TREATMENT OF AN ARIZONA GOLD ORE

by

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CHAPTER I.--INTRODUCTION

General

This paper gives the results of treatment tests made on gold ore from the Oro Blanco district in Santa Cruz County, Arizona, about 70 miles southwest of Tucson. Treatment tests have never been made on this material to the writer's knowledge. The object in selecting this subject was to study gold-milling methods and incidently to determine, if possible, the milling methods best adapted to the ores of this district.

In a problem of this kind the metallurgist makes preliminary studies which deal with the character of the material involved. These studies include: (a) The association of the gold with other minerals; (b) the coarseness of the gold; and (c) the presence of detrimental minerals.

The association of the gold with other minerals has a direct bearing on the treatment process because if the gold is not liberated from these minerals by grinding, then the character of the associated mineral may control the selection of a process rather than the gold, as the associated mineral usually predominates in quantity.

The coarseness of free gold in an ore not only influences the selection of a process to recover the gold, but also controls the degree of grinding required to liberate the gold.

The presence of minerals detrimental to certain milling processes is sometimes the controlling factor in selecting a treatment method. The effect of oxidized copper minerals in the cyanide process, and the effect of arsenic or lead minerals in the amalgamation process are cited as examples of minerals detrimental to the processes noted.

When the general character of the ore is known it is sometimes possible to eliminate some treatment methods as not being adapted to the material involved and thereby save considerable experimental work. A short confirmatory test may be required to prove the point beyond question, but on the whole considerable experimental work is saved by a preliminary study of the character of the particular ore involved.

Amalgamation

Amalgamation depends upon the affinity of gold for mercury. In order to effect a satisfactory recovery of the gold by this method the gold must be liberated from associated minerals by grinding. With most gold ores it is not possible to liberate all the gold by grinding, hence the amalgamation method usually yields a low recovery compared to processes not requiring all the gold to be liberated. In the amalgamation method the surfaces of both gold and mercury must be bright, and since certain minerals and foreign substances darken the mercury, the ore must be free of these substances or some method must be introduced to eliminate the effect of these deleterious substances. Amalgamation is particularly effective in recovering free coarse gold and in doing so it makes the direct production of a high-grade gold bullion possible. In present gold-treatment plants the amalgamation method is used mostly as an auxiliary method to remove free coarse gold and is usually supplemented by some other process to recover gold other than that described.

Cyanidation

The principles and applications of the cyanide process have recently been described in a bulletin[1] published by the Arizona Bureau of Mines, which states that the cyanide process for the recovery of gold from its ores is based upon the principle that dilute solutions of sodium or potassium cyanide will dissolve gold from crushed or ground ores under certain conditions. The method is distinctly a chemical one and requires positive control of alkalinity, cyanide quantities, and assays of both solutions and residues. The dissolved gold is recovered from the pregnant solution by the addition of zinc dust or shavings.

Two general methods of applying cyanidation to the recovery of gold from its ores are in common use--namely, the percolation method, and the agitation method. These methods differ in the size to which the ore must be reduced for treatment.

The cyanide method of recovering gold usually yields a high recovery as compared to amalgamation or flotation, since the solvent is able to recover not only the free gold, but also portions of the gold attached to gangue minerals.

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[1] Chapman, T. G., Treating Gold Ores: Arizona Bureau of Mines Bulletin No. 133, April, 1932, p. 24.

Gravity Concentration

The basic principle of gravity concentration is the fact that in a liquid ore pulp gold and other particles of high specific gravity settle rapidly and concentrate at the bottom of the pulp bed. Agitation, as exemplified by vanners and concentrating tables, promotes this rapid settling.

Gravity concentration usually yields a low recovery, but it has the advantage of low initial and operating cost.

Flotation

The most recent advance in the metallurgy of gold is the application of flotation methods of concentration. In the past three years gold has been floated with success in numerous concentrators, giving efficient metallurgical results.

Flotation depends upon the adhesion of air bubbles for minerals having a bright metallic surface. Under the proper conditions, air bubbles rising through a liquid ore pulp attach themselves to metallic lustered particles and carry them to the surface, thereby concentrating them at that point where they can be removed and further treated to produce a bullion.

In the flotation of gold ores the proper conditions are produced by the addition of small amounts of reagents to the ore pulp. Experience at the University of Arizona has shown that amyl xanthate and sodium aerofloat are satisfactory collectors, and that General Naval Stores No. 5 pine oil is a satisfactory frothing agent. Lime is used to give the desired alkalinity.

Flotation has the advantage of recovering gold in the form of included grains and gold that is intimately associated with sulphides, as well as fine free gold.

CHAPTER II.--MATERIALS AND APPARATUS USED

The ore used for the experimental work came from the Oro Blanco District in Santa Cruz County, Arizona. The gold occurs in a quartz vein, together with minor quantities of hematite and magnetite. There are no metallic sulphides present in the ore. The gold is free and fairly coarse.

The amalgamation tests and cyanide tests were carried out in bottles of 2.5-liter capacity. Agitation was obtained by placing the bottles on horizontal wooden rollers having a speed of 60 revolutions per minute. The plate amalgamation tests were carried out on an 8 by 60 inch copper plate coated with silver amalgam.

Preliminary small-scale flotation tests were conducted in Fahrenwald laboratory flotation machines of 500 and 2,000 gram capacities. The flotation machine used for large-scale continuous tests was a 5-cell Fahrenwald machine equipped with a conditioner and feeder. In past work with this machine the five froth products were kept separate, thus producing unfinished middling products. The writer designed and constructed a launder which made the return of the middling products to the first cell possible, thus eliminating unfinished products.

A scavenging launder equipped with corduroy bottom was used in continuous tests in place of a table for scavenging the flotation tailing. This launder was made of soft pine wood 7 inches deep, 8 inches wide, and 8 feet long set at a slope of 2 inches to the foot. The bottom was covered with heavy ribbed corduroy, the ribs being transverse to the length of the launder.

CHAPTER III.--SMALL-SCALE EXPERIMENTAL WORK

Bottle Amalgamation

Test 1

Duplicate samples of ore ground to minus 20-mesh were mixed with 5 per cent of mercury and enough water to produce the desired pulp consistency. The bottles were placed on the roller previously mentioned and the contents mixed for 5 hours. After agitation the amalgam was separated from the ore pulp by panning. The average results of these tests are given in Table 1A and an average screen-assay analysis of the amalgamation tailings is given in Table 1B.

Table 1A.--Average Results of Bottle Amalgamation Tests

	Weight, grams	Assay, ounces gold per ton	Weight of gold mg.	Weight of gold, ounces, based on 100 tons of ore	Per cent of total gold
Heads........	1,022.5	0.512	--	(1)51.2	100.0
Amalgam......	--	--	8.56	24.4	47.7
Tailing......	--	0.268	--	26.8	52.3

(1)Products assay.

Table 1B.--Average Screen-Assay Analysis of Test 1 Tailings

Screen size, mesh	Weight, grams	Tons in 100	Assay, ounces gold per ton	Weight of gold, ounces	Per cent of total gold
-20 +28.....	156.3	15.29	0.29	4.47	16.7
-28 +35.....	266.8	26.29	0.32	8.41	31.4
-35 +48.....	131.2	12.83	0.28	3.62	13.5
-48 +65.....	121.7	11.90	0.27	3.18	11.8
-65 +100....	116.5	11.39	0.24	2.73	10.2
-100 +150...	59.6	5.83	0.25	1.43	5.3
-150 +200...	46.5	4.54	0.23	1.02	3.8
-200........	121.9	11.93	0.17	1.97	7.3
Composite...	1,022.5	100.00	0.27	26.83	100.0

Test 2

The object in making this test was to determine the amount of gold in the so-called "rusty condition." The conditions in Test 2 were the same as in Test 1 except that sodium was added to the mercury, forming sodium amalgam, which usually reduces and amalgamates "rusty" gold. Table 2A gives the average results of Test 2, and Table 2B gives the average screen-assay analysis of tailings produced.

Table 2A.--Average of Bottle Amalgamation Tests Using Sodium Amalgam

	Weight, grams	Assay ounces gold per ton	Weight of gold, mg.	Weight of gold, ounces, based on 100 tons of ore	Per cent of total gold
Heads....	1,022.5	0.52	---	(1)51.9	100.0
Amalgam..	---	---	9.26	26.4	50.9
Tailing..	---	0.26	---	25.5	49.1

(1)Products assay.

Table 2B.--Average Screen-Assay Analysis of Test 2 Tailings

Screen size mesh	Weight, grams	Tons in 100	Assay, ounces gold per ton	Weight of gold, ounces	Per cent of total gold
-20 +28....	169.7	16.60	0.29	4.81	18.9
-28 +35....	258.3	25.26	0.31	7.83	30.7
-35 +48....	122.3	11.96	0.27	3.25	12.8
-48 +65....	136.6	13.36	0.28	3.70	14.5
-65 +100...	111.7	10.93	0.22	2.40	9.4
-100 +150..	61.8	6.04	0.22	1.33	5.2
-150 +200..	44.4	4.34	0.17	0.74	2.9
-200.......	117.7	11.51	0.13	1.44	5.6
Composite..	1,022.5	100.00	0.26	25.50	100.0

Conclusions from Bottle Amalgamation Tests

The results given in Table 1A show that 47.7 per cent of the total gold was amalgamated, which indicates that approximately half the gold is in the coarse free condition when the material is ground to minus 20-mesh. The results given in Table 2A indicate that very little, if any, of the gold is in a so-called "rusty" condition, since the average recovery in Test 2 amounted to only 3.2 per cent more with the sodium amalgam as compared with mercury.

Referring to the screen-assay analyses given in Tables 1B and 2B, although the coarser sizes contain more gold per ton than the finer sizes, amalgamation with finer grinding is not likely to produce a tailing with less than 0.17 ounce gold per ton compared with an average tailing of 0.27 ounce gold per ton obtained by grinding to 20-mesh.

Plate Amalgamation

Test 3

A sample weighing 50 pounds was ground for 50 minutes in a 2-foot Hardinge ball mill with a 350-pound charge of balls, which produced a product containing 1.5 per cent of plus 65-mesh and 63.6 per cent minus 200-mesh. The ground ore was fed by a mechanical feeder to two copper amalgamating plates at the rate of 1/2 pound per minute. These plates were coated with silver amalgam and placed in series with a vertical drop of 1/2 inch between them. Each plate was 8 by 30 inches in size and set at a slope of 1.5 inch to the foot. An amalgam trap followed the plate. The pulp density of the feed was 6 water to 1 of solids.

Table 3A gives the results of the plate amalgamation test, and the screen-assay analysis of the tailing produced is given in Table 3B.

Table 3A.--Results of Plate Amalgamation Test

	Weight, pounds	Assay, ounces gold per ton	Weight of gold, mg.	Weight of gold, ounces, based on 100 tons of ore	Per cent of total gold
Heads........	50.00	0.55	--	(1)54.6	100.0
Amalgam......	--	--	189.01	24.2	44.3
Tailing......	--	0.30	--	30.4	55.7

(1)Products assay.

Table 3B.--Screen-Assay Analysis of Tailings from Test 3

Screen size, mesh	Weight, grams	Tons in 100	Assay, ounces gold per ton	Weight of gold, ounces	Per cent of total gold
+65.........	94.4	9.44	0.54	5.05	16.6
-65 +100....	219.9	21.99	0.30	6.60	21.7
-100 +150...	243.9	24.39	0.27	6.59	21.7
-150 +200...	120.5	12.05	0.29	3.49	11.5
-200........	321.3	32.13	0.27	8.68	28.5
Composite...	1,000.0	100.00	0.30	30.41	100.0

Conclusions Reached from Consideration of Results of Test 3

Referring to Tables 1A and 3A, plate amalgamation was found to give a recovery of 44.3 per cent of the gold, while bottle amalgamation gave a recovery of 47.7 per cent, a difference of 3.4 per cent.

As a general rule, bottle-amalgamating tests yield from 10 to 15 per cent higher recovery than plate tests, which is accounted for by the better contact obtained in the bottle as compared to the plate. As the degree of grinding becomes finer there is a greater difference in the recovery by plate amalgamation as compared to bottle amalgamation, especially in the finest size, as indicated in the assays of the minus 200-mesh tailings given in Tables 1B and 3B, amounting to 0.17 and 0.27 ounce of gold per ton, respectively. A consideration of this fact allows the conclusion that the gold in this material is coarser than average, since the plate and bottle tests yielded recoveries not far apart.

Flotation

Test 4

A sample of the tailing from Test 3 was conditioned for 20 minutes in a laboratory ball mill with reagents as follows:

	Lbs. per ton of ore
Lime...............	1.0
Sodium aerofloat...	0.1
Amyl xanthate......	0.1
Pine oil, G.N.S.No.5	0.1

The conditioned pulp was then treated in a Fahrenwald flotation machine. Two concentrates were removed, representing 10-minute periods. The alkalinity of the pulp was maintained at a pH value of 7.8, determined by means of a La Motte block colorimetric comparator.

The flotation tailing was treated on a Wilfley table, producing concentrate, middling, and tailing products. Table 4 presents the results of this test in detail.

Table 4.--Summary of Flotation and Table Treatments of Amalgamation Tailing

	Weight, grams	Tons in 100	Assay, ounces of gold per ton	Weight of gold, ounces	Per cent of total gold
Heads	500.00	100.0	(1)0.30 (2)0.33	33.00	100.0
Flotation concentrate No. 1	17.32	3.5	5.52	19.10	58.1
Flotation concentrate No. 2	24.01	4.8	0.42	2.02	6.1
Table concentrate	63.70	12.7	0.52	6.63	20.2
Table middling	44.90	9.0	0.18	1.62	4.9
Table tailing	350.07	70.0	0.05	3.50	10.7
Composite	500.00	100.0	0.33	32.87	100.0

(1) Heads assay. (2) Products assay.

Test 5

A 2,000-gram sample of the amalgamation tailing from Test 3 was conditioned as in Test 1 with the same reagent quantities and treated in a Fahrenwald flotation machine. Four 5-minute concentrates were removed. Table 5A presents the results of this test in detail.

A screen-assay analysis was made of the flotation tailing and is given in Table 5B.

A portion of the flotation tailing was treated on a Wilfley table to produce a concentrate and a tailing. The results of this test are given in Table 5C.

Table 5A.--Results of Treating Amalgamation Tailing by Flotation

	Weight, grams	Tons in 100	Assay, ounces of gold per ton	Weight of gold, ounces, based on 100 tons ore	Per cent of total gold
Heads........	2,000.00	100.0	0.30	30.00	100.0
Concentrates:					
No. 1......	108.00	5.4	4.07	21.98	73.9
No. 2......	19.94	1.0	1.56	1.55	5.2
No. 3......	18.10	0.9	0.81	0.74	2.5
No. 4......	31.30	1.6	0.29	0.46	1.5
Tailing......	1,822.66	91.1	0.06	5.01	16.9
Composite....	2,000.00	100.0	0.30	29.74	100.0

Table 5B.--Screen-Assay Analysis of Test 5 Flotation Tailing

Screen size, mesh	Weight, grams	Tons in 100	Assay, ounces of gold per ton	Weight of gold, ounces	Per cent of total gold
+65.........	40.7	5.0	0.060	0.30	5.5
-65 +100....	264.5	33.0	0.065	2.15	38.9
-100 +150...	209.2	26.2	0.050	1.31	23.7
-150 +200...	110.0	13.8	0.040	0.55	10.0
-200........	175.6	22.0	0.055	1.21	21.9
Composite...	800.0	100.0	0.055	5.52	100.0

Table 5C.--Results of Table Treatment of Test 5 Flotation Tailing

	Weight, grams	Tons in 100	Assay, ounces of gold per ton	Weight of of gold, ounces, based on 100 tons	Per cent of total gold
Concentrate....	69.1	7.7	0.27	2.08	36.0
Tailing........	830.9	92.3	0.04	3.69	64.0
Composite......	900.0	100.0	0.06	5.77	100.0

Test 6

A sample of the original ore was conditioned with reagents as before and treated by flotation without having been previously treated by amalgamation.

Table 6 presents the results of this direct flotation treatment test in detail.

Table 6.--Results of Direct Flotation Test

	Weight, grams	Tons in 100	Assay, ounces of gold per ton	Weight of gold, oz., based on 100 tons of ore	Per cent of total gold
Heads............	500.0	100.0	0.52	52.00	100.0
Concentrate No. 1	77.8	15.6	2.86	44.50	85.0
Concentrate No. 2	46.7	9.3	0.20	1.87	3.6
Tailing..........	375.5	75.1	0.08	6.01	11.4
Composite........	500.0	100.0	0.52	52.38	100.0

Conclusions Reached from Consideration of Small-Scale Flotation Tests

A summary of amalgamation, flotation, and table treatment compiled from the results given in Tables 4, 5A and 6 is given in Table 7.

Referring to this table, it should be noted that recovery of the gold by amalgamation amounts to 42.4 per cent. Flotation yields an additional recovery of 33.5 per cent in a concentrate assaying 5.52 ounces of gold per ton. The middling products, comprising flotation concentrate No. 2, the table concentrate, and table middling, account for 17.8 per cent of the gold. These products would be reground and retreated by flotation. The final tailing assayed 0.05 ounce gold per ton and contained 6.3 per cent of the total gold. The indicated concentration ratio is 28.5 tons into 1, and it should be noted that no cleaning operations were attempted.

Table 7.--Summary of Results Given in Tables 3A and 4

	Tons in 100	Gold Weight, mgs.	Gold Assay, ounces per ton	Weight of gold, ounces	Per cent of total gold
Heads	100.0	--	(1)0.57	57.00	100.0
Amalgam	--	189.01	--	24.20	42.4
Flotation:					
Concentrate No.:					
1	3.5	--	5.52	19.10	33.5
2	4.8	--	0.42	2.02	3.5
Table:					
Concentrate	12.7	--	0.52	6.63	11.5
Middling	9.0	--	0.18	1.62	2.8
Tailing	70.0	--	0.05	3.50	6.3
Totals	100.0	--	0.57	57.07	100.0

(1)Products assay.

Table 8 presents a duplicate summary of amalgamation, flotation, and table treatment. It has been compiled from Tables 3A, 5A, and 5C. In this summary the amalgamation recovery is 44.7 per cent. Flotation gives an additional recovery of 40.6 per cent in a concentrate assaying 4.07 ounces of gold per ton. The middling products, consisting of flotation concentrates 2, 3, and 4, and the table concentrate, which would be reground and retreated, account for 8.4 per cent of the gold. The tailing contained 6.2 per cent of the gold and assayed 0.04 ounce of gold per ton.

Table 8.--Summary of Results Given in Tables 3A, 5A, and 5C

	Tons in 100	Gold		Weight of gold	Per cent of total gold
		Weight, mgs.	Assay, ounces per ton		
Heads	100.0	--	(1)0.54	54.00	100.0
Amalgam	--	189.01	--	24.20	44.7
Flotation:					
Concentrate No.1	5.4	--	4.07	21.98	40.6
Concentrate No.2	1.0	--	1.56	1.55	2.8
Concentrate No.3	0.9	--	0.81	0.74	1.3
Concentrate No.4	1.6	--	0.29	0.46	0.8
Table:					
Concentrate	7.0	--	0.27	1.89	3.5
Tailing	84.1	--	0.04	3.36	6.2
Totals	100.0	--	0.54	54.18	99.9

(1)Products assay.

Referring to Table 5A, 73.9 per cent of the gold recovered by flotation was obtained in the first 5-minute period of treatment. The remaining 15 minutes of treatment only recovered an additional 9.2 per cent of the gold. This leads to the conclusion that the material may be classified as a fast-floating ore.

CHAPTER IV.--
LARGER-SCALE CONTINUOUS TREATMENT BY AMALGAMATION, FLOTATION, AND GRAVITY METHODS

The purpose of the tests which follow was to determine the indicated results that would be obtained in practice if this ore were treated by combined amalgamation, flotation, and gravity concentration methods.

Test 7

A sample of 120 pounds of ore was crushed to pass a 20-mesh screen by a Dodge-type crusher and rolls. The crushed product was ground dry in 60-pound batches in a Hardinge ball mill to 1.5 per cent plus 65-mesh and 63.6 per cent minus 200-mesh. After grinding, dry lime was mixed with the ore in sufficient amount to produce a pH value of 8.8 in the pulp water.

The ground product was fed by means of a mechanical feeder at the rate of 1 pound per minute to an amalgamation plate. Water was introduced at the rate of 4 parts water to 1 solids at the head of the plate. The slope of the plate was 2 inches to the foot. The amalgamation tailing passed over a mercury trap and thence to the flotation conditioner where the remaining reagents were introduced.

After conditioning, the pulp was treated in a 5-cell Fahrenwald flotation machine. The first cell of this machine produced a finished concentrate; all other concentrate froths were returned intermittently to the conditioner. The flotation tailing was passed over a scavenging launder equipped with a corduroy bottom, which produced the final tailing. The launder tailing was sampled at 5-minute intervals, each sample being taken for 10 seconds. After all ore was fed, the trap residue was quickly panned to recover amalgam. The residue from panning was added to the flotation conditioner. The residue left in the flotation machine at the end of the test was disposed of by passing it over the scavenging launder. This method of treatment yielded final products with the exception of the scavenging launder concentrate, which would be returned to the ball mill in milling practice.

The results of this continuous test are given in Table 9A; Table 9B gives the reagents used; and Table 9C gives the gold assays of the froths from the individual flotation cells.

Table 9A.--Results of First Continuous Amalgamation, Flotation, and Gravity Concentration Test

	Weight, kgs.	Tons in 100	Gold		Weight of gold, ounces	Per cent of total gold
			Weight, mgs.	Assay, ounces per ton		
Heads..........	54.48	100.0	--	[1]0.49	49.00	100.0
Amalgam........	--	--	[2]398.20	--	[2]21.32	[2]43.5
Flotation concentrate....	1.13	2.1	--	10.52	21.88	44.7
Launder residue..........	1.82	3.4	--	0.32	1.07	2.2
Tailing.......	51.53	94.5	--	0.05	4.73	9.6
Composite.....	54.48	100.0	--	0.49	49.00	100.0

(1) Heads assay (2) By difference

Table 9B.--Reagents Used in Test 7

Reagent	Pounds per ton of ore treated
Lime................	1.0
Sodium aerofloat.....	0.1
Amyl xanthate........	0.1
Pine oil, G.N.S.No.5	0.1[a]

[a]The pine oil was varied somewhat according to the condition of the froth.

Table 9C.--Gold Contents of Froths from Individual Flotation Cells

	Cell No.				
	1	2	3	4	5
Ounces per ton.	(1)	10.52	5.30	3.81	1.52

(1)Conditioner discharge introduced into cell No. 2, as cell No. 1 was not in operating condition at the time of this test.

Test 8

A sample of 163 pounds of ore was crushed as in Test 7 and ground dry with the required amount of lime in a Hardinge ball mill to 2.8 per cent plus 65-mesh and 58.9 per cent minus 200-mesh.

The ground product was fed as in Test 7 to the head of the plate, where water was added at the rate of 4 1/2 parts of water to 1 of solids. Reagents in the quantities indicated in Table 10B were introduced into the conditioner. The first cell of the machine produced a final concentrate as before, and all other concentrate froths were returned continuously to the conditioner discharge as it entered the first cell. The flotation tailing was treated as previously described in Test 7, and time samples of the final tailing were taken as before. The clean-up was made in the manner described in Test 7. The pH value of the pulp water in the circuit was 7.9.

Table 10A presents the results of this test in detail; Table 10B gives the reagents used; Table 10C gives the screen-assay analysis of the tailing produced; and Table 10D gives the gold assays of the froth from the individual flotation cells.

Table 10A.--Results of Second Continuous Amalgamation, Flotation, and Gravity Concentration Test

	Weight, kgs.	Tons in 100	Gold: Weight, mgs.	Gold: Assay, ounces per ton	Weight of gold, ounces	Per cent of total gold
Heads..........	74.00	100.0	--	(1)0.42	42.00	100.0
Amalgam........	--	--	359.61	--	14.19	34.2
Flotation concentrate.....	0.42	0.6	--	33.56	19.13	46.0
Launder residue	2.67	3.6	--	0.42	1.57	3.7
Tailing........	70.91	95.8	--	0.07	6.71	16.1
Composite......	74.00	100.0	--	0.42	41.60	100.0

(1)Heads assay.

Table 10B.--Reagents Used in Test 8

Reagent	Pounds per ton
Sodium aerofloat.....	0.20[a]
Lime................	0.75
Amyl xanthate........	0.10
Pine oil, G.N.S.No.5	0.10[b]

[a]Half of the aerofloat was added to the conditioner and half to the third flotation cell.

[b]The pine oil was varied somewhat according to the condition of the froth.

Table 10C--Screen-Assay Analysis of Test 8 Tailing

Screen size, mesh	Weight, grams	Tons in 100	Assay, ounces gold per ton	Weight of gold, ounces	Per cent of total gold
Heads...........	500.0	100.0	(1)0.06	6.00	100.C
+65.............	7.0	1.4	0.09	0.13	1.7
-65 +100........	62.0	12.5	0.08	1.00	13.6
-100 +150.......	76.0	15.2	0.08	1.22	15.2
-150 +200.......	79.0	15.8	0.07	1.11	16.7
-200............	276.0	55.1	0.07	3.86	52.8
Composite.......	500.0	100.0	0.07	7.32	100.0

(1)Heads assay.

Table 10D.--Gold Contents of Froths from Individual Flotation Cells

	Cell No.				
	1	2	3	4	5
Ounces per ton	33.56	21.44	8.77	4.43	3.73

Conclusions from Results of Continuous Large-Scale Tests

Referring to Tables 7 and 8, which give the results of small-scale intermittent operation, and Tables 9A and 10A, which present the results of larger-scale continuous treatments, it should be noted that the amalgamation recoveries in all cases were about the same. The recoveries by flotation varied somewhat, dependent upon the number of middling products produced, but the total gold accounted for in the concentrate and middling products by flotation in all tests was approximately the same. The scavenging operations, tabling for small-scale tests and a corduroy launder for larger-scale tests, produced results approximately the same in that they produced final tailings the gold content of which varied from 0.04 to 0.07 ounce per ton.

The small-scale tests produced final concentrates assaying 4.07 and 5.52 ounces of gold per ton, while the larger-scale continuous tests produced concentrates which assayed 10.52 and 33.56 ounces of gold per ton. The higher grade of concentrate produced by continuous larger-scale operation is accounted for by the retreatment of the middling products and the stabilization of the circuit attained in continuous large-scale operation. The higher grade of concentrate produced in Test 8 is attributed to the continuous retreatment of flotation middling products.

CHAPTER V.--

CYANIDATION OF FLOTATION CONCENTRATES PRODUCED BY LARGER-SCALE CONTINUOUS TREATMENT

Introduction

The object of the cyanidation tests was to determine the feasibility of cyaniding high-grade gold-bearing flotation concentrates, special attention being given to the consumption of cyanide.

Two difficulties may arise in the cyanidation of high-grade gold concentrates: First, a mechanical difficulty in the filtering operation due to a concentration of colloidal material along with the values in the concentrate. Such a concentration of colloidal material might also cause difficulties in washing operations and cause undue losses of cyanide by adsorption. The second difficulty was believed possibly due to a concentration of Cyanicides ~~cyanides~~ in the material. If such concentration occurs, it may cause the cyanide consumption to rise to a point where it becomes prohibitive.

To the writer's knowledge the only information on record concerning the cyanidation of gold-bearing Southwestern concentrates is the work of Evans[2] on Creston ore.

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[1]Evans, C. E., Treatment of Gold Ores by Flotation and the Cyanidation of Gold-Bearing Concentrates Produced by Flotation Methods: Thesis, University of Arizona, 1932, p. 47.

His conclusions are that flotation concentrates produced from the treatment of Creston ore may be cyanided, but that his tests were too superficial to be accepted for more than indications of what might be expected in the cyanidation of gold-bearing concentrates.

Consumption of Lime

Fifty-gram samples of the flotation concentrates produced in Tests 7 and 8 were agitated for 20 minutes with 100 c.c. of N/10 NaOH. The solution was separated by filtration and a portion of it was titrated with standard oxalic acid. The results so obtained were converted into lime.

The results obtained indicate that the concentrate from Test 7 would consume 3.9 pounds of lime per ton, and that the concentrate from Test 8 would consume 4.9 pounds of lime per ton.

Cyanide Consumption

Fifty-gram samples of the above-mentioned concentrates were agitated for 2 hours with lime, 1 pound per ton in excess of the indicated lime consumption, and 200 c.c. of 0.25 per cent NaCN solution. At the end of the agitation period cyanide consumption was determined by titrating with standard silver nitrate solution and found to be 3 pounds per ton for the concentrate produced in Test 7 and 9.6 pounds per ton for the concentrate produced in Test 8.

Extraction of Gold by Cyanide

For this test the concentrates of Test 7 and Test 8 were mixed and a sample of the mixture weighing 300 grams was agitated for 24 hours with 1,200 c.c. of 0.25 per cent sodium cyanide solution and lime amounting to 5 pounds per ton. Samples of solution were taken every 4 hours to determine the rate of solution of the gold and to insure the presence of sufficient cyanide. The following tabulation presents these results in detail.

	NaCN consumed, lbs. per ton	Gold dissolved, mgs.	Per cent of total gold
After 4 hours' agitation	3.80	130.80	86.8
After 8 hours' agitation	4.87	137.88	91.5
After 12 hours' agitation	4.87	140.20	93.1
After 16 hours' agitation	5.59	142.48	94.6
After 20 hours' agitation	6.34	144.72	96.1
After 24 hours' agitation	6.94	148.15	98.4
Residue..................	--	(1)2.47	1.6
Total gold...............	--	150.62	100.0

(1)Gold undissolved in 24 hours.

Referring to this tabulation, it should be noted that after 24 hours' contact the recovery of the gold from the concentrate was 98.4 per cent with a cyanide consumption of 6.94 pounds of cyanide per ton. No difficulty was encountered in the filtering operation.

Practically complete recovery of the gold was indicated when agitation was continued for 4 to 8 hours longer. The cyanide consumption is not excessive. Assuming a concentration ratio of 75 to 1 by flotation, the mean concentration ratio of Tests 7 and 8, the consumption of cyanide computed on the basis of consumption per ton of ore milled amounted to only 0.09 pound of sodium cyanide.

CHAPTER VI.--CONCLUSIONS

Detailed conclusions have been given with each test made; hence, it will be sufficient to state that the ore treated is amenable to amalgamation methods supplemented by flotation and gravity concentration.

From a consideration of results obtained in cyaniding the flotation concentrates, it is believed that little difficulty will be encountered in the treatment of gold-bearing flotation concentrate by cyanide methods if the original ore is siliceous, free of cyanicides, and amenable to cyanide treatment.