The Bald Mountain Mining Company and Cyanide Gold Recovery in the Black Hills

By Richmond L. Clow

The Bald Mountain Mining Company was organized in 1928, three decades after the introduction of cyanide gold recovery practices to South Dakota's Black Hills. Despite its late start, this company was the second largest gold producer in the Black Hills. What makes this feat so important was that the company mined and milled geologically complex, refractory, siliceous, low-grade gold ores that required the application of skillful practices to capture the precious metal. This made the company an important innovator of refractory milling practices, developing ideas borrowed from its predecessors and academic laboratory experiments.

The technological and economic importance of the Bald Mountain Mining Company to the northern Black Hills began decades before the company itself was organized. At the turn of the twentieth century, the precursors to the Bald Mountain Mining Company, the Mogul and the Gold Reward, replaced their stamping and cyanide decantation methods with Chilean mills and processed slimes by the Moore process.[1]

Nor were either the region's or company's metallurgical efforts unique in their attempts to recover metals from difficult ores. Miners throughout America's western camps discovered deposits of "rebellious" gold ores, so named because they refused to release metallic values except when treated with complex, often expensive, recovery technologies. Californians encountered sulphurets in quartz ore; Colorado miners confronted tellurides; Black Hills operators wrestled Cambrian siliceous ore, locally called refractory ore.

Metallurgical skills and processes were required to capture gold in paying quantities from each of these ores. Some mining operations were fortunate. Instead of fighting their refractory ores, Homestake and other early companies worked the "fossil place deposits in the basal conglomerates of the Deadwood formation." The ore from these formations was free-milling, its gold recovered by the time-proven California amalgamation process.[2]

The situation changed in 1877, when A. J. Smith discovered the Bald Mountain ores.[3] Unlike the large companies working the region's free-milling ore, a number of small mining companies staked claims to the Bald Mountain mines west of Lead. But these small companies had a difficult time raising capital to conduct expensive experiments on refractory ores. As a result, the Bald Mountain Mining Company's nineteenth-century predecessors began as small operations that were frequently reorganized and consolidated, a circumstance probably "more one of necessity than design due to the problems connected with mining and treatment of the highly refractory siliceous ores bodies, problems beyond the scope and capabilities of small, individual operators."[4]

This difficulty in capturing the gold was even more troubling when siliceous refractory red oxidized and blue unoxidized ores were found on the surface of the limestone from the nearby Ragged Top District "averag[ing] $100 per ton in car-load lots." Even tests on richer $200-a-ton ore produced only $10 in gold per ton.[5] With such high values waiting to be taken, the refractory ore puzzle had to be solved.

The Bald Mountain Mining District was located near the base of Terry Peak. The district was two miles by five miles, lay southwest of the Lead-Deadwood Mining District, and was locally known by its subdivisions, named after the Ruby Basin, Portland, and Trojan mines. Most of these Bald Mountain deposits had a general value of three to five dollars per ton and the varied nature of the ores included quartz ledge replacement deposits, siliceous tellurides, red ores, and blue ores.[6]

Over time, mining engineers learned that the district's complex ore structure and mineralization was created "by Tertiary igneous intrusions into the Precambrian and Paleozoic sequences. This is silver-rich and contains the usual types of mineral assemblages, such as tellurides." The early major companies working these deposits along Nevada, Fantail, Stewert, Box Elder, Terry, and Annie Creeks were the Golden Reward, the Horseshoe, the Mogul, and the Trojan. The last and most important operation was the Bald Mountain Mining Company.[7]

Black Hills miners classified the refractory ores as either red or blue. The red ore was oxidized rock, ranging from several to a few hundred feet below the surface, that had been exposed to oxidizing activity. Blue ore came from deep in a mine and included pyrites that had not been subjected to oxidation. No distinct demarcation separated the two ores, but as the depth of a mine increased, more pockets of blue ore were uncovered. Straight cyanidation solved most of the difficulties associated with recovering gold from red ore, capturing as much as 85 percent of its gold. Blue ore, however, did not yield its wealth so readily. Effective gold recovery from blue ore was further complicated by its variable sulphur content, which would dictate, to some extent, effective recovery processes. Years of research would be devoted to finding a profitable method of treating the Black Hills blue ores found in the Bald Mountain Mining District.[8]

The first refractory-ore experiments attempting to recover gold from both red and blue ores began in 1879 at the Empire Mine and continued the following year at the Portland. These properties, along with the Clinton Mine, later became properties of the consolidated Bald Mountain Mining Company.[9] Initially, the costs of processing and experimentation imposed upon these small companies that mined both red and blue ores required ore values of $100 per ton. On the other hand, matte smelting and chlorination permitted lower-value refractory ores to be processed.

Between 1883 and 1890, the Portland Mining Company conducted many experiments on these difficult gold ores. The company tried roasting the ore before stamp amalgamation, but only recovered 30 percent of the gold. Later "bromine and cyanide lixiviation were tried," and failed, forcing the company to send low-grade ores to the Deadwood smelter or to a custom cyanide mill at Terry, probably the Lundberg, Dorr, and Wilson. By the beginning of the twentieth century, the Portland Mine's rich Bald Mountain high-grade refractory ore deposits paid the cost of out-of-state smelting.[10]

Experiments were also conducted on Welcome Mine ore in 1883, and three years later more tests were conducted at the Buxton Mine. None were successful. During these early years of failure, large quantities of higher-grade blue ore and blue-ore concentrate were shipped to outside smelters for final reduction. Local companies continued to experiment on the blue and red ores, hoping to discover a profitable treatment process.[11]

In May 1887, the Golden Reward Mining Company was incorporated, bringing "the Golden Reward, Double Standard, Little Bonanza, Harmony, and Stewart" mines under one company. The new company installed a barrel chlorinator in 1889, and shortly thereafter the Deadwood and Delaware Smelting Company

Trojan Mill exterior from the west, c. 1918-28, showing the site with all of its supporting buildings. (Historic American Engineering Record, Library of Congress.)

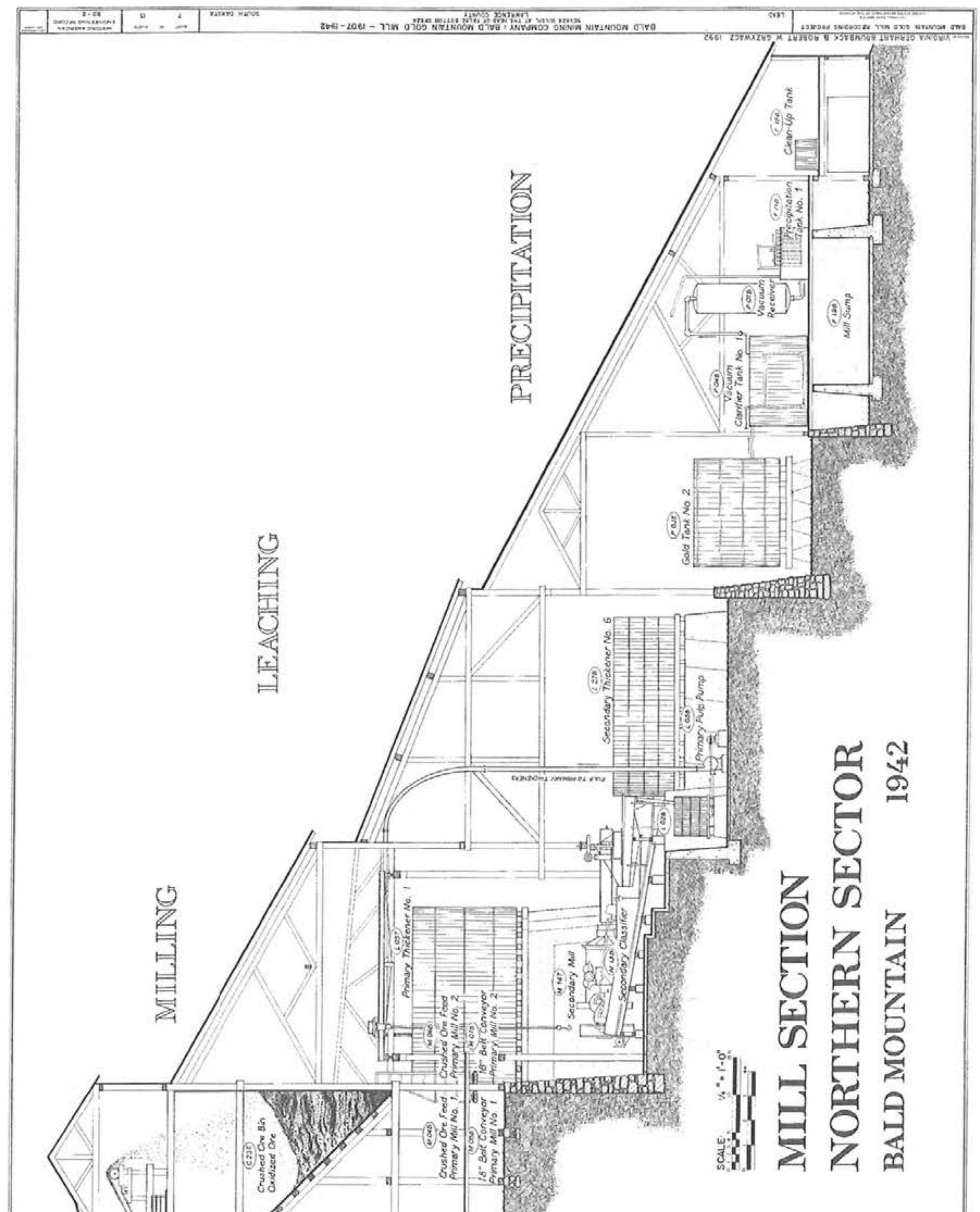
completed a smelter. Each company's process recovered gold from both blue and red ores, but at a high cost. Smelting costs ranged from $4.75 to $5.75 a ton, and chlorination costs from $3.50 to $4.50 a ton. Only high-grade refractory ore was sent to these plants.[12]

These matte smelting and chlorination practices were successful, but too expensive when applied to low-grade refractory ores. Cyanidation was introduced into the Black Hills in 1893 in the hope of decreasing the cost of treating gold ore. This process was cheaper than either smelting or chlorination, costing as little as $1.17 per ton at the Dakota cyanide mill in Deadwood.[13]

Early cyanide operations were simple. Ore was crushed and rolled to a thirty mesh, then leached in cyanide tanks and precipitated with zinc shavings. The most important work on the process in the district was conducted at the Lundberg, Dorr, and Wilson custom cyanide mill at Terry. There John V. N. Dorr developed a classifier to treat sands and slimes separately in 1904, a continuous thickener for the slimes in 1905, and an agitator in 1907. These machines made "continuous counter-current decantation cyanidation" possible, but more knowledge and technology were needed to treat the blue ore.[14]

Initially, the straight cyanide process was used on both red and blue ores. From the former it recovered 70 to 85 percent of the gold contained, but from the latter it often yielded as little as 35 percent, which was not enough to make a profit. C. G. Warnford Lock, an English mining engineer, and F. H. Bousfield, employed at the Black Hills Gold and Silver Extraction Mining and Milling Company of Deadwood, conducted blue-ore cyanidation experiments in 1895. After achieving a recovery rate of less than 48 percent, Lock concluded that cyanide would not treat blue ore raw. Consequently, most mining operators ignored these difficult unoxidized deposits.[15]

The mining companies' disappointing experiments encouraged scientists to examine these ores. Frank Clemes Smith, on the faculty of the South Dakota School of Mines, began experiments in the 1890s, spurred by the economic importance of the Potsdam sandstone refractory ores to the northern Black Hills. He worked from



This 1942 cross-section of the Bald Mountain Mill illustrates where the three major processes of gold-recovery occurred in the structure and in relationship to each other. Coarse and fine crushing happened in the upper section of the structure. Cyanide leaching to extract the gold took place in the middle section of the building. Gold recovery from the cyanide solution occurred in the lower part of the building. (Historic American Engineering Record, Library of Congress.)

the premise that tellurium—a semi-metallic element related to selenium and sulfur that is a silver-white brittle crystalline form—often combined with other metals discovered in the Potsdam ores using red and blue samples from the Welcome Mine.

Having conducted his experiments, Smith eliminated amalgamation as a treatment method, but supported smelting that lost the tellurium, and the chlorination and cyanide process, where tellurium might be saved. Based on the last two reduction methods, roasting was incorporated in several mill flow charts and set a pattern for future experiments. Walter P. Jenny commented on Smith's work, emphasizing that this "district is well worthy of the attention of the Institute and should be brought to the attention of the United States Geological Survey, that the formation and peculiar occurrences of these ore deposits may be carefully worked out."[16]

In 1907, B. D. O'Brien, another professor at the South Dakota School of Mines, guided experiments on the blue ore, hoping to discover a cost-effective treatment. Reporting on his work two years later, O'Brien concluded that blue ore, if finely ground, roasted, and then leached with potassium cyanide, would yield as much as 80 percent of its gold. He further surmised that use of bromocyanide and agitation and aeration during the treatment process could increase that yield to 90 percent. O'Brien's experiments introduced extra procedures into the treatment process, but he believed that treatment of Black Hills blue ores by cyanidation alone would remain ineffective, concluding that a "radical departure from present methods must be made if these ores are to be successfully treated."[17]

After these early School of Mines experiments, a decade-long Black Hills cyanide boom ended in 1909, when labor troubles that began in 1906 finally shut down nearly every operation. Homestake alone locked out twenty-five hundred workers. This labor unrest also closed the refractory mines at Bald Mountain, and hindered the region's mining companies from trying to implement any new metallurgical developments to increase gold recovery rates from the region's blue siliceous gold ores.[18]

After the labor troubles ended, millions of dollars waited to be made from the low-grade refractory ores found in Bald Mountain mines. The less-than-successful experiments did not stop investors from organizing the Trojan Mining Company, the forerunner to the Bald Mountain enterprise. The Trojan Mining Company was founded in 1911, consolidating the Portland, Clinton, American Eagle, and other Bald Mountain properties.[19] This "represented the consolidation of the old Portland Mining Company holdings with the Clinton and American Eagle properties."[20]

Most of the company's officers were from Chicago, but H. S. Vincent was from Deadwood. Since many Black Hills mills and mines were idle, their deposits having been played out, the company assumed control of the American Eagle Mill on False Bottom Creek, a one-hundred-ton cyanide plant built in 1908.[21] After the Trojan Company obtained the American Eagle hillside gravity mill, the company extensively remodeled the facility making it

> one of the best in the Black Hills. Large concrete foundations, resting on solid rock, support the machinery and retaining walls. The superstructure is of wood, the frame throughout being put together with mortise and tenon joints, secured by wooden pegs. A feature is the almost entire absence of iron bolts in the frame. Splices are rare, [and] only occur in unimportant parts of the frame. The frame is housed with one-inch sheeting and the whole covered with heavy rubberoid [*sic*] building paper.[22]

This description of the Trojan Mill, built on the American Eagle's structure, reveals the utilitarian architecture employed in the region's gold mills, but also the fine craftsmanship employed in constructing them.

Initially, the Trojan was a dry-crushing cyanide plant, with a twenty-four hour capacity of three hundred tons. The mill's unique structure of three ore bins permitted ores to be sorted into different bins. The ore bins emptied into a crusher pit, where a No. 5 Gates crusher did the preliminary crushing in a cyanide solution. The ground ore was then moved by belt to two Eclipse rolls, where a strong cyanide solution—three pounds per ton—was added. Then the ore moved to one of two Monadnock mills, and from there onto the Dorr duplex classifiers that separated sands from slimes. The sands were treated in launders, while the slimes went to a Dorr thickener and then on to the final slime treatment, which was a stationary leaf filter. Slimes were agitated in Pachuca tanks. Zinc box precipitation, using zinc shavings, was used to recover the gold from the pregnant solution. Despite the state-of-the-art cyanide practice, blue ore recovery rates remained low, so high-grade ore was sent to a smelter in either Denver or Omaha.[23]

The ongoing blue-ore puzzle provided both an economic and intellectual dilemma. As a result, another series of experiments began after the Trojan Mining Company commenced operations. Another researcher from the School of Mines, Amil A. Anderson, class of 1913, published the results of his experiments on blue ore several years after O'Brien's first experiments. Anderson selected ore samples from four mines—the Hardscrabble, Trojan, Bismarck, and Golden Reward—subjecting samples from each to thirteen separate recovery processes to assess their effectiveness. Anderson's conclusions, while not echoing O'Brien's results, were similar. Anderson recommended crushing, roasting, and cyanidation as the primary elements of a successful treatment process for blue ores.[24]

C. G. Willard, another student at the School of Mines, conducted laboratory tests after Anderson's experiments. Willard, the future superintendent at the Golden Reward Mining Company, exposed the ore to temperature extremes by heating crushed ore to four hundred degrees centigrade before dropping it into cold water. The resulting rapid contraction of the ore caused it to shatter, permitting subsequent cyanidation of the ore to achieve a recovery rate of 91 percent.[25]

While laboratory experiments sometimes demonstrated that high blue-ore recovery rates were possible, those rates were not always realized when processes based on those experiments were implemented in the mill. The Golden Reward adopted a roasting treatment along the lines suggested by O'Brien's and Anderson's early work, and initiated the first large-scale commercial effort to process blue ore.[26]

In 1913, the company installed a Wedge mechanical furnace at its Astoria Shaft Mine a few miles southwest of Lead. This furnace was capable of roasting sixty-five tons of crushed ore in a twenty-four-hour period, gradually heating the ore to the preferred temperature by moving it slowly through a series of progressively hotter levels. The ore was fed into the furnace's upper level near its outer circumference. Rabble blades, known as plows, attached to a shaft running vertically through the furnace continually raked the ore, moving it gradually (at eighteen to nineteen revolutions per hour) toward the inner circumference of the hearth. Upon reaching the inner circumference, the heated ore dropped through holes in the hearth floor to the next level, where another set of rabble blades slowly moved it to the outer circumference, where it fell through drop holes to the next level. It took ore five hours to pass through the furnace.[27]

Furnace temperature increased as the ore fell from one level to another, with the exception of the bottom level, which functioned as a cooling hearth. Between the top hearth on level seven and the fire hearth on level two, temperatures ranged from two hundred to twelve hundred degrees Fahrenheit. Water cooled the oil-burning furnace. The roaster consumed as much as eleven gallons of oil to roast one ton of hard blue ore, half that amount to treat a ton of soft blue ore. A base-metal thermocouple—an electric device that accurately measured temperature differences between dissimilar metals—controlled the temperature of the roaster.[28]

Temperature control was extremely important to the successful roasting of blue ore because proper roasting temperatures varied from batch to batch, depending upon the sulphur content of the ore being roasted. Soft blue ores were high in sulphur content, averaging 11 percent or more sulphur. Roasting soft ores required a maximum temperature of eight hundred degrees Fahrenheit, while hard ores, low in sulphur, required twelve hundred degrees.[29]

Once roasted, ore was carried by rail to the Golden Reward cyanide mill in Deadwood, where hard blue ore was discharged into a weak cyanide solution and the gold extracted. Soft blue ore was first washed with water to remove cyanicides, the base metal residues that inhibited the cyanide gold recovery process from working properly.[30] Golden Reward refractory ores were not coarse but tightly compacted ores, and roasting was necessary to open the pyrites to expose the fine gold particles to a cyanide solution.[31]

The roaster did not solve the problem of recovering gold from blue ore. Joseph P. Connolly, professor of mineralogy, reported that the company's preliminary roasting still gave "very erratic results, and so far has not been commercially feasible." The poor results discouraged mining companies, which mined only the oxidized red ore as a result. But by 1920, "most of the oxidized ore [had] been worked out," Connolly wrote, while "probably several millions of tons of blue ore still [remained] in the district." As mining companies depleted their red-ore deposits, they began to close because the available recovery technology for blue ore was unprofitable.[32]

Owners were unwilling to mine deposits worth only eight to ten dollars a ton to treat them with processes that recovered a relatively small percentage of their gold. "The proper solution of the problem," Connolly concluded, "would thus add millions of dollars to the mineral resources of the northern Black Hills." The Golden Reward Company, for example, was thought to have more than one-half million tons of blue ore available for exploitation when a commercially viable method of recovery was found.[33]

Based on the blue-ore milling and roasting experiments at the School of Mines, the Trojan Mining Company initiated its own experiments in 1915. The company enlarged the mill to increase the capacity of its Dorr thickener and to provide more work room around the Chilean mills, a circular mill with center pivot arms that crushed ore against the mill's steel sides. When the ore was fine enough, it was discharged through screens on the sides. This mill improved the fine crushing of refractory ores.[34] Then the company installed "a Holt-Dern roaster and the recovery was increased to ninety percent if the ores could be given a chloridizing roast."[35] From these "exhaustive [on-site] tests it appear[ed] practically certain that a preliminary roast [would] make a large proportion of the [blue] ores amenable to cyanidation."[36]

The Trojan Company mined both red and blue ores, despite less-than-successful on-site recovery rates for the more difficult blue ores. As recovery rates dropped, the Trojan Mining Company treated fewer tons of ore. Despite reduced production, in 1919 the company increased wages to $5 per eight-hour shift for its underground workers and $4.50 for an eight-hour mill shift.[37] Mining and treating low-grade blue ore with a low recovery rate forced the company to purchase additional properties in 1921, seeking more profitable ore.[38]

The mill shut down in March 1923, but exploratory work continued in the hope of finding higher-grade refractory ore.[39] General Manager C. E. Dawson stated: "Continued high cost has influenced us in reaching this decision. It has been necessary to confine our mining operations to a higher grade of ore than formerly, in order to pay operating expenses. This has translated into a reduction in tonnage, with very little reduction in costs." Even with the mill idle, the company completed several modifications to make it a modern plant "in accordance with the best cyanide practice."[40]

These early blue-ore experiments did not lead to a key to unlocking the secrets of increasing the region's gold recovery rates from its unoxidized blue ore; when the Trojan mill closed, it was merely another operation that fell victim to the refractory ore. Despite its lack of high-grade refractory ore, Trojan Mining Company, with its low-grade ore, was the district's second highest producer of gold between 1918 and 1923, after Homestake. High operating costs and unprofitable gold recovery rates from blue ores idled the mine and mill in February 1923.[41] After the war, mill operating costs had risen and "gradually overtook the margin of profit realized from the low-grade [red and blue] ores of the area with the 70% to 75% gold recoveries then possible."[42]

The operators' problems with reducing local low-grade, refractory gold ore did not end the Trojan's mining and milling efforts; instead it was a lack of capital and credit. Based on past operating success, the Lead and Deadwood branches of the First National Bank of the Black Hills loaned the company $28,000. With operations suspended during World War I, the borrower lacked the funds necessary to repay the loan, making it impossible for the company to remain on a solid financial footing. Trojan's financial problems continued to mount, as the bank won a judgment against the loan, a debt

Bald Mountain Mill exterior from the northeast, c. 1940-59. The roaster and other unoxidezed ore circuit additions are present, along with secondary thickener no. 7 and additions to the machine shop. (Historic American Engineering Record, Library of Congress.)

added to $20,000 in unpaid taxes and pre-existing labor liens.[43]

The search for more productive blue reduction practices continued despite the Trojan's shutdown, as other mine owners wanted a better blue-ore reduction process so that they could reopen their idle mines. The search for a solution became more intense in the early 1920s, when Connolly, along with graduate students Arthur I. Johnson and George S. McCracken, conducted experiments on the blue ore's bonding properties at the South Dakota School of Mines.[44]

They concluded that as much as 65 percent of the gold contained in blue ore was bonded to fine grains of pyrite, which, in turn, were bonded to the quartz. Since the quartz prevented the cyanide solution from dissolving the gold, the ore would have to be more finely ground for the cyanide process to work. Still, this discovery was only one step toward understanding the composition of the blue ore, and it did not completely solve the problem. Connolly, Johnson, and McCracken determined that fine grinding alone would not increase recovery rates to a profitable level because most of the gold values were still bonded to pyrite and quartz.[45]

In 1924, several Black Hills mine owners requested that the United States Bureau of Mines initiate new blue-ore experiments. These miners wanted the bureau to expand blue-ore studies beyond the work conducted at the School of Mines. The bureau agreed, first conducting small laboratory experiments, then constructing a one-ton demonstration mill at the South Dakota School of Mines for larger trials.[46]

Bureau engineers worked from the premise that arsenic, a cyanicide found in the blue ore, prevented dissolution of the gold in cyanide. Ore was first coarsely crushed, then subjected to a short, low-temperature roast of sufficient heat and duration to prevent the arsenic from forming destructive base compounds and to oxidize the pyrite in order for dissolution of gold to occur in the cyanide. Slaked lime (calcium hydroxide) in water was added to each ton of ore after roasting. The lime created sufficient alkalinity in the pulp to minimize the loss of cyanide in the subsequent treatment process. After the lime was added, the ore was ground fine and put through a "standard cyanide treatment."[47]

Using this process on blue ore from the Trojan Mine, the Bureau of Mines obtained recovery rates of slightly over 97 percent of gold, and 91 percent of silver.[48] Connolly, from the School of Mines, attempting to expand on the bureau's tests, reporting in 1927 that a "water quench after roast at 800 [degrees] C gave very good results," but his results could not be duplicated.[49]

Despite these promising bureau tests, a second cyanide boom was not forthcoming. Economic conditions in the 1920s that included a low price for gold and high start-up costs prevented operators from reopening idle refractory mines. Despite these gloomy circumstances, the promising experiments gave one group of investors the courage to reopen the Trojan properties at Bald Mountain.[50] Previous production provided some reason for optimism, as over $31 million in gold was recovered from Bald Mountain mines from 1875 to 1933.

Bald Mountain Mining District
Gold Production to 1933

Company	Value	Tonnage
Golden Reward	$21,000,000	3,570,000 (?)
Mogul	$4,750,000	807,500 (?)
Annie Creek	$875,000	148,500 (?)
Trojan	$5,250,000	892,789
TOTAL	$31,875,000	5,405,789

(From Hummel, "Structure and Mineralization," p. 68.)

The Trojan mining properties and mill, idle since 1923, began a new life five years later when the Bald Mountain Mining Company was organized. There were several keys to financing this new company. One was outside money, made possible by an improvement in the honesty of the local mining community—this after incidents like the Harney Peak tin venture, when one backer described Black Hills companies as run by "bunko steers, confidence men and horse thieves."[51] The Lead and Deadwood branches of the First National Bank of the Black Hills also provided good financial support.

The First National wanted to make good its loan against the Trojan property and reopening it was the best way for the bank to recover its money. So local bankers were instrumental in starting the Bald Mountain Mining Company. Robert H. Driscoll and his son Robert E. Driscoll, and W. E. Adams, the Lead and Deadwood officers of the First National Bank "were willing to bet any amount on a deal which in their judgment had merit."[52]

Robert E. Driscoll eventually convinced a group from Clinton, Iowa, and Chicago to front the two hundred thousand dollars necessary to free the Trojan company from its financial troubles so that operations could begin.[53] Their only stipulation was that "the bank would ride with them for part ownership." The bank's officers "agreed on condition that the amount we had in labor liens and taxes be paid first and that we be given preferred stock for our original debt and interests, together with $10,000 of common stock for which we paid this amount."[54]

The new company, a consolidation of Trojan and Mogul holdings,[55] controlled "the Trojan Mining Company, Imperial Mining Company, Two Johns Mining Company, and part of the holdings of the Mogul Mining Company."[56] All told, the new company owned 2,100 patented acres and the remodeled Trojan mill, five miles west of Lead, with which to begin their quest to make a profit from low-grade blue and red refractory ores.[57] While the Bald Mountain properties began production, the Golden Reward remained closed and, in 1942, Anaconda Copper Mining Company purchased the mine.

C. E. Dawson, general manager of the Trojan Mining Company, was hired to supervise the Bald Mountain Mining Company's start up. He began development work in 1928 and stopped two years later.[58] Development consisted of driving a 1,270-foot tunnel at a twenty-seven degree negative slope "from the bottom of the Two Johns Mining Company, which had faulted downward from the old Rua workings on the rim of the canyon."[59]

As this exploratory work began, Bruce C. Yates, general manager of the Homestake Mining Company, hired consulting geologist Donald H. McLaughlin to report on the Bald Mountain mines. Obviously, Yates was interested in the Bald Mountain mines as potential Homestake properties. McLaughlin reported that the first Gold Reward diamond drill hole produced poor results. On the positive side, the Tornado Shaft had blue ore that averaged five dollars per ton, and low-grade brown ore was distributed everywhere.

Overall, McLaughlin did not see an optimistic future for the Bald Mountain mines. The low-grade ore might produce a profit, but he concluded that the "reward, however, can not be considered particularly attractive in view of the effort that would be needed to make the enterprise a success."[60] McLaughlin's pessimistic report steered Homestake away from purchasing any interest in the Bald Mountain Mining Companies.

In 1933 the price of gold rose,[61] and the Bald Mountain Mining Company reopened its mines, taking both red and blue ores. The company was the only major gold-mining operation besides the Homestake to initiate both underground mining and surface reduction operations in the Black Hills. In January 1934, the mill was operating again.[62] The government-sponsored increase in the price of gold "from $20.67 to $35 per ounce . . . created an entirely new profit picture, and in 1934, the mines were placed in operation and the old Trojan Mining Company mill began treating two hundred tons daily."[63] With the new price, "profits soared, the two banks recovered their original loan—the preferred stock was retired at par and the common stock paid the banks nearly $50,000 dividends in the next ten years."[64]

As the potential to make a profit increased, Bald Mountain Mining Company improved its mill recovery practices. The plant was converted "to an all-sliming counter-current decantation [plant] with a daily capacity of 350 tons."[65] The plant also roasted some of the dense refractory ores and, all told, these mill practices removed a second barrier to profit, permitting 80 to 85 percent gold recovery, which, in turn, "initiated a new round of activity."[66]

The Bald Mountain Company primarily took oxidized refractory red ore from its Portland Mine. Mill operators processed this ore with a straight cyanide solution using an all-sliming process. The only major changes in the extraction process at this plant, compared to earlier cyanide mills that reduced red ore, were the addition of seven to eight pounds of lime per ton after the initial crush, and the use of a rotary vacuum filter for slime filtration. The lime neutralized the ore's acidity, aiding in the oxidation process. Three circular, continuous Portland filters were installed; these consisted of light metal frames, twelve feet in diameter, covered with a light cloth to remove the fine particles from the slime. The filters operated in a slime vat, where vacuum pressure continuously forced the slime through the filter.[67] These small changes converted the mill "to an all-slime, counter-current decantation plant."[68]

To work its underground mines and surface mill, the Bald Mountain Mining Company instituted the contract labor system "to create incentive and stimulate interests" at the operation for all jobs. The company carefully studied mine and mill positions to establish a fair labor rate for all, hence "very few objections were voiced by the personnel." In the mine, employees were paid $6.65 a foot for running the jackleg machine that required mucking and using the tram to move ore. A man hand-mucking in a drift with a raise and stope was paid $1.40 for every ore car he filled.[69]

At first, only small amounts of blue ore were mined, and little concern was shown for the low gold recovery from blue ore. Gradually, blue-ore tonnage increased, until roughly a third of the ore processed daily at Bald Mountain was unoxidized blue ore. Faced with the reality of mining more blue ore in the future, Bald Mountain investors determined to add a roasting process based upon the 1928 Bureau of Mines' tests. As a result of this decision, a roasting unit, crushers, and drying equipment were purchased, and the mill was remodeled, making the Bald Mountain mill a technically advanced blue-ore treatment facility.

The first step in redesigning the plant's flow chart required separating the treatment of red and blue ores. The latter would be roasted, which was an added expense. Experiments at the Trojan Mill, the South Dakota School of Mines, and the U.S. Bureau of Mines had demonstrated the importance of roasting blue ore. The Bald Mountain Mining Company tried several commercial roasters, but none were satisfactory. That forced the company to design a roaster specifically for the blue ores from its mines. In 1937, the company, seeking simplicity and efficiency, constructed a rotating hearth roaster.[70]

Following preliminary crushing, blue ore was discharged into a cylindrical drier four feet in height and twenty feet in diameter. After drying, the ore dropped into a locally-designed, revolving, donut-shaped roaster fifty feet in diameter. The roaster's revolving hearth was fired with natural gas and regulated to give the ore a maximum roast of two hours at 620 degrees centigrade. After roasting, the ore dropped into a Baker cooler measuring five feet in height and forty feet in diameter. Finally, the blue ore entered the same circuit as the red ore, and was treated with a cyanide solution.[71]

By using the roaster and the all-sliming cyanide process, the Bald Mountain plant increased gold recovery rates from refractory ore—primarily blue ore—from 20 to 80 percent. The large furnace operated from 1939 to 1941 on highly refractory ore from the Two Johns Mine. When the company reopened near the end of the war, the roaster was too expensive to operate, so all blue ore was treated only with crushing and cyanide. But the secret the Bald Mountain Company had discovered was that "by using modern cyanide techniques, more of the blue ore can be treated commercially, without a preliminary roasting, when fine grinding is carefully maintained," since fine grinding enables the cyanide solution to dissolve the gold quickly.[72]

Fine grinding of sands and slimes at 65 percent minus two-hundred mesh resulted in the largest percentage of gold recovered from the slimes. Even on Portland Mine blue ores, fine grinding worked better than a cheaper course crush, enabling more gold particles to be exposed to the cyanide solution.[73] Due to fine grinding, the cyanide solution dissolved 53.85 percent of the gold recovered in the crushing circuit, with the remainder recovered in the primary thickeners (7.69 percent), agitators (19.23 percent), and secondary thickeners (19.23 percent).[74]

Notwithstanding these technological innovations at the Bald Mountain facilities, from 1934 to 1942 the company benefitted from plentiful labor, and "high efficiency and supply costs [that] were reasonable." Although incorporating many labor saving devices, Bald Mountain "continued to use the outdated hand labor methods until the mines closed in 1942"[75] under the War Production Board's Closing Order L-208 requiring the nation's gold mines to cease operations.[76]

When the company resumed operations after the war, mine mechanization improvements reduced manpower by 30 percent compared to 1941. The "wage-supply cost inflationary spiral speeded up after 1950, and constant efforts had to be made to maintain cost of production." Preventative maintenance reduced breakage, innovations improved efficiency, but increasing operating costs negated these measures and inflation accelerated after 1950. With ore reserves dwindling, the company lacked the capital

Gold in the Mill Circuit

Position in the Mill	Gold in Pulp Ozs per Ton	Gold in Solution Ozs per ton
Mill Feed	0.150	-------
Bowl Classifier Overflow	0.080	0.062
Primary Thickener Underflow	0.070	0.073
No. 1 Agitator	0.065	0.100
No. 2 Agitator	0.060	0.100
No. 3 Agitator	0.055	0.106
No. 4 Agitator	0.045	0.104
No. 5 Agitator	0.025	0.097
No. 1 Secondary Thickener Underflow	0.040	0.038
No. 2 Secondary Thickener Underflow	0.035	0.020
No. 3 Secondary Thickener Underflow	0.025	0.010
No. 4 Secondary Thickener Underflow	0.040	0.048
No. 5 Secondary Thickener Underflow	0.035	0.039
No. 6 Secondary Thickener Underflow	0.030	0.015
No. 7 Secondary Thickener Underflow	0.020	0.003

(From Miller, "Study of the Bald Mountain Mining Area," 97.)

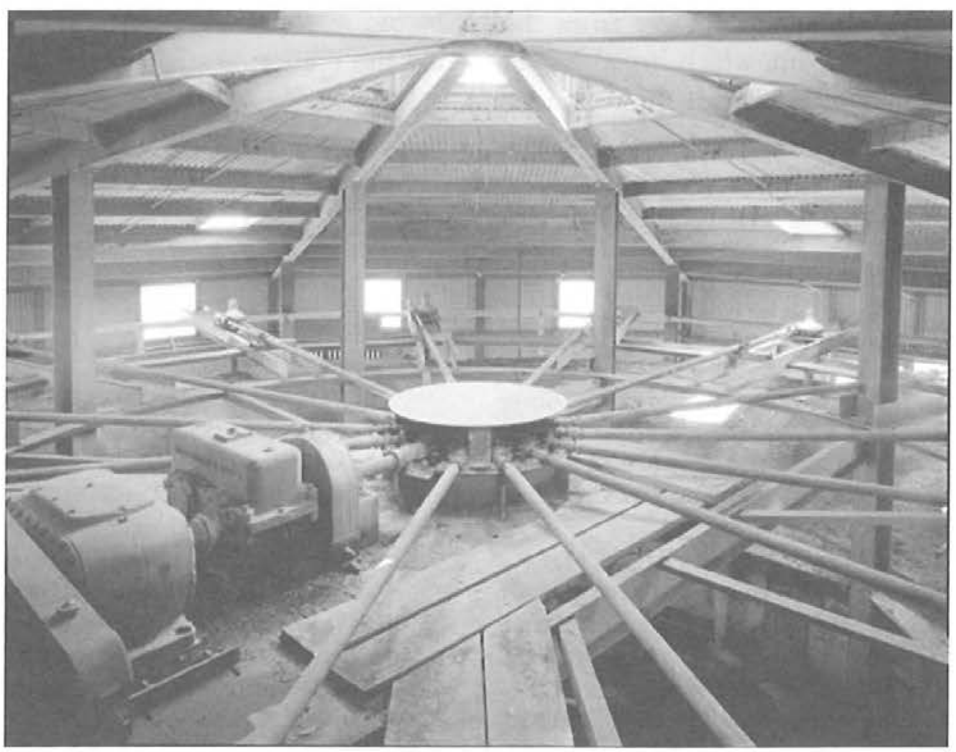
needed to open new ore reserves. To make matters worse, development work had fallen "behind schedule and the outlook for a [gold] price increase was poor."[77]

Based upon these factors, the company dismissed employees and redesigned its contract labor system during its last five years of operations, but to no avail; the mine and mill closed in 1959.[78] The shutdown occurred so quickly that "everything was left on company property, all the tools in the machine shop, office equipment, files, etc."[79]

To reopen the mill, engineers would have to improve the plant's technology. To improve classification of sands in the secondary crushing circuit, a new and larger bowl classifier would have to be installed, since the current small classifiers did not drop sands fast enough. Cone classifiers would have to replace the Dorr rake classifiers to improve overall sand and slime classification. The zinc precipitation method would have to be changed to a new charcoal or resin pulp ion precipitation. Last, greater automation would lower costs, reduce human error, and provide more uniform gold recovery.[80]

The Bald Mountain mines and the Bald Mountain Mining Company were significant for two reasons. One was that, despite its ups and downs, the Bald Mountain Mining Company became the second largest gold producer in the history of the Black Hills after the Homestake. Bald Mountain Mining Company terminated operations in July 1959, due to the low fixed price of gold and the steadily increasing costs of running its mining and milling operations, but from 1934 until 1959, it produced $13,948,720 in gold and $628,411 in silver, demonstrating that there was more to mining in the Black Hills than just the Homestake.[81]

The other reason for the company's place in



The Roaster - addition interior from the Southwest, with a view of the rabble drive system. (Historic American Engineering Record, Library of Congress.)

mining history is that its operation represented the high point of blue-ore reduction technology in the era of underground blue-ore mining at Bald Mountain. Technological and process innovations brought the company success. The Bald Mountain Mining Company returned profits for over three decades by mining and milling low-grade refractory red and blue ores and processing them with sophisticated roasting techniques, improved fine-crushing machinery, and an evolved cyanide process. Through perseverance and innovation, management of the Bald Mountain Mining Company and its predecessors mined and milled large quantities of low-grade blue ore for decades, creating a stable mining operation.[82]

Ultimately, the company could not produce adequate profits in the face of increasing operating costs, in part because operating revenues could not pay for added improvements after World War II. Even so, the Bald Mountain Mining Company was the most technically advanced blue-ore treatment plant to emerge from the Black Hills cyanide boom, which began late in the nineteenth century and made the region famous for recovering gold from low-grade ores. Despite this, Bald Mountain's mill never achieved the renown of the Lundberg, Dorr, and Wilson cyanide mill at Terry, where Dorr invented machinery that improved gold recovery from the cyanide process throughout the world.

Although neither the region's largest nor most celebrated enterprise, Bald Mountain was the most technically interesting gold recovery operation in the Black Hills. It proved that the region's metallurgists and mill engineers could develop blue-ore recovery practices from laboratory experiments into profitable operations. The next cyanide boom, in the 1980s, was made possible by heap leaching, with its massive open pits, ore piles, and leach ponds that forever ended the era that the Bald Mountain Mining Company represented. ■

Richmond L. Clow, a native of South Dakota, is professor of Native American Studies at the University of Montana in Missoula. He received his doctorate in history from the University of New Mexico in 1977. His research interests include Black Hills mining and milling history, and he is the author of Chasing the Glitter: Black Hills Milling, 1874-1959, *a history of the region's gold recovery processes.*

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