Hunt of Sill Coll.

MINING
METALLURGY
CHEMISTRY

ORE TESTING
PLANT DESIGN
METALLURGICAL RESEARCH
ASSAYS & ANALYSES

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ITEM 13

September 12th, 1927.

Messrs. W. M. and H. H. Armstrong,
Los Angeles,
California.

Gentlemen:

In response to your request that I make a preliminary investigation of the Key West Mine, in Clark County, Nevada, to determine whether or not this property warrants a more detailed examination, I have spent a part of one day at the mine and herewith offer you the results of my findings.

The Key West Mine lies about 24 miles southeast of Moapa on the Union Pacific Railroad and is reached over a good highway for the first 14 miles, the remainder of the road being in a passable but not good condition.

There are no surface improvements of any kind at the property and in the rehabilitation of the mine, a complete camp and mine equipment must be established. No water for domestic purposes is available at present but I am informed by the lessees of the Key West that a spring in the higher hills a mile and a half distant will furnish sufficient water by gravity to supply the camp for domestic purposes and a 50 ton milling plant. My very limited time at the property did not permit me to visit the source of the water supply. The mine is partially filled with water but whether from surface seepage or having reached ground water level I could not determine.

The former operator of the Key West states that the mine is developed to a vertical depth of 312 feet and that at that depth they had to resort to pumping.

There is a probable tonnage of not to exceed 1500 tons of dump ore with sufficient value to be available for milling. These dumps while not contiguous, lie within a radius of a few hundred feet of the mill site and could be transported to the mill cheaply.

TABLE CONCENTRATION TEST - KEY WEST MINE

DUMP SAMPLES

108 pounds of ore taken from all of the ore dumps were crushed to minus 40 mesh and tabled with a resultant concentrate weighing 5.1 pounds or a ratio of concentration of 21.17 tons into 1. This ore is very complex and contains in addition to the gangue minerals, nickel, cobalt, copper, platinum, palladium, gold and silver in addition to a considerable amount of iron, all occurring in the sulphide form. The ore taken from the dumps to comprise this sample has been mined for many years and subjected to oxidizing forces which have greatly altered the original sulphides and added to the difficulty of their concentration. A preliminary test, crushing to 20 mesh, showed by a microscopic study and chemical analysis that a considerable percentage of the values were still occluded in the gangue and that finer grinding was necessary to liberate the values sufficiently to give a satisfactory recovery. Under the best conditions of grinding and classification a considerable loss will be sustained due to the excessive degree of decomposition and oxidation of the various minerals present. A microscopic study of the crushed material showed that crushing to minus 40 mesh liberated most of the values.

The following table gives the analysis of the various products and the resultant extractions:

	Gold Ozs.	Silver Ozs.	Platinum Ozs.	Palladium Ozs.	Nickel %	Cobalt %	Copper %
Heads	Trace	0.18	.03	.02	0.98	0.19	1.36
Concentrates	"	3.2	0.62	0.41	8.58	2.4	11.3
Middlings	None	.4	Trace	Trace	3.0	0.11	3.93
Tails	None	Trace	None	None	0.43	.08	0.55

Percentage Metal in Products

	Gold	Silver	Platinum	Palladium	Nickel	Cobalt	Copper
Heads	100	100	100	100	100	100	100
Concentrates	-	83.95	97.6	96.8	41.34	59.65	39.24
Middlings	-	16.05	-	-	22.68	4.29	21.40
Tails	-	-	-	-	38.55	37.0	35.54

* Ratio of concentration -- 21.17 into 1
** Ore crushed to minus 40 mesh.

TABLE CONCENTRATION - KEY WEST MINE

MINE ORE - 25' above 75' level

5 pounds of mine ore were crushed to minus 20 mesh with a resultant concentrate of .386 pounds or a ratio of concentration of 13 into 1. This ore like the dump ore is badly oxidized and the entire face of the vein was covered with a heavy coating of copper sulphate. Because of the small amount of ore obtainable, the concentrates and middlings were combined. The tailings show that finer crushing is necessary to free the mineral from the gangue and as in the case of the dumps the ore should be ground to a maximum of 40 mesh.

The following table gives the analysis of the various products and the resultant extractions:-

	Gold Ozs.	Silver Ozs.	Platinum Ozs.	Palladium Ozs.	Nickel %	Cobalt %	Copper %
Heads	.02	0.22	0.21	0.18	0.69	0.23	2.49
Concentrates	.16	2.52	2.4	3.0	4.5	1.62	9.8
Tails	.005	Trace	.03	Trace	0.37	0.11	1.2

Percentage Metal in Products

	Gold	Silver	Platinum	Palladium	Nickel	Cobalt	Copper
Heads	100	100	100	100	100	100	100
Concentrates	61.7	90.0	88.23	99+	51.1	55.9	55.6 ?
Tails	38.3	10.0	11.77	-	49.9	44.1	44.4

With a milling capacity of 50 tons per day there is approximately one month's supply of ore obtainable from the dumps. This is not sufficient to warrant the installation of a mill. The mine is only partially available for examination, being filled with water to a point slightly below the 75' level. However, at that horizon there is a strong mineralized dike showing approximately 20' in width which should develop a considerable tonnage of ore if it maintains its present width and value to the asserted depth of 312' or bottom of the mine. In my opinion this mine warrants the unwatering of the lower workings provided a satisfactory metallurgical treatment can be applied to an ore of such extreme complexity and a satisfactory market provided for the metals obtained.

The following are average samples of the three ore dumps:

DUMP SAMPLES

Sample	Gold Ozs.	Silver Ozs.	Platinum Ozs.	Palladium Ozs.	Nickel %	Cobalt %	Copper %
Main ore dump	Trace	.20	.03	.025	1.13	.29	1.56
Ore and waste dump	Trace	.14	.02	.01	0.63	0.14	0.63
Red iron dump	Trace	.18	.06	.07	1.64	0.26	2.0

The ore occurs in a badly decomposed basic dike of probably pre-Cambrian age intruded in gneisses of the same age. The mine was filled with water to the 75' level and was, therefore, only partially available for examination. However, at this horizon the vein shows a width of approximately 22' and a sample cut across 14' gave the following analysis:

Sample	Gold Ozs.	Silver Ozs.	Platinum Ozs.	Palladium Ozs.	Nickel %	Cobalt %	Copper %
25' above 75' level	.02	0.22	0.21	0.18	0.69	0.23	2.49
Muck in drift	.01	0.12	0.02	.03	1.25	0.25	1.56

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KEYWEST MINE

REPORT ON ORE TREATMENT FOR MR. LOUIS THOMPSON

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The sample of dump ore submitted for treatment was found to contain the following values per short ton:

(Ag.) Silver	(Pt.) Platinum	(Pd.) Palladium	(Cu.) Copper	(Co.) Cobalt	(Ni.) Nickel
.68 ozs.	.27 ozs.	.32 ozs.	1.3%	.44%	.53%

This ore was first ground through 30-mesh for tabling with the attendant results - (see Table #1)

The overall extraction was poor, particularly in the platinoids. To discover the reason for this, a separation of the tails was made at 80-mesh; this showed that 95% of the platinum and palladium contents were in the fines.

	% Material	Ag.	Pt.& Pd.	Cu.
+ 80-mesh	36.6	.30	.07	.59
- 80-mesh	63.4	.34	.74	.78
Calculated Values	100	.325	.495	.71
Table Tailing Assays		.32	.50	.78

It was evident from this grading analysis that the platinoids could only be recovered by some other method.

The total tailings were then treated by flotation. Two tests were run, using as reagents a combination of Pine Oil, Potassium Xanthate and P. E. oil; these tests showed that the table tailings were amenable to flotation, but required finer grinding to give a satisfactory recovery.

The material was reground to 7% on 65-mesh.

Test #3

Water ratio 3.5 to 1
Reagents Pine oil ½# per ton of ore
P. E. Oil 3/10# " " " "
Potassium Xanthate 2# " " " "

	% Material	% Copper	% Distribution
Flotation feed	100	.89	100
" Concentrates	32	2.47	87.8
" Tailings	68	.16	12.2

Test #4

Was made with the object of reducing quantity and increasing grade of concentrates produced without increasing tailings loss. The concentrates from this test were cleared.

Water ratio 3.5 to 1
Reagents - Pine Oil 4/10# per ton of ore
Potassium Xanthate 1½# " " " "

Full analysis of this test is shown on table #2.

Table #3 is a summary of the table test and flotation test #4.

From a study of these tables, it appears that the tabling of this ore can be dispensed with, without in any way affecting the metallurgical losses.

Test #5

Direct flotation on original dump ore ground to 100-mesh.

Water ratio 3.5 to 1
Reagents Pine Oil ½# per ton of ore
" P.E. Oil 2/10# per ton of ore
Potassium Xanthate 1# " " " "

	% Material	% Copper	Distribution of Recovery
Heads	100	1.176	100
Concentrates	11	5.9	55.2
Middlings	21	1.8	32.1
Tailings	68	.22	12.7

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Test #6

Direct flotation on original dump ore gound to 100-mesh.

Water ratio	3.5 to 1
Reagents lime	5# per ton of ore
Pine Oil	3/10# " " " "
Potassium Xanthate	½# " " " "

	% Material	Copper Assay	%	% Recovery
Heads	100	1.3	100	
Concentrates	20	4.75	74.2)	
Middlings	24.4	.93	17.7)	91.9
Tailings	55.6	.19	8.1	
Calculated Heads		1.278		

	% Material	Platinum & Palladium Assay	%	% Recovery
Heads	100	.59	100	
Concentrates	20	1.82	58.3)	
Middlings		.84	32.8)	91.1
Tailings		.10	8.9	
Calculated Heads		.6245		

In the regular operation of a mill, the middlings will be returned to head feed; this will tend to increase the grade of concentrates.

Ratio of concentration 5 to 1.

S U M M A R Y

From the results obtained on the sample of dump ore from the Key West Mine, submitted to me for testing purposes, I advise direct flotation.

The benefits to be derived from direct flotation are:

1st. An increase in grade with a decrease in amount of concentrate produced over tabling preceding flotation.

2nd. Simplicity of operation.

3rd. Decrease in installation and operating costs.

The work so far done has shown that the platinoid minerals are in very close association with the sulphides, grinding to 100-mesh parts to liberate them effectively for separation by selective methods. A bulk concentrate has to be produced to make a satisfactory saving of the valuable contents.

A certain proportion of the iron can be dropped out of the concentrates, but if the dropping of the iron is carried too far, a portion of the valuable contents go with it. This can be accounted for as the bulk of the iron, is contained in the minerals Pentlandite, Chalcopyrite and Nickeliferous Pyrrhotite.

Mill work should be guided by the procedure of test #6. It will probably be found that the amount of reagents required will be slightly lower than used in these tests. The lime requirements will vary with the nature of the water.

Consulting Engineer.

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KEY WEST Contd.

A sample of coarse mine ore was later submitted for treatment; this was found to contain the following values per short ton.

Ag.	Pt.	Pd.	Cu.	Co.	Ni.	Insol
.48 Ozs.	.20 Ozs.	.22 Ozs.	1.07%	1.05%	2.72%	50.5

This sample contained considerably more iron than the dump ore and the percentage of Cobalt and Nickel were also much higher but there is a decrease of 29% in the platinum, palladium content. The ore was ground as follows:-

	%
+ 65 mesh	8.
+ 100 "	16.
+ 150 "	14.4
+ 200 "	15.7
- 200 "	45.9
	100.

and treated by direct flotation. With the high sulphide content selective flotation to a certain degree was essential. The following tests were run on above feed with a water ratio of 3.5 to 1.

Test #7

Reagents — Lime 1# per ton ore
Aerofloat Oil — 4/10# " " "
Tailings .8% Cu.

Test #8

Reagents — Lime 1# per ton ore
Pine Oil 4/10# per ton ore
Potassium Xanthate 1# per ton ore
Tailings - .44% Cu.

K E Y W E S T M I N E

RECAPITULATION TABLE TEST AND FLOTATION TEST #4

TABLE #1

	% Material	Ag. Assay	Ag. %	Pt. Assay	Pt. %	Pd. Assay	Pd. %	Cu. Assay	Cu. %	Co. Assay	Co. %	Ni. Assay	Ni. %
Heads	100	.68	100	.27	100	.32	100	1.30	100	.44	100	.53	100
Table Concentrates	2.6	1.68	7	1.39	13	.48	4	9.00	18	2.40	14	4.64	24
Table Middlings	5.9	1.18	10	.33	7	.36	7	5.83	26	.99	13	.94	10
Recovery Table C&M	8.5	-	17	-	20	-	11	-	44	-	27	-	33
Table Tailings	91.5	.32	43	.23	78	.27	77	.78	55	.34	71	.36	62
Recovery - Heads less Tails		-	57	-	22	-	23	-	45	-	29	-	38

TABLE #2

TABLE TAILINGS REGROUND AND FLOATED

Flotation Heads	91.5	.32	43	.23	78	.27	77	.78	55	.34	71	.36	62
Rougher Concentrates	22.	.95	30.7	1.06	86.2	1.04	67.8	2.58	43.8	1.18	59.1	1.4	57.9
Cleaned "	9.2	2.16	29.2	1.00	34	1.11	31.8	5.60	39.8	2.30	48.3	2.90	50.2
Flotation Middlings	12.8	.08	1.5	1.11	52.2	.98	36.	.41	4.	.37	10.8	.32	7.7
" Tailings	69.5	.12	12.3	.04	10.1	.06	12.9	.18	9.6	.07	11.1	.09	11.8
" Cons.,Flotation Middlings & Tailings	91.5	-	43.	-	96.3	-	80.7	-	53.4	-	70.2	-	69.7

TABLE #3

Total Recovery C&M	30.5	-	47.7	-	106.2	-	78.8	-	87.8	-	86.1	-	102.7
Tailings - loss	69.5	-	12.3	-	10.1	-	12.9	-	9.6	-	11.1	-	11.8
Recovery H-T		-	87.7	-	89.9	-	87.	-	90.4	-	89.9	-	88.2
Combined Concentrates & Middlings	30.5	1.05		.95		.86		3.75		1.25		1.59	

Ratio of Concentration - 3.3-1

Test #9

Reagents	Lime	2# per ton ore
	Pine Oil	1/2# " " "
	Potassium Xanthate	1.7# " " "
	Tailings	.16% Cu.

Test #10

Reagents	Lime	5# per ton ore
	Aerofloat Oil	4/10# " " "
	Potassium Xanthate	1# " " "
	Tailings	.61% Cu.

Test #11

Reagents	Lime	5# Per ton ore
	Pine Oil	2/10# " " "
	Potassium Xanthate	1½# " " "
	Tailings	.14% Cu.

Test #12

Reagents	Lime	5# per ton ore
	Pine Oil	2/10# " " "
	Potassium Xanthate	2# " " "
	Tailings	.19% Cu.

This test was carried to completion, the rougher concentrates cleaned with the addition of 2½# lime per ton ore. Table of results attached.

Test #13

With 10# lime per ton, Xanthate and pine oil gave evidence of improvement in grade of product; further tests are being conducted with high lime content and results will be submitted when completed.

Test #14

In an acid circuit using 2# sulphuric acid per ton and increasing amount to 5# per ton, in an endeavor to clean up concentrates proved of no avail.

Test #15

With Sodium Silicate for same purpose gave no evidence of any improvement.

Test #12	% Material	Ag. Assay	%	Pt. Assay	%	Pd. Assay	%	Cu. Assay	%	Co. Assay	%	Ni. Assay	%
Heads	100	.48	100	.20	100	.22	100	1.07	100	1.05	100	2.72	100
Cons.	25	1.12	60.8	.56	65.2	.62	64.9	3.03	78.	3.51	72.	7.05	79.3
Mids	24	.54	28.2	.12	13.4	.18	18.1	.48	12.	.90	17.7	.95	10.2
Tails	51.	.10	11.	.09	21.4	.08	17.0	.19	10.	.25	10.3	.46	10.5
Recovery Cons. and Midlings			89.		78.6		83.		90.		89.7		89.5
" H-T			89.4		77.		81.5		90.9		88.		91.4

Calculated Ratio of Concentration 3.3 to 1.

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I have made a preliminary examination of the Key West Mine to determine the character and extent of the ore bodies. This investigation was necessarily superficial as the mine is filled with water to a point just below the 75 foot level.

I am informed by the former superintendent of the property during its entire period of operation that the mine is developed by a vertical shaft 312 feet deep with levels at 75, 200, 250 and 300 feet. My informant states that the mineralized area was 48 feet in width on the bottom level. Because of the physical condition of the property, I am unable to substantiate these statements but am inclined to accept them because on the 75 foot level, which is available for examination, the vein shows a width of approximately 22 feet while at points on the surface it shows an even greater width, and a sample cut across 14 feet gave the following analysis:

Sample:	Gold Ozs.	Silver Ozs.	Platinum Ozs.	Palladium Ozs.	Nickel %	Cobalt %	Copper %
25' above 75' level	.02	0.22	0.21	0.18	0.69	0.23	2.49
Muck in drift	.01	0.12	0.02	.03	1.25	0.25	1.56

DUMP SAMPLES

Sample	Gold Ozs.	Silver Ozs.	Platinum Ozs.	Palladium Ozs.	Nickel %	Cobalt %	Copper %
Main ore dump	Trace	.20	.03	.025	1.13	.29	1.56
Ore and waste dump	Trace	.14	.02	.01	0.63	0.14	0.63
Red iron dump	Trace	.18	.06	.07	1.64	0.26	2.0

The ore occurs in a badly decomposed basic dike of probably pre-Cambrian age intruded in gneisses of the same age. These basic dikes show on the surface to be from 10 to 40 feet in width. As indicated in my metallurgical test, the ore is composed of copper as chalcopyrite, iron principally as pyrite

in association with occasional pieces of pyrrhotite together with platinum, palladium, small amounts of gold and silver, also nickel-iron-sulphide occuring as pentlandite and polydymite together with cobalt as cobaltite.

A combination of these minerals presents a complex problem in metallurgy but I believe from a study of the vein at the 75 foot level that you are justified in unwatering the mine to determine the value and extent of the ore bodies reported on the lower levels.

Consulting Engineer.

HAS:GM

KEY WEST MINES Cont'd.

FURTHER TESTS ON MINE ORE

TEST #16:

Ore ground in pebble mill from 20 mesh to 100 mesh with 7.5# lime per ton. Indicated alkalinity after grinding - .01% Ca O per ton ore. Floated with:

Potassium Xanthate - 1# per ton ore
Pine oil - 3/10# " " "
Water ratio - 3 to 1
Concentrates cleaned and two products taken.

	% Material	Pt & Pd		Cu		Co		Ni	
		Assay	%	Assay	%	Assay	%	Assay	%
Heads	100	.42	100	1.07	100	1.05	100	2.72	100
1st Cons.	22.4	.38	21.	3.7	78.2	.92	20.	2.33	19.
2nd "	14.3	.92	32.5	1.06	14.3	1.3	18.	7.12	37.4
Mids.	22.5	.62	34.4	.19	4.	1.45	32.	3.49	28.9
Tails	40.8	.12	12.1	.09	3.5	.75	30.	.98	14.7
Recov. C+M	--	--	87.9	--	96.5	--	70.	--	85.3
" H-T	--	--	88.3	--	96.5	--	70.9	--	85.3
Calculated Heads		.405	--	1.06	--	1.02	--	2.72	

This test showed the possibility of making two products, one high in copper, low in nickel and cobalt; the other low in copper and high in nickel and cobalt. There was also some indication of the platinoids following the nickel.

TEST #17:

Was run with the object of increasing grade of the two products and making a higher recovery of the nickel.

Ore ground in pebble mill from 20 mesh to 80 mesh with 10# lime per ton ore. Indicated alkalinity after grinding .09% Ca O per ton ore. Floated with:

Potassium Xanthate - 1/2# per ton ore
Pine Oil - 2/10# " " "
Water ratio - 3.5 to 1
Concentrates cleaned and two products taken.

TEST#17:

	%Material	Ag Assay	%1	Pt Assay	%	Pd Assay	%	Cu Assay	%	Co Assay	%	Ni Assay	%	In Sol Assay
Heads	100	.48	100	.20	100	.22	100	1.07	100	1.05	100	2.72	100	50.5
1st Cons.	7.5	.61	9.6	.20	7.3	.22	7.2	11.7	71.8	1.08	7.7	3.25	8.9	12.6
2nd "	16.	1.3	43.8	.59	45.8	.63	44.3	1.1	14.4	3.9	60.	9.60	55.5	13.6
Mids	16.	.63	21.2	.34	26.4	.35	24.6	.29	3.8	.56	8.6	3.6	20.5	--
Tails	60.5	.20	25.4	.07	20.5	.09	23.9	.2	10.	.41	23.7	.69	15.1	--
Calc. Heads	100	.475	--	.205	---	.228	---	1.22	--	1.04	--	2.77	--	
Recov. C+M			74.6		79.5		76.1		90.		76.3		84.9	
" H-T			74.8		78.8		75.3		90.		76.4		84.6	

Calculated ratio of Concentration 3.67 to 1.

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TEST #18:

In cyanide solution with same reagents as in other tests, gave no evidence of any possible improvement over previous work.

TEST #19:

Same conditions and reagents as Test #17 but finer grinding. No improvement; with finer grinding more gangue comes over with concentrates.

TEST #20:

Ore ground from 20 mesh to 60 mesh with 3# lime per ton ore. No indicated alkalinity after grinding. Floated with same reagents but found that with no indicated alkalinity, concentrates were higher in insoluble.

TEST #21:

Ore ground in pebble mill from 20 mesh to 60 mesh with 5# lime per ton, pulp faintly alkaline after grinding, floated with:

Potassium Xanthate - 2# per ton ore
Pine oil - 3/10#" " "
Tailings - .64% Cu.
Concentrates dewatered and reground with 5# lime per ton ore.

Object of this test to float all sulphides. By regrinding concentrates with more lime and floating again with less Xanthate, it was hoped that a more selective copper concentrate could be made. This was not found to be the case.

	% Cu	% Ni
1st Concentrate	11.8	3.96

This method does not show any evidence of improvement over Test #17.

CONCLUSIONS:

From the results obtained on the sample of Key West ore, I have arrived at the following conclusions:

1. The ore is amenable to flotation methods.

2. A satisfactory extraction of all valuable contents in a bulk concentrate can be made; ratio of concentration 3.3 to 1.

3. It is not possible to reduce the amount of concentrates produced in any appreciable degree without high tailings losses.

4. It has been found that an alkaline circuit is necessary. An indicated alkalinity in pulp of .01% CaO gives best results; this will require from 8 to 10# lime per ton of ore. Lime should be added at ball mill.

5. Potassium Xanthate and Pine oil are the only reagents so far found to be of any service. These can be added after grinding.

6. Grinding through 65 mesh liberates the sulphides; finer grinding tends to increase insoluble in concentrates.

7. The table of results for Test #17 shows that a separation, by flotation, of the copper and nickel, can be made; with most of the cobalt, platinum and palladium, going into the nickel concentrates. Marketing conditions will determine whether this separation is practical or not.