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# Treatment of an Arizona gold ore

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# TREATMENT OF AN ARIZONA GOLD ORE.

-by-

S. D. Callaway

H. F. Adams

LIBRARY MISSOURI SCHOOL OF MINES

A

THESIS

submitted to the faculty of the

SCHOOL OF MINES AND METALLURGY OF THE UNIVERSITY OF MISSOURI

in partial fulfillment of the work required for the

DEGREE OF

BACHELOR OF SCIENCE IN MINE ENGINEERING

Rolla, Mo.

1912

Approved by Durward Copeland.
Professor of Metallurgy.

14233

Table of Contents.

# Treatment of an Arizona Gold Ore.

This thesis is a description of experiments preformed to determine the best scheme of treatment of a gold ore.

## Description of Ore.

The ore is a well weathered rock, and is chiefly silica with streaks of iron oxide and alumina with a small amount of copper. The copper is to a large extent present as carbonate although there is a very small amount of sulphide of copper. The ore is clayey in nature indicating difficulty in filtration. Our sample comes from a depth of about 10 feet below the surface.

Chemical Composition;

| | | |
|---|---|---|
| Insoluble | 82.5% | |
| Alumina * | 1.85% | |
| Ferric Oxide | 13.95% | |
| Calcium oxide | 0.24% | |
| Magnesium oxide | trace | |
| Sulphur trioxide | 0.01% | |
| Copper | 0.90% | |
| Silver | 0.0013% | 0.4 Oz. per ton |
| Gold | 0.0034% | 1.00 Oz. per ton |
| Total | 99.45 | |

Acidity:

There is no soluble acid in the ore, the latent acidity is equal to 0.6 lb of CaO per ton of ore. This was determined from samples of 50 grams.

The gold and silver values are reported in ounces troy per avoirdupois ton of 2000 pounds.

The assay of original ore:

| | |
|---|---|
| Silver - - - - - - - - | 0.40 Oz. |
| Gold - - - - - - - - - - | 1.00 Oz. |

Gold values of the ore so far exceed the silver values that in all the following experiments no notice was taken of the effect of the various operations on the silver content.

Perculation Tests:

A few tests were made to determine the rate of perculation of water thru ore crushed thru 30, 40, 60, and 80 mesh respectively. A glass tube, three-fourths inches in diameter was filled to a depth of three inches with sized ore and a volume of water equal to that of the ore. The time was taken for the water to perculate thru the ore.

| | | | hr. | min. | sec. |
|---|---|---|---|---|---|
| 30 | mesh | required - - | 0 | 0 | 25 |
| 40 | " | " | 0 | 5 | 23 |
| 60 | " | " | 0 | 37 | 30 |
| 80 | " | " | 1 | 30 | 0 |

The rate of perculation on the other sizes was not determined because the time increased so greatly with the fineness of the ore that it seemed impracticable to use ordinary perculation in these finer sizes.

## Screen Analysis.

Object:

The object of this experiment is to determine whether on crushing the gold values enter the coarse or the fine. This information would aid in the mechanical preparation of the ore for any solution process.

Method:

A sample of 500 grams of ore was crushed until it passed a 30 mesh (0.41 m m.) screen. Then the ore was placed on a nest of screens consisting of 40, 60, 80, 100, and 150 mesh. The material remaining on each screen also that thru 150 mesh was weighed and assayed. The results of the experiment are given in Table No. 1.

Table 1.

| Material | wt grams | assay Oz.per.ton. gold | silver | % of total wt. | % gold | total silver |
|---|---|---|---|---|---|---|
| Raw ore | :500 | 1.00 | 0.40 | | 100 | --- |
| Thru30 on 40mesh .41 m.m." 0.31mm. | 66 | 0.68 | -- | 13.2 | 8.9 | --- |
| Thru40 on60mesh " 0.31mm".20 m.m | 122 | 0.80 | -- | 24.4 | 19.5 | --- |
| Thru60 on 80mesh " .20m.m" 0.15m.m | 107 | 0.80 | -- | 24.4 | 17.0 | --- |
| Thru80 on100mesh " 0.15mm"0.12mm | 70 | 1.08 | -- | 14.0 | 15.1 | --- |
| Thru100on150 mesh " 0.12mm".08 m.m | 93 | 1.28 | -- | 18.6 | 24.0 | --- |
| Thru 150 mesh | 34 | 1.68 | -- | 6.8 | 11.40 | --- |
| Loss by difference | 8 | --- | --- | 1.6 | 4.00 | --- |

The minerals in the ore which are soft and therefore e easily crushed are the limonite, the oxidized copper minerals, the clayey material, and it is probable that the gold may exist to the greatest extent in one or all of those minerals. It would be interesting to assay the ore on 60 and thru 150 mesh for iron and for copper to see if there is a large difference in the iron and copper contents of these sizes as is shown in the case of the gold.

## Concentration Tests.

Object:

The object of this experiment is to determine whether concentration can be utilized to better the extraction, to lessen the cyanide consumption or lower the cost of crushing.

(1) By concentration it may be possible to remove some of the constituents detrimental to the cyanide process.

(2) It may be that all the ore is suited to the cyanide process, but that the heavy minerals may be more efficiently treated by finer grinding and longer contact which more expensive scheme may not be necessary for the lighter portion of the ore.

Method:

Ore (1100 grams thru 60 mesh) = 37.8 assay tons

Pan

| Concentrate | tailing |
|---|---|
| wt.250 gm.- 8.6 A.T. -22.8% | Wt.770 gm.- 26.5 A.T = 70% |
| Assay--2.16 Oz. Au | Assay-- 0.32 Oz. Au |

The results of this experiment are as follows:

The ratio ofconcentration is 4.4 to 1. The ore produced a fich concentrate being 2.16 times as high in gold as original ore and a relatively low grade in tailing. The loss due to sliming was fairly large. Two experiments along this line were not taken up thoroughly.

## Amalgamation Tests.

Object:

The object of this experiment is to determine the extraction by amalgamation followed by a solution treatment of the amalgamation tailing.

Method:

A series of experiments were carried out on ore crushed thru 60, 100, 150 and 200 mesh, and upon the concentrate and tailing obtained from paning 60 mesh ore. For the first tests 5 A.T. of ore in each case was made into a pulp in a 500 c.c. flask. Fifteen to seventy-five grams of mercury were added in each case, and the flask was shaken by means of a vanner from one to three hours. A silver plated amalgamating plate 3 1/2 feet X5 feet was also tried using a sample of 100 and 150 mesh ore, the ore in each case being run over plate four times. The results were very satisfactory.

From the above experiments it seems that the gold is in a coarse condition, and by using long enough plates and proper care practically all of the gold could be obtained.

The tailing if necessary could be cyanided to recover remaining values.

All experiments indicate that it is necessary to crush the ore fine for efficient action of solution upon the ore. As the solution is a surface effect, and the speed of solution is proportional to the surface exposed. The fact that the gold is in a coarse condition indicates that for solution process fine grinding should be used. This ore slimes badly, and the slimes carry considerable values in gold which would be an important factor to consider in milling.

The results of the experiments on amalgamation are given in Table II.

Table II.

| Screen mesh | Amt. of ore A.T. | Method used | Amt. of Hg in grams. | assay of tails in Au Oz. per ton. | % Extraction of Au |
|---|---|---|---|---|---|
| 60 | 5 | shaken in bottle | 15 | 0.30 | 70 |
| 100 | 5 | " | 15 | 0.14 | 86 |
| 100 | 5 | " | 20 | 0.20 | 80 |
| 100 | 15 | 4 times over plate | -- | 0.16 | 84 |
| 100 | 10 | shake in bottle | 30 | 0.14 | 86 |
| 100 | 10 | " | 40 | 0.14 | 86 |
| 100 | 6 | " | 25 | 0.14 | 86 |

Table II. (continued)

| Screen mesh | Amt. of ore A.T. | Method used | Amt. of Hg in grams | assay of tails in Au. Oz. per ton | % extraction of Au |
|---|---|---|---|---|---|
| 150 | 5 | shaken in bottle | 30 | 0.12 | 88 |
| 150 | 5 | " | 15 | 0.24 | 76 |
| 150 | 15 | 4 times over plate | — | 0.08 | 92 |
| 150 | 10 | shaken in bottle | 75 | 0.14 | 86 |
| 200 | 5 | " | 50 | 0.22 | 78 |
| * tails from 60 mesh | 3 | " | 40 | 0.16 | 50 |
| * " | 5 | " | 30 | 0.10 | 68.9 |
| # Heads from 60 mesh | 3 | " | 30 | 0.22 | 90 |
| # " | 5 | " | 35 | 0.16 | 92.5 |

* Tails from concentration test page 5 assayed 0.32 oz. Au.

# Heads from concentration test page 5 assayed 2.16 Oz. Au.

The tailing from the last 150 mesh, tails from 60 mesh and Heads from 60 mesh were cyanided, and the results are given in Table III.

Table LII.

Cyanidation of Tailing from Amalgamation.

| Screen Mesh | lb. of KCN per Ton of Solution | A.T. of Solution used | Volume of Solution after Filtering | KCN consumed per Ton of Ore | % of Total KCN used which was consumed | alkali consumed per Ton of Ore | Time in Hours | assay of Tails Au oz. per Ton | % of extraction of Au |
|---|---|---|---|---|---|---|---|---|---|
| Heads 100 | 6 | 4 | 11.7 | 18.2 | 75 | 1.2 | 24 | .10 | 54.5 |
| " | 6 | 4 | 20.1 | 16.0 | 66.5 | 1.0 | 24 | .10 | 37.5 |
| " | 1 | 8 | 9.9 | 6.0 | 75 | 1.0 | 24 | .10 | 54.5 |
| " | 1 | 8 | 10.8 | 4.8 | 60 | 1.1 | 24 | .12 | 25.0 |
| " | 1 | 8 | 10.3 | 2.8 | 35 | 1.0 | 24 | .18 | 18.2 |
| " | 1 | 8 | 8.6 | 5.4 | 67.5 | 1.2 | 24 | .12 | 25.0 |
| Tails 100 | 6 | 4 | 7.5 | 21.0 | 87.5 | 2.0 | 24 | .08 | 50 |
| 100 | 6 | 4 | 10.5 | 21.0 | 87.5 | 1.2 | 24 | .04 | 60 |
| " | 1 | 8 | 6.5 | 6.1 | 76.3 | 3.7 | 24 | .08 | 50 |
| " | 1 | 8 | 8.7 | 4.5 | 56.2 | 1.3 | 24 | .08 | 20 |
| " | 1 | 8 | 7.5 | 5.8 | 72.5 | 2.0 | 24 | .08 | 20 |
| 150 | 1 | 8 | 7.9 | 5.6 | 70.0 | 2.6 | 24 | .06 | 42.8 |

The sample for concentration was crushed thru 60 mesh.

The concentrate and tails were crushed thru 100 and 150 before cyaniding.

## Cyanidation by Percolation.

Object:

These experiments were to determine whether the ore could be cyanided without agitation.

Method:

The ore was crushed thru the mesh as given in the following Table. We used varying strengths of solutions, amounts of solution and time.

Table IV.

| Screen Mesh | lb of KCN per Ton of Solution | A.T. of Solution used | Volume of Solution after filtering | KCN consumed per Ton of Ore | % of Total KCN used which was consumed | alkali consumed per Ton of Ore | Time in days | Assay of Tails Au oz. per Ton | % Extraction of Au |
|---|---|---|---|---|---|---|---|---|---|
| 30 | 2 | 1.5 | 2.6 | 2.7 | 90 | 2.0 | 4 | .68 | 32 |
| 30 | 6 | 2.0 | 2.6 | 4.0 | 33 | 2.4 | 4 | .80 | 20 |
| 30 | 10 | 5.0 | 2.6 | 41.0 | 82 | 2.4 | 4 | .81 | 19 |
| 60 | 6 | 2.0 | 2.6 | 11.0 | 91.5 | 3.1 | 8 | .80 | 20 |
| 60 | 4 | 5.0 | 5.3 | 18.4 | 92 | 3.5 | 8 | .56 | 44 |
| 60 | 10 | 5.0 | 2.3 | 49.0 | 98 | 2.7 | 8 | .14 | 86 |
| 100 | 10 | 2.0 | 2.1 | 17.0 | 85 | 3.0 | 8 | .72 | 28 |
| 100 | 2 | 1.5 | 2.3 | 2.8 | 93 | 2.6 | 12 | .92 | 8 |
| 100 | 10 | 3.0 | 5.2 | 29.4 | 98 | 2.4 | 12 | .62 | 38 |
| 100 | 6 | 2.0 | 3.0 | 11.5 | 95.7 | 3.2 | 12 | .62 | 38 |

The ore on standing four and eight days formed Prussian Blue. The large KCN consumption and the poor extraction shows the impossibility of treating the ore by this method.

## Cyanide Tests.

Object:

The object of these experiments is to determine whether it is possible to cyanide the ore direct.

Method:

The ore was crushed thru the mesh as given in the tables and put into an agitator with varying amounts of solution, strength of solution varying from ½ lb. to 10 lbs. of KCN per ton of ore and the time varying from 15 to 48 hours.

The agitation was carried out in a battery of 12 agitators. The agitators were made of grape juice bottle from which the bottom had been removed. The air was admitted thru the neck of the bottles. Considerable difficulty was encountered due to the lack of constant air pressure.

The irregularities in the following experiments may be due to the following causes:

1. Poor and irregular agitation.
2. Loss of ore due to spattering caused by fluctuating air pressure.
3. Gold in a coarse condition would effect the solution speed as well as the sampling of the coarser ore.
4. Copper content of ore being 0.9 5 and mostly as malachite would consume cyanide.

The results of the experiments are found in the tables 5, 6, 7 and 8.

Table V.

| Screen Mesh Thru .20MM. | lb of KCN per ton of Solution | a.T. of Solution used | Volume of Solution after Filtering | KCN consumed per Ton of Ore | % of KCN used which was consumed | Alkali consumed per Ton of Ore | Time in Hours | Assay of Tails Au oz. per ton | % Extraction of Au |
|---|---|---|---|---|---|---|---|---|---|
| 60 | 2 | 4 | 5.1 | 7.5 | 93.9 | 5.5 | 24 | .14 | 86 |
| 60 | 4 | 4 | 6.2 | 15.8 | 98.5 | 8.2 | 24 | .16 | 84 |
| 60 | 6 | 4 | 8.3 | 23.2 | 96.7 | 7.4 | 24 | .08 | 92 |
| 60 | 8 | 4 | 5.1 | 29.9 | 93.5 | 6.8 | 24 | .10 | 90 |
| 60 | 2 | 4 | 5.1 | 7.5 | 93.9 | 8.9 | 48 | .40 | 60 |
| 60 | 4 | 4 | 4.4 | 15.1 | 94.5 | 10.3 | 48 | .40 | 60 |
| 60 | 6 | 4 | 3.7 | 23.3 | 97.0 | 11.2 | 48 | .50 | 50 |
| 60 | 6 | 4 | 12.0 | 15.6 | 65.0 | 3.4 | 15 | .52 | 48 |
| 60 | 8 | 4 | 11.5 | 24.0 | 75.0 | 4.6 | 15 | .40 | 60 |
| 60 | 10 | 4 | 12.5 | 27.0 | 67.5 | 5.6 | 15 | .28 | 72 |
| 60 | 1 | 2 | 7.4 | 0.5 | 25.0 | 7.3 | 24 | .64 | 36 |
| 60 | 1 | 4 | 11.5 | 0.7 | 17.5 | 7.8 | 24 | .64 | 36 |
| 60 | 2 | 4 | 6.2 | 6.8 | 85.0 | 11.5 | 48 | .46 | 54 |
| 60 | 1 | 4 | 6.0 | 2.2 | 55.0 | 12.0 | 48 | .74 | 26 |
| 60 | 0.5 | 4 | 7.9 | 0.4 | 20.0 | 13.0 | 48 | .80 | 20 |

KCN consumption is less with weaker solution and short agitation.

KCN is in some cases nearly all consumed and this would cause irregularities in extraction.

Acidity which develops on standing may be due to oxidation.

The copper content of ore is 0.9 % and is present as malachite. This might account for the large KCN consumption.

Table V. (continued)

The extraction grows less with increased time which may be due to irregularities in agitation or greater solution of copper causing the gold to precipitate.

The gold is in a coarse condition and with the irregularities in agitation may account for varying results.

Table VI.

| Screen Mesh Thru 0.15mm. | lb of KCN per Ton of Solution | A.T. of Solution used | Volume of Solution after Filtering | KCN consumed per Ton of Ore | % of total KCN which was consumed | alkali consumed per Ton of ore | Time in Hours | assay of Tails Au oz. per Ton | % Extraction of Au |
|---|---|---|---|---|---|---|---|---|---|
| 80 | 2 | 4 | 6.5 | 6.70 | 83.8 | 4.2 | 24 | .04 | 96 |
| 80 | 4 | 4 | 9.2 | 14.20 | 88.0 | 4.2 | 24 | .16 | 84 |
| 80 | 6 | 4 | 7.2 | 20.4 | 83.5 | 4.3 | 24 | .08 | 92 |
| 80 | 8 | 4 | 7.5 | 26.7 | 83.4 | 4.0 | 24 | .20 | 80 |
| 80 | 2 | 4 | 7.5 | 16.4 | 84.4 | 3.5 | 48 | .35 | 65 |
| 80 | 4 | 4 | 6.2 | 15.4 | 96.3 | 3.4 | 48 | .33 | 67 |
| 80 | 6 | 4 | 3.8 | 22.2 | 92.5 | 4.5 | 48 | .56 | 44 |
| 80 | 6 | 4 | 13.0 | 17.5 | 72.8 | 3.2 | 15 | .08 | 92 |
| 80 | 8 | 4 | 10.3 | 23.0 | 71.8 | 4.7 | 15 | .20 | 80 |
| 80 | 10 | 4 | 17.7 | 27.0 | 67.5 | 5.0 | 15 | .20 | 80 |
| 80 | 1 | 2 | 7.2 | 0.5 | 25.0 | 3.2 | 24 | .44 | 56 |
| 80 | 1 | 4 | 9.8 | 1.0 | 25.0 | 3.2 | 24 | .40 | 60 |
| 80 | 2 | 4 | 6.8 | 6.6 | 82.5 | 13.2 | 48 | .28 | 72 |
| 80 | 1 | 4 | 5.8 | 2.8 | 70.0 | 12.1 | 48 | .52 | 48 |
| 80 | 0.5 | 4 | 3.8 | 1.3 | 65.0 | 11.3 | 48 | .40 | 60 |

Table VI. (continued)

Ore crushed to 8o mesh gives better extraction in general than 60 mesh, but shows the same heavy KCN consumption.

It seems that all the KCN is used down to a certain small amount. It might be remedied by using dilute solutions for a longer time. This would lessen the KCN consumption by not dissolving so much copper. The 0.3 % solution in both 60 and 80 mesh gives good extraction. It is as good in 15 hours as in 24 or 48 hours. This is probably due to continued solution of the malachite with time. Some difficulty was experienced in having large enough samples to assay which might cause some error.

Table VII.

| Screen Mesh Thru. m.m. | lb of KCN per Ton of Solution | A.T. of Solution used | Volume of Solution after Filtering | KCN consumed per Ton of Ore | % of Total KCN used which was consumed | Alkali consumed per Ton of Ore | Time in Hours | Assay of Tails Au oz. per Ton | % Extraction of Au |
|---|---|---|---|---|---|---|---|---|---|
| 100 | 2 | 4 | 8.8 | 5.4 | 67.5 | 6.1 | 24 | .20 | 80 |
| 100 | 4 | 4 | 13.8 | 13.2 | 82.5 | 7.5 | 24 | .08 | 92 |
| 100 | 6 | 4 | 7.0 | 21.2 | 88.2 | 6.4 | 24 | .60 | 40 |
| 100 | 8 | 4 | 6.7 | 28.5 | 89.0 | 4.2 | 24 | .20 | 80 |
| 100 | 2 | 4 | 4.3 | 7.3 | 91.2 | 3.5 | 48 | .24 | 76 |
| 100 | 4 | 4 | 4.2 | 15.7 | 98.0 | 4.2 | 48 | .70 | 30 |
| 100 | 6 | 4 | 4.8 | 23.0 | 96.0 | 3.9 | 48 | .40 | 60 |
| 100 | 6 | 4 | 12.9 | 16.0 | 67.0 | 4.4 | 15 | .02 | 98 |
| 100 | 8 | 4 | 10.5 | 24.0 | 75.0 | 4.3 | 15 | .28 | 72 |
| 100 | 10 | 4 | 12.8 | 27.0 | 67.5 | 5.2 | 15 | .02 | 98 |
| 100 | 1 | 2 | 11.3 | 0.9 | 45.0 | 6.4 | 24 | .56 | 44 |
| 100 | 1 | 4 | 10.3 | 1.9 | 47.5 | 8.9 | 24 | .40 | 60 |
| 100 | 2 | 4 | 5.0 | 7.0 | 87.5 | 10.2 | 48 | .24 | 76 |
| 100 | 1 | 4 | 4.0 | 3.2 | 80.0 | 9.4 | 48 | .28 | 72 |
| 100 | 0.5 | 4 | 4.0 | 1.3 | 65.0 | 11.2 | 48 | .40 | 60 |

A comparison of 60, 80 and 100 mesh is not possible due to the fact that the gold is in a coarse condition and other irregularities encountered.

Table VIII.

| Screen Mesh Thru .09 m.m. | lb. of KCN per Ton of Solution | A.T. of Solution Used | Volume of Solution after Filtering | KCN consumed per ton of ore | % of Total KCN used which was consumed | alkali consumed per Ton of ore | Time in Hours | assay of Tails Au oz. per ton | % Extraction of Au |
|---|---|---|---|---|---|---|---|---|---|
| 150 | 2 | 4 | 4.5 | 7.5 | 93.7 | 1.8 | 48 | .40 | 60 |
| 150 | 4 | 4 | 5.5 | 15'.4 | 96.4 | ..8 | 48 | .60 | 40 |
| 150 | 6 | 4 | 4.25 | 23.7 | 98.7 | 4.1 | 48 | .10 | 90 |
| 150 | 6 | 4 | 13.1 | 14.9 | 62. | 4.3 | 15 | .10 | 90 |
| 150 | 8 | 4 | 11.3 | 23.0 | 72. | 4.4 | 15 | .06 | 99.4 |
| 150 | 10 | 4 | 12.0 | 29.0 | 72.5 | 3.4 | 15 | .06 | 99.4 |
| 150 | 1 | 4 | 11.3 | .8 | 40. | 5.2 | 24 | .46 | 54. |
| 150 | 1 | 4 | 11.3 | 1.8 | 45. | 4.8 | 24 | .45 | 55 |
| 150 | 2 | 4 | 3.4 | 7.3 | 91.5 | 6.2 | 48 | .45 | 55 |
| 150 | 1 | 4 | 3.7 | 3.2 | 80.0 | 5.5 | 48 | .44 | 56 |
| 150 | 0.5 | 4 | 4.7 | 0.5 | 25. | 3.8 | 48 | .72 | 28 |

In 150 mesh there is the same heavy KCN consumption. The gold extraction lessens rather than improves by longer time of treatment.

All of the experîments were made on 1 A.T. of ore. The fact that small amounts of pyrite and marcasite exists in ore might cause some KCN consumption.

The concentration experiment proved that it was possible to concentrate the ore when crushed to 60 mesh in the ratio 4.4 to 1. Amalgamation of head and tailing obtained gave an extraction of 68.9 %, 92.5 % respectively. Then the treatment of both head and tailing after amalgamation by agitation with a weak solution of cyanide for a long time could extract the values down to a certain small amount. The concentration is not necessary and if used many difficulties would arise in milling due to loss of values in slimes. The loss of values in slimes could be prevented by using settling tanks or filter presses.

The experiments along cyanidation lines alone by percolation or agitation proved that the ore is not adapted directly to this treatment. The gold being in a coarse condition would require long time for solution and 0.9 % copper as malachite would cause an enormous KCN consumption.

Amalgamation experiments indicated that fine grinding is essential for good recovery. Ore crushed to 100 and 150 mesh gave the best extraction. If necessary the tailing could be cyanided to recover any remaining values, but it is supposed that in practise conditions for amalgamation would be better and higher extraction obtained.

The best treatment for the ore seems to be to crush relatively fine 100 to 150 mesh and amalgamate over plates and if necessary cyanide the tails using agitation with dilute solution.

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