Increasing Profits by Selective Mining.

A THESIS.

Submitted to the Faculty of the College of Engineering Science
in candidacy for the Degree of Engineer of Mines.

DEPARTMENT OF MINING.

By

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Approved by _____

Accepted by _____

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INCREASING PROFITS BY SELECTIVE MINING.

I. INTRODUCTION.

The profits derived from mines encourage people to invest in and operate them. These profits are subject to great variation as a result of changes in the price of metals, the cost of supplies and labor, and the mining conditions. During the World War some metal mines, stimulated by an advance in the value of their particular metals, harvested large profits. Others, not affected by an advance in the market price of their special metals, were forced to close down- as the high cost of labor and materials ate up their profits; while some mines were forced to operate on reduced profits for the same reasons. At the close of the war, many of the previously profitable mines were forced to close down on account of a decline in the metal market, with labor and materials remaining as high as during the war.

At least once in the history of every mine it becomes necessary to increase profits or to close down. Some of the methods that may be used to increase profits, tho conditions will determine which will be the most beneficial, follow: 1. Increase the tonnage, keeping the operating expenses and value of the ore about the same; 2. Decrease the tonnage and increase the value of the ore by sorting out the waste; 3. Sacrifice a portion of the ore thus obtaining a lower mining cost; 4. Reduce the working force and keep the daily tonnage and value of the ore the same; 5. Introduce the leasing system; 6. Employ that of selective mining. In certain cases each of these systems has been tried by mining companies and has met with success.

II. EXAMPLES OF DIFFERENT METHODS OF INCREASING PROFITS.

1. The Hollinger Mining Company increased profits by increasing tonnage, as shown:

1.

	1922	1921
Tons Milled	1,491,381	1,072,493
Average Value	$8.53	$9.67
Gross Value	$12,726,549.77	$10,367,901.07
Loss in Tailings	452,435.00	336,850.50
	$12,274,114.77	$10,031,050.57
Operating Cost per Ton Milled	$4.255	$4.8698 *

2. A mine in Michigan Copper Country, was changed from a non-paying mine to a paying proposition by sorting.

" T.W. Denton, in the Michigan Copper Country, on the Baltic Lode, solved one, an irregular copper spotted mass, in the following way: The vein as a whole yielded in the mill 14 pounds of copper and contained six additional pounds of copper that were lost in the milling process. By picking out the waste or low-grade ore in the mine, it was found that 40 percent that would run no better than the mill tailings, could be rejected. This selection yielded the following results: 100 tons mined contained 2000 pounds of copper, 40 tons were rejected containing 240 pounds of copper, this left 60 tons of material containing 1760 pounds of copper, or 29 pounds to the ton." #

Another example of increasing the profits by sorting was the Alaska Juneau Mine.

The Alaska Juneau trammed 213,400 tons, they rejected 119,300 tons as coarse tailings. 94,100 tons were milled, the recovery per ton milled was $1.52. The operating costs per ton milled were $1.16. The recovery per ton trammed was $0.67, and the operating cost per ton trammed was $0.51. More than half of the ore trammed was rejected in order to secure a profit on each ton of ore handled.

3. Profits of a mine may be increased by wasting a portion of the ore, as:

" For instance, suppose an ore worth $2.00 a ton can be mined with a 90 percent extraction for $1.25 a ton, but that by another method, a 75 percent extraction, it can be mined for 90 cents a ton. One hundred tons of ore in the ground would in the two cases yield

* Engineering and Mining Journal-Press, March 3, 1923 - Page 417.

Finlay's "Cost of Mining". Page 235.

the following results:

Ore worth $2.00 per ton.

	Tons	Cost	Value	Profit.
First Case	90	$112.50	$180.00	$67.60
Second Case	75	67.50	150.00	82.50
			Gain	$14.90

It is evident therefor, that even in the most homogeneous materials the cost of mining is directly affected by the value of the product. The portion of the deposit that may be sacrificed to obtain lower costs increases as the margin of profits diminishes. When that margin becomes zero obviously its value is zero and the whole deposits being unworkable is left in the ground". *

4. Profits may be increased by reducing the working force, as:

" A few months ago a mine in California changed managers. The new head reduced the number employed one-third without impairing the amount of work accomplished." #

5. Profits may be increased by leasing.

January 1919, the Goldfield Consolidated Mines Company ceased operating its properties at Goldfield, Nevada, as there was a material loss each month. Their mining claims were thrown open to leasers. The leasing system still continues. For the year 1922, 4782 tons of ore were mined - fifty six leases were issued- from which the Goldfield Consolidated Mines Company received $28,365.18 in royalties. **

III. PROBLEM AT NEVADA HILLS MINE, FAIRVIEW, NEVADA.

The Nevada Hills Mine was located on the west side of Fairview Peak, in the south eastern part of Churchill County, Nevada, at an altitude of 4600 feet. The nearest railway station was Fallon, Nevada, at a distance of 45 miles from the mine. The road lay thru alkali flats and sand. All supplies were delivered by freight teams for $0.007 per pound. The concentrates were back hauled for $0.0035 per pound. Most of the water used was pumped from West Gate, a

*Finlay's "Cost of Mining". Page 54
'Principles of Mining". by Herbert Hoover. Page 165
** From the Sixteenth Annual Report of the Goldfield Consolidated Mines Company for the year 1922.

distance of 6 miles. At the West Gate pumping station the pump was operated with a gasoline engine, and half way between this station and the mine was an electrically driven relay pump. About 3000 gallons of water a day were pumped out of the mine.

The ore was mined from two sources- the Nevada Hills Vein and the Eagle Vein. The Nevada Hills Vein was in Early Andesite and outcropped for 1500 feet, had an average depth of 125 feet, a dip of 65 degrees and varied in width from 4 to 15 feet. The gangue was quartz. A large percentage of the high-grade ore had been mined and shipped before the twenty stamp mill and cyanide plant were built. The Eagle Vein had about the same strike and dip as the Nevada Hills Vein. It also occured in Early Andesite. The ore had been left intact as it was too low-grade to ship.

The beginning of the year 1915 found it costing the Nevada Hills Mining Company as much to produce an ounce of silver as it would br bring on the market - and the price of all supplies was advancing rapidly. It was decided to try changing the method of operation before considering a shut-down. Of the six methods given above, that of increasing the tonnage was chosen for the new method in the belief that it would bring the best results.

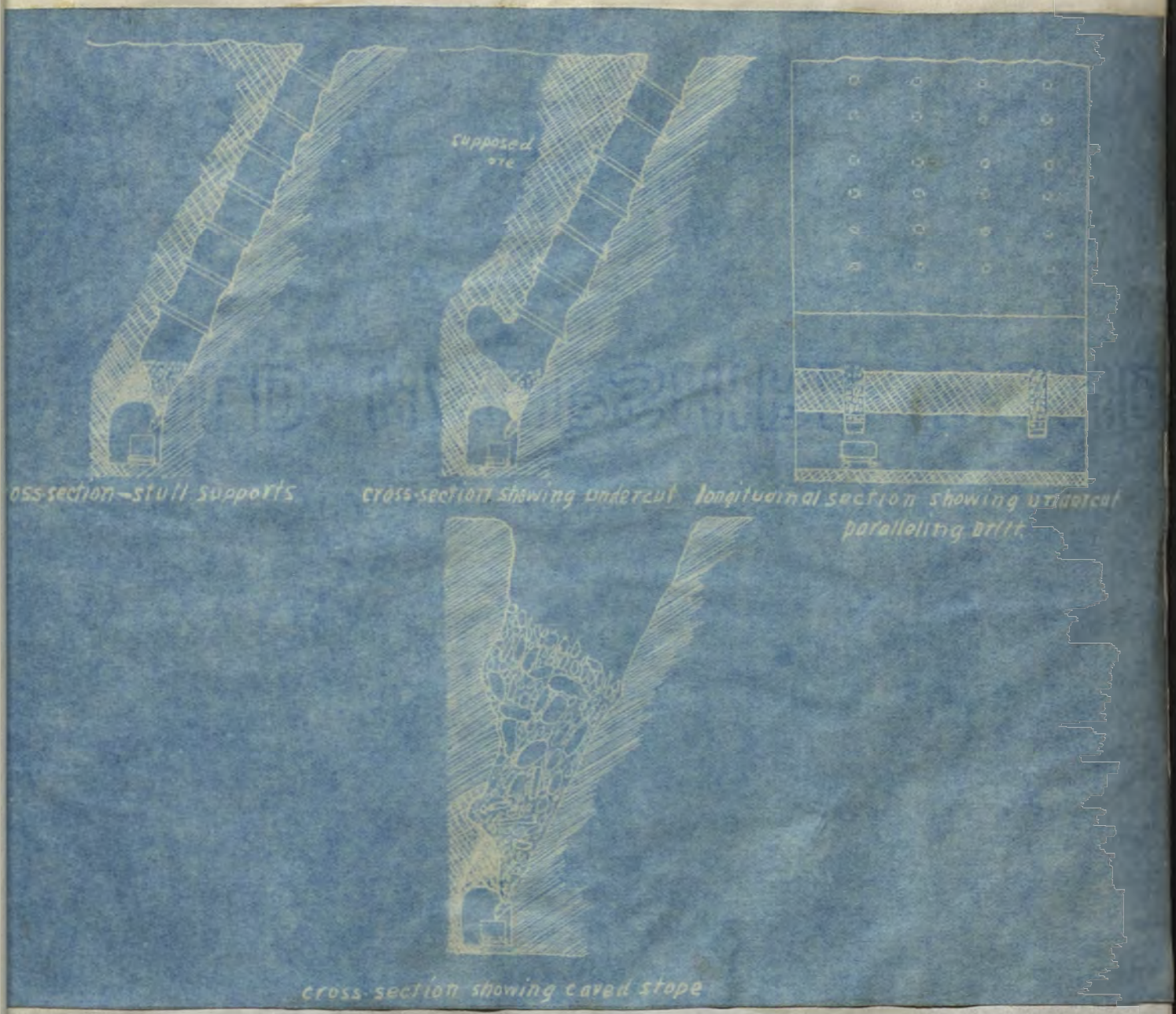
IV. ATTEMPT TO INCREASE PROFITS BY INCREASING TONNAGE.

The manner in which this attempt to increase profits, by increasing the tonnage, was handled and some of the difficulties encountered and overcome are here described.

The mill was designed for 4500 tons a month. As high as 5848 tons of ore and 310 tons of tailings were treated in one month. The ore bodies were not very extensive, and to keep up this tonnage, speed replaced efficient mining.

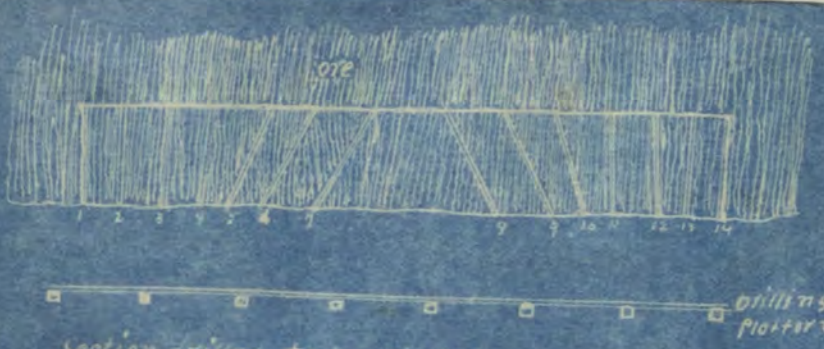
In the Nevada Hills Vein two methods were used in mining the remaining ore - the caving system and the open stope system, supported by stulls.

The caving system was used in the stopes that were stripped of the high-grade ore. An under-cut was made, paralleling the drift, 6 feet into the hanging-wall, about 4 feet above the back of the drift or farther if the ground was loose and there was a chance of disturbing the back. Six foot holes were drilled in the bottom of this cut and "looking up". These holes were loaded with 6 sticks of 40 percent powder. The stulls that supported the hanging-wall were drilled with an inch auger 2/3 of their diameter and loaded with 1/3 of a stick of powder. The fuses of the stulls and drill holes were "spit" at the same time, the stulls, having the shorter fuses, shooting out first. When the drill holes exploded the section caved clear to the surface. The ore was drawn from the caved stopes thru chutes spaced at about 20 foot centers along the drift below.

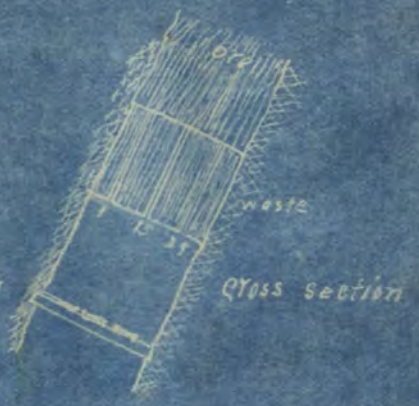


The caving system was very disappointing, the hanging-wall broke back for 30 feet in some places diluting the ore with waste. Large boulders and stulls blocked the chutes, making it slow and expensive work to draw out the ore. All the big boulders had to be drilled and blasted in the chutes. In many cases the chutes were destroyed and had to be replaced.

The open stope system was used to mine out sections of the ore that had not been interfered with, being too low-grade to ship. Stulls of 8 x 8 Oregon Pine were placed in hanging-wall and foot-wall hitches, 6 foot centers horizontally and 5 foot centers vertically. Each cut taken from the back advanced the stope 5 feet. The ore was drawn from the stopes every day.

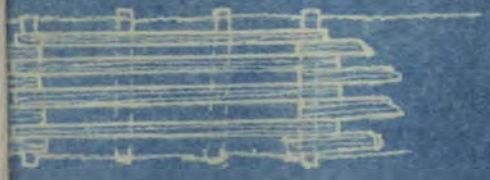


Section drilled to be shot down on stulls-42 holes

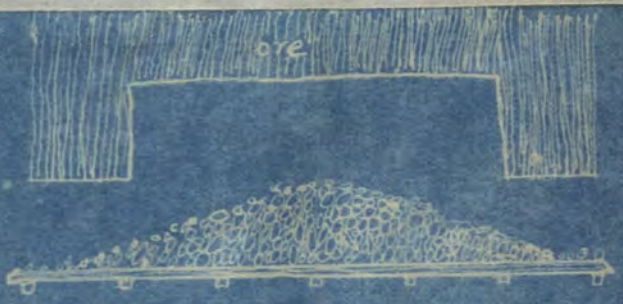


Cross section

Stulls were frequently shot out or broken, often three or four at a time. Shooting timbers were placed on top of the 8 x 8 stulls next to the backs and ore was shot down on top of these timbers. The big boulders were broken up and dropped down the stope along with the fine ore. These shooting timbers were raised to the next row of stulls, and the miners used them for a platform from which they drilled the next cut across the back.



on-Shooting timbers

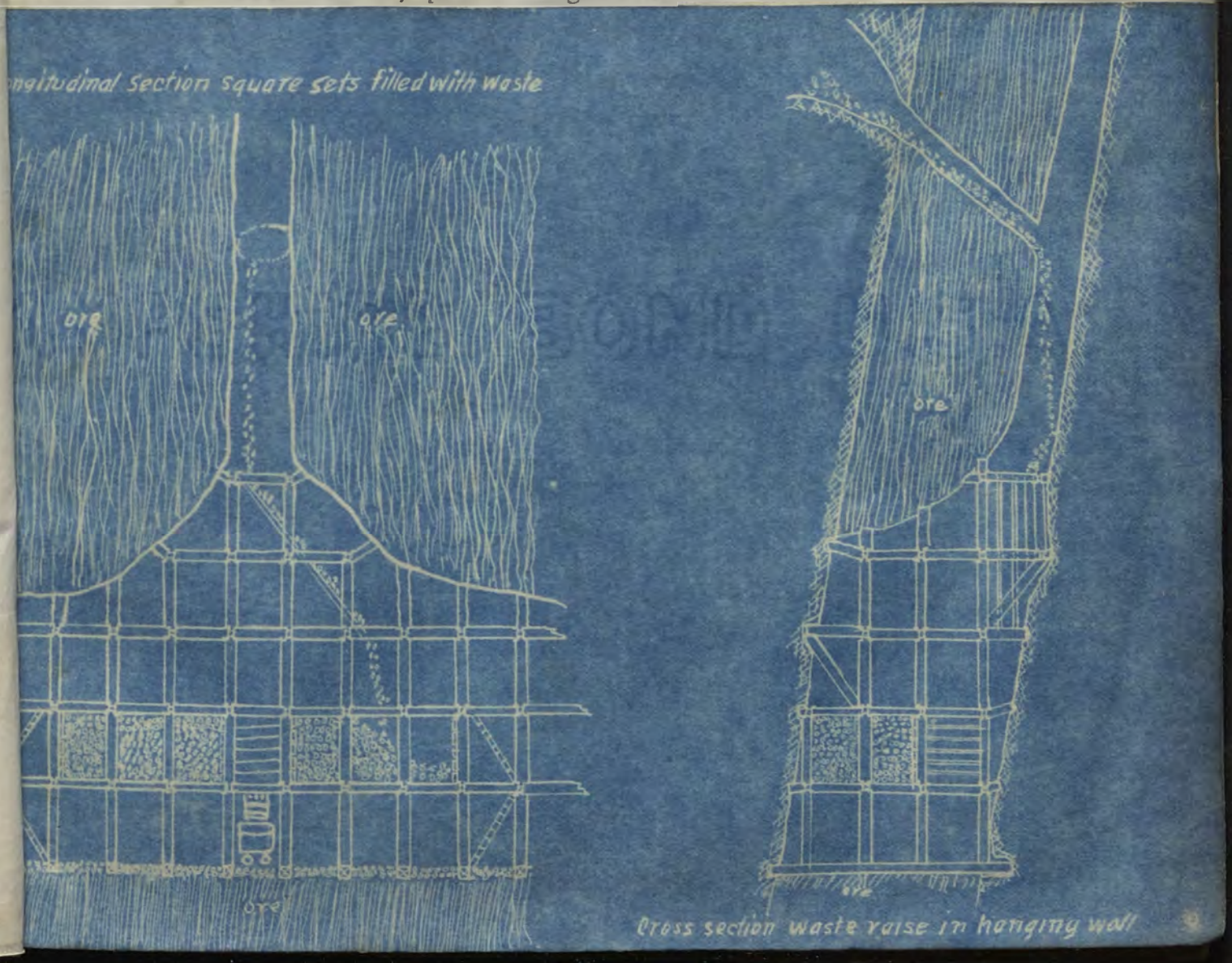


Section of ore shot on timbers

The country rock could be drilled easier and faster than the quartz and careless miners would drill the holes into waste.

hole drilled in hanging wall

The Eagle Vein ore body was 150 feet long, from 10 to 15 feet wide, extended down 350 feet and the vein dipped about 70 degrees. The hanging-wall and the vein, calcite, were crumbly and required square set timber to hold the ground. The square sets were kept filled within one set of the backs, with waste secured from hanging wall raises driven at different intervals above the stope. The starting point of the raise was taken in a winz, intermediate or level above the stope. If the raise was started on an intermediate or level it was started close to the winze so the waste when shot down would run direct to the stope. Slides were put in the winze to divert the waste to either side of the stope. After the sets were filled and leveled up, lagging was laid over the waste to make a floor for the ore which was shot down from the backs to make room for other sets. The ore was shoveled down the ore-passes, directly or conveyed to them by wheel barrow. These ore-passes were lined with 2" x 12" x 5' Oregon Pine lagging. On top of the caps of every other set was placed a baffle of 8" x 8" x 5' Oregon Pine timbers, closing half the ore-passage. These baffles broke the fall of the ore and saved the timbers from undue wear. Ore accumulated on top of the baffle boards, protecting them.



Plan- Ore on Baffle.

Baffle.

Cross-section Showing Baffles.

Offset in ore pass.

The vein was breast stoped. This form of mining made it harder for the miner to put in the holes. The drillings would not run out of the flat holes, causing delays as the machine miner had to stop often and clean out the holes. When the round was shot, the ore was thrown against shooting timbers placed on top of the square sets. If holes were drilled straight up the ore was shot against the posts and would often break or dislodge them. Vertical holes were drilled faster and easier, but the breakage of timbers was greater.

Breast Stoping arrow showing ultimate force of shots. Overhand stoping

Section of stope after the holes of the breast stope were shot.

plan showing shooting timbers resting on caps.

By breast stoping the cost of drilling was 17 percent more, but the breakage of timbers 87 percent less.

When the tonnage from the mine slackened, the richest mill tailings were sluiced into a tank, then pumped to the mill and retreated.

V. RESULTS OF INCREASING THE TONNAGE.

The mining costs gradually decreased and were followed by a like decrease in the value of the ore and in the production, except in an instance or two where stopes containing a good grade of ore furnished the largest part of the tonnage for that month. These are the results obtained during the nine months in which the cost per ton method was used.

Month 1915	Tons Mined	Value Ore	Mining Cost	Milling Cost	General Expense (Taxes & Marketing)	Total Cost per Ton.
January	5752	$5.34	$2.54	$2.15	$ .636	$5.39
February	5305	5.92	2.43	2.42	.671	5.52
March	5950	4.40	2.08	1.96	.512	4.54
April	5400	4.45	1.73	2.00	.519	4.25
May	5750	5.15	1.47	1.91	.523	3.91
June	5260	5.29	1.53	1.97	.514	4.01
July (4900 ore 310 tailings)	5210	4.06	1.40	2.22	.504	4.13
August (5848 ore 466 tailings)	6314	3.01	1.36	1.97	.532	3.87
September (5516 ore 318 tailings)	5834	3.41	1.16	1.94	.377	3.48
Amount produced	50775					
Averages	5661.6	$4.56	$1.77	$2.06	$ .532	$4.33

The exact cost of producing an ounce of silver was found by subtracting the value of gold obtained from the gross costs and dividing the result by the number of ounces of silver produced, as for instance: Month of January 1915.

398.275 ounces of gold x $20.00, gold value= $7965.50, total for gold.
$30,986.024, gross costs - $7,965.50, total value of gold = $23,020.524, net costs.
$23,020.524, net costs ÷ 46,050.28 ounces of silver produced = $ .4999, cost per ounce of silver produced.

The following table shows this cost per ounce, also profit per ounce of silver produced for the nine months:

MONTH 1915	OUNCES OF SILVER PRODUCED	VALUE RECEIVED FOR AN OUNCE OF SILVER	COST TO PRODUCE AN OUNCE OF SILVER.
January	46,050.28	$ .4853*	$ .4999
February	42,626.30	.5054	.4761
March	39,057.29	.5038	.5034
April	36,201.62	.4989	.4582
May	45,918.04	.4921	.3270
June	43,456.36	.4777	.3034
July	31,208.50	.4730	.4979
August	29,435.74	.4891	.5554
September	28,253.10	.4975	.5060
Amount Produced	322,207.13		
Average Value		$ .4914	$ .4586

*Quotations taken ten days after date of shipment, from the "Engineering and Mining Journal."

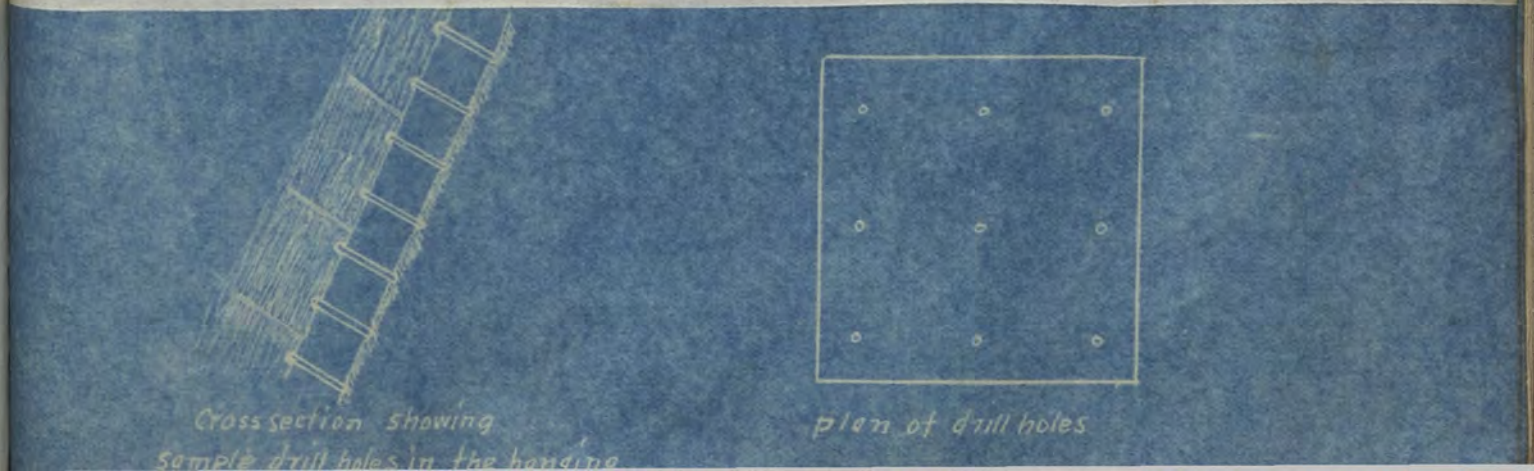
$ .4914, average value of an ounce of silver - $ .4586, average cost to produce an ounce of silver = $ .0328, profit.

This system of mining was not found to be profitable as the increase in tonnage was more than counterbalanced by the decrease in the value of the ore. The profit of $ .0328 was more discouraging as the cost of labor and supplies were increasing and the ore values were decreasing.

VI. ATTEMPT TO INCREASE PROFITS BY SELECTIVE MINING.

Careful mining was tried and the greatest profit that could be obtained from each ton of ore mined was the first consideration.

Sample drill holes in the hanging-wall of the sections stripped of the high-grade in the Nevada Hills Vein, showed the values varied. They were controlled by hanging-wall fault slips, parallel to the strike of the vein and at right angles to the vein. Wherever these slips occured the values extended back into the hanging-wall, sometimes 15 feet. Other places there were no values.



Cross section showing sample drill holes in the hanging

plan of drill holes

Cross section ore bounded by fault slips on the hanging wall.

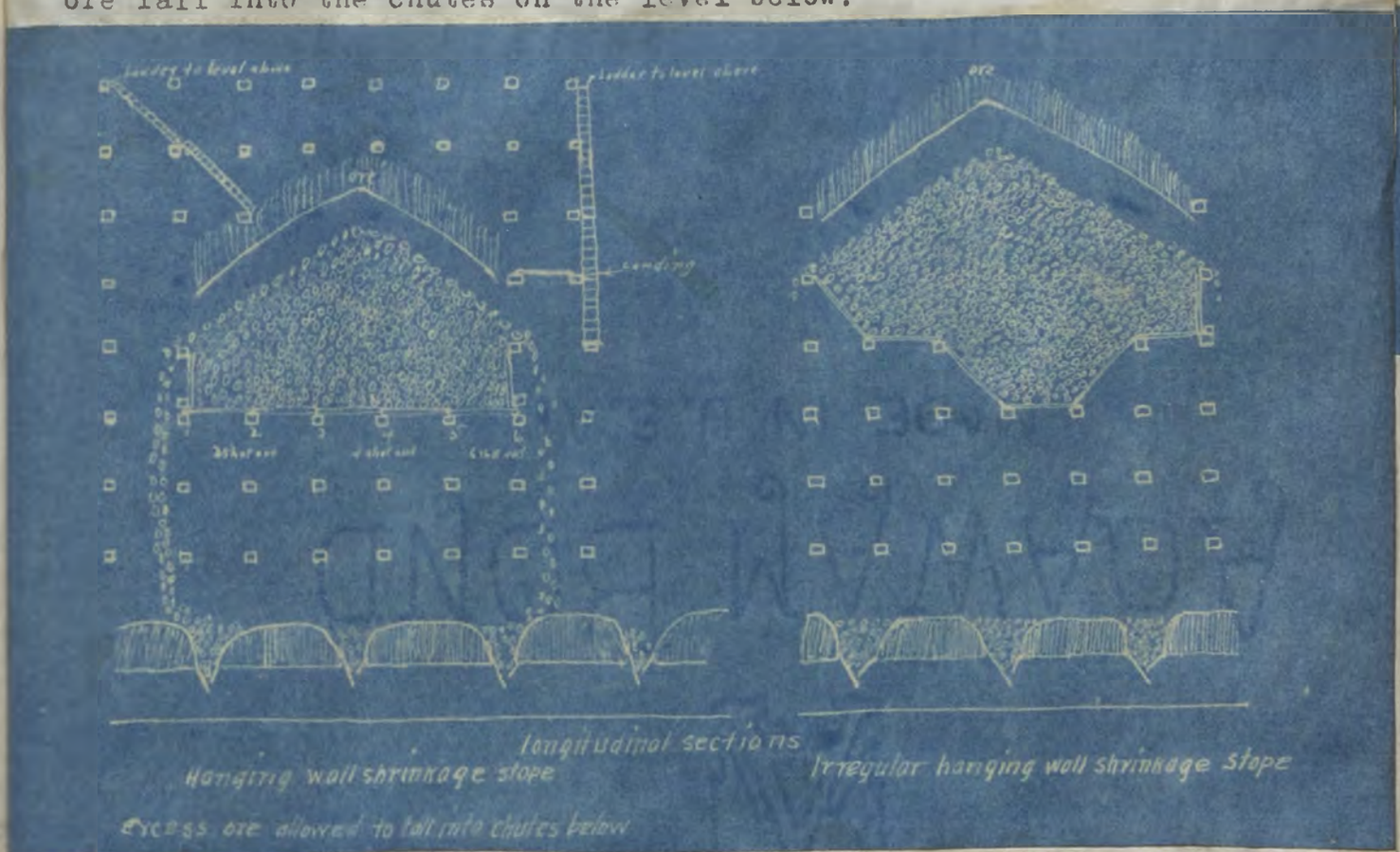
"Right angle fault zone"-ore in hanging wall.

"Right angle fault zone"-dip and movement.

If there was an enrichment in the hanging-wall at the level, mining was started above the level and the shrinkage system was used. Manways were carried on each side of the section to be stoped. The boulders were broken up after each shot and stulls shot out were dropped down either one of the manways at the end of the stopes.

Cross section of "shrinkage" stope.

When an enrichment occured above the level, 10 x 10 Oregon Pine stulls were placed 3 feet below it, spaced at 5 foot centers, paralleling the lower boundaries of the ore. These stulls were lagged over with waste timbers, or 2" x 12" lagging, and the shrinkage system started from the top of the lagging. Miners called these aeroplane stopes. The center of the stope was carried ahead of the two ends; the backs resembles the roof of a barn and the excess ore rolled over the ends of the stope. The stulls, shot down, were thrown over the ends of the stope and piled up on the level below, or were used to reinforce the hanging-wall above. The large boulders were broken up. After all of the ore in one of these stopes was mined, every other one of the bottom stulls was shot out, letting the ore fall into the chutes on the level below.



Mining the hanging-wall this way had several difficulties. What they were and how they were overcome follows:
The hanging-wall would slab off above the miners endangering their lives. More stulls with head boards were placed against the slabby hanging-wall. A moveable bulkhead was carried on top of stulls above the miners, protecting them from any rocks falling from above. Ore shot down on top of the lagging would break the lagging and stulls. To stop this breakage the lagging was covered over with 3 feet of ore before any heavy shooting was done on top of them. Stulls that were broken by ore falling on top of them were replaced or reinforced by stulls placed on each side of the one broken. The weight of ore on the stulls caused the long ones to sag in the center, shortening

them and weakening their hold in the hitches. Posts were placed from foot-wall hitches against the center of the stulls and held in place by scabs placed against the top and the hanging-wall. At times there was not enough ore in parts of the stope so that miners could drill the backs; if there was an excess of ore in another part of the stope, that could be moved easily, it was shoveled to the low place; if this ore was not available, the miner drilled from staging which he removed before shooting. The hanging-wall was weak adjacent the cross faults and sometimes caved before all the ore could be drawn from the stope. The weak hanging-wall was reinforced by stulls after the ore was removed. These stulls were laid on top of the ore so they would not be broken by the falling ore from the next round of holes shot.

Part of the ore remaining in the caved stopes was removed. Openings were made into the two ends of the caved stope. The waste was piled in the stopes, the ore was passed down through the openings until the next chutes were reached. The first openings were closed and filled with waste, the ore passed down through the second openings. This system was used until the ore was recovered. In places where the hanging-wall sluffed the ore was lost as it would not pay to timber up the hanging-wall to make it safe enough to recover the ore.

The open stope system was continued; drill hole samples of the hanging-wall and cut samples of the backs were taken after every round, to make sure no ore was being left on the hanging-wall or waste being mined with the ore.

The square set system of mining the Eagle Vein was discontinued, as the ore was too low-grade to pay for this system. The open stope stull system was used to mine out the portion of the foot-wall that contained the best values. Stulls with head-boards were used. Small pillars were left wherever the hanging-wall showed a weakness.

Trouble was encountered in changing from the square set system to the open stope system. Removing the foot-wall portion of the vein weakened the rest of the vein. The excess weight on the square sets caused them to settle and crush. The square sets were filled up to and tamped under the backs of the hanging-wall section of the vein. After the filling was packed, the settling stopped and made it easier to hold the ground with stulls.

The retreatment of tailings was discontinued. The value extracted would not pay the retreatment costs.

Assay Value of Tailings	$1.75	per ton
Retreatment Costs	1.67	per ton
Recovery - Extraction 56%	1.09	
Loss	$ .58	per ton.

VII. RESULTS OF SELECTIVE MINING.

During the time the working force was becoming efficient in this system of mining, the cost per ton increased from $3.48 to $5.01; but this cost soon began to decrease as the force became more efficient and this system was more profitable than the cost per ton method had been.

The following table gives the results of 15 months operation under the profit per ton system:

Month	Tons Mined	Value Ore	Mining Cost	Milling Cost	General Expense (Taxes & Marketing)	Total Cost Per Ton
1915						
October	5282	$4.51	$1.07	$2.16	$ .394	$3.62
November	5097	5.77	.94	2.11	.427	3.47
December	4609	8.18	1.08	2.30	.509	3.89
1916						
January	4366	7.68	1.13	2.61	.564	4.31
February	3866	7.44	1.41	3.05	.555	5.01
March	4134	7.06	1.45	2.54	.696	4.69
April	4806	7.17	1.34	2.28	.476	4.10
May	4550	6.74	1.35	2.66	.531	4.54
June	4764	7.05	1.13	2.53	.553	4.31
July	3794	8.60	1.04	3.03	.792	4.76
August	4830	8.47	.81	2.61	.723	4.15
September	4102	8.81	.87	2.88	.792	4.44
October	4336	7.51	.76	2.79	.593	4.14
November	4458	7.42	.62	2.59	.554	3.66
December	4430	8.39	.59	2.57	.522	3.78
Total	67424					
Averages	4495	$7.18	$1.04	$2.57	$ .579	$4.19

The following table will give the value received and the cost to produce an ounce of silver:

MONTH 1915	OUNCES OF SILVER PRODUCED.	VALUE RECEIVED FOR AN OUNCE OF SILVER	COST TO PRODUCE AN OUNCE OF SILVER.
October	26,179.12	$ .5072	$ .4326
November	27,612.19	.5480	.4358
December	34,873.64	.5653	.2203
1916			
January	29,992.49	.5900	.3320
February	27,515.44	.5907	.4240
March	27,779.80	.6468	.4298
April	27,376.30	.7476	.4372
May	28,956.21	.6604	.4340
June	31,292.52	.6430	.3615
July	31,732.66	.6490	.2982
August	36,695.53	.6860	.2827
September	32,210.30	.6737	.3094
October	28,390.90	.7074	.3650
November	26,749.37	.7523	.3138
December	28,046.22	.7500	.2921
Amount produced	444,601.59		
Average Value		$ .6472	$ .3446

$ .6472, average value received for an ounce of silver - $ .3446 cost to produce an ounce of silver = $ .3026, profit per ounce.

$ .4586, cost to produce an ounce of silver by cost per ton method - $ .3446, cost to produce an ounce of silver by profit per ton method = $ .1140, decrease in the cost of producing an ounce of silver.

VIII. POSSIBILITIES OF INCREASING PROFITS BY INCREASING TONNAGE.

While increasing tonnage did not increase the profits at the Nevada Hills Mine, there are cases in which this method has proved advantageous and met with great success.

In one case, a mine's tonnage was increased from 3794 to 5834 tons a month. The cost of almost all items decreased materially, as these tabulated items show:

	Cost per Ton when 3794 tons were mined	Cost per Ton when 5834 tons were mined.	Decrease in Cost.
Mine Assaying & Sampling	$ .026	$ .022	$ .004
Mine Water & Pumping	.029	.019	.010
Mine General Expense	.052	.035	.017
Mine Foreman & Bosses	.062	.059	.003
Hoisting & Dumping	.126	.108	.018
Stamping	.255	.214	.041
Settling & Agitation	.860	.704	.156
Tube Milling	.030	.026	.004
			$ .253

5834 - 3794 = 2040, increase in tonnage.
2040 x $ .253 = $516.12 profit made from eight items, by increasing the tonnage 2040 tons. A greater profit is shown by the gross returns.

Tons	Value of Ore		Gross Returns.
5834	$9.60		$56,006.60
3794	10.00		37,940.00
2040		Gross Profit	$18,066.60

These figures show this plan worked satisfactorily in this particular case and probably would in all mines with a large body of homogeneous ore.

As another instance, at Virginia City, Nevada, several attempts were made to work the high-grade shoots in the low-grade ore bodies of the Comstock with low tonnage reduction plants of a capacity of about 200 tons a day. The Consolidated Virginia, Mexican and Union endeavored to work the Lode, milling this low selected tonnage, but found it unprofitable. The United Comstock Mines Company is attacking these low-grade ore bodies without selective mining, with a plant treating 2500 tons daily and is meeting with success.

IX. CONCLUSIONS.

If a profit on each ton of ore mined is used for the foundation of the operative plan, the operating force has more chance to show its ingenuity and the possible means of securing profits by using this system are unlimited. The tonnage can be increased to secure a greater profit. In the case of a very large deposit of base metals the tonnage could be decreased, retarding the output, keeping the demand greater than the supply and securing a greater profit by keeping the prices of the metals up. Another method would be to decrease the tonnage by sorting, increasing the mining cost, but also increasing the value of the ore and the profit per ton.

It is a debatable question whether there are more advantages in basing the operation of a mine on a low cost per ton oreon a profit per ton. Under careful, efficient management they would probably have the same resultant. In this particular case there was a difference, which may be summed up as follows:

During the first nine months of 1915, in which the Nevada Hills Mine was operated on a low cost per ton basis, the price of all commodities increased two percent. The cost of producing each ounce of silver was $ .4586. From the first of October 1915, when the system was changed to selective mining, to the first of January 1917, the cost of all commodities increased forty-two percent. Each ounce of silver cost $ .3446, a decrease of $ .1140, or 24.8 percent. Taking the average value of silver as given in the table on page 13, which was $ .4914 per ounce, the profit would be $ .1468 as against a profit of $ .0328, made when operated by the cost per ton method. This gives a profit increase of 347 percent, and does not take into consideration the rise in the market value of silver during this period. From these figures, it can be seen that a large percentage of the profits may be overlooked by paying more attention to the low cost of mining a ton of ore, than to recovering the greatest profit from a ton of ore.