Cyaniding the Buckhorn clay

Paul Richardson Cook

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CYANIDING THE BUCKHORN CLAY.

BY

PAUL R. COOK

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

ENGINEER OF MINES

Rolla, Mo.,

1916.

Approved by

Professor of Metallurgy and Ore Dressing.
The Buckhorn, Nevada, gold mine is peculiar in being a shallow kaolinized mass of material with basalt walls, having no direct connection with any of the usual gold bearing rocks, the average ore containing 16% water of hydratum.

The cyaniding of this hydrant clayey material offered unusual difficulties compared with the usual gold quartz ore of Nevada. The ore body was thoroughly developed; then the mill was built according to the latest cyanide practice, with such changes as was thought the peculiar nature of this ore demanded.

Upon starting the mill, the ore proved more difficulty to handle than had been anticipated. It is hoped that an account of how these difficulties were met may prove of interest to anyone having a clayey ore to handle and the profession in general.

**Mining.**

The first difficulty was to get the ore out of the mine. The ore beginning at the grass roots and ending at a depth of 175 feet, with a width of 50 to 80 feet and length of 1400 feet, the "glory hole" system of mining was adopted. The ore was broken thru 8 inch grizzlies into 18 chutes extending from surface to an intermediate level, on which it was trammed by hand to 3 chutes leading to the 200 foot level, and trammed by electric motors thru a 1000 foot tunnel to the mill.

In the summer there was little trouble; but the ordinary rain and snowfall of a Nevada winter made it almost impossible to keep the chutes open as first built. After reconstructing with opening for barring at every set of timbers, (See sketch #1), it became
possible to keep the mill supplied with ore during all kinds of weather. During wet weather all the cars had to be scraped with a shovel after dumping, and unusual care was required to keep a sticky load from carrying car and all into ore bin or over the dump, (30% of tonnage mined went to waste dump).

**Ore Bin and Crusher.**

The next problem was to get the ore out of the mill bin and crushed. The bin was an ordinary circular steel bin with natural earth bottom and side gate. This ore absolutely refused to run from the bin. The mill was built to treat 300 tons a day. With one man in the ore bin, and two at the crusher, it was impossible to get over 150 tons thru in 24 hours. The large kaolin lumps gave the most trouble in crushing. The jaw crusher simply marred up their edges, refusing to crush them, and they had to be practically chiseled to pieces and poked thru by hand.

The replacement of the jaw crusher with a high speed toothed roll, gave the desired crushing capacity. This machine (See Fig. 2) was developed at one of the Bingham Canyon, (Utah), properties, and is manufactured by a Salt Lake firm. It is certainly a wonderful machine for sticky ores. The Buckhorn ore contains an occasional "nigger head" of very hard "malapi" or basalt. The mill crew were all afraid one of these would break the teeth off the crusher shell, and they were very carefully picked out at first; but after a few had gone thru by accident, and also a few pieces of drill steel, etc., had been chopped up, we quit worrying. All the boulders that had been sorted out were later put thru, as it was found that the easiest way to keep the teeth free of adhering clay was to occasionally
throw thru a boulder of hard rock.

To do away with the necessity of a man per shift to shovel the ore out of the bin, a 36 inch conveyor belt was installed to feed the crusher automatically. Tunnel was driven under bin and belt installed without interrupting milling operations. The opening in bottom of bin, over the belt, was closed by means of short pieces of mine rail which could be removed a few at a time and ore drawn from any point desired.

Belt was driven from crusher line shaft by means of a ratchet and dogs, and belt could be started or stopped, from either floor of the crusher building, by means of a rope connected with the dogs. With these improvements, crushing required only a part of one man's time. Two men per shift attended to crusher, rolls, two ball mills, two classifiers and two tubes.

Rolls.

The 45"by15" Anaconda Type rolls with smooth shells cleared themselves fairly well, except when one of the shells had a channel about 1 inch wide by 1/2 inch deep machined in it. It was troublesome to keep a groove in the shells as they wore down. A corrugated or toothed shell would have been better.

Ball Mills.

One six foot Hardinge ball mill was intended to handle the whole tonnage. After plastering the balls to the side of the mill with clay a few times, the shiftmen learned to tell by the sound of the mill when it was beginning to coat up. By shutting off the feed at this point, it took only a few minutes for it to grind itself out.
The installation of a duplicate ball mill made it possible to keep the rest of plant going while grinding out the ball mills, one at a time, and allowed the rolls to be set coarser on troublesome ore. With a good run of ore, 300 tons per day was sometimes put thro one mill. Our monthly tonnage (8500 tons per month) would have been seriously lowered, however, without the second ball mill to run when necessary.

**Classification and Tube Milling.**

Ball mill discharge was classified in 2-5'x18' tubes with Komata liners. Tube mill discharge was classified in a home made drag classifier. The small per cent of material requiring regrinding consisted largely of fragments of the basalt "nigger Heads". This material was almost as hard as the pebbles themselves, and of low assay value. Occasionally it accumulated in the circuit enough to be troublesome and was thrown away. A small amount of it was thought to help the grinding. 80% of the product delivered to "Treatment" plant would pass a 150 mesh screen.

**Agitation.**

80% of the mill head value was dissolved in crusher plant. Only a trifling additional extraction could be obtained either in the mill or experimentally. The real trouble was to remove the dissolved value from the clayey pulp, so the 3-32'x14' Dorr Agitators were changed to Thickeners. This was easily done without emptying the tanks. The tanks were built with discharge pipe in center of bottom. This was used for underflow. Overflow launders were built, speed of rakes reduced from 2 R.P.M. to 1/4 R.P.M., the agitating air shut off and underflow opened up.

**Thickening.**
These three "converted" agitators settled 300 tons per day of 1 to 10 pulp, as delivered from crusher plant, to a Sp. Gr. of 1.15. This was 8 sq. ft. of settling area per ton settled in 24 hours, sufficient to settle an average Nevada quartz ore to a Sp. Gr. of 1.33. Overflow was precipitated, and underflow mixed with the barren solution and fed to 6-36'x12' Dorr Thickeners, delivering a 1.23 Sp. Gr. underflow to the filters. This was 20 sq. ft. of settling area per ton settled in 24 hours, 3 times the area required to settle an average Nevada quartz ore to a Sp. Gr. of 1.33. Primary Thickeners were held with 2' of clear solution; secondary with 6'. It was impossible to settle the raw Buckhorn ore beyond a Sp. Gr. of 1.26, either in the mill or experimentally.

**Filtering.**

50 tons per day was the maximum capacity of each of the 4-14' diam.x12' face Oliver Filters, less than half their capacity on a Nevada quartz ore. An additional 14' diam.x24' face filter had to be added to handle 300 tons per day.

**Dehydration.**

A sample of Buckhorn ore carefully dried at a temperature below 100° Cent. had a Sp. Gr. of 1.9. A higher temperature gave an additional loss of 16% in weight, and entirely changed the physical properties of the ore. The dehydrated sample had a Sp. Gr. of 2.4, and settled and filtered almost as well as a quartz ore. Dehydrating also removed the sticky milling qualities. Both samples, however, gave the same extraction with cyanide. The temperature of a laboratory electric hot plate "on high" was sufficient to dehydrate a sample nicely. As CO₂ etc., would not be driven off at this temperature, this loss in weight must be due to water of dehydration.
With a cheap duel supply dehydration before milling would be the best treatment for this class of material; the ore would mill and classify easier; the thickeners and filters would have normal capacity; and dissolved valued be more completely removed. The temperature of a commercial drier would dehydrate the ore with about the same fuel consumption as that required to remove the $18\% \text{H}_2\text{O}$ if it existed in the form of moisture, or 100 pounds of coal per ton of ore.

A freight rate of $10.00 per ton from the S.P.R.R. to Buckhorn added to the already high price of fuel at the R.R., eliminated dehydration at Buckhorn. The ore was milled raw at Buckhorn at a cost of $1.59 per ton (see table #1). Power cost $8.00 per horse power per month. It was transmitted at high tension from a steam plant, at the R. R., burning crude oil costing $1.58 per bbl.

Samples had to be dehydrated, to get them thru the ordinary laboratory grinding machinery. The true settling and filtering rate of the raw ore could not be obtained from this sample, but required a tube milled sample of the raw ore. There are a number of very handy laboratory tube mills on the market, and they should be generally used in testing an ore for cyanide treatment.

The careful drying at a temperature below $100^\circ$ Cent. of a large number of samples, in the ordinary equipped cyanide plant assay office would be a rather tedious operation; so the regular moisture and assay samples at Buckhorn were dehydrated. All assay, moisture, tonnage, etc., figures are on this basis.

To compare with other ores the figures obtained by drying below $100^\circ$ Cent. should be used. Both sets of figures are given in Table #2.
Geology. (See Fig. 4)

The Buckhorn ore body lies along a North and South fault plane of perhaps 1000 feet dislocation, that can be traced for miles; but the only other known mineralization consists of similar ore in the "Murphy" mine a mile further north.

The east or hanging wall is hard and smooth, a typical fault plane. The best ore is along this wall, gradually grading down toward the west, till at 30 to 60 feet it is too low grade to mine. The country rock on the west consists of alternating layers of hard and soft basalt and basalt scoria, pitching toward the mine.

One of these basalt layers on the hillside a little above the mine is marked for three or four miles in length by a line of springs which seep put along it. Perhaps the surface drainage down these basalt layers encountering the fault plane solutions explain the formation of the Buckhorn ore body.

Beneath the oxide ore there is a smaller body of almost pure marcasite of about the same assay value. Beneath this (250 foot level) there doesn't seem to be any further mineralization.
Fig-1
Section Thru Ore Chute.
FIG. 2
SECTION THRO "WALL" CRUSHER SHELLS
Scale - 1" = 8"
TABLE 1 A.
BUCKHORN MINING COSTS.

Ore milled 10000 Wet Tons. H2O 19%
8100 Dry Tons.

ORE BREAKING.
LABOR. Per ton.
Miners $.176
Muckers .043
Samplers .015
Teamsters .003
Teams .001
Tool Sharpener .021 .259

SUPPLIES.
Powder .090
Fuse .002
Maps .001
Drill Steel .001
General Supplies .004 .098 .357

TRAMMING 100 ft. Level.
LABOR.
Muckers .000
Trammers .043
Trackmen .001 .044

SUPPLIES.
Candles .002
Lubricants .000 .002 .046

TIMBERING. .013

ELECTRIC HAULAGE.
LABOR.
Motormen .025
Helpers .021
Mechanics .003
Electrician .005
Chutes Tenders .030 .084

SUPPLIES. .006
POWER. .022 .112

GENERAL EXPENSES.
SURFACE DRAINAGE .004
HAULAGE TUNNEL REPAIRS .039
ASSAYING & SAMPLING .027
SURVEYOR .011
FOREMAN .026
SHIFTERS .041
INCIDENTALS .024
DEVELOPMENT .083
OVERBURDEN & WASTE .174 .429

GRAND TOTAL .957
TABLE 1 B
BUCKHORN MILLING COSTS.

CRUSHER & ROLLS (Wall toothed ROLL & 45" ROLL).

<table>
<thead>
<tr>
<th>Labor</th>
<th>Per ton</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Crushermen</td>
<td>$0.042</td>
<td>0.057</td>
</tr>
<tr>
<td>Machinists</td>
<td>0.015</td>
<td>0.027</td>
</tr>
</tbody>
</table>

SUPPLIES

<table>
<thead>
<tr>
<th>Supplies</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Belting</td>
<td>0.002</td>
</tr>
<tr>
<td>Genl. Supplies</td>
<td>0.001</td>
</tr>
</tbody>
</table>

POWER

<p>| |</p>
<table>
<thead>
<tr>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>0.034</td>
</tr>
<tr>
<td>0.094</td>
</tr>
</tbody>
</table>

HARDING BALL MILLS (2-5' Mills)

<table>
<thead>
<tr>
<th>Labor</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Crushermen</td>
<td>$0.036</td>
</tr>
<tr>
<td>Other labor</td>
<td>0.014</td>
</tr>
</tbody>
</table>

SUPPLIES

<table>
<thead>
<tr>
<th>Supplies</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Repair parts</td>
<td>0.004</td>
</tr>
<tr>
<td>Lubricants</td>
<td>0.002</td>
</tr>
<tr>
<td>Steel Balls</td>
<td>0.018</td>
</tr>
<tr>
<td>Genl. Supplies</td>
<td>0.001</td>
</tr>
</tbody>
</table>

POWER

<table>
<thead>
<tr>
<th></th>
<th>0.076</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.151</td>
<td></td>
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</tbody>
</table>

ELEVATING & SEPARATING (2-36" Akins Classifiers).

<table>
<thead>
<tr>
<th>Labor</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0.006</td>
</tr>
</tbody>
</table>

SUPPLIES

<p>| |</p>
<table>
<thead>
<tr>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>0.001</td>
</tr>
</tbody>
</table>

POWER

| 0.009    |

TUBE MILLING (2-5'x18')

<table>
<thead>
<tr>
<th>Labor</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0.011</td>
</tr>
</tbody>
</table>

SUPPLIES

<table>
<thead>
<tr>
<th>Pebbles</th>
<th>0.048</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lubricants</td>
<td>0.001</td>
</tr>
</tbody>
</table>

POWER

<table>
<thead>
<tr>
<th>0.092</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.152</td>
</tr>
</tbody>
</table>

AGITATIONS (3-32'x14' DORRS)

<table>
<thead>
<tr>
<th>Labor</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0.028</td>
</tr>
</tbody>
</table>

SUPPLIES

<p>| |</p>
<table>
<thead>
<tr>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>0.006</td>
</tr>
</tbody>
</table>

POWER

<table>
<thead>
<tr>
<th>0.027</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.061</td>
</tr>
</tbody>
</table>

CHEMICALS

<table>
<thead>
<tr>
<th>Cyanide</th>
<th>0.218</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lime</td>
<td>0.293 (about 20#/ton of ore)</td>
</tr>
<tr>
<td>Lead Acetate</td>
<td>0.024</td>
</tr>
<tr>
<td>0.535</td>
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</tbody>
</table>

CONTINUOUS DECANTATION (6-35'x12' DORRS)

<table>
<thead>
<tr>
<th>Labor</th>
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</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0.004</td>
</tr>
</tbody>
</table>

SUPPLIES

<p>| |</p>
<table>
<thead>
<tr>
<th></th>
</tr>
</thead>
</table>

POWER

<table>
<thead>
<tr>
<th>0.017</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.021</td>
</tr>
<tr>
<td>Activity</td>
</tr>
<tr>
<td>--------------------------------</td>
</tr>
<tr>
<td><strong>FILTERING &amp; DISCHARGE</strong></td>
</tr>
<tr>
<td>(6-14'x12' Oivers)</td>
</tr>
<tr>
<td><strong>PRECIPIATION</strong></td>
</tr>
<tr>
<td><strong>RETURN PUMPING</strong></td>
</tr>
<tr>
<td><strong>REFINING</strong></td>
</tr>
<tr>
<td><strong>ASSAYING &amp; SAMPLING</strong></td>
</tr>
<tr>
<td><strong>SUPT. &amp; FOREMEN</strong></td>
</tr>
<tr>
<td><strong>EXPERIMENTS</strong></td>
</tr>
<tr>
<td><strong>GENERAL EXPENSE</strong></td>
</tr>
<tr>
<td><strong>WATER SUPPLY</strong></td>
</tr>
<tr>
<td><strong>GRAND TOTAL MILLING</strong></td>
</tr>
<tr>
<td><strong>GRAND TOTAL MINING</strong></td>
</tr>
<tr>
<td><strong>GRAND TOTAL MINING &amp; MILLING</strong></td>
</tr>
</tbody>
</table>
FIG. 3.

A. Gold Sumps—Overflow from Primary Thickeners.


C. Clarifying presses for Gold Solution.

D. Filter Vacuum apparatus.

E. Gold Solution Storage.

F. Filter Discharge Solution Storage—Pumped to B.

G. Luster Storage—Feed to Filters.

H. Luster Storage—For emptying filters into.

I. Air Compressor.

J. Precipitating pumps.

K. Merrill Precipitating presses.
<table>
<thead>
<tr>
<th>Ore milled per month</th>
<th>Figures obtained by Dehydrating samples</th>
<th>Figures obtained by drying below quartz 100 Cent.</th>
<th>Comparative figure for</th>
<th>Weight of Tons</th>
<th>Moisture %</th>
<th>Dry Tons</th>
</tr>
</thead>
<tbody>
<tr>
<td>10,000 Gross Tons</td>
<td>19% 6100</td>
<td>4% 9600</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ore milled per day</td>
<td>19% 270</td>
<td>4% 320</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>333 Gross Tons</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ball mill discharge</td>
<td>48% 270</td>
<td>36% 320</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sp. Gr. 1.439</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tube mill discharge</td>
<td>52% 260</td>
<td>40% 309</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sp. Gr. 1.394</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Akins Classifier</td>
<td>38% 175</td>
<td>35% 208</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>sand product</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Slime to Treatment</td>
<td>11.5 270</td>
<td>1 to 320</td>
<td>1 to 7</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>plant-Sp. Gr. 1.045</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Primary Thickeners</td>
<td>1 to 270</td>
<td>1 to 320</td>
<td>1 to 2 or better</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>underflow Sp. Gr.1.15</td>
<td>3.5 270</td>
<td>2.57 320</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Secondary Thickener</td>
<td>2.1 270</td>
<td>1.5 320</td>
<td>1 to 1 or better</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>underflow-Sp.Gr.1.23</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Filter Cake</td>
<td>43% 270</td>
<td>30% 320</td>
<td>29%</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
TABLE -3-
FLOW SHEET and SCREEN TESTS.

MILL.
6" GRIZZLY.

ELECTRIC HAULAGE.

MILL BIN.

FEED BELT.

SHAKING GRIZZLY. (Openings closed)

19% H_2O 270 DRY TONS.

"WALL" CRUSHER

39% H_2O 270 DRY TONS.

On 2" 1" 1/2" 3/8" 1/4" 1/6" 20 Mesh -26 Mesh.

1/2" TROMMEL.

112 DRY TONS. 50% H_2O.

On 1/2" - 12%
3/8" - 10%
1/4" - 20%
1/6" - 21%
20 Mesh - 14%
-20 Mesh - 23%

48% H_2O 270 DRY TONS.

On 2" 1" 1/2" 3/8" 1/4" 1/6" 20 Mesh -20 Mesh.

- 9% 37% 11% 10% 11% 18% 9%

48% H_2O 270 DRY TONS.

On 1/8" 20 Mesh 40 60 80 100 -100 Mesh.

10% 23% 13% 6% 4% 3% 36

2-6' HARDINGE BALL MILLS.

2-36" AKINS CLASSIFIERS.
TABLE 3

2-36" AKINS CLASSIFIERS.

SLIME:
123 DRY TONS. 1.5 SPI.GR.
98% R 0 .175 DRY TONS.
- on 60 Mesh - 4%
- on 20 Mesh - 11%
- on 1/8" - 11%
- on 1" - 9%
- on 60 - 5%
- on 100 - 4%
-

20 GALLON CONES.

OVERFLOW UNDERFLOW.
1.15 SPI.GR. 1.12 SPI.GR.
95 DRY TONS. 28 DRY TONS.
- on 60 - 3%
- on 60 - 12%
- on 80 - 3%
- on 80 - 13%
- on 100 - 7%
- on 100 - 19%
- on 100 - 6%-

2-5' x 18" TUBES.
52% R 0 .262 DRY TONS.
- on 100 - 1"
- on 100 - 7%
- on 100 - 11%
- on 100 - 12%
- on 100 - 56%

HOMEMADE DRAG CLASSIFIER.

SAND SLIME.
59 DRY TONS. 1.65 SPI.GR. 175 DRY TONS.
- on 20 - 3%
- on 20 - 6%
- on 80 - 11%
- on 80 - 8%
- on 80 - 16%
- on 80 - 4%

- .45 SPI.GR. 27 DRY TONS. 85% - 100 Mesh.

TREATMENT PLANT.
The ore deposit of the Buckhorn Mines Co., Buckhorn, Nev., is peculiar in being a shallow kaolinitic mass of material with basalt walls, and having apparently no direct connection with any of the usual gold-bearing rocks. The average ore contains 18 per cent. water of hydration, and the cyaniding of this hydrous clayey material offered unusual difficulties as compared with the typical gold quartz ores of Nevada.

The difficulties encountered and how they were met will be of interest to anyone having a clayey ore to handle.

The first difficulty was to get the ore out of the mine. Since the orebody extended from the grass roots to a depth of 175 ft., with a width of 50 to 80 ft. and a length of 1,400 ft., the "glory-hole" system of mining was adopted. The ore was broken through 8-in. grizzlies into 18 chutes extending from the face to an intermediate level, on which it was trammed by hand to three chutes leading to the 200 ft. level and hauled by electric motors through a 1,000 ft. tunnel to the mill.

In the summer little trouble was experienced; but the ordinary rain and snowfall of a Nevada winter made it almost impossible to keep the chutes open, as first built. After reconstructing, so as to provide an opening for barming at each set of timbers (see Fig. 1), it became possible to keep the mill supplied with ore during all kinds of weather. During wet weather all the cars had to be scraped with a shovel after dumping; 30% of the tonnage mined went to the waste dump.

The mill bin was of the ordinary circular steel type, with natural earth bottom and side gate, from which the ore absolutely refused to run. The mill was built to treat 300 tons a day, but even with one man in the ore bin, and two at the crusher, it was impossible to get over 150 tons through in 24 hr. The large kaolin lumps gave the most trouble in crushing.

The replacement of the jaw crusher with a high-speed toothed roll (see Fig. 2) gave the desired crushing capacity. It was found that the easiest way to keep the teeth free of adhering clay, was occasionally to throw in a boulder of hard rock. To do away with the necessity of a man on each shift to shovel the ore out of the bin, a 36-in. conveyor belt was installed to feed the crusher automatically. The opening in the bottom of the bin, over the belt, was about 2 ft. wide, and the belt was driven from the crusher line shaft by means of a rope connected with the dogs. With these improvements, crushing required only a part of one man's time. Two men each shift attended to crusher, rolls, two ball mills, two classifiers, and two tube mills.

Balls. The 45 by 18-in. Anacona type rolls with smooth shells would clear themselves fairly well, if one of the shells had a channel about 1 in. wide by 1 in. deep machined in it, but it was troublesome to keep a groove in the shells as they wore down. A corrugated or toothed shell would have been better for this ore.

Ball Mills. One 6-ft. Hardinge ball mill was intended to handle the whole tonnage. After plastering the balls to the side of the mill with clay, a few times, the shiftmen learned to tell by the sound of the mill, when it was beginning to coat up. By shutting off the feed at this time, it took only a few minutes for the coating to be ground out. The installation of a duplicate ball mill made it possible to keep the rest of the plant going while grinding out the ball mills, one at a time, and allowed the rolls to be set coarser on troublesome ore. With a good run of ore, 300 tons per day was sometimes put through one mill.

Classification and Tube Milling. This ball mill discharge was classified in two 36-in. Akko classifiers, the sand from which was fed to two 5 by 18-in. tube mills with Komata liners. The tube mill discharge was classified in a home-made drag classifier. About 80 per cent. of the product delivered to the treatment plant would pass a 150-mesh screen.
additional extraction could be obtained either in the mill or experimentally. The real trouble was to remove the dissolved value from the clayey pulp. Accordingly the three 32 by 14 ft. Dorr thickeners were changed to thickeners. The three "converted" thickeners settled 300 tons per day of 1 to 10 pulp, as delivered from crusher plant, to a specific gravity of 1.15. The 8 sq. ft. of settling area, provided per ton of this ore settled in 24 hr., would be sufficient to settle an average Nevada quartz ore to specific gravity of 1.25. The overflow was precipitated, and the underflow mixed with the barren solution and fed to six 36 by 12-ft. Dorr thickeners, delivering a 1.25 specific gravity underflow to the filters. The 20 sq. ft. of settling area per ton settled in 24 hr. is three times the area required to settle an average Nevada quartz ore to a specific gravity of 1.35. Primary thickeners were held with 2 ft. of clear solution; the secondary thickeners with 6 in. It was impossible to settle the raw Buckhorn ore beyond a specific gravity of 1.25, either in the mill or experimentally.

Filtering. The maximum capacity of each of the four 14-ft. diameter by 12-ft. face Oliver filters with 300 tons per day, about one-half their capacity, on a Nevada quartz ore. An additional filter, 14-ft. diameter by 24-ft. face had to be installed to handle 300 tons per day.

Dehydration. A sample of Buckhorn ore carefully dried at a temperature below 110°C had a specific gravity of 1.9. A higher temperature gave an additional loss of 10 per cent. in weight, and entirely changed the physical properties of the ore. The dehydrated sample had a specific gravity of 2.4, and settled and filtered almost as well as a quartz ore. Dehydrating also removed the sticky milling qualities. Both samples, however, gave the same extraction with cyanide. The temperature of a laboratory electric hot plate was sufficient to dehydrate a sample nicely. As CO₃, etc., would not be driven off at this temperature, this loss in weight must be due to water of hydration.

With a cheap fuel supply, dehydration before milling would be the best treatment for this class of material. The ore would mill and classify more easily; the thickeners and filters would have normal capacity; and dissolved values would be more completely removed. The temperature of a commercial drier would dehydrate the ore with about the same fuel consumption.

Dehydration.

A sample of Buckhorn ore carefully dried on a laboratory electric hot plate was dehydrated at a temperature of 110°C. The temperature of the dehydrated sample was above 110°C.

Dehydration of the Buckhorn ore was almost as well as a quartz ore. Dehydrating the ore would mill and classify more easily; the thickeners and filters would have normal capacity; and dissolved values would be more completely removed. The temperature of a commercial drier would dehydrate the ore with about the same fuel consumption.

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Cyaniding, Chaspy Ores, Gold Extraction

(100 lb. of coal per ton of ore) as in removing the 18 per cent of H₂O if it existed in the form of moisture.

The high price of fuel delivered at Buckhorn prevented the adoption of dehydration at this mill. The ore was milled raw at the cost of $1.50 per ton (see Table 1). Power cost $8 per horsepower per month.

The careful drying at a temperature below 110° C of a large number of samples, with the equipment of an ordinary cyanide plant assay office, would be a rather tedious operation, so the regular moisture and assay samples at Buckhorn were dehydrated. All assay, moisture, tonnage, etc., figures are on this basis.

To compare with other ores the figures obtained by drying below 110° C, should be used. Both sets of figures are given in Table 2. Table 3 shows the mill flow sheet.

**TABLE 2. MILLING DATA**

<table>
<thead>
<tr>
<th>Figure obtained by dehydrating samples</th>
<th>Figure obtained by drying below 110° C</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ore milled per mo., 10,000 oz., tons</td>
<td>19</td>
</tr>
<tr>
<td>Ore milled per day, 805 oz., tons</td>
<td>19</td>
</tr>
<tr>
<td>Ball mill discharge Sp. Gr. 1.430</td>
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<tr>
<td>Tube mill discharge Sp. Gr. 1.394</td>
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<td>Akins classifier, sand product</td>
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<tr>
<td>slime to treatment plant Sp. Gr. 1.045</td>
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</tr>
<tr>
<td>Primary thickener underflow Sp. Gr. 1.15</td>
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<tr>
<td>settling area 8 sq. ft. per ton</td>
<td>1.5</td>
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<tr>
<td>settling area 20 sq. ft. per ton</td>
<td>1.2</td>
</tr>
<tr>
<td>Filter cake</td>
<td>270</td>
</tr>
</tbody>
</table>

**TABLE 3. Flow Sheet**

- **Mine**
  - 8-in. dryly
  - Electric Hoist
  - Mill
  - Feed Belt
  - Shaking Grizzly
  - 1½ ft. Trommel

- **Underflow**
  - 45 by 15-c. Concave Rolls

- **2 8-ft. Harder Mill Mills**
  - 2 Elevators
  - 2 by 8-c. Akins Chambers

- **Name**
  - 2 5½ by 20 ft. Tube Mills
  - 2 Auto-Weigh Chambers

- **Stacker**

- **Trommel Plant**
  - 150 hp. 275 dry tons 85 per cent 100 tons
Fig. 4.
Geology of the Buckhorn Mine

Distinct Outcrop of Alternating Layers of Hard and Soft Basalt and Basalt Scoria

Line of Springs

4 Miles