the final cleanup difficult by gravity methods alone. Adding mercury to amalgamate the gold flakes increases recovery, but three conditions must be present for mercury to attract gold: (a) the gold particle must have a clean surface, (b) the mercury must be in contact with the gold, and (c) the gold must be liberated from the matrix or at least have enough surface exposed to adhere to the mercury.

A weak solution of less than 500 parts per million (ppm) cyanide will dissolve gold.

The primary requirement for solution is a clean surface on the gold particle. The chemical reaction:

$$4Au + 8CN^- + O_2 + 2H_2O \longrightarrow 4Au(CN)_2^- + 4OH^-$$

In treating these placer concentrates, interfering ions such as zinc or copper were present in concentrations of less than 110 ppm; they did not appear to consume cyanide.

In addition to the cyanide (CN^-), oxygen (O_2) is required and the solution must be basic. In practice, the solution is buffered with CaO to hold a pH of 10 or better.

Acknowledgements. The author gratefully acknowledges the assistance of Fred Wilkinson, Joe Vogler, and E N Wolff for providing samples, P D Rao and Wolff for their suggestions, and the laboratory section of DGGS for the analyses. D R Stein performed the assays.

Table 1. Sieve analyses of sample JV-1

Mesh size	*Weight (g)*	*Percent of total*	*Percent passing*	*Percent retained*	*Remarks*
+16	0		100.00	0	No visible gold
−16 +32	2.88	0.72	99.28	0.72	Visible gold
−32 +60	40.44	10.11	89.17	10.83	Visible gold
−60 +120	342.24	85.56	3.61	96.39	Visible gold
−120	14.44	3.61	0	100.00	No visible gold
Total	400.00	100.00			

Table 3. Sieve analyses of sample JV-2

Mesh size	*Weight in (g)*	*Percent of total*	*Percent passing*	*Percent retained*	*Remarks*
+8	0	0	100.00	0	
−8 +16	0.84	0.21	99.79	0.21	Visible gold
−16 +32	93.16	23.05	76.74	23.26	Visible gold
−32 +60	306.00	75.70	1.04	98.95	Visible gold
−60 +120	3.40	0.84	0.20	99.80	Visible gold
−120	0.84	0.21	0	100.00	Several colors
Total	404.24	100.01			

Table 2. Gold recovery from sample JV-1

Gold	*Weight (mg)*	*Percent of total*
Recovered by amalgamation	60.62*	87.45
Recovered by cyanidation	8.28	11.94
Remaining in tails	0.42	0.61
Total	69.32	100.00

Computed assay of heads = 5.05 oz/ton
Assay of tails = 0.03 oz/ton
Total recovery of gold = 99.39 percent

*Including silver

Table 4. Gold recovery from sample JV-2

Gold	*Weight (mg)*	*Percent of total*
Recovered by cyanidation	159.06	99.80
Remaining in tails	0.32	0.20
Total	159.38	

Computed assay of head 11.62 oz/ton
Assay of tail 0.02 oz/ton
Total recovery of gold 99.80 percent

PROCEDURE

In these experiments, the procedure outlined by Dorr and Bosqui (1950) was followed.

Each sample was separated into the basic particle-size fractions and visually examined for gold and mineral content. The samples were then amalgamated with mercury. Six cyanide tests were completed, with and without grinding. Gold was precipitated by zinc dust, activated carbon, and Dowex 21K.

Samples Submitted by Vogler

Nearly all the quartz and rock had been removed in the samples, and 99.9 percent of the material had a specific gravity of over 2.88 (bromoform heavy-liquid separation). If magnetite was originally present, it had been removed and the remaining material was mostly wolframite, a tungsten mineral with a specific gravity of 7 to 7.5, and cassiterite, a tin mineral with a specific gravity of 6.8 to 7. The specific gravity of the sample was 7.0.

Sample JV-1 was separated into size fractions and examined for gold flakes as indicated in table 1.

A 400g sample was then amalgamated for 2h with 1g of mercury. The mercury was recovered by panning and dissolved in nitric acid. The residue contained 60.62mg of gold, or the equivalent of 4.42oz of placer gold per ton (this includes the silver alloy with the gold.) The sample was then treated in a solution containing 500ppm potassium cyanide and buffered with 0.90g of calcium oxide to keep the pH of the solution above 11.0. The solution was sampled for gold after 3 and 5 hours of agitation. The assay of the solution was constant at the equivalent of 8.28 ppm, or equal to 8.28mg of gold. The tails assayed 1.06ppm (0.424mg) gold. The test is summarized in table 2.

A second Vogler sample of slightly coarser similar material (table 3), was dissolved in cyanide without removal of gold by amalgamation (table 4). It took 72h to dissolve the gold.

Samples Submitted by Wolff

Ernest N Wolff provided two samples from Coal Creek. These samples consisted of about 87% almandine, 8% spessartine, and 3% andradite garnet. Less than 0.5% of the sample was floated in a heavy-liquid (specific gravity 2.88) separation. The grain-size analyses of sample EW-1 is indicated in table 5.

Gold was visible in all size fractions and observations under a 30-power binocular microscope revealed that it had not been liberated from the quartz grains. The sample was then amalgamated with 1g of mercury for 1.5h. Quartz grains containing gold adhered to the mercury. The mercury was dissolved by acid and then the quartz dissolved with hydrofluoric acid; 643.4mg of placer gold was recovered from the 400.0g of sample. This is the equivalent of 46.91oz of placer gold per ton. Assuming a fineness of 905 (Smith 1937), then 643.4 × 0.905 = 582.28mg of gold, or 42.22oz/ton (46.91 × 0.905).

The sample was then ground to − 100 mesh and treated with cyanide. There was no increase in gold in the cyanide solution after 8h. The solution contained 19.6mg of gold; 1.8mg remained in the tails (table 6).

A sample of slightly coarser material (EW-2) from Coal Creek was tested. Tables 7 and 8 show the results.

The 400g sample was treated in a cyanide solution for 48 hours.

Sample submitted by Wilkinson

The sample submitted by Fred Wilkinson had been amalgamated, and no gold was noted by casual visual observation. A preliminary assay indicated 0.80oz of gold per ton. The screen analysis indicated the material was not as well sorted as the Vogler and Wolff samples (table 9).

In this sample 44% of the material was lighter than 2.88 specific gravity. The light fraction was composed primarily of metamorphic rock fragments and mica grains. The heavy fraction (56%) contained a variety of minerals, including cassiterite, garnet, scheelite, ilmenite, magnetite, zircon, tourmaline, pyrite, arsenopyrite, and galena. The sample assayed 6.45% tin and 3.68% tungsten.

The sample was first subjected to a cyanide test without grinding (table 10); the recovery is indicated in table 11. The gold was effectively dissolved in 5h.

A second trial (table 11) was made with the same material ground to − 100 mesh; dissolving time was 5h.

Inasmuch as the Wilkinson sample represented the greatest amount of concentrate, a second screen analysis was completed for a heavy-liquid separation. Each grain-size fraction was separated into sink-float fractions, examined with a binocular microscope, and assayed. The results are shown in table 12.

One characteristic of the gold particles was a length-to-width ratio of at least 3. The gold appeared to be clean and should have been collected by the mercury. The flakes of gold probably did not come in contact with mercury during the amalgamation process.

Table 5. Sieve analyses Coal Creek sample EW-1

Mesh size	*Weight (g)*	*Percent of total*	*Percent retained*	*Percent passing*	*Remarks*
+ 10	1.36	0.34	0.34	99.66	Visible gold
− 10 + 16	27.24	6.81	7.15	92.85	Visible gold
− 16 + 35	197.16	49.29	56.44	43.56	Visible gold
− 35 + 60	145.68	36.42	92.86	7.15	Visible gold
− 60	28.60	7.15	100.00	0.00	Visible gold
Total	400.04	100.01			

Table 7. Sieve analyses, Coal Creek sample EW-2

Mesh size	*Weight (g)*	*Percent of total*	*Percent retained*	*Percent passing*	*Remarks*
+ 10	0.84	0.21	0.21	99.79	
− 10 + 16	31.96	7.99	8.20	91.80	Visible gold
− 16 + 35	231.92	58.00	66.20	33.80	Visible gold
− 35 + 60	106.71	26.69	92.89	7.10	Visible gold
− 60	28.40	7.10	100.00	0.00	Visible gold
Total	399.83	99.99			

Table 6. Gold recovery, Coal Creek sample EW-1

Gold	*Weight (mg)*	*Percent of total*
Recovered by amalgamation	582.28	96.01
Recovered by cyanidation	19.60	3.23
Remaining in tails	4.60	0.76
Total	606.48	100.00
Computed assay of heads	43.99 oz/ton	
Assay of tails	0.14 oz/ton	
Recovery	99.24 percent	

Table 8. Gold recovery, sample EW-2

Gold	*Weight (mg)*	*Percent of total*
Recovered by cyanidation	41.42	83.19
Remaining in tails	8.39	16.81
Total	49.81	100.00
Computed assay of heads	3.029 oz/ton	
Assay of tails	0.612 oz/ton	
Recovery	83.19 percent	

Recovery of Gold from Solution

Gold was recovered by three different methods: (a) zinc precipitation, (b) activated charcoal absorption, and (c) absorption on a resin (Dowex 21K). Ion exchange offers a fourth option. The charcoal absorption is now favored over zinc precipitation, the method of the 1930s. The new technology may be ion exchange, using liquid or resin.

The zinc precipitation requires a clarified solution and removal of dissolved air (oxygen). It is improved by the addition of a lead salt such as lead acetate or nitrate. In a test, 1g of zinc dust was added to 0.85litre of deaerated solution assaying 19.6 ppm gold (table 13).

Charcoal will absorb gold from a cyanide solution. Loading is a function of surface area, and there does not appear to be a uniform maximum; rather, the amount of charcoal needed depends on the method of charcoal manufacture. Apparently, the charcoal or activated carbon will load to over 1000oz of gold per ton of carbon. The practice at Homestake is to load to 450oz per ton (McQuiston and Shoemaker, 1975). About 2pounds (avoirdupois) of activated carbon is required to collect 1oz (troy) of gold. In commercial mills, gold is stripped from the charcoal by the Zadra process (Zadra and others, 1952). In the laboratory, gold was recovered from the charcoal by slow oxidation. This method could be used by a small operator. The laboratory results with 1.2litre of solution assaying 115.6 ppm are shown in table 14.

Gilmore (1967) describes a resin in pulp ion-exchange method. In the laboratory, 3.8litre of solution assaying 4.46 ppm was stripped with 10g of Dowex 21K. The gold was recovered by slow oxidation of the resin (table 15).

Adamson (1973) suggests that gold be stripped by a liquid ion exchange, but laboratory tests were inconclusive.

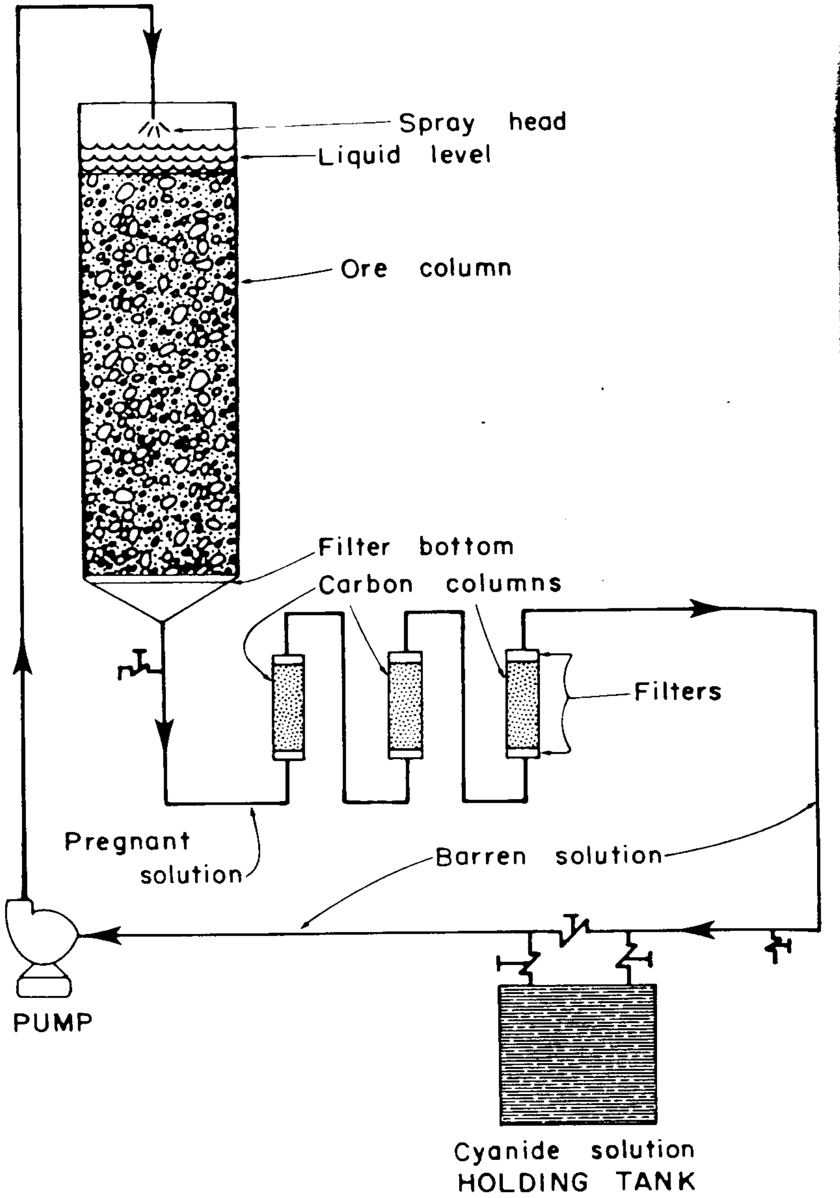

Figure 1. Flow diagram of gold recovery by cyanide solution

Table 9. Sieve analyses of sample FW-1

Mesh size	*Weight (g)*	*Total percent*	*Percent passing*	*Percent retained*
+10	0.32	0.08	99.92	0.08
−10 +18	62.72	15.71	84.21	15.79
−18 +32	113.04	28.31	55.90	44.10
−32 +60	138.96	34.80	21.10	78.90
−60 +120	70.84	17.74	3.36	96.64
−120 +250	11.16	2.79	0.57	99.43
Pan	2.28	0.57		
Total	399.32			

Table 10. Gold recovered without grinding, sample FW-1

Gold	*Weight (mg)*	*Percent of total*
Recovered by cyanidation	7.22	73.30
Remaining in tails	2.63	26.70
Total	9.85	100.00
Computed assay of heads	0.72 oz/ton	
Assay of tails	0.18 oz/ton	
Recovery	73.30 percent	

Table 11. Gold Recovered with grinding sample FW-1

Gold	*Weight (mg)*	*Percent of total*
Recovered by cyanidation	20.88	91.42
Remaining in tails	1.96	8.58
Total	22.84	100.00
Computed assay of heads	1.67 oz/ton	
Assay of tails	0.14 oz/ton	
Recovery	91.42 percent	

In our experiments, stripping with activated carbon and subsequent oxidation of the charcoal appeared to be the best method for a small operation. After dissolving the zinc dust in hydrocloric acid to recover the gold, the gold dust adhered to the beaker. The gold remained as delicate spheres after the Dowex 21K was oxidized; if the fumes were properly vented, this could be the second choice to charcoal. Figure 1 shows the flow of the

Table 12. Sink-float analyses, sample FW-1

Sink or float***		*Weight*	*Percent of total*	*Percent of sink*	*ppm*	*ppm times weight*	*Remarks*
−10 + 18	F	41.71	10.59		0.87	36.29	
	S	34.27	8.70	45.10	26.80	918.44	
		75.98	19.29				
−18 + 35	F	55.96	14.20		0.30	16.79	Visible gold
−18 + 35	S	61.43	15.59	52.33	62.50	3,839.38	
		117.39	29.79				
−35 + 60	F	37.18	9.44		0.31	11.53	Visible gold
−35 + 60	S	48.38	12.28	56.55	116.31	5,627.08	
		85.56	21.72				
−60 + 120	F	33.36	8.47		0.44	14.68	Visible gold
−60 + 120	S	68.45	17.37	67.23	43.88	3,003.59	
		101.81	25.84				
−120	F	5.20	1.32		0.75	3.90	
−120	S	8.07	2.05	60.83	19.10	154.14	
		13.27					
Total		394.00	100.01			13,625.82	

**Specific gravity less than 2.88
*Specific gravity greater than 2.88
Computed assay 34.58 ppm gold or 1.01 ounces per ton.
Note: 41 percent of gold is in the −35 +60 sink fraction.

cyanide solution through the concentrate and stripping of the gold from the pregnant solution by charcoal.

Gold Recovery Summarized

This procedure is recommended for the recovery of gold from placer concentrates:

(1) Screen and size the concentrate.

(2) Recover as much of the gold as possible by gravity methods.

(3) Recover particulate gold by amalgamation. This step may require cleaning of the gold particles by chemical action or attrition. Many operators use either an amalgamation rotating drum or cement mixer to provide the contact of gold with the mercury and the agitation necessary to clean the gold.

(4) Recovery of the balance of the gold from the concentrate by cyanidation, which is a chemical process requiring careful solution control. Both the pH and strength of the solution must be carefully controlled, and the solution should be assayed to determine when the reaction has reached completion. The stripping of the solution requires careful control. The concentrate must be analyzed to determine if the gold is free or, as in the Coal Creek samples, in quartz, so that grinding is required for liberation. If the proper procedures are followed, additional gold can be recovered by cyanidation. Figure 1 is a flow diagram of gold recovery by using cyanide and carbon.

Table 13. Recovery of gold from solution by zinc dust

Solution	*Gold (mg)*
Pregnant	16.6
Stripped	0.14
Recovery	99.16%

Table 14. Recovery of gold from solution with activated carbon

Solution	*Gold (mg)*
Pregnant	138.72
Stripped	0.20
Recovery	99.85%

Table 15. Recovery of gold by resin, Dowex 21K

Solution	*Gold (mg)*
Pregnant	16.95
Stripped	0.65
Recovery	96.31%

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