This history of hardrock milling technology in South Dakota begins with the Black Hills gold rush of 1875. In the early years, milling devices were simple, hand-run machines, but once the era of placer mining was over, milling—the process or processes whereby gold is extracted from the ore—evolved into an industry of its own. Most Black Hills gold ore was low grade, which meant that the amount of gold per ton of ore was extremely low. Over the years, the mining industry came to depend on efficient extraction techniques to render a profit for the mining companies. The history of South Dakota's hardrock mills is the story of their scientific and technological triumph over low-grade ore.

By the time of the large-scale mining operations of the 1880-1920 era, mining and milling were separate industries. Some large operators, such as the Homestake Mining Company, could handle the entire process from mining to extraction, but most mining companies relied upon independently run mills to perform the task of extraction. While mining companies frequently invested in these mills, they did not usually own the entire enterprise. Workmen in the two industries were treated differently. Mill men were paid at a lower rate than the miners were, presumably because mill work was regarded as less dangerous and less skilled than work in the mine. Indeed, when min-
ers organized into trade unions, mill workers were completely overlooked. Not until the late 1890s and the early decades of the twentieth century did the unions take up the mill workers' grievances for an eight-hour day, better pay, and safer working conditions.

This photographic essay grew out of a 1983 historic-sites survey, conducted by the State Historical Preservation Center, of historic mines and mills of the Black Hills. It focuses primarily on the evolution of the milling techniques that assured the economic success of the mining and milling industries.
Crushing

The Black Hills gold milling industry employed many different techniques to extract the gold from the ore. Each technique has been refined or completely revolutionized over the hundred-year history of the industry in South Dakota.

Crushing the gold ore was the first step in any extraction process, and it involved two stages. During the early years of mining and milling, the first, or primary, crushing was accomplished in a crude and wasteful manner; often the ore was reduced with sledge hammers. Another early crushing device was the arrastra, which employed mules to drag a large stone across a flat bed covered with ore. Later, more efficient methods introduced the use of power-driven machinery, including jaw crushers and the Gates gyratory and cone crushers.
Gates gyratory crusher, Cleopatra Mine, 1983

Gates cone crusher, Cleopatra Mine, 1983
Standby
Mill (above)
and stamps, 1983
The secondary crushing was done with heavy stamps, rolls, and tube mills. At this stage, water and various chemicals could be introduced to provide a wet crush, or the rock could be pulverized without liquid to provide a dry crush. Because each extraction process and each type of ore dictated its own particular type of crush, crushing became a finely calibrated technique. At the Standby Mill, Blake rock crushers were used in the primary crushing stage, and large stamps, pictured here, provided a fine, wet secondary crush. The Standby, erected in 1879-1880, was active until 1909. Its present owner, George Beardshear, reopened the mill briefly in the 1930s.

As the milling industry grew, many new machines and techniques were introduced, and mills reached huge capacities. The Golden Star Mill, which was a 200-stamp mill, was one of five such mills owned by the Homestake.
Amalgamation

Throughout the most active years of milling in the Black Hills, the amalgamation process played an important role in the business of extracting gold from ore. The method reached the height of its popularity in 1892, when ninety percent of the world’s gold was recovered in this way. Amalgamation worked most efficiently on free-milling ore, that is, ore in which the gold was not bonded to other minerals in the rock. In the amalgamation process, water and sometimes mercury were added to the ore during secondary crushing. The mercury attracted the gold and silver, forming an alloy called amalgam. The water and ore solution then flowed over mercury-coated copper tables that caught any gold that had escaped amalgamation during the crushing. In the final step, the amalgam was heated to distill the mercury and recover the gold.

Both the Caledonia No. 1 and the Deadwood Terra No. 2 in Terraville, South Dakota, were plate amalgamation mills. The town of Terraville, located between Deadwood and Lead, was the heart of the milling industry in the Black Hills. It remained active long past the era of free-milling ore and the amalgamation process, but it was ultimately abandoned. In 1982, it succumbed to renewed mining activity when the Homestake decided to rework its Open Cut and the remains of the town were razed to make way for the new operation.
Terraville, South Dakota, with Caledonia No. 1 and Deadwood Terra No. 2 at the top, 1888
Bromine and chlorine extraction made up a significant, if short-lived, chapter of milling history. Between 1885 and 1900, these two techniques dominated the industry. Chlorination processing originated in 1848 when C. F. Plattner developed the first successful treatment. In 1877, the United States issued a patent for what became known as the Newbery-Vautin method, which was the chlorine process used widely throughout the Black Hills.

The chlorination process was quite simple although rather dangerous. Basically, roasted crushed gold ore and water were mixed in a vat or barrel into which chlorine gas and compressed air were introduced. The chlorine combined with the gold to form gold chloride, which could then be flushed from the ore with water. The gold was precipitated chemically or by slowly running the solution over charcoal filters, which caught the gold particles and were then burned to retrieve the gold.

The first chlorination treatment plant in the Black Hills was built in 1888-1889 by the Deadwood Smelting and Reduction Works Company. It burned down within a few weeks of completion, and the Golden Reward Mining company began work on a replacement mill.
within the same year. The Golden Reward chlorination plant ultimately became the largest and most successful chlorination plant in the area. The Black Hills Chlorination Plant of Rapid City, located adjacent to the School of Mines, was the last chlorination works to be built in the area, and it eventually converted to the bromine process.

Bromine processing was less widely used, and it varied from mill to mill. In the Rapid City plant, the crushed roasted ore was placed in a vat or revolving barrel and was saturated with bromine, which dissolved the gold out of the ore. The gold solution dropped through filters into a second vat, where the gold was precipitated from the bromine solution by the introduction of ferrous sulfate, sulfur dioxide, or sulfured hydrogen gas.

Because of the unstable nature of the chemicals and gases used, the bromine and chlorination processes were quickly supplanted in 1900 by cyanide. Chlorination produced toxic gases that forced workers to breathe through thick sponges. It was also costly and inconvenient as the chemicals could be used only once. Bromine extraction was also dangerous, but the chemicals could be reused. Bromine, however, did not dissolve quickly in pure water, making the process cumbersome.
Smelting

Smelting was a process that also had a limited but important history. First used to capture silver and lead ores in the 1877-1890 period, smelting later became a successful technique for reducing refractory gold ore. The Deadwood and Delaware Smelter was the preeminent smelter in the Black Hills. It was built upon the success of Franklin Carpenter’s iron-pyrite smelting experiments. As dean of the South Dakota School of Mines, Carpenter was actively involved in the creation of new milling techniques. His experiments in 1888
and 1889 led to erection of the Deadwood and Delaware, the first pyritic smelter in the Hills.

The pyritic-smelting process developed by Carpenter required a mixture of four tons of refractory gold ore, two tons of iron pyrite, and two tons of iron oxide or roasted iron pyrite, heated with one ton of coke. Once the mixture reached a sufficient temperature, the material melted or fused. Sulfur in the iron pyrite became monosulfide, called “matte,” which carried the gold and silver to the bottom of the furnace. The residue, called “slag,” was drawn off. A second smelting process refined the gold from the matte.
Cyanide and Related Innovations

Because of the extremely narrow margin of profit in the mining and milling industries, major technological innovations often concentrated on making the process of gold extraction faster, cheaper, and more efficient. The most significant discovery in gold milling occurred in 1886, when three Scotsmen discovered a new process that used potassium or sodium cyanide to dissolve gold out of low-grade refractory ore and zinc particles to precipitate the gold from the cyanide solution. This method revolutionized the industry, and the cyanide era was born. Profitable extraction still required unique treatment for each type of ore, however, and several years of testing and experimentation at individual mills were required before the real boom was on. By 1900, twelve cyanide mills were operating in the Black Hills.

The Homestake Mining Company, incorporated in 1877, was the most successful mining and milling enterprise in the Black Hills and was responsible for many of the innovations in the field. Charles
Merrill, metallurgist at the Homestake, recommended that the company use cyanide to reprocess its tailings, i.e., the refuse left after amalgamation. With the construction of Sand Plant No. 1 in 1901 and the Homestake North Side Tailings Plant No. 2 in 1902, the company began recovering over half a million dollars yearly from what had previously been considered waste.

Individuals working in Black Hills metallurgy also left their marks on the industry. Between 1900 and 1910, John Van Nostrand Dorr, of the Lundberg, Dorr, and Wilson milling company, developed several inventions for use in cyanide processing. Two of his most important inventions, the Dorr Classifier and the Dorr Thickener, were later adapted to other industries. After the gold ore was crushed, the Dorr Classifier agitated the mixture of ground ore and water, known as pulp, to separate it into finer particles (slimes) and coarser particles (sand). The two grades of pulp could then be treated separately and more efficiently. While the gold-dissolving cyanide solution readily percolated down through the sand, it would not leach through the
slimes, which tended to pack firmly. The Dorr Thickener removed water from the slimes as an intermediate step in the filtering, increasing efficiency in the leaching process. Charles Merrill, the innovative Homestake metallurgist, solved the problem of getting cyanide through slime by developing a fabric-sided filter press that held a thin cake of slime through which the cyanide solution could be forced under pressure.
Promotion

At the height of the cyanide boom in the early twentieth century, South Dakota mine and mill owners advertised the success of their industries in a number of flamboyant ways. One promotion scheme was this full-scale, working replica of a “Black Hills Gold Reduction Plant,” which was displayed in 1904 at the Louisiana Purchase Exposition in Saint Louis. As the sign on the photograph indicates, the Colorado Iron Works, a major supplier of milling machinery to South Dakota, equipped the mill. Indeed, Colorado supplied not only equipment but also technological improvements, refineries, and investment capital for the Black Hills mills.

Much of the impetus behind these exhibits and advertisements was the need to attract investors. In the same year as the Saint Louis exposition, the Black Hills Mining Men’s Association published a lavish promotional book entitled The Black Hills Illustrated: A Terse Description of Conditions Past and Present of America’s Greatest Mineral Belt, which described mining and milling companies, local history, and civic improvements. Railroad companies and mine owners also distributed promotion-filled pamphlets and stockholders’ prospectuses. Perhaps the advertising did work, for entrepreneurs from Delaware, New York, Iowa, Colorado, and California all invested in the Black Hills.
Foreign Workers

European immigrants looking for work in the mining and milling industry flooded into the northern Black Hills between 1880 and 1910. Among them were the Finns, who numbered eight hundred in 1910, the peak year of the industry. Most worked in Lead and Deadwood, where the men worked in the...
mines or mills and the women labored as maids. Throughout the Black Hills, Finns worked primarily at lower-echelon jobs such as those performed by Finnish miners working for the Homestake in Terraville about 1904. Others worked in the mine-related lumbering business at nearby Roubaix and Custer Peak. During the 1905-1910 era, when labor unrest struck the mining industry, many Finns abandoned mining for homesteads in rural Lawrence, Butte, and Harding counties. The severe conditions of farming and ranching, however, often led to the men's return to the mines during the winter months in order to supplement the family income.

The domestic and social life of immigrants in the mining communities often centered on the boardinghouse. Mrs. Niva's Boarding House, on Lead's North Bleecker Street adjacent to the Finn Hall, was located in the heart of the Finnish and Scandinavian business districts. Those immigrants who could afford homes usually lived in ethnic neighborhoods. In Lead, the Finns clustered on Park Avenue and South Sawyer, pictured at top right in the photograph of Lead. It was on Park Avenue that the last public steam bath, or Finnish sauna, closed in the 1950s.
Roasting

Successful treatment of blue, or unoxidized, refractory ore is the most recent phase in the history of gold milling technology. While red ore, which has already been partly decomposed through oxidation, had been successfully treated for years, efficient extraction methods for blue ore eluded mining engineers until the twentieth century. From experiments conducted at the South Dakota School of Mines, engineers learned that the gold in highly refractory blue ore is closely bonded to fine-grained pyrite, which is itself so locked into the ore’s quartz that cyanide solutions cannot reach most of the gold. The low gold-recovery rate for the blue ore (about thirty-five percent of the total gold in the ore) was due to the fact that cyanide extraction worked only on gold bonded to coarse-grained pyrite. The key to profitable processing of blue ore lay in finding an inexpensive way of breaking it down to an extremely fine size so that the cyanide could reach more of the gold.
Between 1924 and 1928, the United States Bureau of Mines conducted experiments on blue ore and discovered that roasting the ore as a preliminary step in cyanide processing allowed for increased gold extraction. Roasting was not a new process—it had been used in the smelting and chlorination methods—but its application here was new. The bureau found that the heating and cooling of the blue ore shattered the quartz that held the gold, making it amenable to cyanidation. The Bald Mountain Mining Company capitalized on this discovery. Their large fifty-foot roaster heated the blue refractory ore to 620 degrees centigrade for two hours. After cooling, the roasted ore fed into a conventional cyanide treatment. The Bald Mountain company was so successful that by 1959, when it closed, it had become the second largest producer of gold in the Black Hills. With the closure of the Bald Mountain works, the blue-ore era came to an end.
Cleanup

The cleanup of the gold mills was a necessary step in milling. From an economic point of view, the most important reason for cleaning the equipment was to capture the small bits of gold lost during the extraction process. Gold loss was a particular problem in dry-crushing cyanide plants where dust settled everywhere. In addition, the dust could easily jam the machines and cause unnecessary wear. Cleaning prolonged the life of the machinery, which had been imported at great expense. The workers, too, benefited from the cleanup. Although mill workers were removed from the dangers of mine cave-ins and fires, they were still subject to upper respiratory and lung problems caused by breathing dust-filled air.
Cleanup at the Deadwood Terra Gold Stamp Mill, one of the Homestake mills, 1888
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