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MINERAL PREPARATION, GRANT GOLD MINE, ALASKA

By
C.N. Conwell

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STATE OF ALASKA

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Cover photo: *Head frame, Grant Mine. View to south.*

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CONTENTS

FIGURES

TABLES

MINERAL PREPARATION, GRANT GOLD MINE, ALASKA

By
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ABSTRACT

The gold in the quartz veins of the Grant Mine can be recovered by gravity separation, amalgamation, flotation, or cyanidation. It liberates at a minus 65-mesh grind.

Gravity separation or amalgamation (or both) will recover about 70 percent of the gold, but a 95-percent recovery can be expected from either flotation or cyanidation.

The best recovery in the bench-scale test was obtained by first removing the coarse gold by amalgamation and then recovering the fine gold by cyanidation.

The mineral preparation tests completed indicate an attractive recovery by froth flotation without pretreatment for the removal of coarse gold. Grinding to minus 65 mesh appears to be adequate.

An alternative method not explored in this study is cyanidation with less comminution. Usually, cyanidation plants cost more to build than flotation plants, but if enough gold and silver could be recovered without grinding, cyanide leaching might be warranted.

The flotation product can be either treated by cyanidation or sold to a smelter. The cyanidation product is precious-metal bullion.

INTRODUCTION

The Grant Mine is located about 15 miles northwest of Fairbanks, Alaska. The free-milling gold ore in this deposit may be representative of gold ores elsewhere in the Ester Dome area, and holders of nearby claims may wish to examine this mineral preparation study to obtain the optimum gold recovery at the lowest plant investment.

The scope of the work includes grindability, screen analyses, sink-float separations (gravity), amalgamation, flotation, and cyanidation tests.

HEAD SAMPLES

Two 75-lb samples were collected from a slope on the 200-ft level. The intent was to obtain a sample diluted by wall rock to approximate the mill heads of ore treated in 1980, which averaged 0.45 oz/ton gold (Anselmo, 1981). The average of two assays was:

Gold	-	0.452 oz/ton*
Silver	-	0.665 "
Copper	-	0.006 percent
Lead	-	0.049 "
Zinc	-	0.014 "
Antimony	-	0.015 "
Arsenic	-	0.595 "

*Troy oz per short ton

The first sample approximated the ore being milled, so it was used in nearly all of the testing.

This second sample was taken by making several channel cuts across a 1-ft-wide quartz vein. This material assayed:

Gold	-	2.14 oz/ton
Silver	-	0.16 "
Lead	-	0.064 percent
Copper	-	0.004 "
Zinc	-	0.016 "
Antimony	-	0.028 "
Arsenic	-	0.538 "

MINERALOGY

The Grant Mine ore occurs as fracture-filling vein deposits. The principal structures are the Irishman vein system and the O'Dea breccia zone (Bundtzen and Kline, 1981). The ore for the mill tests was taken from the latter zone on the 200-ft level.

The principal gangue minerals are quartz, geothite, and muscovite. The principal sulfide mineral in the samples is arsenopyrite, about 1.2 percent by weight. Sphalerite and galena are present. Other heavy minerals are siderite, rutile, zircon, tourmaline, garnet, and magnetite. Trace amounts of scheelite and cinnabar were detected. The principal value is free gold, but assays indicate an unidentified silver mineral present. DGGS assayer D.R. Stein (oral commun., 1981) stated that the fineness of the gold was about 830. Parting the gold recovered by amalgamation indicates a similar fineness.

Photomicrographs of the gold grains illustrate their size and shape (fig. 1). Grains 1A and 1B are from polished sections and show the gold occurring as discrete grains in a quartz matrix. Figures 1C, 1D, and 1E are polished grain mounts in an epoxy matrix with gold

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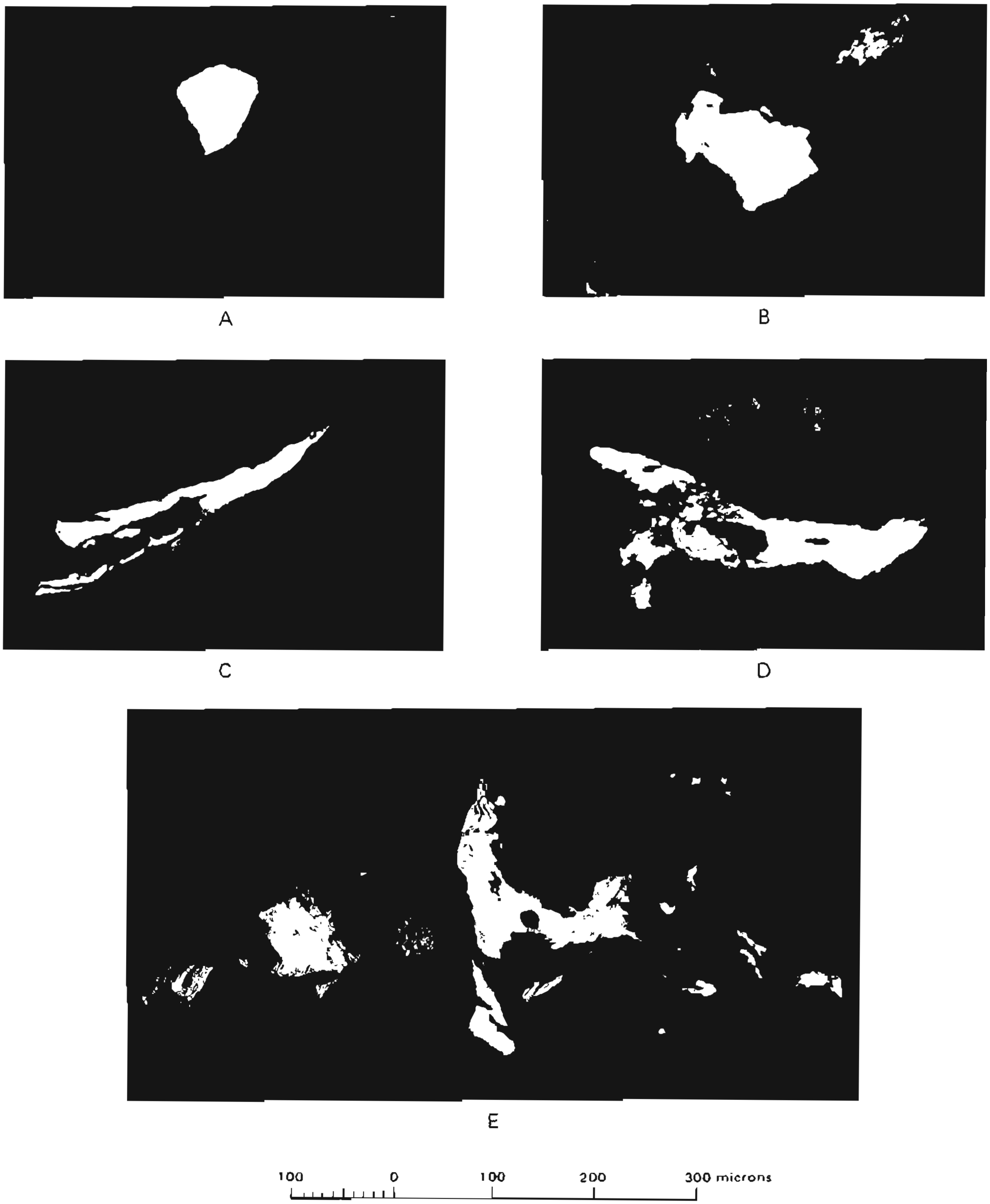

Figure 1. Photomicrographs of gold from the Grant Gold Mine. A and B - Gold grams in a quartz matrix (polished section); C, D, and E - Gold grains from sink product in a plastic matrix.

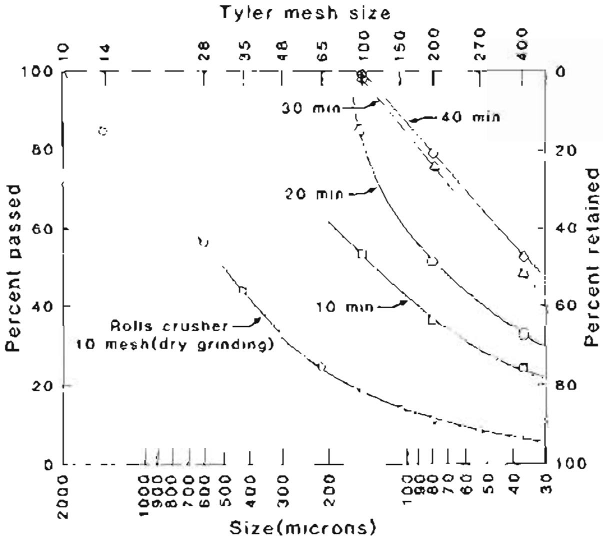

Figure 2. Sieve analyses. Sample reduced to minus 10 mesh in a rolls crusher and then wet ground for 10, 20, 30, and 40 min.

grains flattened by grinding balls. The photomicrographs indicate that the gold, which is confined to quartz, was liberated at a minus 65-mesh grind. A few wires as small as 20 microns were found in an amalgamation product, and some particles as large as 1,000 microns were identified in a concentrate at the mine.

GRINDING

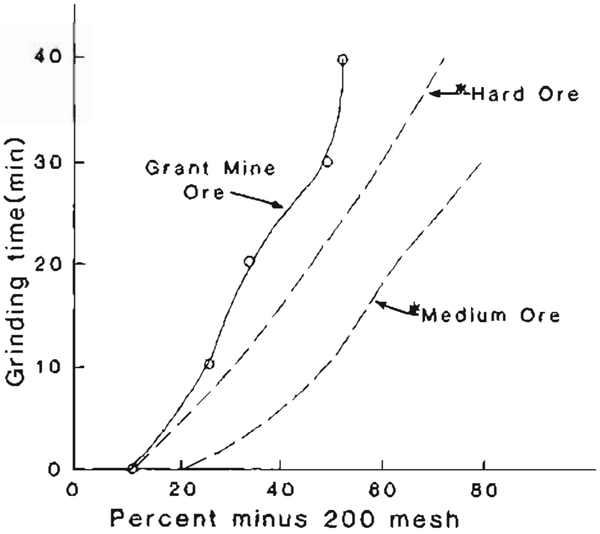

Figure 3. Graph comparing the grindability of Grant Gold Mine ore with a hard ore and a medium ore. (* - Standard provided by Denver Equipment Co., Bulletin B2-B34A).

The grinding characteristic was determined by a method suggested in Denver Equipment Co. Bulletin B2-B34A. First, the samples are crushed to minus 10 mesh and then wet ground in a ball mill. The percentage of material passing a 200-mesh screen is then compared with a standard in the bulletin. This comparison, when entered into the Denver Equipment ball-mill slide rule, determines the size of ball mill that will be required to provide a specific product given a particular feed size to a ball mill (flow sheet, p. 14). The screen analysis and grinding tests are shown in tables 1 through 5 and plotted as figure 2. Figure 3 compares Grant Mine ore with a typical hard and a medium-soft ore.

Gold is very malleable, and it will flatten instead of pulverize in the ball mill. Overgrinding will result in a loss of gold in a gravity (table) recovery.

Table 6 shows where the gold reports in the various size fractions. Note that the assay value of gold in the plus 100-mesh-size fraction increases correspondingly

Table 1. *Sieve analysis of ore reduced to minus 10 mesh in a rolls crusher.*

Tyler mesh	Weights on or between sieves		Total screen percentage	
	Grams	Percent	On	Passing
+10	-0-	-0-	-0-	100.00
-10 +14	78.6	15.45	15.45	84.55
-14 +28	143.4	28.19	43.64	56.36
-28 +35	62.4	12.27	55.91	44.09
-35 +48	56.0	11.01	66.92	33.08
-48 +65	39.4	7.75	74.67	25.33
-65 +100	37.5	7.37	82.04	17.96
-100 +150	20.2	3.97	86.01	13.99
-150 +200	16.0	3.15	89.16	10.84
-200 +270	11.0	2.16	91.32	8.68
-270 +400	11.3	2.22	93.54	6.46
-400 (pan)	32.9	6.47	100.00	0.00
	508.7			

with the length of grinding, from 0.29 to 36.45 oz/ton. By plotting the cumulative percent of total gold in each size fraction (table 6), a noticeable break occurs between the 20- and 30-min grinding times. In figure 2, the curve displayed for 20 min of grinding flattens to a straight line after 30 min. Thus, liberation probably occurred at about 25 min of grinding time, or at about 98 percent minus 65 mesh.

SINK-FLOAT SEPARATION

Each mesh-size fraction was separated with the heavy liquid bromoform (specific gravity 2.86) into a sink product and a float product. Each product was then assayed for gold and silver. Table 7 shows the size fraction, weight, assay value, and percent recovered; table 8 provides similar information for silver on the same sample. Figure 4 illustrates the grind required to liberate gold and silver by plotting the assay value of

Table 2. *Sieve analysis after 10 min. of wet grinding.*

	Weights on or between sieves		Total screen percentage	
Tyler mesh	Grams	Percent	On	Passing
+100	234.5	46.67	46.67	53.33
-100 +200	84.19	16.75	63.42	36.58
-200 +400	56.31	11.21	74.63	25.37
-400 (pan)	127.50	25.37	100.00	-0-

Table 3. *Sieve analysis after 20 min. of wet grinding.*

	Weights on or between sieves		Total screen percentage	
Tyler mesh	Grams	Percent	On	Passing
100	72.74	14.44	14.44	85.56
-100 +200	170.20	33.80	48.24	51.76
-200 +400	90.65	18.00	66.24	33.76
-400 (pan)	170.00	33.76	100.00	-0-

Table 4. *Sieve analysis after 30 min. of wet grinding.*

	Weights on or between sieves		Total screen percentage	
Tyler mesh	Grams	Percent	On	Passing
100	7.86	1.56	1.56	98.44
-100 +200	109.84	21.84	23.40	76.60
-200 +400	139.20	27.67	51.07	48.93
-400 (pan)	246.20	48.93	100.00	-0-

Table 5. *Sieve analysis after 40 min. of wet grinding.*

	Weights on or between sieves		Total screen percentage	
Tyler mesh	Grams	Percent	On	Passing
100	1.5	0.30	0.30	99.70
-100 +200	101.7	20.28	20.58	79.42
-200 +400	134.9	26.88	47.46	52.54
-400 (pan)	262.7	52.54	100.00	-0-

the float fraction (tailings) and particle size. As shown in figure 5, a plot of the percent of gold recovered versus particle size, a minus 65-mesh size is required for satisfactory recovery.

Similar information on sample 2 is contained in tables 9 and 10 and plotted as figures 6 and 7. The interpretation is similar, namely, that grinding to minus 65 mesh is required for optimum recovery. The overall recovery on sample 1 was 68.33 percent for the gold; 71.92 percent was recovered in sample 2. This may indicate a slightly higher recovery on higher grade ore. The recovery of silver is lower.

In tables 7-10 (figures 6 and 7) inclusive, a decline in recovery is indicated, with an increase in value of the tails below 270 mesh. This is partly due to the difficulty in making a good separation in fine material. In a gravity recovery system, gold this fine will be lost as a slime.

AMALGAMATION

In many instances, gold should be recovered by gravity separation or amalgamation (or both) before further treatment by cyanidation or flotation. McQuiston and Shoemaker (1975) report that the Dome Mine in Canada recovers about 55 percent of the gold by gravity and amalgamation and another 42.4 percent by cyanidation, for a total recovery of 97.4 percent. Homestake Mining recovers from 20 to 25 percent by gravity and amalgamation; the rest of their total 94.6 to 95 percent recovery is obtained by cyanidation.

Hedley and Tabachnick (1968) report that "a researcher found the maximum rate of dissolution of gold by cyanide to be 3.25 mg/cm^2/hr." If so, much coarse gold (plus 65 mesh) might not be dissolved in a reasonable time, and the undissolved particles would go into the tailings. According to Glembotskii and others (1963), the maximum size of a gold spherical particle that can be floated is 0.2 mm or 65 mesh (Tyler). Removal of coarser gold by gravity or amalgamation before flotation or cyanidation will improve the overall recovery and prevent accumulation of gold in the bottom of the classifier or in the ball-mill scoop box.

Four amalgamation tests were completed: two each on samples 1 and 2. In each test, about 0.5 g of mercury and water equal to 1.5 times the sample weight (1,000 g) was added. Next, the sample was rotated in a barrel amalgamator in the laboratory for 2 hr and the

Table 6. *Assay of value of fractions and percent of total gold in each size fraction.*

Tyler mesh	Weight (g)		Assay (oz/ton)			Percent total
			10-min. grind			
100	234.50	x	0.29	=	68.01	36.38
-100 +200	84.19	x	0.98	=	82.51	44.13
-200 +400	56.31	x	0.33	=	18.58	9.94
-400 (pan)	127.50	x	0.14	=	17.85	9.55
	502.50		0.37		186.95	100.00
			20-min. grind			
100	72.74	x	1.00	=	72.74	32.76
-100 +200	170.20	x	0.57	=	97.01	43.69
-200 +400	90.65	x	0.32	=	29.01	13.06
-400 (pan)	165.40	x	0.14	=	23.30	10.49
	499.99		0.44		222.06	100.00
			30-min. grind			
100	7.79	x	5.10	=	39.73	23.37
-100 +200	109.84	x	0.52	=	57.12	33.51
-200 +400	139.20	x	0.26	=	36.19	21.29
-400 (pan)	246.20	x	0.15	=	36.93	21.73
	503.03		0.34		169.97	100.00
			40-min. grind			
100	1.41	x	36.45	=	51.39	21.05
-100 +200	101.70	x	0.66	=	67.12	27.50
-200 +400	134.90	x	0.23	=	31.03	12.71
400 (pan)	262.70	x	0.36	=	94.57	38.74
	500.71		0.49		244.11	100.00

Table 7. *Sink-float weights, gold assay values, and percent gold recovered, sample 1.*

Mesh-size fraction	Weight (g)	Percent total	Assay (oz/ton)[c]	Percent recovered
+14 F[a]	71.7	14.74	0.55	
+14 S[b]	6.4	1.32	0.51	7.63
-14 +28 F	128.5	26.42	0.30	
-14 +28 S	14.2	2.92	1.88	40.92
-28 +35 F	52.9	10.88	0.15	
-28 +35 S	7.5	1.54	1.35	56.06
-35 +48 F	38.8	7.98	0.06	
-35 +48 S	6.0	1.23	2.79	87.78
-48 +65 F	33.3	6.85	0.08	
-48 +65 S	6.0	1.23	5.21	92.16
-65 +100 F	33.7	6.93	0.08	
-65 +100 S	5.9	1.21	11.68	97.59
-100 +150 F	8.3	1.71	0.05	
-100 +150 S	3.1	0.64	6.45	97.34
-150 +200 F	13.6	2.80	0.04	
-150 +200 S	2.1	0.43	9.23	97.25
-200 +270 F	8.9	1.83	0.03	
-200 +270 S	1.0	0.21	7.03	96.37
-270 +400 F	8.9	1.83	0.09	
-270 +400 S	1.2	0.25	4.49	87.08
-400 F	29.5	6.06	0.16	
-400 S	4.9	1.01	1.60	62.43
	486.4	100.02	0.64 (weighted avg)	68.33 (weighted avg)

[a] Float product.
[b] Sink product.
[c] oz per short ton.

Table 8. *Sink-float weights, silver assay values, and percent silver recovered, sample 1.*

Mesh size fraction	Weight (g)	Percent total	Assay (oz/ton)	Percent recovered
-10 +14 F	71.7	14.74	0.47	
-10 +14 S	6.4	1.32	1.38	20.76
-14 +28 F	128.5	26.42	0.32	
-14 +28 S	14.2	2.92	2.23	43.51
-28 +35 F	52.9	10.88	0.30	
-28 +35 S	7.5	1.54	1.02	32.53
-35 +48 F	38.8	7.98	0.22	
-35 +48 S	6.0	1.23	2.41	61.48
-48 +65 F	33.3	6.85	0.23	
-48 +65 S	6.0	1.23	3.70	74.35
-65 +100 F	33.7	6.93	0.36	
-65 +100 S	5.9	1.21	0.75	26.75
-100 +150 F	8.3	1.71	0.33	
-100 +150 S	3.1	0.64	4.21	82.58
-150 +200 F	13.6	2.80	0.25	
-150 +200 S	2.1	0.43	5.88	78.41
-200 +270 F	8.9	1.83	0.32	
-200 +270 S	1.0	0.21	7.85	73.36
-270 +400 F	8.9	1.83	0.65	
-270 +400 S	1.2	0.25	9.74	69.91
-400 F	29.5	6.06	0.99	
-400 S	4.9	1.01	3.56	37.38
	486.4	100.02	0.65 (weighted avg)	48.23 (weighted avg)

Table 9. *Sink-float weights, gold assay values, and percent gold recovered, sample 2.*

Mesh size fraction	Weight (g)	Percent total	Assay (oz/ton)	Percent recovered
+14 F	64.9	13.07	1.95	
+14 S	9.4	1.89	2.26	14.37
-14 +28 F	150.1	30.23	1.81	
-14 +28 S	24.0	4.83	4.19	27.01
-28 +35 F	51.2	10.31	1.14	
-28 +35 S	10.3	2.07	3.01	34.69
-35 +48 F	33.5	6.75	0.93	
-35 +48 S	7.8	1.57	0.69	14 72
-48 +65 F	28.7	5.78	0.49	
-48 +65 S	7.4	1.49	6.84	78.26
-65 +100 F	21.0	4.23	0.15	
-65 +100 S	5.9	1.19	8.78	94.26
-100 +150 F	18.0	3.62	1.96	
-100 +150 S	6.0	1.21	169.87	96.65
-150 +200 F	14.6	2.94	0.14	
-150 +200 S	3.7	0.75	22.79	97.63
-200 +270 F	8.2	1.65	0.11	
-200 +270 S	2.2	0.44	17.15	97.67
-270 +400 F	7.4	1.49	0.35	
-270 +400 S	2.1	0.42	11.86	90.59
-400 F	19.7	3.97	0.70	
-400 S	0.5	0.10	11.34	29.14
	496.5	100.00	4.01 (weighted avg)	71.92 (weighted avg)

Table 10. *Sink-float weights and silver assay values, sample 2.*

Mesh size fraction	Weight (g)	Percent total	Assay (oz/ton)	Percent recovered
-10 +14 F	64.9	13.07	0.89	
-10 +14 S	9.4	1.89	1.55	20.14
-14 +28 F	150.1	30.23	1.19	
-14 +28 S	24.0	4.83	2.31	23.69
-28 +35 F	51.2	10.31	0.51	
-28 +35 S	10.3	2.07	1.60	38.69
-35 +48 F	33.5	6.75	0.62	
-35 +48 S	7.8	1.57	6.22	70.02
-48 +65 F	28.7	5.78	0.33	
-48 +65 S	7.4	1.49	3.08	70.06
-65 +100 F	21.0	4.23	0.40	
-65 +100 S	5.9	1.19	4.29	75.08
-100 +150 F	18.0	3.62	1.24	
-100 +150 S	6.0	1.21	32.11	89.62
-150 +200 F	14.6	2.94	0.12	
-150 +200 S	3.7	0.75	9.11	95.06
-200 +270 F	8.2	1.65	0.49	
-200 +270 S	2.2	0.44	6.70	78.57
-200 +400 F	7.4	1.49	1.01	
-200 +400 S	2.1	0.42	7.50	67.83
-400 F	19.7	3.97	1.85	
-400 S	0.5	0.10	21.60	22.86
	496.9	100.00	0.64 (avg)	54.81 (avg)

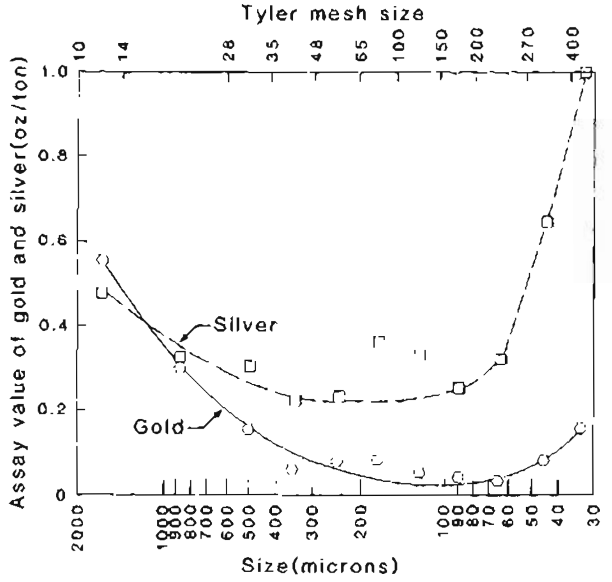

Figure 4. Gold and silver values of the float fraction (tails) for each size fraction, heavy-liquid separations, 2.86 specific gravity, sample 1.

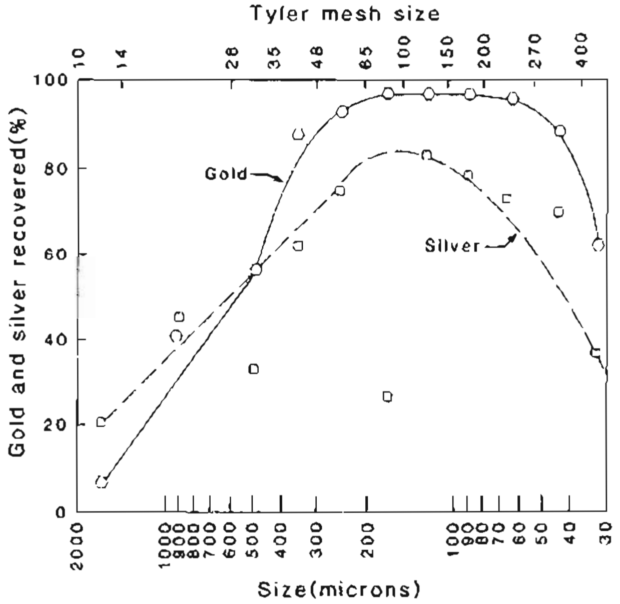

Figure 5. Percent of gold and silver recovered in the sink fraction (concentrate) for each size fraction, heavy-liquid separation, 2.86 specific gravity, sample 1.

Table 11. *Amalgamation test 1, sample 1 (10-min. grind, 76 percent minus 65 mesh).*

	Gold (oz/ton)	Percent	Silver (oz/ton)	Percent
Heads	0.34	100	0.54	100
Recovered	0.25	73.5	0.18	32.5
Tails	0.09	26.5	0.36	67.5

Table 12. *Amalgamation test 2, sample 1 (20-min. grind, 88 percent minus 65 mesh).*

	Gold (oz/ton)	Percent	Silver (oz/ton)	Percent
Heads	0.45	100	0.57	100
Recovered	0.31	68.9	0.09	15.8
Tails	0.14	31.1	0.48	84.2

Table 13. *Amalgamation test 3, sample 2 (10-min. grind, 76 percent minus 65 mesh).*

	Gold (oz/ton)	Percent	Silver (oz/ton)	Percent
Heads	2.04	100	1.15	100
Recovered	1.57	76.8	0.31	27.0
Tails	0.47	23.2	0.84	73.0

Table 14. *Amalgamation test 4, sample 2 (20-min. grind, 88 percent minus 65 mesh).*

	Gold (oz/ton)	Percent	Silver (oz/ton)	Percent
Heads	2.03	100	0.77	100
Recovered	1.84	90.6	0.22	28.6
Tails	0.19	9.4	0.55	71.4

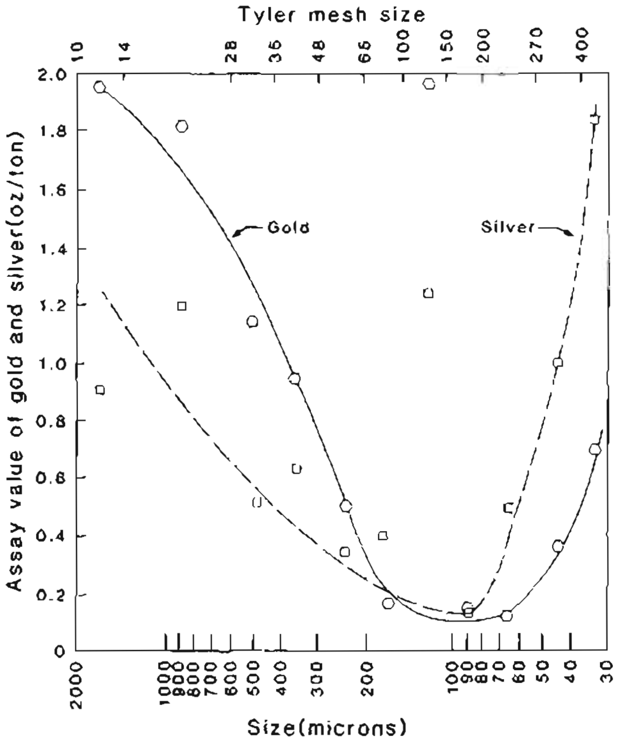

Figure 6. Gold and silver values of float fractions from sink-float separations (tails), sample 2.

amalgam was recovered by panning. The mercury was then removed by dissolving in nitric acid. The gold was annealed, weighed, and parted to determine the amount of silver present (tables 11-14).

About 70 percent of the gold was recovered in sample 1. In sample 2 (amalgamation test 4), 90.6 percent gold was extracted. Only the silver alloyed with gold was recovered by amalgamation; the silver recovery was low, 15 to 32 percent.

FLOTATION

Precious metals may be recovered by flotation to produce a high-grade concentrate for direct sale to a smelter or as a pretreatment for a cyanidation plant. Refractory ores such as those containing arsenic, a cyanicide, require roasting. Concentrating ores by flotation permits reducing the size of the roasting and cyanidation plant. Woolf and Jackson (1939) reported that flotation, roasting, and cyanidation at the Getchel Mine in Nevada increased recovery of gold from 52.7 percent to over 90 percent; at the Maitland Mine, also in Nevada, recovery increased from 28.15 to 90.3 percent with the same methods.

Six flotation tests were completed, two with the coarse gold removed by amalgamation and four without. In each test the following reagents were used: Aerofloat-208 (sodium diethyl and sodium di-secondary butyl dithiophosphate), 0.1 lb/ton; Aeroxanthate-301 (sodium secondary butyl xanthate), 0.1 lb/ton; and Dow froth 250, 0.1 lb/ton (pH 6.8-8). The mixing time was 10 min and flotation time was 5 min (tables 15-20).

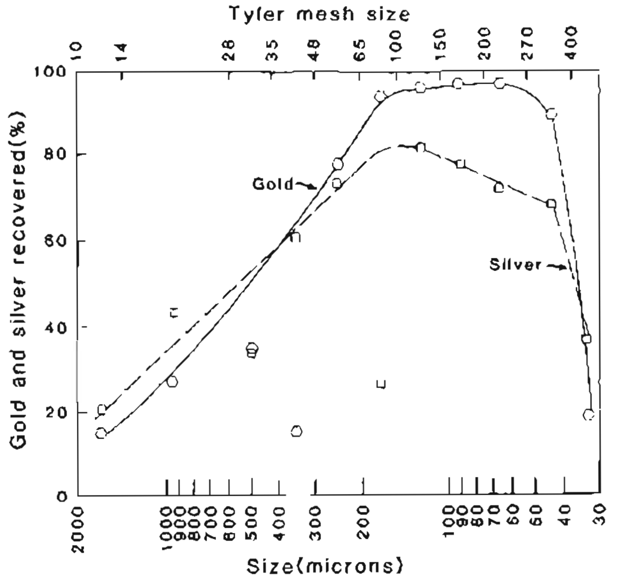

Figure 7. Percent of gold and silver recovered in each sink-size fraction from sink-float heavy-liquid separations, sample 2.

In short, the flotation tests without pretreatment recovered 95 percent of the gold and 60 percent of the silver in a concentrate averaging 7.55 oz/ton gold and 5.40 oz/ton silver with a concentration ratio of about 18:1. Although no effort was made to depress the arsenopyrite, most of the arsenic remained in the tails and the concentrate had only 0.03 percent arsenic, versus 0.48 percent in the heads.

In flotation tests 1 and 2, where 73.5 and 68.9 percent of the gold was removed by amalgamation (tables 12 and 13), 58.2 and 56.2 percent of the remaining gold was recovered, respectively. This computes to an extraction of 88.9 percent with pretreatment versus 95 percent without. Silver recovery increased from 60 percent to 65.4 percent, and thus appears to have been slightly improved by pretreatment.

CYANIDATION

Cyanidation alone may be used to recover gold and silver or it may be used as a posttreatment to gravity, amalgamation, or flotation. The cyanide salts of sodium, potassium, or calcium in very dilute solutions (1 lb of cyanide salt per ton of ore) dissolve the two precious metals. The solution must have a free metal face for the chemical to attack with (preferably) no cyanicides—copper, zinc, or arsenic minerals—present in the ore. However, if cyanicides are present,

Table 15. *Flotation test 1, sample 1 (tails from amalgamation test 1).*

	Weight (g)	Gold (oz/ton)	Percent	Silver (oz/ton)	Percent
Heads	839	0.09	100.0	0.36	100.0
Flotation conc.	76	0.56	58.2	2.17	54.6
Tails	763	0.04	41.8	0.18	45.3
Total recovery (amalgamation plus flotation)			87.0		66.8

Table 16. *Flotation test 2, sample 1 (tails from amalgamation test 2).*

	Weight (g)	Gold (oz/ton)	Percent	Silver (oz/ton)	Percent
Heads	895	0.14	100.0	0.48	100.0
Flotation conc.	110	0.64	56.2	2.12	54.3
Tails	785	0.07	43.8	0.25	45.7
Total recovery (amalgamation plus flotation)			88.8		66.9

Table 17. *Flotation test 3, sample 1 (25-min. grind, 98 percent minus 65 mesh).*

	Weight (g)	Gold (oz/ton)	Percent	Silver (oz/ton)	Percent
Heads	501	0.41	100.0	0.23	100.0
Flotation conc.	23	8.34	92.9	1.72	35.1
Tails	488	0.03	7.1	0.15	64.9

Table 18. *Flotation test 4, sample 1 (25-min. grind, 98 percent minus 65 mesh) duplication of test 3.*

	Weight (g)	Gold (oz/ton)	Percent	Silver (oz/ton)	Percent
Heads	520.5	0.35	100.0	0.26	100.0
Flotation conc.	65.2	2.62	94.9	1.13	55.5
Tails	455.3	0.02	5.1	0.13	44.5

Table 19. *Flotation test 5, sample 1 (25-min. grind, 98 percent minus 65 mesh).*

	Weight (g)	Gold (oz/ton)	Percent	Silver (oz/ton)	Percent	Arsenic (%)
Heads	489.82	0.52	100.0	0.60	100.0	0.48
Flotation conc.	27.82	8.76	96.4	7.85	74.7	0.03
Tails	462.0	0.02	3.6	0.16	25.3	0.51

Table 20. *Flotation test 6, sample 1 (25-min. grind, 98 percent minus 65 mesh).*

	Weight (g)	Gold (oz/ton)	Percent	Silver (oz/ton)	Percent	Arsenic (%)
Heads	484.2	0.42	100.0	0.58	100.0	0.47
Flotation conc.	19.2	10.48	95.6	10.90	75.0	0.03
Tails	46.50	0.02	4.4	0.15	25.0	0.48

either pretreatment (including roasting) or excessive amounts of cyanide (up to 16 lb/ton) may be required, as at Benquet, in the Phillipine Islands (McQuiston and Shoemaker, 1975). The precious metals are recovered by precipitation with zinc dust or by absorption on charcoal. Tests are required to determine if the ore is amenable to cyanidation, reagent consumption, and grinding. Crushing and heap leaching can sometimes generate a fair recovery (Potter, 1969).

In the first set of five tests, a 500-g sample was treated in a 1,000-g solution of 0.05 percent potassium cyanide (KCN) buffered with either 0.5 g calcium oxide (CaO) or 1 lb KCN and 1 lb lime per ton of ore (tables 21-25). The tests indicate a peak and then a continual decline in recovery with finer grinding (fig. 8).

Arsenic is present in the ore. Hedley and Tabachnick (1968) state, "The inhibiting effects of the sulfide compounds resulting from the decomposition of arsenic or antimony sulfide minerals is a surface phenomenon. These compounds or their ions are attached to the gold surfaces, and interaction of the gold, the oxygen, and the CN ions is partially prevented."

In the absence of arsenic and antimony sulfides (cyanicides), finer grinding could be expected to im-

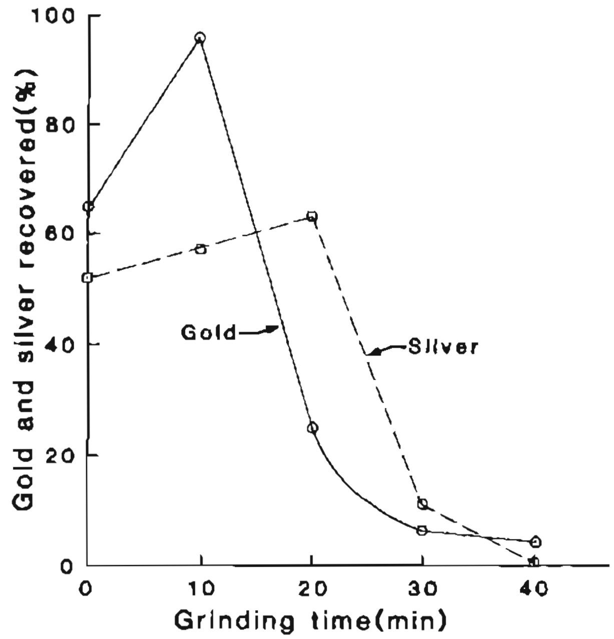

Figure 8. Effect of particle size on the recovery of gold and silver by cyanidation. Dissolution time, 24 hr.

Table 21. *Cyanidation test 1, sample 1 (no grinding, minus 10 mesh, pH = 9.3).*

	Gold (oz/ton)	Percent	Silver (oz/ton)	Percent	KCN consumed (lb/ton)
Heads	0.48	100.0	0.60	100.0	0.81
Recovered	0.31	64.6	0.31	51.7	
Tails	0.17	35.1	0.29	48.3	

Table 22. *Cyanidation test 2, sample 1 (10-min. grind, 72 percent minus 65 mesh, pH = 8.6).*

	Gold (oz/ton)	Percent	Silver (oz/ton)	Percent	KCN consumed (lb/ton)
Heads	0.59	100.0	0.77	100.0	0.90
Recovered	0.57	96.61	0.43	55.84	
Tails	0.02	3.39	0.34	44.16	

Table 23. *Cyanidation test 3, sample 1 (20-min. grind, 84 percent minus 100 mesh, pH = 8.8).*

	Gold (oz/ton)	Percent	Silver (oz/ton)	Percent	KCN consumed (lb/ton)
Heads	0.47	100.0	0.51	100.0	0.92
Recovered	0.12	25.53	0.32	62.75	
Tails	0.35	74.47	0.17	37.25	

Table 24. *Cyanide test 4, sample 1 (30-min. grind, 90 percent minus 100 mesh, pH = 8.8).*

	Gold (oz/ton)	Percent	Silver (oz/ton)	Percent	KCN consumed (lb/ton)
Heads	0.35	100.0	0.39	100.0	0.94
Recovered	0.02	5.71	0.04	10.26	
Tails	0.33	94.29	0.35	89.74	

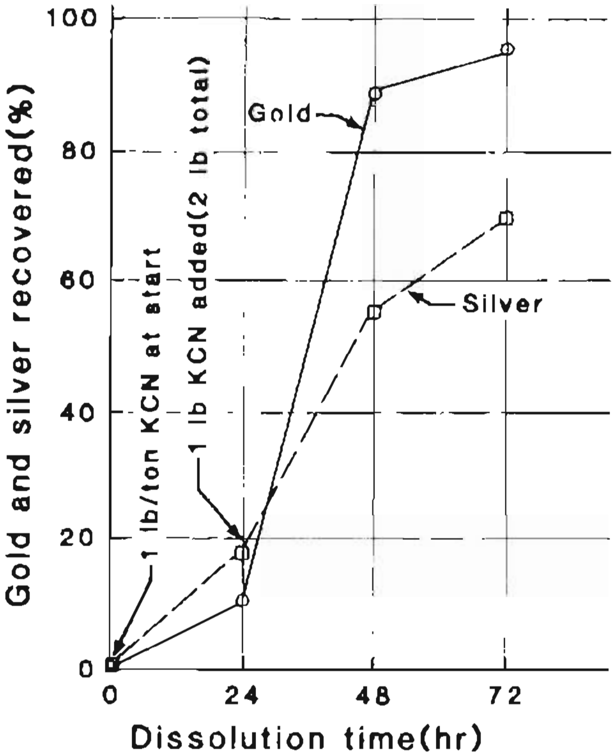

Figure 9. Effect of dissolution time and addition of cyanide on the recovery of gold and silver. Grinding time, 25 min.

prove the efficiency of cyanidation by increased liberation of gold. However, with cyanicides present, finer grinding increases the surface area of the sulfides and causes them to consume cyanide and thus limit the extraction of gold. In these tests, cyanide was consumed and recovery decreased with finer grinding. Because the cyanide was consumed, recovery might be increased by adding more cyanide and extending the contact time. Test 6 was completed thusly, with more cyanide plus lead nitrate and a longer contact time (table 26, fig. 9).

Cyanide tests 7 and 8 (tables 27 and 28) were conducted to determine the effect of extracting gold from a flotation concentrate and the value, if any, of calcining (roasting) the concentrate. The tests indicate that roasting resulted in a lower gold recovery and an abysmal silver recovery. Cyanide consumption was lowered. Additional testing should concentrate on the use of a stronger cyanide solution, additional retention time, and possibly grinding the calcine prior to cyanidation. The overall recovery of gold by flotation and cyanidation was 88.5 percent; with roasting, 71.7 percent.

Two additional cyanide tests were completed on the tailings from amalgamation tests 3 and 4 (tables 29 and 30). Cyanidation of tailings from the amalgamation tests improved recovery of gold as shown in table 30, where 99 percent of the gold was extracted.

Table 25. *Cyanide test 5, sample 1 (10-min. grind, 99 percent minus 100 mesh, pH = 8.9).*

	Gold (oz/ton)	Percent	Silver (oz/ton)	Percent	KCN consumed (lb/ton)
Heads	0.73	100.0	0.28	100.0	0.96
Recovered	0.03	4.11	0.00	-0-	
Tails	0.70	95.89	0.28	100.0	

Table 26. *Cyanide test 6, sample 1 (25-min. grind, 98 percent minus 100 mesh, pH = 9.0). Added 1 lb/ton lead nitrate, 1 lb/ton KCN at start of test, 1 lb/ton added after 24 hr.*

	Time (hr)	Gold (lb/ton)	Percent	Silver (oz/ton)	Percent	KCN consumed (lb/ton)
Heads		0.45	100.0	0.56	100.0	
Recovered	24	0.05	11.1	0.10	17.86	0.95
Recovered	48	0.40	89.0	0.31	55.4	1.76
Recovered	72	0.43	95.6	0.39	69.6	1.94
Tails		0.02	4.4	0.17	30.4	

Table 27. *Cyanide test 7, flotation concentrate (flotation test 5, pH = 12.0).*

	Gold (oz/ton)	Percent	Silver (oz/ton)	Percent	KCN consumed (lb/ton)
Heads	8.76	100.0	7.85	100.0	
Recovered	8.04	91.8	6.31	80.4	0.76
Tails	0.72	8.2	1.54	19.6	

Table 28. *Cyanide test 8, flotation concentrate. Flotation test 6 (concentrate roasted at 650°C for 6 hr, pH = 12).*

	Gold (oz/ton)	Percent	Silver (oz/ton)	Percent	KCN consumed (lb/ton)
Heads	10.48	100.0	10.90	100.0	
Recovered	7.86	75.0	3.48	31.9	0.01
Tails	2.62	25.0	7.42	68.1	

Table 29. *Cyanide test 9 (tailings from amalgamation test 3, pH = 8.4).*

	Gold (oz/ton)	Percent	Silver (oz/ton)	Percent	KCN consumed (lb/ton)
Heads	0.47	100.0	0.84	100.0	
Recovered	0.35	74.5	0.44	52.4	0.74
Tails	0.12	25.5	0.40	47.6	
Total recovery		94.1		47.9	

Table 30. *Cyanide test 10 (tails from amalgamation test 4, pH = 9.3).*

	Gold (oz/ton)	Percent	Silver (oz/ton)	Percent	KCN consumed (lb/ton)
Heads	0.19	100.0	0.55	100.0	
Recovered	0.17	89.5	0.36	65.5	0.76
Tails	0.02	10.5	0.19	34.5	
Total recovery		99.0		75.4	

RECOVERY SUMMARY

a. Ore from the Grant Mine is classified as a 'hard ore' to grind.
b. Grinding to minus 65 mesh (210 microns) is required to liberate the gold.
c. The curves of sink-float fractions indicate that a 65 to 75 percent recovery of gold might be expected in gravity (table) recovery system at a minus 48-mesh grind.
d. Recovery by amalgamation varied from 68.9 to 90.6 percent.
e. Flotation of mine-run ore averaged 95 percent recovery of gold and 60 percent recovery of the silver. The overall recovery by flotation of amalgamation tailings was lower than with untreated ore.
f. An excellent recovery was made by cyanidation of mine-run ore ground to 72 percent minus 65 mesh. Additional grinding lowered recovery. The addition of cyanide with lead nitrate improved recovery.
g. The best overall recovery was obtained by cyanidation of the tails from sample 2 after removal of gold by amalgamation: 99 percent of the gold and 75 percent of the silver.

FLOW SHEET

Figure 10 is a suggested flow sheet for a flotation concentrator with a cyanidation circuit to produce a gold-silver bullion. The flow sheet does not show all of the pumps that would be required, nor does it include a stripping section for recovery of gold and silver from the charcoal. In designing the flow sheet, the following criteria were used:

a) For crushing and grinding:
    1) A size-reduction ratio of 4:1 was used. A 10- by 16-in. crusher can reduce 8 in. rock to 2 in. at 12 to 18 tons/hr. A 20-in. gyratory crusher has a similar capacity in reducing 2-in. rock to minus 1/2 in. This combination is admittedly overdesigned for 50 tons/day, but it is considered preferable to smaller crushers, where sticking of ore might be a problem. If the mill were increased to 100 tpd, no increase in size of the crushing plant would be required (for one shift/day operation).
    2) The ore is considered a hard one to grind (fig. 3). A 5- by 5-ft ball mill will be required to grind 50 tons per 24 hr from minus 1/2 in. to minus 65 mesh.

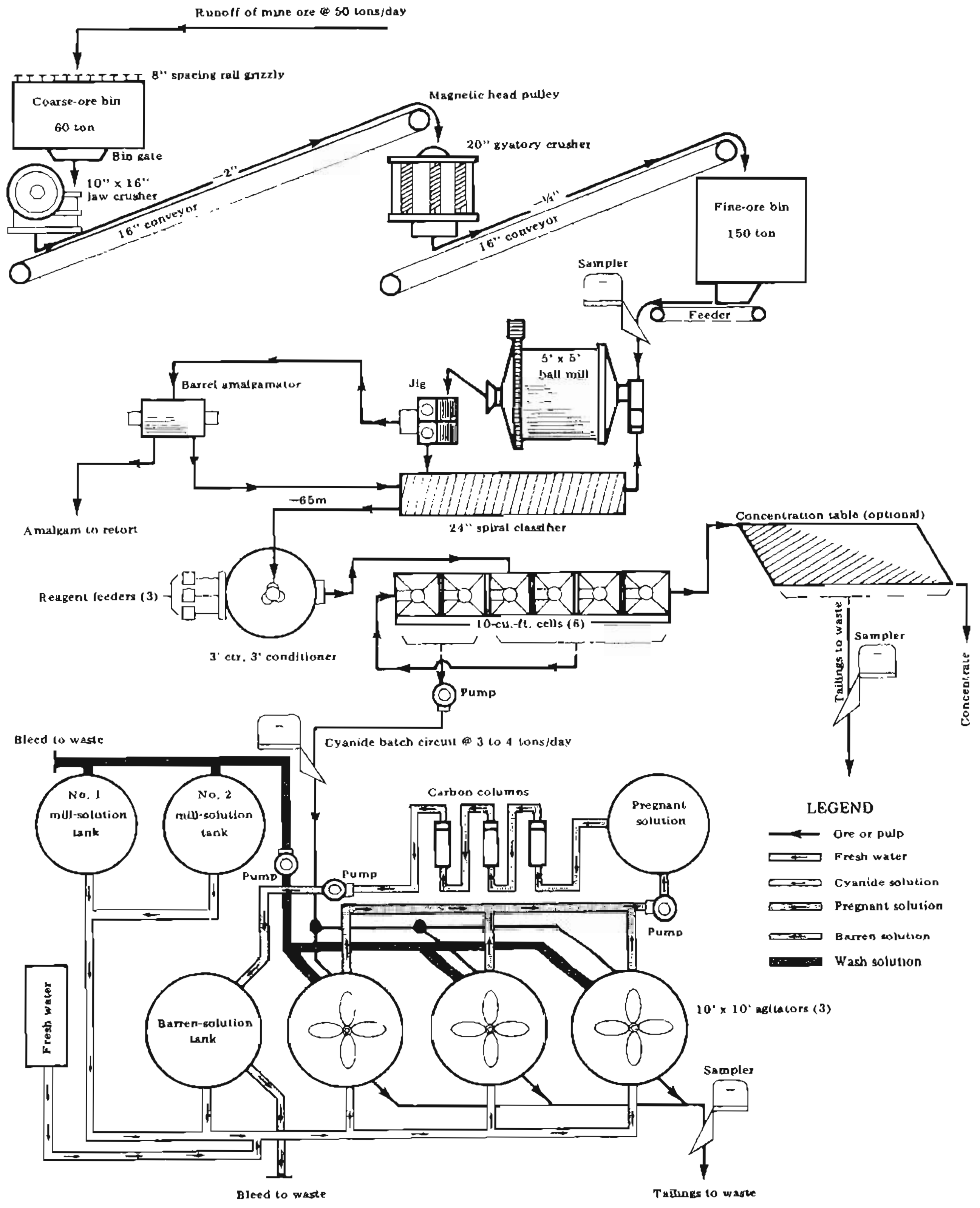

Figure 10. Flow sheet to 50-tpd gold flotation concentrator with a 4-tpd batch cyanide circuit.

b) For classification, a 24-in. spiral classifier was selected to operate with the ball mill in closed circuit. (Use of a hydrocyclone also merits investigation.)

c) For flotation:
   1) A gold particle size of minus 65 mesh (0.2 mm) or less is required for gold flotation: the tests indicate a minus 65-mesh grind is adequate for liberation.
   2) The conditioner and flotation cells have been sized for adequate reaction time with the flotation reagents.

d) For the jig and amalgamator:
   1) These are considered optional items, but would remove coarse gold grains.
   2) The flow sheet shows the tails from the amalgamator being returned to the classifier.

e) For the table:
   1) The table is optional but would provide visual control of the effectiveness of flotation.
   2) The heavy nonmetallic or nonsulfide minerals might be concentrated for a valuable by-product.

f) For the cyanide circuit:
   1) The cyanide circuit is provided as an alternative to selling the flotation product to a smelter.
   2) An assumption is made that at least 48 hr of dissolution time will be required.
   3) About 2.8 tpd of concentrate will be produced, but 4 tpd was allowed in the design.
   4) The charcoal absorption columns are shown, but precipitation by zinc could be considered.

The suggested flow sheet should be tested by a pilot-plant test run at an established laboratory. Plant operation should determine the amount of reagents required for the flotation circuit, the cyanide consumption for cyanidation, and the dissolution time.

The tests were made on samples taken on February 9, 1981. They are believed to be representative of the ore going to the small mill from the O'Dea vein. However, ore characteristics may change as mining progresses, and pilot-plant work should be conducted before final mill design.

RECOMMENDATIONS

a) Prepare a cost analysis of the proposed flotation plant and the cyanidation batch plant.

b) Have a commercial laboratory make a continuous pilot-plant run by flotation on a representative sample of ore.

c) Evaluate these options:
   . Flotation with a sale of the concentrate to a smelter.
   . Flotation followed by a batch cyanide process.
   . Cyanidation.

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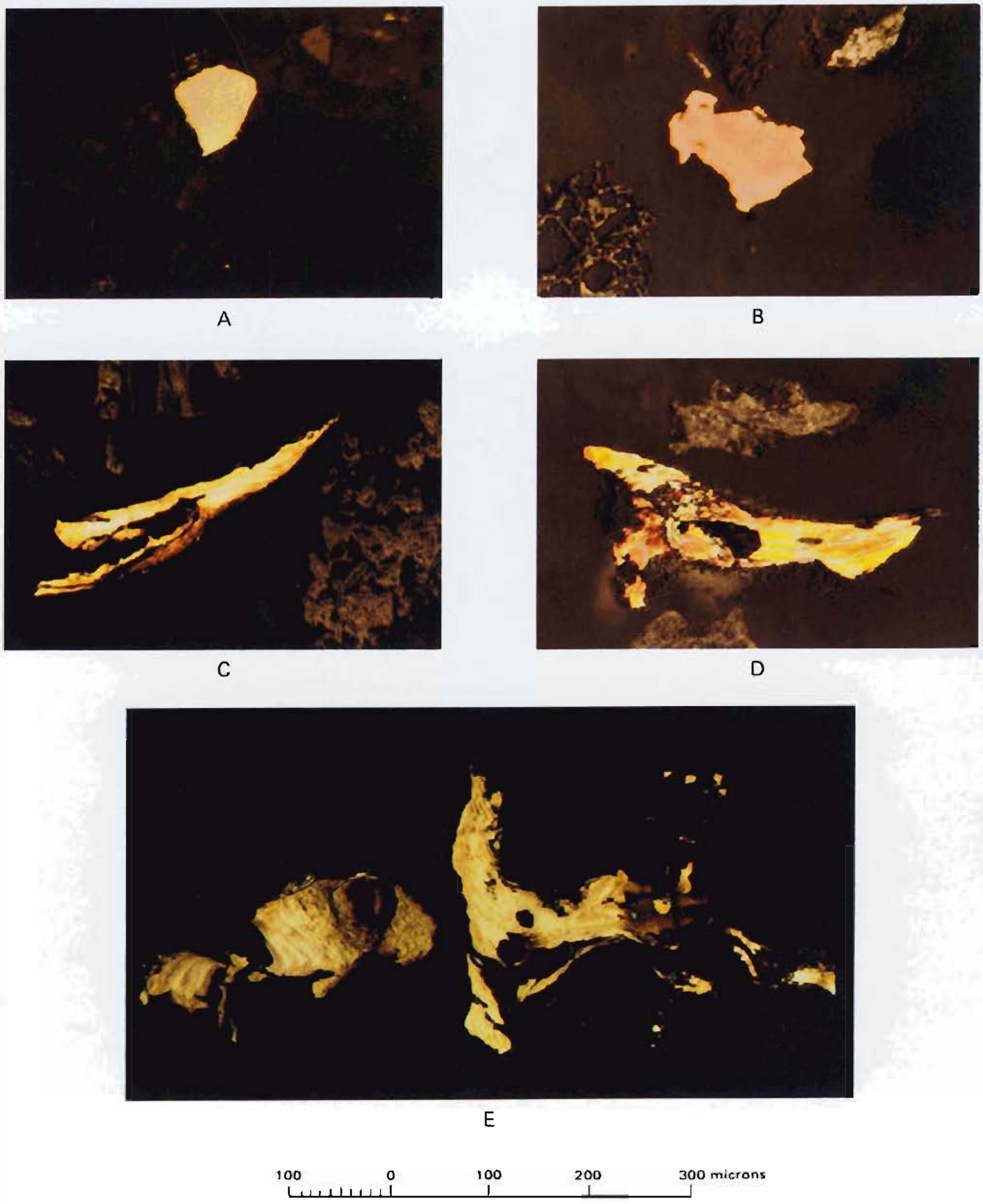

Figure 1. Photomicrographs of gold from the Grant Gold Mine. A and B - Gold grams in a quartz matrix (polished section); C, D, and E - Gold grains from sink product in a plastic matrix.

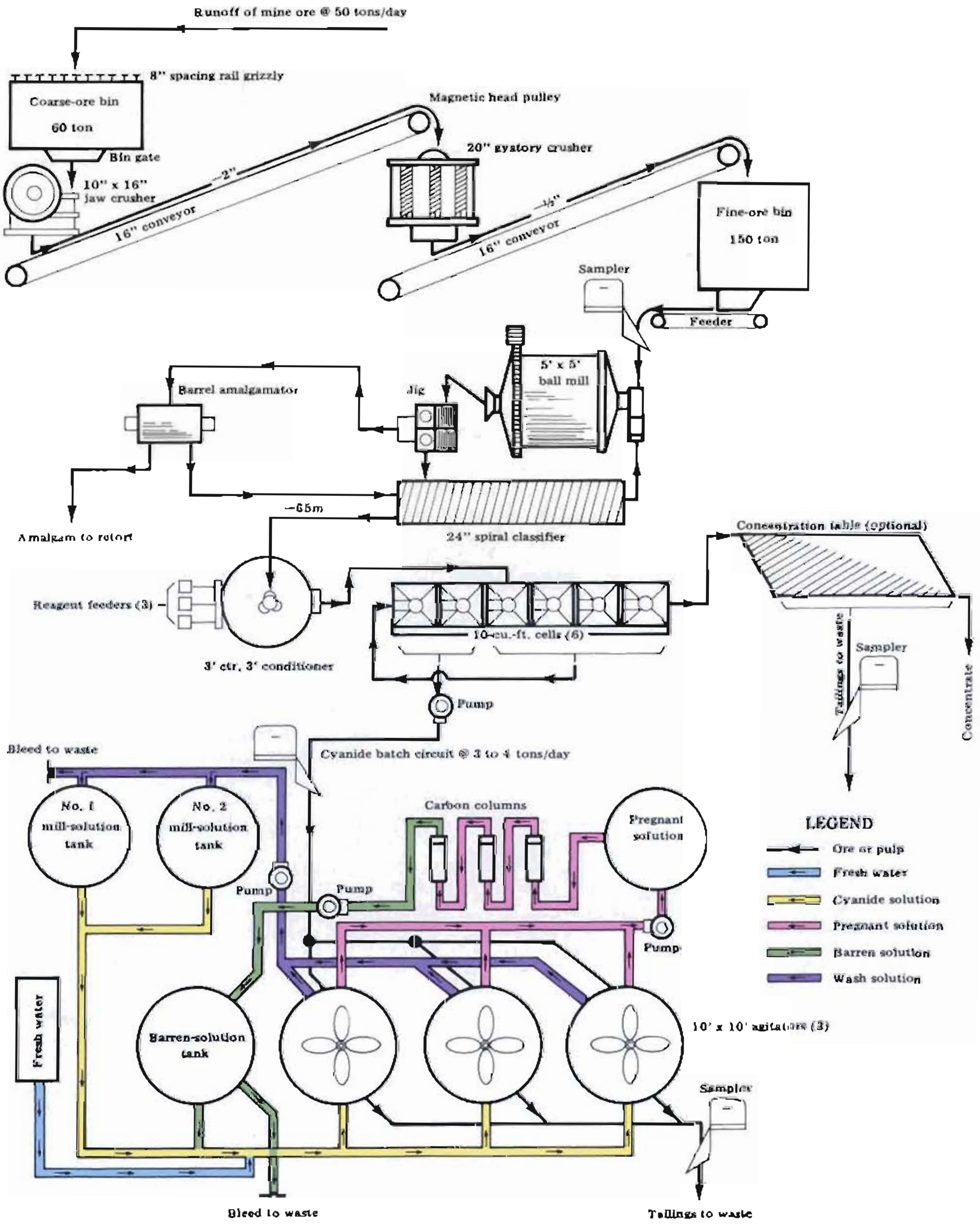

Figure 10. Flow sheet to 50-tpd gold flotation concentrator with a 4-tpd batch cyanide circuit.