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Treatment of a complex Arizona gold and silver ore

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TREATMENT OF A COMPLEx ARIZONA GOLD AND SILVER ORE.

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The object of this thesis is to work out a commercially successful treatment of an Arizona Gold and Silver Ore.

The ore assyas two ounces of gold and six and forty-four one hundredths ounces of silver.

The aim is not only to get an extraction of gold but also of silver, either by leaching methods alone,or by concentration and leaching combined.

Composition of Ore.

The first thing that was done was to make a complete qualitative analysis.

This showed the presence of lead,zinc,iron,sulphur,silica,magnesium, and a trace of manganese,the lead,zinc and iron being in the form of sulphides.

Following this, quantitative determinations were made for lead, zinc,iron,sulphur and insolubles,by the following methods:-

For Lead - - - - - - Molybdate Method

" Zinc - - - - - - Ferro-cyanide "

" Iron - - - - - - Permanganate "

" Sulphur - - - - -Gravimetric "

" Insolubles - - - Differente

Following are the results:-

Lead	6.69%
Zinc	2.14%
Iron	20.31%
Sulphur	22.01%
Insolubles	48.85%

The gangue minerals were silica and some basic silicates; on one face of the original sample, serpentine was plentiful.

PRELIMINARY TREATMENT.

Since concentration was to be considered as a possible factor, and since, in general, fine crishing must be avoided as much as possible, the ore was given a preliminary crushing with the aim of forming as small an amount of slimes as possible, not crushing finer than was necessary for concentration.

The total weight of ore before crushing was eighty three pounds, and this was all crushed so as to pass a quarter inch sieve and have as much stay on eight inch mesh as possible.

The crushing was started in a little hand crusher, but since this took a great deal of time and about one-half the resulting product was fines, it was decided to put the ore through the rolls.

The sample was spalled to proper size, fed into the Dodge Crusher in the laboratory, and then put through the rolls.

The fines were screened out through a quarter inch sieve and all oversize returned to the rolls, until the whole sample passed the quarter inch sieve.

After crushing, a five pound sample was taken for assays and quantitative determinations. This was re-sampled by hand and the second sample put through one hundred mesh and assayed.

A ten pound sample was also taken and carefully sized, the size being kept for future work.

Screens used were eight, twenty, fifty, eighty and one hundred mesh. Samples were taken of each size, bucked through one hundred mesh, and assayed.

Following are the results:-

All through quarter inch assayed six ounces gold and six and forty-four ounces silver.

	Amt. Gms.	Percent	Assay Gold	Assay Silver	R.P.
Through 1/4 inch on 8 mesh	3630	46.12%	2.00	5.52	4.6
" 8 mesh on 20 "	2804	35.63%	2.81	5.19	4.5
" 20 " " 50 "	729	9.26%	2.40	8.78	4.9
" 50 " " 80 "	159	2.02%			5.4
" 80 " "100 "	101	1.28%	2.68	11.72	
" 100 "	448	5.69%	2.32	13.61	

The reducing power is added to show the relative amounts of sulphurets in each size.

The object of this sizing was to discover, if possible, where the gold and silver values lay, as well as the behavior of the component minerals of the ore, in crushing-e.g. sliming and consequent distribution of values. Also, panning tests showed that the amounts of galena and pyrite increased with the fineness, while the silica decreased.

Taking these two facts together, it can be assumed,with fairly good reason, that the values lie in the sulphides, and that the silver lies in the galena.

This result was confirmed simultaneously with the concentration tests which followed, by separating the galena,pyrite and gangue, and assaying each product.

These products were obtained by panning the sorted products which resulted from treating jig concentrates in the tubular classifier,as given below in concentration tests.

The pure galena assayed seven and seventy six one hundredths ounces gold and forty nine and fourteen one hundredths ounces silver, while the pyrite assayed two and sixty four one hundredths ounces gold and seven and seventy four one hundredths ounces silver.

The low assay of the pyrite showed that the surprising amount of gold in the galena could not be due to any pyrite left in the galena. Hence the conclusion was that the galena must be auriferous as well as argentiferous.

The galena was next examined under a high power microscope,no evidence of free gold was observed, but a particle of free silver was picked out and examined.

This result led to an amalgamation test on two hundred grams of the ore, put through twenty mesh, but the recovery of gold and silver was so small it was not deemed of much importance to continue the investigation.

The silica carried practically no values, as is shown in the concentration tests below.

CONCENTRATION TESTS.

In order to get the limit of crushing-i.e.- the maximum size at which all the mineral components would be freed, the above sized products were jigged and examined.

The first jig was a small hand jig,constructed for the purpose, shown in the sketch.

The screen used on the eight mesh ore was a twenty-four mesh.

The stroke of the jig was varied by the operator at the end of the handle,as well as by changing the relative lengths of the lever arms by changing the connection at A.

The suction and pulsion were regulated also by alternating the speed and the depth of water on the ore bed.

The operation consisted simply of jigging the ore,scraping off the tailings,then themiddlings,if any,and lastly the concentrates.

This jig gave clean concentrates on the bed,but the line of separation between these and the layer above was not distinct,nor were the tailings free from sulphides,so the jig was abandoned for the Allis-Chalmer's Laboratory Hand Jig,which was arranged to be operated by a one half Horse Power electric motor,as shown in Plate 1.

The cell in which the ore was contained was six inches by seven inches and the bed was about six inches.

Results were satisfactory with this jig,and by varying the stroke, speed,screens,etc.,a separation clean enough for the purpose was obtained.

RESULTS OF PRELIMINARY JIGGING.

On eight mesh was found to be entirely too coarse, there being really no separation at all.

It could easily be seen from inspection that in many grains two and three minerals were still closely associated.

The next size- through eight mesh on twenty mesh- was also too coarse,although there was an improvement, less middlings and cleaner concentrates being produced.

Through twenty mesh on thirty mesh gave the best separation,which would represent a clean separation if the ordinary conditions of jigging could be more closely realized.

In fact,in all the jigging done, the main trouble lay in the fact that some concentrates,which were evidently entirely free from adhering gangue,stayed in the tailings and failed to settle to the bed on the screen.

In this case there was less pyrite in the tailings and the line of separation between concentrates and tailings was distinct.

After deciding that twenty-thirty mesh was the largest size that could be well concentrated, the original lot of ore was screened through twenty mesh and all oversize crushed in rolls until all passed through twenty mesh.

A sizing test on this gave the following results:-

Through twenty mesh = whole sample = 1917 grams.

	Wt.Gms.	Percent	Assay Gold	Assay Silver
On 40 mesh	982	51.22	5.40	2.44
" 60 "	289	15.07	5.98	2.02
" 80 "	90	4.70	7.40	2.30
"100 "	125	6.52	7.72	2.40
"120 "	45	2.35	9.58	2.62
Through120 "	381	19.88	9.46	1.84
	1912	99.74		

Percent loss = 26/100%

This points to the same conclusions noted above under similar tables.

It is of importance to note also the increase of slimes due to finer crushing.

CONCENTRATION FOR METALLURGICAL TESTS.

Thirty pounds of the original ore was now jigged on the same jig as before.

The tailings and concentrates were scraped off occasionally, when the bed became too thick.

The screen used at first was an eight mesh but as no satisfactory motion of the bed could be obtained,owing to the slow retreat of the water and the clogging action of the fines, a fifty mesh screen replaced the first.

This was satisfactory and three products were obtained,namely,hutch product, finer than fifty mesh, bed concentrates,and tailings.

The tailings contained considerable coarse pyrite, as well as some fine galena and pyrite.

TREATMENT OF TAILINGS.

To get rid of the concentrates in the tailings, the latter were run over the small Card table shown in Plate II.

This was a model of the standard table, forty-eight inches long by eighteen inches wide, operated by the same motor that was used in jigging..

The speed was kept at about two hundred and forty revolutions per minute. Owing to the small surface over which the ore passed, it was difficult to get a satisfactory stratification in the riffles before the end of the table was reached, and the values were still mixed with the tailings at the overflow side. So a plane surface was added at both the head and tailings discharges, with the expectation that the combination of plane surface and wash water would ~~five~~ form a "fan" similar to that found in other makes of tables.

This was not satisfactory,however, for the minerals had not had enough of the action of the riffles before reaching the plane,while the latter required too little slope for the rest of the table.

So the plane surface was removed,and the table used in its original form.

The heads secured from running the jig tailings were sorted in a ninety mm current in the tubular classifier, described below, and set aside to be treated with the rest of the sorted products.

A sample of the tailings from this run was assayed,while another sample of one hundred grams was panned for sulphurets,and yielded four percent,chiefly pyrite, with a small amount of fine galena.

The tailings from the panning test, representing practically pure gangue were also assayed.

Results:-

	Gold	Silver.
Tailings from table	0.61oz	1.51 oz.
" " pan	.04oz	1.52 oz.

This shows that the gangue carries practically no values, or if it does, such values would have to be neglected.

The fact that the silver was the same in both cases might have been due to the silica carrying silver, though it is more likely that galena in the form of slimes was present in both cases.

TREATMENT OF BED CONCENTRATES AND HUTCH PRODUCT.

These products were classified in the tubular classifier, preparatory to tests on the separation of pyrite and galena on the table.

The classifier was operated as follows:

The proper current was first obtained by trial; water was run in at A from the faucet until the quantity was as near right as could be judged by the eye. The water overflowing in a given length of time was then accurately weighed, and thus the overflow per second became known.

Knowing the cross-section of the tube, the velocity per second could be calculated.

By repeating the operation, the desired quantity and velocity could be easily obtained in one or two trials.

With the proper current flowing, the ore was fed in at the funnel until the latter was pretty well filled, then a constant head of water was kept above the ore in the funnel, while the velocity of the current in the tube B caused a slight reduction of pressure in the arm C.

The effect of this arrangement was to cause a steady downward flow of the ore in the arm C,giwing a very uniform feed.

The head of water on the ore was so small that its effect on the sorting current was negligible.

The currents used are shown in the following table,as well as the amount of product obtained in each case, and the mesh of the galena particle which would just rise in each current:

Current.	Cor. Galena grain	Amt.gms.	% total ore
130 m.m. per sec	30 mesh .37 m.m.	1088	7.97
90 "	40 " .28 "	878	6.44
75 "	50 " .21 "	64	0.47
60 "	80 " .17 "	877	6.43
40 "	100 " --	527	3.86
20 "	-- --	1007	7.39
10 "	-- --	579	4.24
Overflow	-- --	191	1.40
Slimes.	-- --	1107	8.12

The distinction made between overflow and slimes is that the"overflow" settled readily, while the "slimes" remained suspended for a time.

A series of concentration tests on the above sizes was made with the table, but it was difficult to get a very clean separation, owing to the small difference in specific gravity. However, the results showed that the ore would concentrate well with a properly designed plant, and would give clean pyrite and galnea for metallurgical treatment later, it being necessary, as shown, to crush to the finer sizes.

Sixty mesh ore gave the best results on this table, but good work could undoubtedly be done on coarser material by a larger machine.

METALLURGICAL TREATMENT OF ORE.

Theoretical Considerations.

The method which would naturally suggest itself from the results of concentration given above would be to get an enriched product of galena and heavy pyrite containing all the silver (Ag) possible and considerable gold (Au), which would be shipped to a smelter, and then treat the tailings, consisting largely of light pyrite, at the mine. The concentrates would assay at least seven ounces of gold and fifty ounces of Silver, making them worth approximately $175.00 per ton. At this rate they could be shipped to considerable distance for smelting and a good profit made. The light pyrite would assay, provided proper concentration was made, about two and fifty one hundredths gold and less than seven ounces silver. This would make a fair ore for leaching and one to which almost any ordinary leaching method could be adapted.

PYRITE USED IN THE TESTS.

Our first aim was to get a pyrite product upon which to perform the series of metallurgical tests. This was obtained by panning the sorted products obtained in the classification of the ore and mixing the panned concentrates together. The sizes thus ranged from through twenty mesh to finer except slimes. In order to get a line on the amount of fines in the product which is very important in any metallurgical work the sizing test below was made. In the test it was particularly noted that the coarser sizes i.e. on thirty mesh and forty mesh embraced the heavier and harder particles of pyrite while the finer sizes contained,as well, the lighter and more easily broken grains.

The lighter grains increased with fineness of the pyrite.

The result of this test is :-

Total ore at beginning 261.5 grams

		Grams	%
	On 20#	None	-----
Thro 20#	" 30#	35	13.4
" 30#	" 40#	65	248
" 40#	" 50#	79.5	304
" 50#	" 60#	46	17.6
" 60#	" 80#	21.5	8.2
Through	80#	14.5	5.6

ASSAY OF PYRITE.

The pyrite obtained above assayed considerably higher than it would in practical work. It ran four and fifty-six one hundredths ounces of Gold and eight and forty-one hundredths silver whereas in actual work a product would be obtained with just about one half as much gold and but little silver. This was of course due to the fact that the means of separation from the galena and gangue were very poor and that the heavy and light pyrite were not separated.

It is very rare in any leaching process to treat ore as rich as this but owing to the fact that no better product could be obtained we performed our tests on it.

METALLURGICAL TESTS.

Three series of metallurgical tests were made. The first one consisted of treating the raw pyrite directly, the second of treating the raw pyrite with the products on 30# and 40# crushed through 40#,while the third was comprised of tests on the roasted ore. In each of the first two series, only the KcN method was tried while on the third both KcN and barrel chlorination were used.

The tests,although not entirely conclusive,owing to the fact that there were so few of them made and moreover because our quantity of ore was small in amount, show that under favorable conditions, a fair extraction can be obtained on the roasted ore with either barrel chlorination or KCN.

The results of the series of tests are given below after which a discussion of them is given.

Series I.

Original Assay = $4\frac{56}{100}$ ounces of Gold and $8\frac{58}{100}$ ounces Ag.

Number of test	Amt.Ore used	KCN Sol. cc	Strength	Hrs.	%Extract au	%KCN used	Assay AFter Au	Assay AFter Ag
1	2 A.T.	60	.13	24	42.9	53.8	2.60	7.20
2	"	"	.22	24		36.4		
3	"	"	.43	24	38.6	21.4	2.80	6.90
4	"	"	.74	24		16.2		
5	"	"	.22	48	53.5	409	1.96	4.44
6	"	"	.43	48	57.0	326	2.12	1.98

Series II

Original Assay = $4\frac{56}{100}$ Au and $8\frac{58}{100}$ Ag.

Number of test	Amt.Ore used	KCN Sol. cc	Strength	Hrs.	% Extract Au	%KCN Consumed	Assay after Au.	Assay after AG.
1	1 1/2A.T.	60	.74	15	60.5	17.6	1.80	6.24
2	"	"	.13	24	50.9	51.7	2.24	6.36
3	"	"	.74	24	12.3	146	4.00	8.00
4	"	"	.22	24		668		
5	"	"	.43	24	63.1	209	1.68	5.72
6	"	"	.13	60	27.6	61.5	3.30	6.02

Series III

Barrel Chlorination Process.

% Roasted Ore Taken

No.of Test.	H_2O used	Acid	Bleach	Treatment
1	80%	4	2	Rotated 3 Hrs.

Result of Test.

	Wght gms.	Assay Au.	Assay Ag.	Wght Ore gms	% Au lost in roast
Raw Ore	250	4.56	858	.039#	
Roasted Ore	171.5	6.80	10.44	.0398	

Ore actually chlorinated = 75 grams.

Assay after treatment = $1\frac{20}{100}$ Au and 6 $\frac{00}{100}$ Ag.

Total gold in tailings = 00309 gms

" " 171.5 gms ore = .00706 "

Gold actually recovered = .0398 - 00706 = 03274 gms.

Precentage recovered based on roasted ore = 82.8 %

Result of Tests with KCN on roasted ore.

Number of test	Amt.Ore used	KCN Sol. cc	Strength	Hrs.	% Extract Au *	% KCN used	Assay. Au	Assay. Ag.
1	1 1/2A.T	60	.43	24	77.0		1.56	7.68
2	"	"	.75	24	45.1		3.72	6.58

* % Extraction is based on assay of roasted ore.

Discussion of Tests on Raw Ore.

It can be readily seen that in no case,in the first two series of tests, was there an extraction of any practical value. The highest was 6,31% and this left altogether too much gold in the tailings.

The second series,however, gave a greater extraction than the first for the same conditions and this would show at a glance that the ore must be crushed through 40# at least to work with any degree of success on the raw ore. Now possibly by using two different strengths of KCN, a fair extraction could be obtained but in no case would the result be of any practical importance. The consumption of cyanide would be high and a great deal of time would be necessary owing to the non-porosity of the pyrite.

On Roasted Ore.

By roasting the pyrite a product resulted easily treated by either KCN or chlorination process. The gold was more easily attacked and time required for a good extraction was much shorter than on the raw ore. In series III the results of tests on the raw ore are recorded. The reason high extractions were not obtained, was that in the roast instead of converting the iron into Fe_2O_3, FeO was obtained and it is well known that oxides in "ous" condition consume in large amounts KCN and chlorine and thus prevent them acting solely on the gold.

Roasting of the Pyrite.

The pyrite was roasted for almost twenty hours and it being removed at intervals to be examined. In spite of anything that was done it would not be oxidized. Ammonium nitrate was added but it simply evaporated without using its oxidizing power. The whole trouble was that our means for roasting were very poor and instead of having a through draft muffle, the work was done in one of the old front draft muffles in the assay room. In this,instead of getting an oxidizing atmosphere, a reducing or neutral,prehaps slightly oxidizing atmosphere was obtained. Finer crushing of the ore did apparantly no good. So at last the idea of getting ferric iron was given up and the tests were

performed on the pyrite as it was.

As seen from the table the extraction was only fair, the highest being 82.8%. This was still too low but under favorable conditions an extraction better than 90% could undoubtedly be obtained.

General Discussion of the Tests.

The reason I have given such a brief discussion of the tests was because definite conclusions would be liable to error. The product in the first place is not exactly the one that is going to be tested in practice (as noted above), the location of the mine would make a great deal of difference in the method of treatment, National conditions,such as water supply,etc. would influence this. etc.

For example, the location of the mine would influence the treatment in this manner. If it was situated near a smelter or if railroad transportation to a smelter was cheap enough,the original ore would make an almost ideal smelting ore. Otherwise,some such treatment as outlined above would have to be adopted.

Treatment of Slimes.

These can be treated on slime tables and concentrates obtained for smelting or they can be briquetted and smelted directly.

Possibly a leaching process could be successfully performed on the roasted slimes if porosity could be secured so as to help percolation, etc.