1916

The development of a copper-silver ore body

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THE DEVELOPMENT OF A COPPER-SILVER ORE BODY

BY

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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.

1916

Approved by C. R. Forbes

Professor of Mining.

INTRODUCTION

During the years 1912 to 1915 the writer had charge of the Ruby Copper Company property near Patagonia, Arizona, and it was suggested that a review of this work, with costs and data, would be helpful to other engineers engaged in similar enterprises.

PROSPECTING

In order to intelligently develop any ore deposit, it should be systematically prospected and the geology studied in order to determine the probable extent and the most favorable places for doing the development work.

Prospecting consists of two steps: first, in obtaining all the available data or information pertaining to a given area and applicable to the problem in hand; and, second, the interpretation of these data.

The interpretation of these data embraces: first, the determination of the coincidence or lack of coincidence between the given area under attack and that of other proven districts; and, second, in actually determining by development work the correctness of these deductions.

Prospecting, in its broadest application, is therefore a process of elimination and, in its more definite application, a process of actual development by workable openings.

This naturally implies that prospecting is a hazard. It is difficult to imagine any business which cannot be correctly classified as a hazard. It should also be remembered that mining does not rank among the most hazardous investments. Prospecting is a commercial undertaking if the opportunity for profit exceeds the possibilities of loss.

The geology of the county was carefully studied so far as surface exposures and work upon adjacent properties was concerned. From this knowledge it was considered that the development of this property would constitute a commercial undertaking, under certain conditions and for a certain consideration. A detailed account of this preliminary examination will not be undertaken with this thesis. It is sufficient to state that there existed, in a quartz-monzonite, a fissure vein (being continuous upon surface for three miles); that this vein, as exposed, showed widths from 3 to 12 feet; that these exposures, at favorable points, contained limonite, quartz, manganese oxides, and a very small percentage of copper carbonate (malachite). This vein intersected a heavily sheared zone, of approximately 200 feet width, at a favorable, topographical, point.

This property is situated 12 miles northwest of Patagonia, Arizona, in Township 21 S., Range 15 E. It is reached by a wagon road. Nine miles of this road are of easy grade, while 3 miles contain 4 short, but heavy (10%) grades. Considerable attention is necessary to keep the road in good condition for heavy travel.

Patagonia is the supply point for a large mining section and is on the Benson-Nogales Branch of the Southern Pacific System. The elevation of Patagonia is 4050 feet, and at the collar of the proposed shaft 5500 feet. There is a good location upon the property for a small camp. Water for camp purposes is not abundant. The location for a shaft is good with ample dump room.

DEVELOPMENT

Power Plant

Choice of Power.- The local supply of fuel consisted of a small amount of second-growth, black oak and could not be considered as a fuel factor. Coal was out of the question, due to its high first cost and the long mountain haul. Fuel-oil, for use in internal-combustion engines, was found to most nearly fulfill the requirements. The California oil fields were not far away hence the price was fair. Oil is also cheaper of transportation than a solid fuel (occupying less space per given weight, and adjusting itself to any form of container). A good grade of fuel-oil (27 degrees plus) was obtained in 55 gallon, iron barrells, for 8 cents a gallon. This same oil was quoted at 6½ cents in carload lots - minimum 3000 gallons. It was decided that the cost of installing storage for such large quantities was out of proportion to the amount saved during the campaign of development.

Amount of Power Necessary to Develop.- The amount of power necessary to be developed brought under advisement the kind of shaft (verticle or inclined) and also whether to install one or two power units. The shaft, being a prospect shaft, it was decided to follow the vein, within certain limitations; since the vein dipped 72 degrees the shaft would be inclined.

Whether to drive the hoist as a separate unit, or to install one power unit to operate both hoist and air-compressor was considered from a number of angles. The internal-combustion engine has certain disadvantages for power for shaft sinking purposes, from a viewpoint of safety (it is not as positive of developing power at an instants notice as is steam). The more requirements placed upon an internal combustion engine the greater is its possibility to be in poor repair and hence in unsafe operating condition. Upon the other hand, the cost of purchasing and installing two power-units was out of proportion to the increased factor of safety. It was therefore decided to install but the one power-unit and to use additional precautions in the handling of men and in the operation of this power-unit.

The uses for power would consist of, power for hoisting and for driving the air-compressor.

The amount of power for hoisting was roughly determined by combining the weight of the bucket of ½ ton capacity with the weight of 550 feet of 5/8 Macomber and White "Yellow Strand" hoisting rope, and allowing for a certain friction loss between the bearing surfaces of the skids and bucket. This resolved into an 1800 pound verticle lift. With a rope speed of 200 feet per minute the required horse power was 11.

The amount of power for the air-compressor depended upon the size and make of machine. Compressed air was required for the operation of two Ingersoll-Rand, B C R - 430 "Jackhammer" Drills; one small feed-water pump (Worthington Duplex 4x2x4); one forge and one trip-hammer (an old 2¼ piston drill permanently mounted vertically). The amount of free-air per minute at 100 pounds initial pressure, for these operations, was 162 cubic feet. No allowance was made for an air operated sinking pump. It was planned to operate a small steam boiler for pumping water if found necessary. It was thought that all water encountered could be bailed out, and such was the case.

<u>Description of Power Plant</u>. The machine purchased was a Sullivan, single-stage, belt driven, air-compressor, class "W G - 3", of a piston displacement of 172 cubic feet - 200 R.P.M. - 5000 feet elevation. Its weight was 4000 pounds. This compressor was purchased second-hand for $450 f.o.b., Patagonia. The required horse-power at the belt was 37. The total horse power required for the plant was 48. Since this maximum power would be needed for only a small portion of the working day, it was decided to purchase a 40 horse power engine and hoist combined, and to minimize this difference in power by installing a large air-receiver and an instantaneous cut-off of power to the compressor.

A 40 horse power, Witte, horizontal, ore-cylinder, 4 cycle, oil engine and hoist was purchased. This machine, complete with bed-plate, friction-clutch pulley etc., weighed 4 tons and cost $1400 f.o.b., Patagonia. This make hoist is not manufactured now. It is my belief that a more expensive but standard smoke hoist, such as the Fairbanks Morse hoists, would have obtained lower final costs. While hoisting men away from shots the engine was operated upon gasoline instead of fuel-oil, and a clean ignitor-block used.

Surface Plant

A plan and section of the surface plant will be found at the conclusion of this thesis.

The front posts and back stays of the headframe were of 8x8 inch sawed timbers set in concrete foundations; while the braces were of 6x6 inch construction.

The bed-plate of the hoist required 36x88 inches of floor space and that of the air-compressor 30x72 inches.

Foundation excavations for both machines were carried to bed-rock, a distance of 3 feet. Concrete foundation were "run" for hoist, compressor, air-receiving tank, water tanks, pit for the oil tank and headframe and building supports.

The buildings were of cheap construction - a frame work of "dimension" lumber covered with galvanized, corrugated, iron. The shaft house was floored with 1 inch boards.

Fuel oil was delivered from the wagons to the unloading platform. A barrel lain horizontally upon this platform delivered (by gravity) its contents through a ½-inch pipe, to the engine supply tank. This tank was housed in a concrete pit, just outside the shaft house. From this tank the oil was pumped to the engine as consumed.

The supply of jacket-water was obtained from the mine. A 500 gallon tank collected the water as hoisted. After a neutralizing treatment with potash, this water was pumped to the circulating water tanks.

The compressor was belt driven by a friction-clutch pulley upon the crank-shaft of the hoisting engine. As there was but 10 feet between centers of drive and driven pulleys (limited floor space) the compressor was equipped with a belt-tightener. The compressor was also equipped with an automatic unloading device. A wire fastened to the lever arm of this unloader was taken to within easy reach of the hoistman, who could "cut-off" the compression of air at any time. For a period of about one hour of the shift (while mucking and drilling were both in progress) it was necessary, at times, to "cut-off" the compressor when hoisting muck. This arrangement worked very satisfactorily and did not appear to subject either hoist or compressor to undue strain.

The plant was operated by two men - an engineer and a top-man.

Shaft Sinking

A 500 foot shaft was sunk in two sections or lifts.

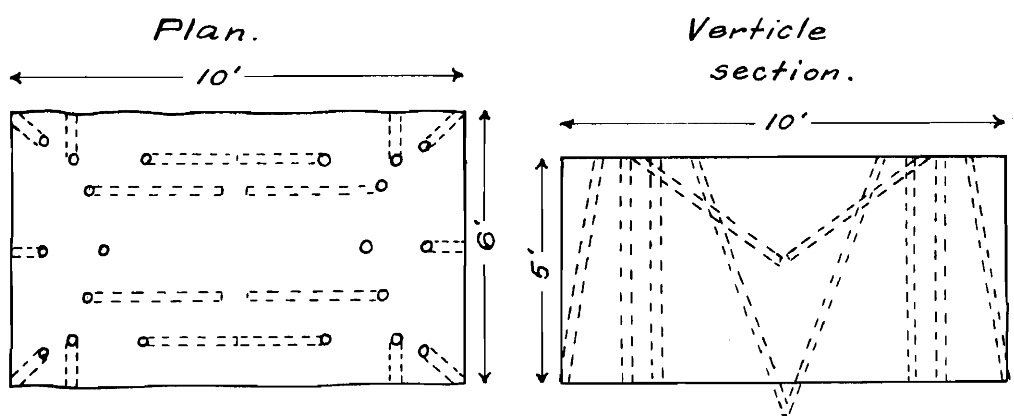
First. A 50 foot shaft was sunk with hand steel and a windlass. This work was being done while the surface plant was under construction. From the 50 foot level the work was done with the plant just described.

Both hanging and foot walls were good. The hanging wall gave considerable trouble whenever it was broken into.

Sinking was advanced from 12 to 24 feet ahead of the timbers.

The size of the shaft as broken was 6x10 feet.

Drilling and Blasting,- The shaft round consisted of 16 to 20 holes, drilled as shown:



The cut-holes were drilled and fired. The muck was removed and if additional cut-holes were needed they were drilled together with the balance of the round. Five foot rounds were "pulled": the cut-holes being from 6 to 6½ feet deep. All holes were drilled "wet". Whenever possible one corner of the shaft was carried 1 foot in advance of the bottom to act as a sump.

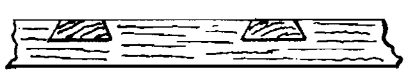
Forty per cent gelatine dynamite was used, with No.6 blasting caps. A good grade of American fuse was found satisfactory.

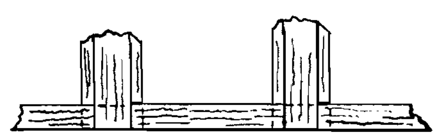
Woolf acetylene lamps gave the best satisfaction.

Mucking,- As soon as the round was fired mucking progressed until the bottom was clean. Short handled, round-pointed, shovels were used exclusively for shaft work.

Timbering,- The square-set method of shaft timbering was used. Inside shaft measurements were 4x8 feet. End and wall plates and posts were of 8x8 inch sawed timbers: dividers were of 6x8 inch timber. Lagging was of 2 inch sawed planks.

All lumber was Oregon fir costing $40 per M at the mine. Square-sets were 6 feet between centers. Skids were 4 x 6 inches with a 1 x 2 inch level, and were secured to the foot-wall plates with log-screws and washers. Ladders were made of 2 x 4 5 (actual measure) with mortised rungs 1½ x 3 inch.





This method of ladder construction was made necessary due to the acid nature of the mine water.

Bearing-sets were placed at 50 foot intervals.

Stations.- Stations were cut at the 50 - 100 - 300 - 400 - and 480 foot levels.

Ventilation.- A 40 foot tunnel connected with the 50 foot station. A light trap-door was built over the man-way compartment just above this level. As the two compartments were separated by a 1 inch board partition, this arrangement caused a natural flow of cool air down the man-way as the warm air flowed up the hoisting compartment.

The underground crew consisted of two miners and one timberman on the day shift and of two miners on the night shift. Two shifts of 8 hours each were operated.

A teamster was also employed. As he worked in the company store one-half of his time, only $1.50 per shift was charged against the mine account.

Cost Data on Sinking.- Cost of first 50 foot section of shaft.

Sinking and timbering (hand labor).

Labor	$355.00
Materials	240.00
General Expense	52.50
Total	$647.50

Cost per foot $12.95

Cost of second 450 foot section of shaft.

Sinking Cost.

Labor			Materials
Drilling	$3.13		$2.98
Mucking	3.50		.96
Steel sharpening	.24		.04
General repairs	.34	Gen. Exp.	.80
Total	$7.21		$4.78

Cost per foot of shaft sunk $11.99

Timbering Cost.

Labor			Materials
	$3.10		$3.26
		Gen.Exp.	.14
Total	$3.10		$3.40

Cost per foot of shaft timbered $6.50

Total cost per foot of shaft sunk and timbered	$ 18.49
Total cost of 450 feet of shaft sunk and timbered	8320.50
Total cost of 500 feet of shaft sunk and timbered	8968.00
Or, a total cost per foot of	$17.936

Station Cutting.

Labor	1st Sta.	2nd Sta.	3rd Sta.	4th Sta.	5th Sta.
Drilling	28.60	32.40	12.00	52.10	41.20
Mucking	36.00	64.80	31.40	60.80	63.00
Material					
Drilling	22.43	27.91	10.12	41.10	36.84
Mucking	11.90	14.65	6.71	36.86	18.90
Timbering					
Labor	29.32	32.72	4.80	56.90	34.40
Material	20.41	30.60	6.34	54.15	21.67
Total cost per station	148.66	203.08	71.37	301.91	216.01

Total cost of 5 stations	$941.09
Average cost per station	$188.22

<u>Miscellaneous</u> <u>Cost</u> <u>Data</u>,- Cost of Drifting (4 x 6½ ft.)

300 foot level,	180 feet,	$9.10	per	ft.	$1638.00
400 " "	240 "	10.40	"	"	2496.00
480 " "	390 "	9.30	"	"	3627.00

Note - Drifting costs were high due to partial employment of Mexican drill runners and to experimental work with Jackhammer drill. Drill was first operated on a trough placed upon temporary stulls, then upon temporary boards as a support, then the drill was hung within a looped rope from a drill steel extending out of a back-hole. The notched-board support proved the best for soft to medium hard ground.

Cost of Cross-Cutting (4 x 6½ ft.)

480 foot level, footwall, 30 feet, $12.20 per ft.	$366.00
480 " " hanging wall, 68 ft., $14.60 " "	$992.80

Cost of Upraising (4 x 7)

400 foot level,	120 feet,	$5.80	per	foot	$696.00
480 " "	210 "	5.60	"	"	1176.00

Cost of Sinking Winze (4 x 6 ft.)

300 foot level, 42 feet, $16.85 per foot	$707.70

Cost of Timbering Upraise.

Level	Labor	Supplies	Per Foot	Total
400	.14	.37	.51	$61.20
480	.19	.40	.59	123.90

Cost of Timbering Chutes.

Level	No.of	Labor	Materials	Per Foot	Total
400	2	7.60	12.10	19.10	39.40
480	2	9.20	14.00	23.30	46.40

"Materials" includes cost of sheet-iron chute gate of $1.60. Chute gate consisted of a semicircular sheet-iron plate, stiffened with 3/8 inch riveted strap-irons, and a lever attachment by which it was operated.

<u>Power</u>,- Average cost per 8 hour shift $2.682. Approximately 40 horse power was developed for 5 hours of the 8 or a cost per horse power hour of $0.0134
Including: Fuel oil at 12 cents per gallon, cylinder oil at 65 cents per gallon, and incidental supplies.
Power cost per machine shift while sinking averaged 64 cents.

<u>Explosives</u>,- In sinking 6.8# of 40% gelatine dynamite were used per foot of shaft or 1.5# per ton of rock removed. Dynamite at 16 cents per pound cost $1.09 per foot of shaft.

<u>Haulage</u>,- Cost per ton to mine plant from Patagonia (12 miles) was $7, or 58 cents per ton, per miles. When hauling both in and out the rate was $4 or 33 cents per ton per mile.

Cost of road repair and maintenance averaged approximately 4 cents per ton trip.

Sinking Averages, - 0.41 tons per man per hour for men underground.
0.22 tons per man per hour for total men employed at mine plant.

Drifting Averages,- 0.375 tons per man per hour for men at headings (Mexican labor at $2.50 per shift)
0.184 tons per man per hour for total men employed at mine plant.

Cross-Cutting Averages,- Were not determined.

Upraise Averages,- 1.02 tons per man per hour for men in raises and tramming.
0.504 tons per man per hour for total men employed at mine plant.

Wages for Day Shift.

7:00 to 11:00 A.M. and 12:00 to 4:00 P.M.

Engineers, 1 - operated hoist and air-compressor and did blacksmithing	$ 5.00
Top-men, 1 - Mexican	2.00
Timberman, 1	4.00
Miners, 2 - at the rate of $4	8.00
Teamsters, 1 - ½ time at the rate of $3	1.50
Total	$20.50

Wages for Night Shift.

Engineers, 1 - no blacksmithing	$ 4.00
Top-men, 1 - Mexican	2.00
Miners, 2 - at the rate of $4	8.00
Total	$14.00

The company provided separate bunk houses for the day and night shifts.

The company operated a dining room, charging $1 per day. Approximately 90% of this amount was spent in the kitchen; the remaining 10% providing for soap, towels, haulage, and office accounting expenses.

Cost of Buildings and Equipment.

Shaft-house, blacksmith shop, headframe	$580.00
Concrete foundations	80.00
Air-compressor	480.00
Air receiver	65.00
Hoisting engine (500' of 5/8" wire rope)	1400.00
2 - ½ ton buckets	12.00
2 Jackhammer drills (complete)	240.00
Drill steel	60.00
Air pipe - 1 and 2"	40.00
3 Water tanks	35.00
1 Small feed-pump	30.00
Mine Equipment total	$3022.00

3 Camp houses		$580.00
Shaft - 500 feet	$8628.00	
Stations - 5	941.00	
Drifting - 810 feet	7761.00	
Cross-cutting - 98 feet	1359.00	
Upraising - 330 feet	2057.00	
Winze - 42 feet	708.00	
Development total	$21,454.00	
Total expenditures	$25,056.00	

ESTIMATING THE ORE BODY

In drifting along the vein the sample interval was ten feet; in drifting within the ore-chute the sample interval was five feet (small rich lenses within this ore-chute necessitated a closer sample interval than did the vein proper).

In upraising and sinking the sample interval was five feet.

In cross-cutting one, continuous, groove, sample was taken. Ten feet sections of this groove were used for each sample unless conditions warranted closer intervals.

As a check, composite samples for each 50 feet of work (comprising 5 ten foot intervals) were taken from the assay pulps.

No samples were taken from each parcel of ore hoisted as a check. This method was tried but proved unsatisfactory.

All samples were assayed for silver and copper. Approximately every tenth sample was assayed for gold, silver, copper, iron, and insolubles.

A "continuous section" method of tabulating the location and nature of the assay samples was not used. Closer estimates would have been obtained had this method been used.

Allowing 12 cubic feet to the ton, there was "proved" to be 1600 tons of shipping ore over a gig:

Copper	12.2%	figured at the rate of	14¢	per	lb.
Silver	16.0 ounces	" " " " "	50¢	"	oz.
Iron	21.0%	" " " " "	5¢	"	unit.
Lime	2.4%	" " " " "	5¢	"	"
Insolubles	33.6%	penalty of above 30%.	8¢	"	"

Ore averaged per ton:

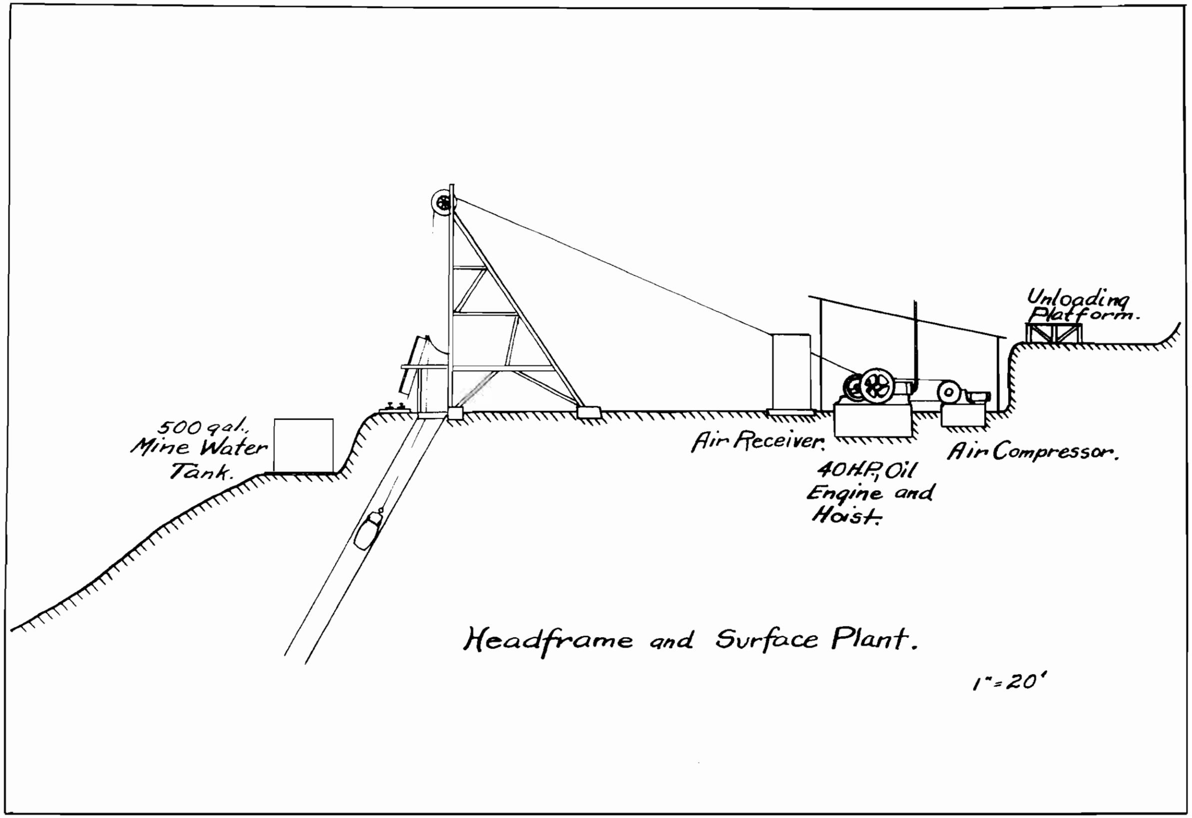
Copper	$34.16	
Silver	8.00	
Iron and lime	1.17	
	$44.33	
Deductions for 3.6% insolubles	.29	
Total value per ton at the smelter.	$44.04	
Total value of 1600 tons	$70,464.00	

This is a smelting grade of ore and the following charges would have to be deducted from the gross value to obtain the net value or profits:

Mining - approximate	$ 3.50	
Hand sorting and loading	.60	
Haul to railroad	4.00	
Freight to smelter	3.00	
Treatment charges	4.50	
Total costs per ton	$15.60	
Total profit per ton		$44.04
Less		15.60
		$28.44

Profit for 1600 tons	$45,504.00

In developing this ore body a considerable tonnage of vein material averaging 5% copper was proven. This vein material is not of shipping grade with a normal copper market, but is amenable to concentration. These concentrates would then be shipped to the custom smelters for beneficiation.



Headframe and Surface Plant.

1" = 20'