The History of Zinc Mining in Friedensville, Pennsylvania

By
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In the late 1840s and early 1850s, the New Jersey Zinc Company conducted experiments at its Newark Zinc Works on treating zinc ore from the Franklin and Sterling Hill, New Jersey, mines. In 1852, this work led to the first limited production of zinc oxide in the United States. However, Bethlehem, Pennsylvania, and Friedensville, located four miles to the south, were to become the center of zinc oxide production in the U. S. starting in 1853, and of zinc metal (spelter) production shortly thereafter. The history of the Friedensville mines is directly tied to the Pennsylvania plants that consumed their ores to make these salable products.

The Birth of the Pennsylvania Zinc Industry

Developments in Pennsylvania started with the discovery of an unusual mineral on the Jacob Uberroth farm in the Saucon Valley near the village of Friedensville in Lehigh County.[1] Around 1830 a wagonload of the mineral was tested at the Mary Ann iron furnace in Berks County. No metal was recovered because of volatilization of the zinc.

In 1845, Theodore William Roepper determined that the material was hemimorphite (also known as calamine, a zinc silicate) and smithsonite (a zinc carbonate). He was able to smelt the ore at the Lehman Foundry in Bethlehem by combining it with native copper to make brass; however, he failed to produce zinc metal. Roepper would later become the first professor of geology and mineralogy at Lehigh University in Bethlehem. In the same year, Andrew Wittman recovered a few globules of zinc metal from the ore.[2]

Roepper interested Robert Earp, a Philadelphia importer, in the deposits. Earp leased the deposits and, in 1846, shipped several tons of the ore to England for testing. Once again, the tests were not successful. By 1847, a number of shallow exploration shafts had encountered zinc ore at several locations in the Friedensville area. Earp then tried to interest New Jersey Zinc in his lease on the property but that offer was rejected.

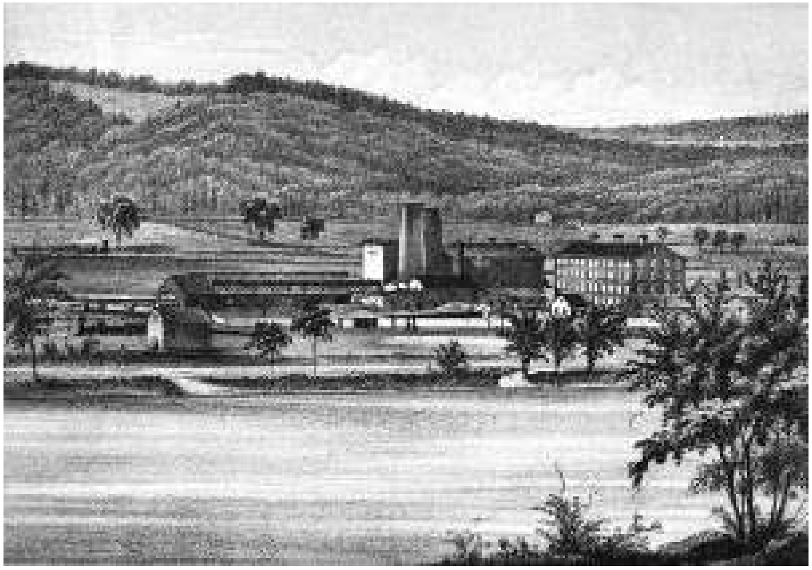
Samuel Wetherill was the son of John Wetherill, who operated a Philadelphia chemical works that made white lead for paint pigment from lead ore mined at Phoenixville, Pennsylvania. The toxicity of lead was already well known and Samuel was researching the use of zinc as a lead substitute. He was superintendent of the Newark Zinc Works and the inventor of a patented furnace for making zinc oxide from zinc ore.[3] Another employee at the zinc works, Samuel T. Jones, patented the means for collecting the zinc oxide particles from the furnace smoke in long muslin bags hung in a multi-story bag house.[4] The combination of the two patents became known as the Wetherill Process, also called the American Process.

Samuel Wetherill visited Friedensville and acquired Earp's lease on the deposits for himself. He offered New Jersey Zinc the use of his furnace patents and his lease on a royalty basis but was refused. He resigned from the company and formed a partnership with Charles T. Gilbert to build the Wetherill and Gilbert Zinc Works in Augusta, Pennsylvania, on the south bank of the Lehigh River. Augusta was renamed South Bethlehem and eventually became part of the city of Bethlehem. Later, Lehigh University and Bethlehem Steel also located in South Bethlehem. The latter eventually expanded to occupy the site of the earlier zinc smelter.

State laws at the time prohibited a company from both mining ore and manufacturing products from that ore. To resolve this problem, the National Mining Company was formed in 1853 under Maryland law by a group of New York investors. Wetherill's leases were assigned to the company. It was quickly renamed the Pennsylvania and Lehigh Zinc Company and chartered in New York.[5] This company was established to supply the Friedensville ore and provide other types of support to the zinc works. Wetherill and Gilbert would make zinc oxide under a twelve-year contract with Pennsylvania and Lehigh Zinc. Five mines operated in Friedensville, four on the lands originally leased by Wetherill. A fifth was on land leased by the Passaic Zinc Company. The individual mines are described later in this article.

Samuel Wetherill.
(Courtesy of the South Bethlehem Historical Society.)

The plant produced its first zinc oxide from Friedensville ore in late 1853 and quickly went on to out-produce the Newark Zinc Works. In the zinc oxide works, the pulverized ore was mixed with anthracite coal and placed on a bed of burning coal on the grates of Wetherill furnaces. Forced air caused the temperature to rise and metallic zinc to be released from the ore. The zinc instantly vaporized and combined with oxygen to form zinc oxide. The oxide was borne by the air-



Pennsylvania and Lehigh Zinc Company's zinc oxide plant, ca. 1860. (From: M. S. Henry, "History of the Lehigh Valley" (Easton, PA: Bixler and Corwin, 1860).)

flow to cooling towers and rooms in which coarse particles of oxide settled out. The finer oxide particles were further conveyed by air to the bag houses, where they were filtered from the air in muslin bags. The oxide was then packed in barrels for shipment to customers.[6]

In the winter of 1853-4, Pennsylvania and Lehigh Zinc Company was taken over by a group of Philadelphia Quaker investors including Joseph Wharton. Not long after production had started, a fire destroyed the zinc oxide plant. It was quickly rebuilt, but the investors were concerned about Wetherill's management ability. In 1854, they sent Wharton to personally oversee the company's operations.[7]

Wharton reorganized the company and improved its management and profitability. Among those improvements was "hiring a competent miner and other persons to dig, concentrate, calcine, and haul the ore to Bethlehem."[8] The "miner" was Richard W. Pascoe, a Cornish mining expert with experience in the mines of Cornwall, Scotland, Pennsylvania's Southern Anthracite Field, and Canada. Pascoe would serve as a Friedensville mine superintendent from 1853 to 1857, and again from 1865 until 1880.[9]

In 1855, under a new state mining law that allowed a company to own both mines and manufacturing plants, the Pennsylvania Legislature incorporated the reorganized Pennsylvania and Lehigh Zinc Company. In 1860 it was renamed the Lehigh Zinc Company. After litigation over ownership of the leased land in Friedensville, the company purchased all of the land outright with the exception of the parcel leased to the Passaic Zinc Company.

From the outset, Wharton disliked many aspects of Wetherill and Gilbert's operation, including the declining quality of the zinc oxide produced from the ore. The decline was attributed to Wetherill's increasing production and sale of excess product for his own account. Wharton reduced ore shipments to the zinc works to sixteen tons per day, the amount needed to meet only the four tons of oxide per day required under his company's contract with Pennsylvania and Lehigh Zinc.[10]

Wharton also objected to Wetherill's personal use of company facilities for experiments to produce spelter. The conflict between Pennsylvania and Lehigh–Wharton and Wetherill and Gilbert came to a head when the company shut down the mines and works during the winter of 1856-7.[11] Finally, in 1857, a financial settlement was reached with Wetherill and Gilbert. They left Pennsylvania and Lehigh Zinc and went their separate ways.

Wharton and his company now had total control of production from mining through oxide manufacturing and distribution.

Wetherill went on to form the Wetherill Zinc Company to produce spelter from Friedensville ore using his process, which was based on the Carinthian furnaces used in Europe. Although he was able to produce spelter, the venture failed after a brief period of production because of its high operating costs. The company was sold to the Lehigh Zinc Company in 1864.[12]

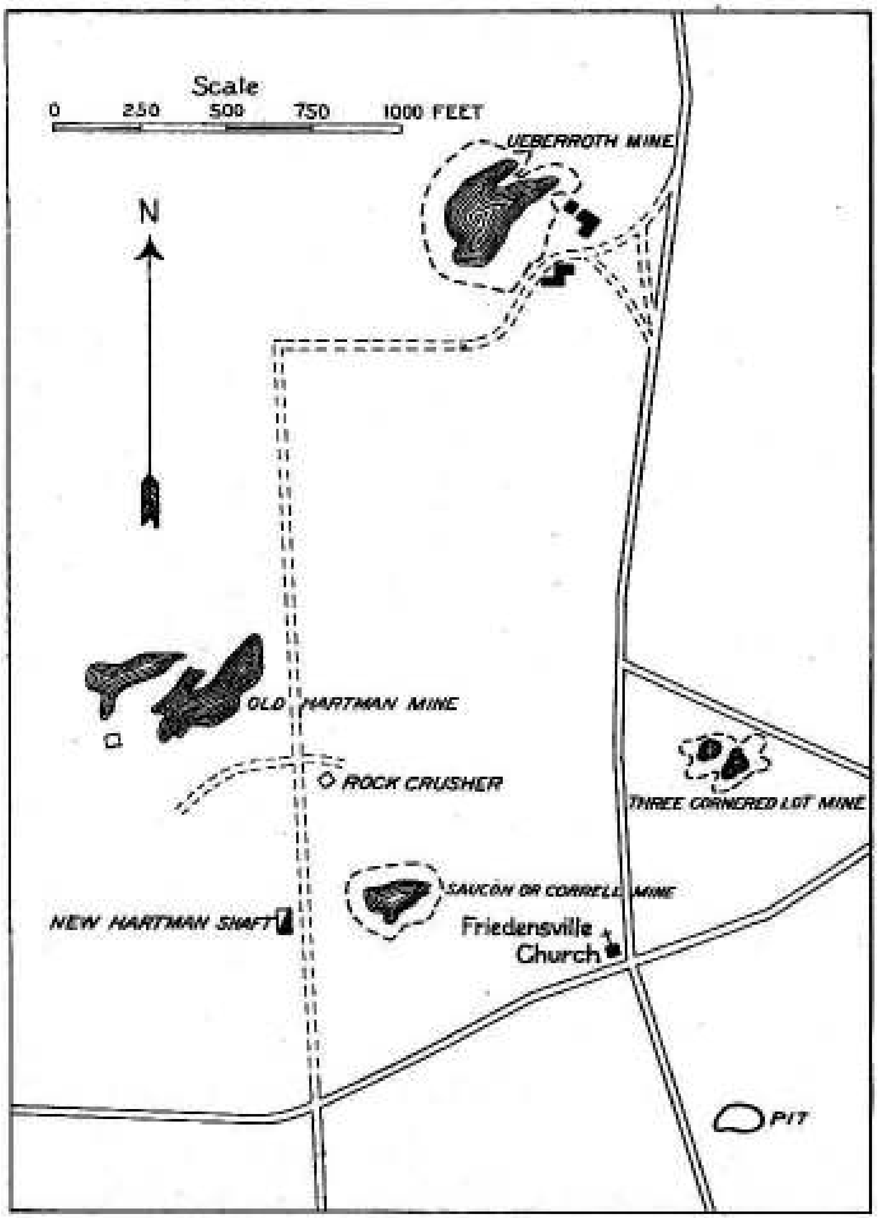
During the financial panic of 1857 zinc oxide sales were slow and unsold inventory increased. The Pennsylvania and Lehigh Zinc Company was nearly out of cash and on the verge of bankruptcy. Wharton was granted a six-month lease on the zinc oxide works and Pennsylvania and Lehigh accepted oxide as payment. Wharton greatly increased production and turned a tidy profit by selling the excess product to foreign customers.[13]

Joseph Wharton, ca. 1850. (From Wikipedia.)

From 1854 to 1859, Wharton studied spelter production and experimented with various furnaces. He achieved success in 1859 by adapting the Belgium Process, in which the ore and anthracite coal were placed in retorts in a furnace and vaporized zinc was collected with condensers. An important factor was the use of New Jersey clays for making the retorts. Wharton hired Belgian consultants and workers to construct and operate his furnaces.[14]

Wharton made several proposals for the construction and operation of a spelter works. Unsure about Wharton's predictions for the success of this new venture, the Pennsylvania and Lehigh Zinc Company contracted with him to build the plant adjacent to the oxide works, purchase ore from the company's Friedensville mines, pay an annual rent, and operate it until January 1863. (That date was later extended until April 1863 as settlement in a dispute over the poor quality of ore being sent to the spelter works.) Under the contract, Wharton assumed nearly all of the risk and agreed to grant the company use of any patents he might receive. In late 1860, he resigned from the Lehigh Zinc Company and devoted his full attention to managing his Bethlehem Spelter Works.[15]

The zinc metal market was depressed in late 1860 and early 1861 because of the uncertainty about the Civil War. A sizable inventory of spelter built up at the plant. However, by late 1861 the market had recovered. Wharton gained profitability and began to pay his debts. The price of zinc rose to fifteen cents per pound during the war while Wharton's production cost was around four cents. In April 1863, when his contract expired, Wharton left Bethlehem and the zinc business at the age of thirty-seven. He had become a moderately wealthy man and had the satisfaction of having started a new American industry. His interest in mining and metallurgy continued with investments in nickel, copper, iron, and coal.[16]



Map of the Friedensville Zinc Mines, 1853-1893. (From: Miller, "Lead and Zinc Ores in Pennsylvania.")

After Wharton's departure, Lehigh Zinc continued to be a major producer of zinc oxide and spelter. A rolling mill was added to the zinc works in 1865. It produced the first sheet zinc in the United States. As the Friedensville mines became deeper, water became a problem and mining costs increased significantly. The expiration of the Wetherill patents enabled other companies with lower-cost ore to compete against Lehigh Zinc.

Financial problems continued through the 1870s. Lehigh Zinc shut down its Friedensville mines in 1876.[17] The company arranged a five-year contract to purchase one thousand tons of ore per month from Franklin-Sterling Hill, New Jersey. In 1880, Lehigh Zinc Company was sold to satisfy bond holders. In 1881, the purchaser, Harry F. West, sold the company to C. August Hechsher and J. Price Wetherill who formed the Lehigh Zinc and Iron Company. Also in 1881, Lehigh Zinc Company's mines were sold to the

Friedensville Zinc Company.

In 1897, New Jersey Zinc consolidated the New Jersey and Pennsylvania zinc mining and smelting companies, ending decades of litigation over the ownership of the Franklin–Sterling Hill mining properties. In 1899, New Jersey Zinc acquired the Friedensville Zinc Company and all of the Friedensville mines.[18] More follows about the impacts of these events on the mines.

Heyday of the Friedensville Mines, 1853-93

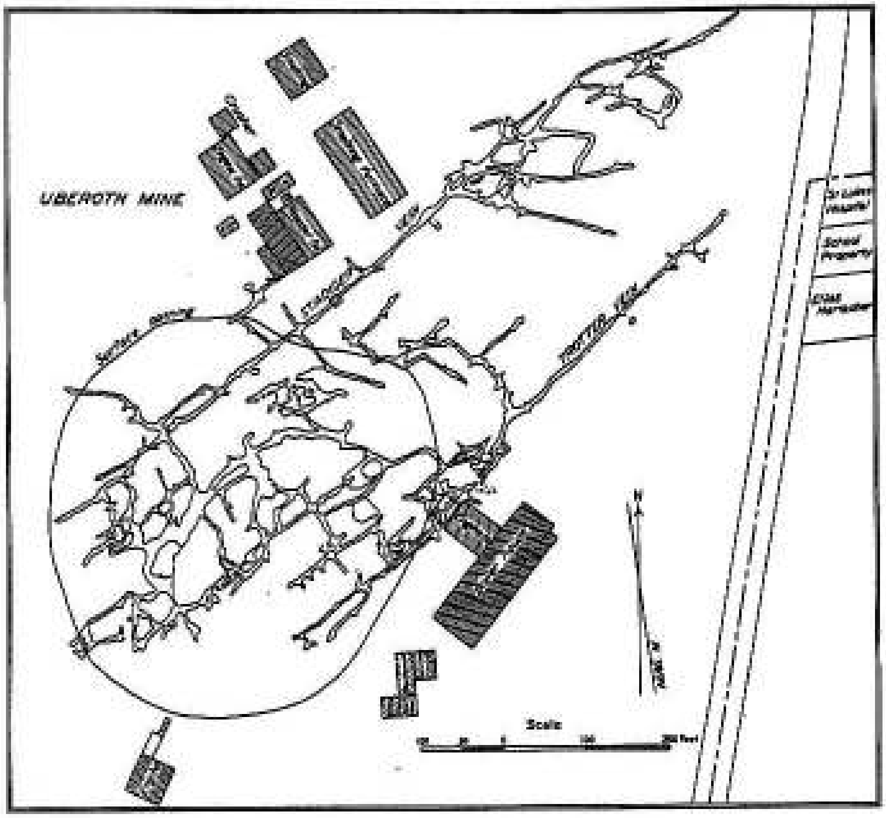
The ore discovery in Friedensville led to the development of six mines. Five of them operated between 1853 and 1893. The sixth mine opened in 1958 and represented the rebirth of the mining district discussed later.

The Uberroth Mine

The Uberroth Mine was the first, largest, and most profitable of the Friedensville mines that operated in the nineteenth century. It was named for Jacob Uberroth on whose farm the mine was located and the first discovery of zinc ore made. It operated continuously from 1853 to 1876, when the Lehigh Zinc Company shut down all of its mines. The Uberroth was operated for short periods of time in 1886 and 1891 by the Friedensville Zinc Company, which had purchased Lehigh Zinc's mines in 1881.[19]

The mine workings followed two large, parallel veins about one thousand feet in length and twelve to forty feet in width. These veins followed the strike and dip of the nearly vertical limestone and dolomite beds. A number of cross veins and

Uberroth Mine with "The President" engine house (at the rear), ca. 1876. (From: Miller, "Lead and Zinc Ores in Pennsylvania.")



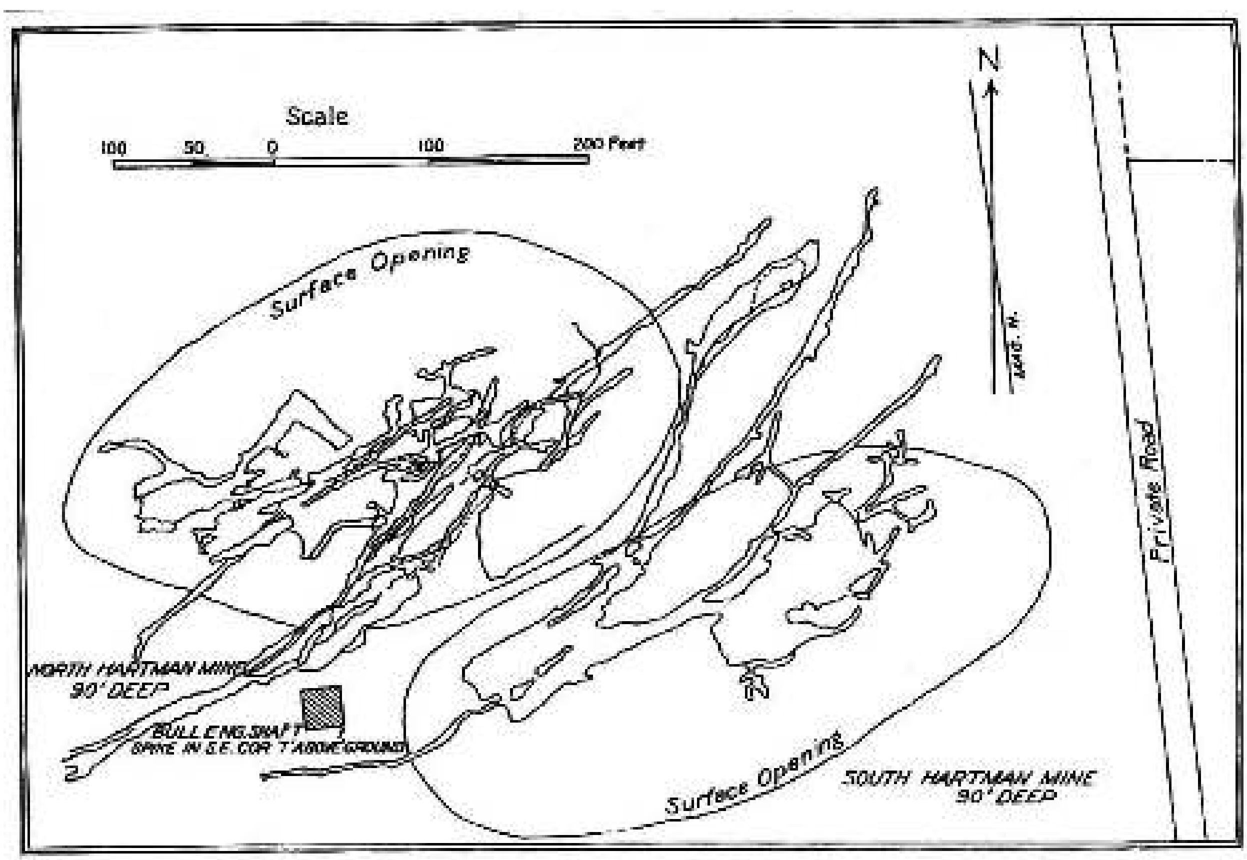
Map of the Uberroth Mine with the 1872 engine house and 1881 zinc smelter. (From: Miller, "Lead and Zinc Ores in Pennsylvania.")

smaller parallel veins interconnected with the two main veins. These veins filled fractures in the limestone country rock. The oxidized ore, hemimorphite and smithsonite, was discovered in a shallow surface depression one hundred to three hundred feet across. It resembled yellow clay. This ore continued to a depth of about 150 feet, after which the primary sphalerite (zinc sulfide) ore continued to an undefined depth below the deepest workings at 225 feet. Because of the vertical attitude of the ore veins, the workings were still in ore when mining stopped.[20]

Miners first excavated the large accumulation of oxidized ore in an open pit before they moved underground. Numerous shafts and inclines were used to access the deeper ore. They excavated only the vein material and used heavy timbers to support the surrounding limestone walls and blocks. The instability of freed limestone blocks was a serious problem and caused some cave-ins. The superintendent, Richard Pascoe, was himself injured in the mine and crippled for the rest of his life.[21] Recent investigations found that miners sometimes backfilled vertical openings with waste rock to provide support and used timber mats to cover the lower workings and prevent falling rocks from injuring workers below.[22]

The Old Hartman Mine

The Old Hartman Mine was located about a quarter of a mile southwest of the Uberroth pit. It was named for David Hartman, the land owner. The ore was a northeast-southwest trending series of near-vertical "veins" or fractures. Two adjacent open pits, covering a total area of about 550 feet



Map of the Old Hartman Mine. (From: Miller, "Lead and Zinc Ores in Pennsylvania.")

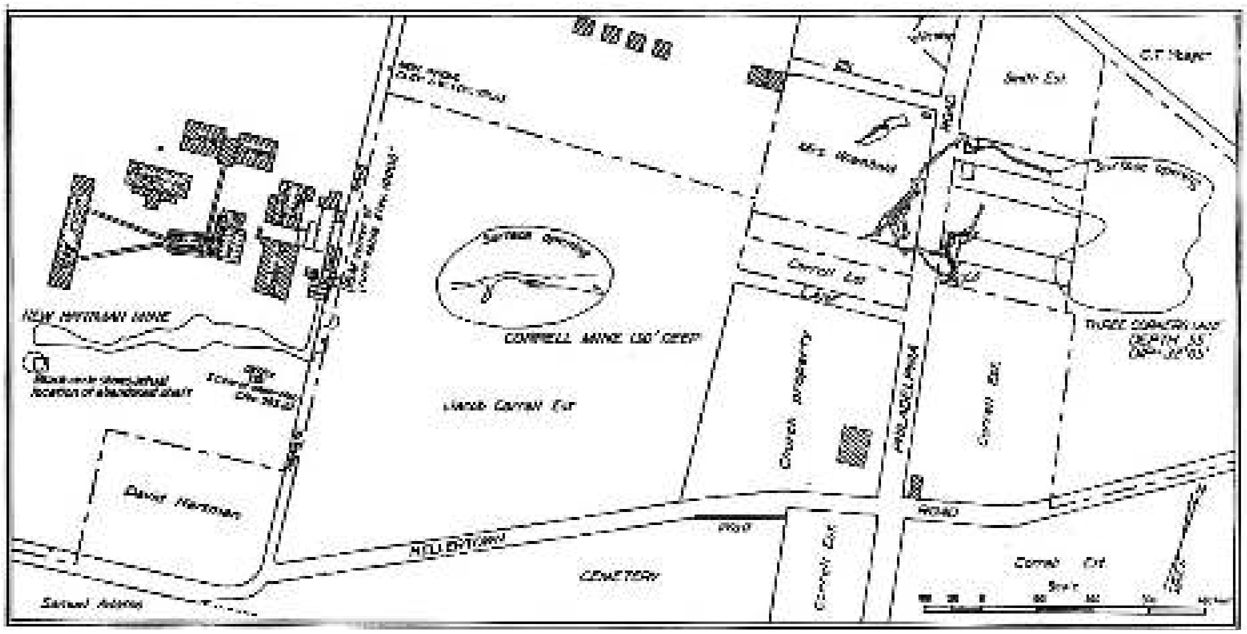
by 350 feet, were used to mine the oxidized hemimorphite and smithsonite ores. Sphalerite ore was also found near the surface. When the pits reached a depth of 90 feet, a shaft and a slope were used to reach the underground zinc sulfides. Mining continued to a depth of 150 feet. The mine was able to continue operating for a year after the district's great pumping engine was stopped at the Uberroth in 1876.[23]

The Three-Cornered Lot Mine

Three mines were developed along an ore zone running under the village of Friedensville in a northeast-southwest direction about a third of a mile south of the Uberroth Mine. All three mines were in strata that dipped toward the south. The Three-Cornered Lot Mine, also known as the Triangle Mine, was located about seven hundred feet northeast of the Friedensville cross roads. It was named for the shape of the property on which it was discovered. The smallest mine in the district, it was initially a shallow, 250-foot-wide open pit. Underground mining followed the ore veins under the village and toward the Correll Mine. The exact years of the mine's operation are not known.[24]

The Correll Mine

The Correll Mine, originally called the Saucon Mine, was located on the west side of the village. It was named for Jacob Correll, Sr., the original land owner, and it had the distinction of being the only one of the early mines not controlled by the Lehigh Zinc Company. The mine was leased by the Passaic Zinc Company until 1875. Passaic Zinc sublet the mine to Lehigh Zinc, which



Map of the Three-Cornered Lot Mine, Correll Mine, and New Hartman Mine with the 1881 zinc oxide plant. (From: Miller, "Lead and Zinc Ores in Pennsylvania.")

paid royalties on the ore it produced. Production started in 1859. When the oxidized ores were exhausted, Lehigh Zinc relinquished its sub-lease.

In 1875, when the Passaic lease expired, Franklin Osgood's Bergen Point Zinc Company obtained a lease and continued to operate the mine, producing sulfide ore using underground mining methods. Osgood formed the Friedensville Zinc Company in 1881 and purchased all Lehigh Zinc's mines. Friedensville Zinc continued to operate the Correll and New Hartman mines until the district shut down in 1893. From 1881 to 1885, the ore was shipped to the Bergen Point Zinc Company's smelter in New Jersey. After 1885, the ore was processed in the smelter and oxide plant in Friedensville. These facilities had seen little production up to that time.[25]

The oxidized ores were exposed in the outcrop of the limestone and dolomite which dipped to the south. An open pit 200 feet wide, 300 feet long, and 150 feet deep followed the footwall of the ore. Below that depth, it became more economical to continue underground. At the west end of the pit, a zone of sphalerite ore was being mined in 1876. It was twelve feet thick and forty to fifty feet wide, dipping to the south and west. This ore was followed underground 250 feet from the west end of the pit until the boundary of the property was reached. At that point, the ore was at a depth of 110 feet. Beyond the property line, it was mined through the New Hartman Mine. The Correll Mine workings eventually extended across the full seven hundred-foot width of the property. Recent investigations found adits running from the east end of the old pit and inclines running south into the old underground workings.[26]

Not all mining accidents occur in the mine. In 1875, Jacob R. Correll, Jr, the mine's superintendent and son of the original owner, was killed in an unusual mining-related accident.

> "Jacob R. Correll, Jr., was the Superintendent of the Correll Mine near Friedensville. In the forenoon of yesterday he ran out of powder. Hitching up his family

horse he drove up to the Uberroth mines to borrow some from Capt. [Richard W.] Pascoe. In the carriage with him was Ruben T. Trumbower. . . . While driving . . . on the main street of Friedensville, the bit parted at the binge joints and the horse was thus placed beyond the control of the driver, Mr. Correll. Mr. Trunbower was the first to leave the carriage. He jumped out at the back. In doing so he fell heavily on the back part of his head and badly fractured his scull [*sic*]. . . . He died within three-quarters of an hour. Mr. Correll . . . proceeded to escape in the same manner. He also fell very heavily. He was but slightly injured about the head, but fatally internally. He suffered great agony . . . until he breathed his last at 8:30 last evening."[27]

The New Hartman Mine

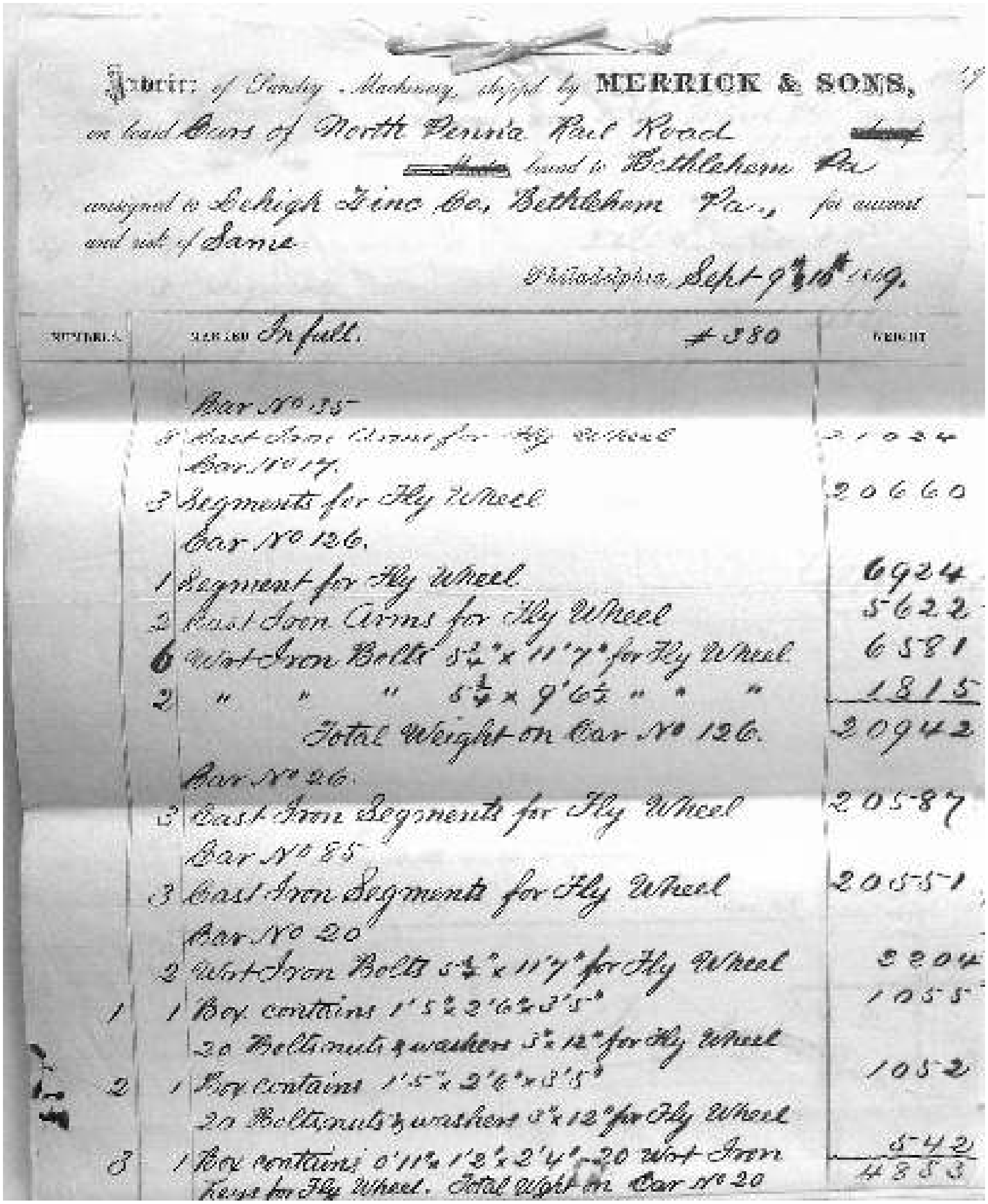
The New Hartman Mine was the westernmost of the three mines close to the village of Friedensville. The ore body was a continuation of that mined in the Correll Mine and was almost exclusively sphalerite. Access to the mine was provided by a 110-foot-deep shaft located close to the property line with the Correll. The mine opened in 1872. By the time the mine closed in 1893, the ore was being worked at a depth of 200 feet. The ore zone being mined was fifty feet in width and, as reported at the Correll, twelve feet thick and dipping to the south and west. From 1881 to 1885, the ore was shipped to the Bergan Point Zinc Company. The Friedensville Zinc Company constructed a roaster and oxide plant at the New Hartman. From 1886 to 1893, the ore was processed in the oxide plant and smelter in Friedensville. The mine continued to operate until 1893, when all mining ceased in the district.[28]

Pumping Water from the Mines

All of the mines at Friedensville were plagued by the constant inflow of water from the surrounding porous limestone and dolomite. The problem was particularly severe at the Uberroth. By the time the mine had reached 150 in depth, attempts to control the water with small pumps proved inadequate. In the late 1860s, Lehigh Zinc and Iron Company decided to erect what would prove to be the largest Cornish-type, walking-beam pumping engine in the world.

The massive engine alone weighed 650 tons. The steam boilers, pumps, and associated equipment raised the total weight of the installation to over 1,000 tons.[29] The engine was designed by John West, an engineer for Lehigh Zinc and Iron. It was constructed by Merrick & Sons' Southwork Foundry of Philadelphia. The pumps were manufactured by the I. P. Morris Company of Philadelphia. It was called "The President" in honor of President Ulysses S. Grant and was intended eventually to pump seventeen thousand gallons per minute from a depth of three hundred feet.

The specifications of the pumping engine were impressive: 3,000 horsepower; a 110-inch steam cylinder; a ten-foot stroke; twelve strokes per minute; four walking beams, each weighing twenty-four tons; two flywheels, thirty-five feet in diameter and weighing seventy-five tons each; and a cost of $350,000. The engine foundation was built on bedrock sixty feet below the surface. The pump shaft, located immediately outside the engine house, measured thirty feet by twenty feet and contained two pump rods, each two feet by three feet. Four thirty-inch lift pumps and four thirty-inch plunger pumps, each with a ten-foot stroke, were attached to the pump rods. The engine was powered by sixteen boilers located in a building adjacent to the engine house.[30] Most of the stone portions of the huge fifty-six by forty-five foot rectangular stone engine house, with its walls up to nine feet thick, still stand as a testament to this engineering accomplishment.



Invoice of Sundry Machinery, shipped by MERRICK & SONS,
on board Cars of North Penn'a Rail Road
bound to Bethlehem Pa
consigned to Lehigh Zinc Co, Bethlehem Pa., for account
and risk of Same
Philadelphia, Sept 9 & 10th 1869.

NUMBERS	MARKED In full. #380	WEIGHT
	Car No 35	
	5 Cast Iron Arms for Fly Wheel	21024
	Car No 17.	
	3 Segments for Fly Wheel	20660
	Car No 126.	
	1 Segment for Fly Wheel	6924
	2 Cast Iron Arms for Fly Wheel	5622
	6 Wrt Iron Bolts 5½" x 11' 7" for Fly Wheel	6581
	2 " " " 5¾ x 9' 6½ " " "	1815
	Total Weight on Car No 126.	20942
	Car No 46.	
	5 Cast Iron Segments for Fly Wheel	20587
	Car No 85	
	3 Cast Iron Segments for Fly Wheel	20551
	Car No 20	
	2 Wrt Iron Bolts 5¾ x 11' 7" for Fly Wheel	2204
1	1 Box contains 1' 5" x 2' 6" x 3' 5" 20 Bolts, nuts & washers 5" x 12" for Fly Wheel	1055
2	1 Box contains 1' 5" x 2' 6" x 3' 5" 20 Bolts, nuts & washers 5" x 12" for Fly Wheel	1052
3	1 Box contains 0' 11" x 1' 2" x 2' 4" - 20 Wrt Iron Keys for Fly Wheel. Total Weight on Car No 20	542 4853

Bill of Lading for "The President" pumping engine. (From the Lehigh Zinc Company Records Collection, Moravian Archives. Courtesy of Moravian College.)

The engine operated continuously from its dedication, on January 29, 1872, until the Uberroth Mine closed on October 28, 1876. It was operated again in 1890-91 for a short period of time to dewater neighboring mines. When the Uberroth was producing ore, pumping costs were estimated to be four to six dollars per ton, although this could have been reduced somewhat had the mine operated for more than one shift per day. Even though the pump usually operated well below capacity, a negative effect of the pumping was that springs, creeks, and wells within several miles of the mine went dry.[31]

It is possible to get a sense of what it was like underground at the Uberroth from the account of a *New York Times* reporter who visited the mine in 1873 while doing a story on the zinc plants, mines, and The President. Unlike most miners and visitors, he chose to enter the mine via the pump shaft rather than by the ladders on the sides of the pit.

> "I went down into this terrible-pumping shaft [of The President], and I am bound to say that there is little poetry in making such a venture. It is blacker than the darkest night down there, and the only light comes from the fitful glare of the little miner's lamp stuck on the peak of your hat. The means of descent is the very simple one of a series of common rung ladders, landing on very small stagings and descending first in one direction, then in the other. The rungs are all wet and slippery,

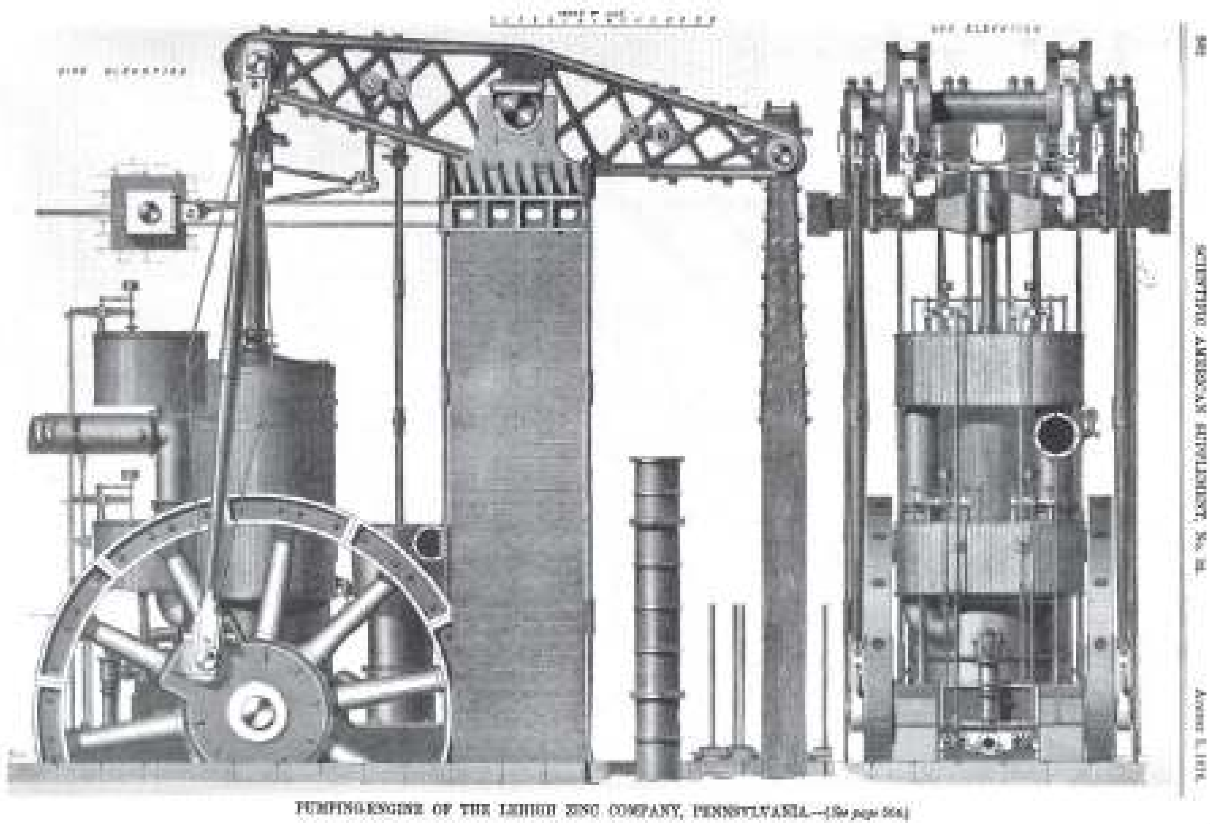


Diagram of "The President" pumping engine. (From "Pumping Engine at the Lehigh Zinc-Works, Friedensville, Pennsylvania," Scientific American *Supplement 1, no. 32, August 5, 1876, (New York: Mumm and Co. Publishing, 1876).)*

as may be expected, and you have literally to feel your way down with your hands and feet. One false step and it would be all up . . . . The noise of the pumping in the shaft—which is only 34 feet square [the actual dimensions were 30 by 20 feet] though 150 feet deep—is very great and confusing, and the streams of drippings find their way down your neck with wonderful ingenuity and perseverance.

We tramped about the mine, candle in hand, for an hour or two, every now and then almost getting wedged in in the narrow galleries, and I gradually accumulating a headache from striking my cranium against the numberless balks of heavy timbers with which the galleries are shored up. I saw the splendid rich veins of carbonate and silicate of zinc, and veins and pockets of the blend or sulphuret of zinc. It sparkled like diamonds in the half light of our farthing dip candles. And then my companion asks me if I could do some rough climbing. "Aye, aye, Sir," I reply, and away he goes again. We climb up an almost perpendicular pile of boulders till we reach a long tunneled hole, through which I just manage to squeeze, and we crawl along at full length till we come to a shoot-up braced with heavy logs. Here again we have a tight squeeze for it, and the sharp fibres of the ore make it nasty work for the hands. At last we see our way into a low, narrow gallery, and sliding down we are once more on our feet, and pushing through some six inches of slush. But we come to the old pumping apparatus which, though still in use and of great magnitude, is a dwarf when compared with the giant finished a year ago; and there is more light, and I fancy I can see more of the workings of the pumps. Back we struggle the same way we came, and when we emerge into daylight we find that we are covered with mud enough to fill a New York street-cleaning car—hands, face, overall suit—everything.

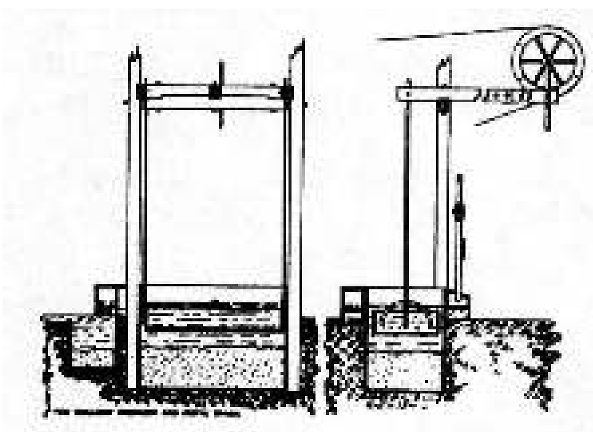
While down in the mines I saw one of those magnificent, powerful and ingenious Burleigh drills in operation. These drills can be taken down and re-erected in another spot in fifteen to twenty minutes, and when put up, they will drill several holes for blasting without the necessity of removal, the particular gearing of the machine admitting the drill being moved horizontally to the extreme length of its beam. The drill can also be turned to drill upward, or downward, or at any angle. By the ordinary process of hand labor it would take three hours to drill a hole three feet deep. The Burleigh drill does the work in twenty minutes. . . .

Interesting as are the mines themselves, I must confess that the big engine was my *piece de resistance*. . . . The engine not only reflects great honor on the company's engineer [John West], who designed it, but redounds to the credit of the company who had the pluck to make so costly an investment, from which capitalists may have well shrunk, and at which some would have stood aghast."[32]

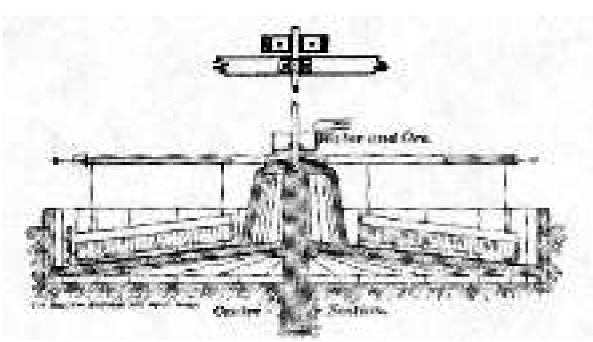
Ore Processing

Ore processing methods were similar at all of the mines in Friedensville. The two types of ore, the near-surface oxidized ore and the deeper sulfide ore, each required a different type of processing. Initially, only the oxidized ore was sent to the smelter. The sulfide ore was discarded. Later, heap roasting of the sulfides was started at the mines and roasting furnaces were used at the smelter to eliminate sulfur.

When the oxidized ore arrived on the surface, large pieces were broken with sledge hammers. Pure pieces were hand sorted and sent directly to the zinc works. Ore containing clay and fragments of limestone was cleaned using log washers, trammels, and screens. Hand sorting was used again to remove impurities from the coarse material before the concentrate was shipped to the zinc works. In the mid-1870s, hand-operated jigs and, later, mechanically powered jigs were used to increase the zinc content of the coarse concentrates. Buddles were used to make a primary concentrate from fine material. An intermediate fine concentrate was reprocessed back through the buddles, and waste tailings were disposed in settling ponds.[33]



Mechanical jig of the type used at the Friedensville mines. (From: H. K. Landis, "Zinc Mining." Metal Mining and The Colliery Engineer *XVII, No. 2, September 1896, (Scranton: Colliery Engineer Company, 1897).)*



Buddle of the type used at the Friedensville mines. (From: Landis, "Zinc Mining.")

Most of the sphalerite at Friedensville was the same gray color as the limestone country rock. This made visual separation of ore from waste on picking tables quite difficult and resulted in the loss of significant quantities of zinc. The sulfide ore was crushed and screened. Large pieces of high-grade sphalerite were hand sorted and sent to the smelter where they were roasted in reverbratory furnaces to remove the sulfur before further processing. Less pure pieces of ore were roasted in piles at the mine to remove the sulfur prior to being sent to the zinc works. Fine material containing sphalerite was initially considered waste and discarded. As with oxide ore processing, jigs and buddles were eventually used to separate small particles of sphalerite from the tailings. High zinc losses were reported from processing both types of ore. Because the zinc content of early rock dumps and disposal ponds was high, these waste materials were eventually sold to the smelter for the production of zinc oxide.[34]

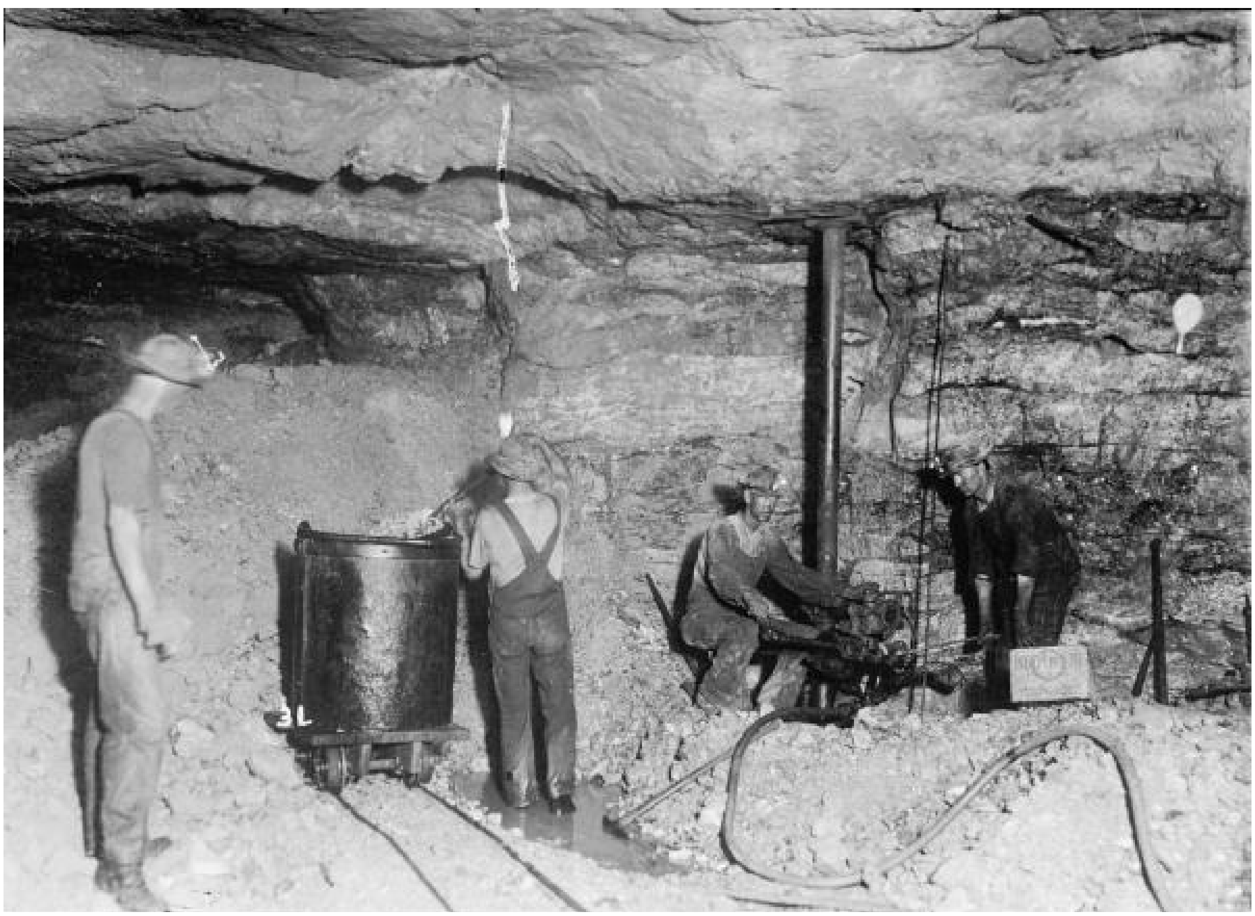
Closure of the Friedensville Mines

The shifting fortunes of the Friedensville mines began in 1876 with the expiration of the Wetherill patents and the closure of Lehigh Zinc Company's mines. While The President succeeded in removing the water from the Uberroth Mine, its high operating cost made mining uneconomic. After Franklin Osgood leased the Correll Mine and later purchased the Lehigh Zinc mines, competition from the lower cost New Jersey ores was fierce. Although it was only occasionally necessary to operate The President at the Uberroth, water was always a problem in the other mines. The historic pumping engine last operated on September 15, 1891. It was sold for scrap in 1892 for ten thousand dollars. The high mining and pumping costs at Friedensville caused all of the mines to finally shut down by 1893.[35]

Rebirth of the Friedensville Mining Area

New Jersey Zinc began acquiring mineral properties in Friedensville in 1899. It purchased the Friedensville Zinc Company through its subsidiary, the New Jersey Zinc Company of Pennsylvania, the operating company for its Palmerton, Pennsylvania smelter. Exploration drilling began almost immediately and indicated a possible extension of the New Hartman orebody. In 1916-17, the New Hartman Mine was dewatered and underground sampling done, but further exploration was delayed until after World War I. Diamond drilling by New Jersey Zinc in 1924 and from 1937 to 1940, and drilling by the U. S. Bureau of Mines during World War II, proved the extension of the New Hartman orebody.[36]

In many historic mining areas, the understanding of the geology improved over time and aided the discovery of additional ore. This was certainly the case at Friedensville. The complex geology was only fully explained over a century after the initial discoveries were made. In essence, the ore deposits were located in certain zones of the limestone and dolomite on the sides and crest of a northeast-southwest trending anticline which plunges to the southwest.[37] The near-vertical veins in the Uberroth Mine followed the strike and dip of the strata on the north side of the anticline. The Old Hartman Mine's veins were in fractures along the crest of the anticline. The ore zones in the Three-Cornered Lot, Correll, and New Hartman mines followed the more shallow dip of the strata on the south side.



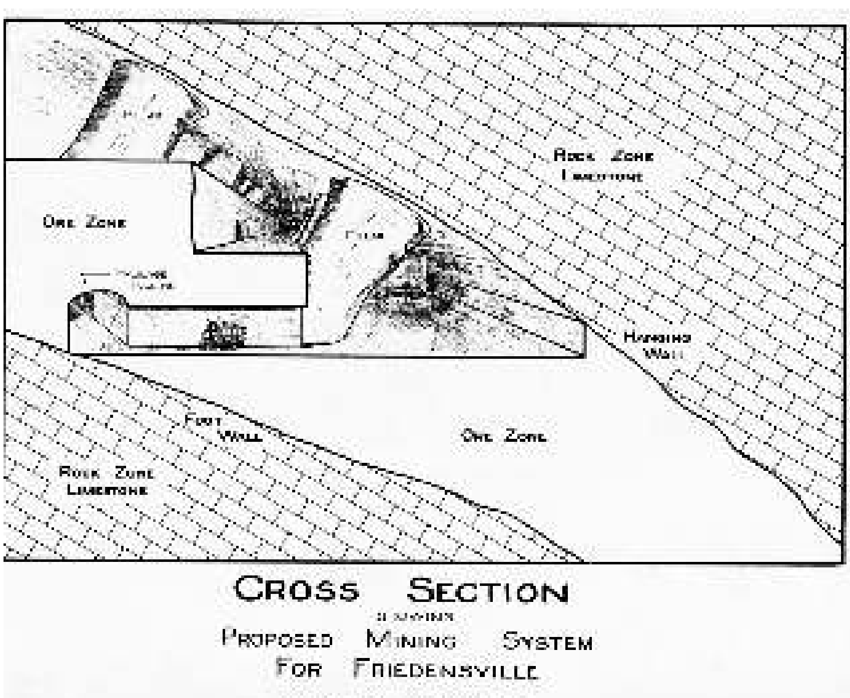
Underground exploration at the New Hartman Mine by the New Jersey Zinc Company, ca. 1916-1917. (Courtesy of the Library of Congress.)

Friedensville Mine and Mill, ca. 1976.
(Courtesy of Ken Cox.)

The Friedensville Mine

In 1945, New Jersey Zinc decided to develop the new Friedensville Mine. The orebody would be accessed by a 1,261-foot-deep shaft that was designed to hoist 2,500 tons per day. Sinking a shaft in the fractured, water-bearing strata was a significant engineering task. The water pressure at the bottom of the shaft was 535 pounds per square inch. Extensive pressure grouting and a reinforced concrete lining were used to seal the shaft. Six shaft stations were cut for crosscut drifts that would extend to the orebody. Three large pumping stations with eight hundred thousand-gallon-capacity sumps were constructed at the 418, 818, and 1068-foot levels. A crusher station was located at the 1121-foot level. Watertight bulkheads were placed on all levels to protect the shaft and pumping stations in the event of mine flooding. Construction of the shaft started on July 1, 1947 and finished on August 24, 1952.[38]

With the shaft completed, the rest of the mine development could proceed. Drifts were driven to the orebody on each level. An ore pass connected each of the mine levels to the crusher station below the 1050 level. A second access to the mine was an incline driven on a 20 percent grade from the bottom of the Old Hartman open pit. It intersected the orebody at the New Hartman Mine workings 275 feet below the surface.



Proposed Friedensville Mine open stope mining system, ca. 1952.
(Courtesy of the New Jersey Zinc Company.)

Scaling loose rock in the Friedensville Mine, ca. 1976. (Courtesy of Ken Cox.)

The incline then followed the footwall in a southwesterly direction as the mine workings expanded downward. It provided access for mobile mining equipment, ventilation, and an alternate escape route.

Mining Method

Mining used a stope-and-pillar design. The ore body was as much as one hundred feet thick in places because bulk mining and flotation processing permitted lower grade ore to be mined. In the upper levels of the mine, at each 25-foot level along the incline, a horizontal drift was driven perpendicular to the incline across the ore body to the hanging wall. From those drifts, lateral drifts which became stopes were driven on 62.5-foot centers. A series of 25-foot benches were used to remove the ore between the footwall and hanging wall. Pillars 25 feet square of ore and rock were left in place to support the workings. Below the 900-foot level, the spacing of the benches was increased to 30 feet, stopes were on 72.5 foot centers, and pillars were 35 by 60 feet.

The initial mining equipment included track-mounted drilling jumbos; rubber-tired front-end loaders; track-mounted, Eimco-type overhead loaders; and ten- to fifteen-ton diesel trucks designed to operate on the steep gradient of the mine workings. The high back (roof) in the open stopes required scaling of loose material and rock bolting. This was accomplished by miners using hydraulic-boom-operated aerial platforms called "giraffes."[39]

Mining started in 1958 and continued downward from the old New Hartman mine workings. As the upper levels were mined out, deeper development work opened up new stopes to mining. A drill-blast-load cycle was followed, with broken muck hauled via the incline to the ore pass on the closest level. The load was then dropped down the ore pass to the crusher station.

From 1971 to 1974, the shaft was deepened to 2,072 feet. Inclines and ore passes connected the lower levels. Front-end loaders and rubber-tired Wagner shuttle trucks were used for ore haulage. Two half-million-gallon sumps were excavated on the 1500 level. The water pressure on the 1850 level was measured at 803 psi. In the late 1970s, a drift was driven from the Friedensville Mine incline to the Old Hartman orebody, but from maps showing the extent of the workings, it appears that little ore was mined.[40]

Pumping Mine Water

Controlling the flow of groundwater that defeated nineteenth century miners was the greatest challenge at the Friedensville Mine. New Jersey Zinc began hydrologic studies in the late 1930s and started groundwater monitoring in 1948. Initially, five three thousand-gallon-per-minute pumps were installed in each of the three pumping stations. A relay pumping arrangement was used, with each station pumping to the station above and the uppermost station pumping to the surface. Pumping capacity was increased as the mine went deeper and water inflows increased. By 1973, the capacity had more than doubled to thirty-one thousand gallons per minute. After the shaft was deepened, the pumping capacity was again raised to forty thousand gallons per minute, with room to expand to fifty thousand.[41]

When pumping started in the 1950s, it caused a severe draw-down of the water table. Many springs and wells in the area dried up. The company paid construction costs for the City of Bethlehem to bring city water to the Saucon Valley. Two water authorities were established to extend water lines to the residents, with temporary

Loading and hauling ore at the Friedensville Mine, ca. 1976. (Courtesy of Ken Cox.)

Underground pumping station at the Friedensville Mine, ca. 1976. (Courtesy of Ken Cox.)

storage tanks provided to water users during construction of the lines. The company also arranged for water authority bonds to finance the projects. Improved fire protection was another advantage of the new water systems.[42]

As a mining engineering student with a summer job at the mine, the author personally experienced the impact of a water emergency at the Friedensville Mine.

> "At 3:00 A.M. on Saturday, August 26, 1961, a power failure due to lightning striking the substation caused the pumps in the underground stations to stop. The bulkheads were sealed to protect the shaft and pump stations from flooding as the mine began to fill with water. The 800 level sumps overflowed and the water rushed down the ore pass until it filled the mine from the 1050 foot level to between the 800 and 900 foot levels. This lower part of the mine was only partially developed at the time. With few open areas, the water level rose fast. It took several hours of pumping at the rate of 26,000 gallons per minute until the water level was back to normal. The after effects of the flood were felt when the hemispherical bulkhead at the ore transfer station could not be opened even with 150 tons of pressure from hydraulic jacks.
>
> Approval was obtained from company headquarters to cut a hole in the bulkhead. When the access hole, about 24 inches in diameter, was completed it was found that fines from the ore pass had washed down and were compacted like a cinder block behind the door. Miners, including two of us college students, were finally able to get behind the bulkhead and use picks, shovels, and a wheelbarrow to dig out the compacted material. It took several shifts to free the bulkhead door so that it could be opened, the transfer conveyor moved into position, and the ore once again [could] be transferred to the crusher.
>
> The flood caused a five day mill shutdown because there was no ore to process. A hatch was installed to cover the hole in the bulkhead and eliminate the need to cut open the door should another similar event occur in the future. Had a second power failure occurred while the door was cut open, the shaft facilities and the mine could have been lost."[43]

Ore Processing

In the mid-1970s, the mine was producing 2,000 to 2,200 tons per day of ore containing 6.4 percent zinc. Deep in the mine, on the 1050 level, a pan feeder transferred ore from the ore pass, through a water protection bulkhead, to the crusher, which reduced it to 1.25-inch size. Six-ton skips hoisted the ore to the surface, where it was conveyed to a 2,500-ton storage silo at the mill. Several stages of further crushing, rod and ball mill grinding, and froth flotation were used to separate the sphalerite from the waste tailings. An innovative on-stream X-ray analyzer was installed to improve zinc recovery by monitoring the metal content of the mill feed, process slurries, concentrate, and tailings. The zinc concentrate was filtered, dried, and trucked to the large New Jersey Zinc smelter complex at Palmerton. Some tailings were sent to a limestone processing plant which produced and sold a dolomitic limestone product for agriculture. Other tailings were either sent to a tailings impoundment or occasionally used as mine backfill.[44]

Mine Closure

New Jersey Zinc was acquired by Gulf and Western, Inc., in 1966. In the 1980s, a combination of depressed zinc prices and high pumping costs reduced the operation's profitability. Finally, after nearly twenty-six years of production,

Uberroth Mine with the engine house.
(Author's photograph, 2007.)

the mine was shut down on September 18, 1983. The mine and mill employed 170 workers at the time of closure. The underground workings had extended to a depth of 1,600 feet and wrapped around the west side of the mine office and mill complex. Substantial ore reserves still remained between the last operating level and the bottom of the mine shaft. Once the pumps were stopped, the mine flooded and the water table was rapidly restored.[45]

Friedensville District Production

The records of production from the early period mines, 1853 to 1893, are very limited. For example, it was reported that 300,000 tons of hemimorphite ore were mined at the Uberroth Mine alone from 1853 to 1876. The average ore grade was reported to be 35 to 40 percent zinc. However, no production was reported for sphalerite and a substantial tonnage is believed to have been mined. The grade of hand-sorted sphalerite ore was high, around 45 percent zinc. Other estimates have been made by working backwards from zinc oxide and spelter production data, but that too is very spotty. Based on all the available historical data, a more recent analysis estimated total production to have been 800,000 tons of ore with an average grade of 30 percent zinc. This estimated production is distributed among the individual mines as: Uberroth Mine, 450,000 tons; Old Hartman Mine, 200,000; Correll Mine, 100,000; and Three-Cornered Lot Mine 50,000.[46]

The Friedensville Mine, which operated from 1958 to 1983, produced ore in bulk with no selective mining or sorting as had been done in the mines during the 1800s. It has been reported that the run-of-mine ore grades ranged between 5.5 and 6.5 percent zinc. Production rates also varied over the life of the mine. For example, a dip in production was reported during the deepening of the shaft in the early 1970s. From published data, it is estimated that the mine produced approximately 14 million tons of ore and 760,000 tons of zinc.[47]

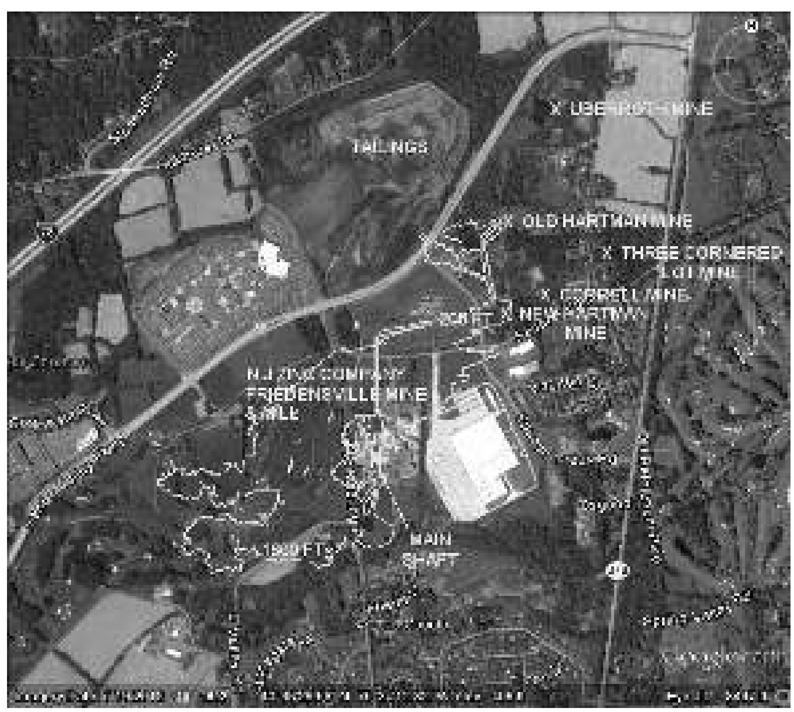
Redevelopment of the Mining District

On May 24, 1984, the Gulf and Western Reality Corp. sold the 1,680-acre Friedensville mining property to the Stabler Land Company, a subsidiary of the Stabler Companies, Inc. Eastern Industries, another Stabler company, announced its intent to sell agricultural lime from the accumulated tailings north of the mining area, a prior practice of the zinc company. Subsequent chemical analyses determined that the tailings contained small amounts of cadmium and arsenic, stopping the sale of the tailings. The tailings area is part of a 755-acre parcel that was given by Stabler to Lehigh University to expand its satellite campus.[48]

Most of the remaining land has been redeveloped. Although the headframe has been removed, New Jersey Zinc's Friedensville mine and mill buildings have been repurposed and look the same as they did when the mine was operating. Immediately to the east of the mine and mill buildings, a warehousing and light industrial park has been built. South of the mine, several housing subdivisions have been developed. North of the mine is the new Penn State Lehigh Valley Center and a swimming facility. The Penn State parking lot and a golf course occupy the area immediately above the underground workings of the mine. The large Promenade Shopping Center has been constructed on the far northwest corner of the property.

Highway 378, the Center Valley Parkway, divides the shopping center and tailings area from the rest of the property. As part of the highway development, a study of the Uberroth Zinc Mine Historical District was conducted.[49] The study documented several of the historic structures still remaining in Friedensville, including the remains of the engine house at the old Uberroth Mine.

Today, a visitor can still see, from a distance, the huge stone engine house once occupied by The President pump at the Uberroth Mine. One can only hope that it will be preserved as an important piece of Pennsylvania's mining and metallurgical history. In the trees just south of the Center Valley Parkway are the water-filled pits of



Aerial view of the Friedensville Mining District showing the historic mine sites and the extent of the Friedensville Mine underground workings at the 1983 closure. (2012 Google Earth background image with annotation by the Author.)

the Old Hartman Mine where the incline for the Friedensville Mine emerged. Other nearby historic buildings include the Friedensville Church, circa 1839; the Jacob Uberroth house, circa 1840, which also served as the residence for the Uberroth Mine's superintendents; and the David Hartman house, circa 1870, near the site of the New Hartman Mine.

Acknowledgements

The author is indebted to several organizations, institutions, and people who assisted this research and the parallel effort to rediscover the history of Richard W. Pascoe, the longest-serving superintendent of the Uberroth Mine. Special appreciation is given to the staffs of the Depart-

Uberroth Mine Superintendent's House, ca. 1840. (Author's photograph, 2012.)

Friedensville Church, ca. 1839. (Author's photograph, 2012.)

ment of the Interior Library, Washington, D.C.; the U. S. Geological Survey Library, Reston, Virginia; the Moravian Archives, Moravian College, Bethlehem, Pennsylvania; the Friends Historical Library, Swarthmore College, Swarthmore, Pennsylvania; and the public libraries of Allentown, Bethlehem, and Easton, Pennsylvania.

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Notes:

1. Only a few authors wrote about the discovery and development of the deposits at Friedensville during the time that the mines were actually in operation in the 1800s: F. L. Clerc, "The Mining and Metallurgy of Zinc in the United States," *Engineering and Mining Journal* XXXVI (8 Sep. 1883): 148-9; H. S. Drinker, "The Mines and Works of the Lehigh Zinc Company (abstract)," *Transactions of the American Institute of Mining Engineers* I (New York: AIME, 1871), 67-75; William C. Reichel, *The Crown Inn, near Bethlehem, Pennsylvania, 1745* (Philadelphia: Printed for E. P. Wilbur and Others, 1872), 141-4 (contains accounts of the discovery of zinc ore at Friedensville, the early attempts to work the mine, and statistics of annual yield, as well as an excellent description of Wharton's use of Belgian workers to build and operate the spelter works); John Eyerman, "The Friedensville Zinc Mines," *Engineering and Mining Journal* XXXVI (6 Oct. 1883): 220; John Eyerman, "The Friedensville Zinc Mines," *Engineering and Mining Journal* XXXVI (15 Dec. 1883): 374; M. S. Henry, *History of the Lehigh Valley* (Easton, PA: Bixler and Corwin, 1860), 235-8; "Pumping Engine at the Lehigh Zinc-Works, Friedensville, Pennsylvania," *Scientific American Supplement* 1, no. 32 (5 Aug. 1876): 502-4; A. K. Wittman, G. W. Foering, and M. Cooper, *Prospectus of the Location and Resources of the Lehigh Zinc Mine near Bethlehem, Pa.* (Philadelphia, 1847).

   Subsequent authors have drawn from these works for the historical background on the mining district and the early development of the Pennsylvania zinc industry: J. P. Lesley, "The Saucon Zinc Mines of Lehigh County," *A Summary Description of the Geology of Pennsylvania,* Pennsylvania Second Geological Survey, v.1 (Harrisburg: Board of Commissioners for the Geological Survey, 1892), 436-9; Benjamin L. Miller, "Lead and Zinc Ores in Pennsylvania," Pennsylvania Geological Survey, *Mineral Resource Bulletin M5* (Harrisburg: Department of Forests and Waters, 1924), 54-85; Benjamin L. Miller, "Mineral Resources," *Lehigh County, Pennsylvania Geology and Geography*, *Bulletin C39*, Pennsylvania Geologic Survey, 4th Series (Harrisburg: Department of Internal Affairs, 1941), 326-54; Robert C. Smith, II, "Zinc and Lead Occurrences in Pennsylvania," *Mineral Resources Report 72,* Pennsylvania Geological Survey, 4th Series (Harrisburg: Pennsylvania Geological and Topographic Survey, 1977), 82-149 (includes a copy of an 1847 map of prospecting shafts and mineral occurrences at Friedensville from Wittman et. al., *Prospectus*); Donald I. Bleiwas and Carl DiFrancesco, "Historical Zinc Smelting in New Jersey, Pennsylvania, Virginia, West Virginia, and Washington, D.C., with Estimates of Atmospheric Zinc Emissions and Other Materials," U. S. Geological Survey, Open File Report 2010-1131 (Washington, D.C.: USGPO, 2010), 36-48, 59-69, 95-7 (smelters using Friedensville ores and the mines are described).

2. Miller, "Mineral Resources," 327.
3. Patent 13866, 13 Nov. 1855, Samuel Wetherill, Improvement in Process for Making Zinc White (www.google.com/patents/US13806?pg=PA1&dq=13806&hl=en&sa=X&ei=nlSlULnqN8iM0QG9qYDICQ&ved=0CDQQ6AEwAA#v=onepage&q=13806&f=false, accessed 15 Nov. 2012). Wetherill's furnace design for roasting zinc ore to produce zinc oxide was used in conjunction with Samuel T. Jones' patent for collecting zinc oxide in fabric bags.
4. Patent 8756, 24 Feb. 1852, Samuel T. Jones, Improvement in the Manufacture of Zinc White (www.google.com/patents/US8756?dq=8,756+Jones&hl=en&sa=X&ei=CVilUOPdL9C80AHUh4CICw&sqi=2&pjf=1&ved=0CDQQ6AEwAA, accessed 15 Nov. 2012). Jones' patent for collecting zinc oxide in cloth bags in bag houses was used in conjunction with Samuel Wetherill's furnace patent to form the Wetherill Process, also called the American Process. W. R. Ingalls, "History of the Metallurgy of Zinc," *Transactions of the American Institute of Mining Engineers* (New York: AIME, 1937), 339-73. The evolution of zinc metallurgy in Europe and America is described. Ingalls cites the European retorting process for the recovery of zinc metal and the Wetherill Process for making zinc oxide as the two most important technological inventions in the industry.
5. Pete J. Dunn, "Mine Hill in Franklin and Sterling Hill in Ogdensburg, Sussex County, New Jersey: Mining History, 1765-1900," Final Report: pt. 1, v. 5, (Alexandria, VA: Self-Published, 2004), 677-96. The author describes the development of the zinc oxide and spelter industry in Bethlehem and the mines in Friedensville, PA, and their relationship to the New Jersey mines and smelters.
6. Henry, *History of the Lehigh Valley*, 236.
7. W. Ross Yates, *Joseph Wharton, Quaker Industrial Pioneer* (Bethlehem, PA: Lehigh University Press, 1987), 70-113.
8. Yates, *Joseph Wharton*, 80.
9. "Joseph Wharton Family Papers (1691-1962)," Friends Historical Library, Swarthmore College, Swarthmore, PA (Joseph Wharton's letter books and other files in the collections contain correspondence between Wharton and Richard W. Pascoe); Letterbooks, "Records of the Lehigh Zinc Company (1841-1881)," Moravian Archives, Moravian College, Bethlehem, PA (the letterbooks contain numerous pieces of correspondence between Pascoe and officials of the Lehigh Zinc Company regarding mine operational matters, all from the second period of his employment at the mine); L. Michael Kaas, "Richard W. Pascoe, Mining Superintendent," *Mining History Journal* 21 (2014): 30-49; "Tax Lists, Upper Saucon Township, Lehigh County, PA, 1858-1880," Lehigh County Historical Society, Allentown, PA.
10. Yates, *Joseph Wharton*, 81.
11. Yates, *Joseph Wharton*, 83; Wharton, letter to Pascoe, 28 Jan. 1857, Wharton Family Papers.
12. Ingalls, "Metallurgy of Zinc," 344. Thomas P. Kettel, "Mining Industry of the United States," in *First Century of National Existence; the United States as they Were and Are*, (Hartford: L. Stebbins, 1875), 96-107. Yates, *Joseph Wharton*, 96 (gives details about Wetherill's and Wharton's experiments to make spelter with different types of furnaces; Wetherill's attempts with Silesian and Carinthian furnaces failed while Wharton's Belgium furnaces were successful).
13. Yates, *Joseph Wharton*, 85-6.
14. Joseph Wharton, "Memoranda Concerning the Introduction of the Manufacture of Spelter into the United States," *American Journal of Science and Arts* (third series) II, no. IX (1871): 168-76 (Wharton describes his role in the early production of spelter, metallic zinc, at the Pennsylvania and Lehigh Zinc Company, Bethlehem, PA); Reichel, *Crown Inn*, 143-4.
15. Yates, *Joseph Wharton*, 98, 105; "Sanborn Fire Insurance Map: Bethlehem and South Bethlehem, Pennsylvania," Sheet 7 (New York: Sanborn Map and Publishing Company, 1885). The Lehigh Zinc and Iron Company's zinc oxide plant and Wharton's spelter plant appear in detail on this map.
16. Yates, *Joseph Wharton*, 112.
17. "The Approaching Abandonment of the Great Zinc Mine at Friedensville, PA," *Engineering and Mining Journal* XXII (30 Sep. 1876): 216.
18. Dunn, "Mine Hill," 684-95; New Jersey Zinc Company, *The First Hundred Years of the New Jersey Zinc Company* (New York: New Jersey Zinc Co., 1948), 17-25.
19. Miller, "Lead and Zinc Ores," 54-9; Miller, "Mineral Resources," 327-30, 351-2.
20. Miller, "Lead and Zinc Ores," 57, 65, 77-80; Miller, "Mineral Resources," 348, 351-3.
21. Kaas, "Richard W. Pascoe," 42.
22. Smith, "Zinc and Lead Occurrences," 145.
23. Miller, "Lead and Zinc Ores," 80-2; Miller, "Mineral Resources," 348, 353.
24. Miller, "Lead and Zinc Ores," 83-4; Miller, "Mineral Resources," 354.
25. Clerc, "Mining and Metallurgy of Zinc," 149; Miller, "Lead and Zinc Ores," 57, 82-3; Miller, "Mineral Resources," 329-30.
26. Smith, "Zinc and Lead Occurrences," 88; Miller, "Lead and Zinc Ores," 82; Miller,"Mineral Resources," 353.

27. "The Sad Accident at Friedensville," *Bethlehem Daily Times*, 21 Dec. 1875.
28. Miller, "Lead and Zinc Ores," 82-4; Miller, "Mineral Resources," 353; H. K. Landis, "Zinc Mining," *Metal Mining and The Colliery Engineer* XVII, no. 2 (Sep. 1896): 63-4; Bleiwas and DiFrancesco, "Historical Zinc Smelting," 38.
29. Bill of lading for engine parts, "Records of the Lehigh Zinc Company (1841-1881)," Moravian Archives, Moravian College, Bethlehem, PA; "Pumping Engine at the Lehigh Zinc Works," 502-4.
30. "The New Pumping Engine of the Lehigh Zinc Company," *Engineering and Mining Journal* XIII (30 Jan. 1872): 65-6 (includes the speech of B. C. Webster, Lehigh Zinc's president, at the ceremony starting "The President"); "A Mammoth Pumping Engine," *Engineering and Mining Journal* XIII (30 Jan. 1872): 73 (cites The President as an example of a judicious management decision and skillful engineering); "Bethlehem," *Engineering and Mining Journal* XIII (21 May 1872): 239 (reports on the success of the new pumping engine in the months after its installation); Clerc, "Mining and Metallurgy of Zinc," 148-9; Drinker, "Mines and Works," 68-71; Miller, *Lead and Zinc Ores*, 74. "Pumping Engine at the Lehigh Zinc Works," 502-4; "Zinc Mining. The Lehigh Company's Mines at Friedensville, Penn.—The Largest Stationary Engine in the World," *New York Times*, 26 Apr. 1873.
31. Miller, "Lead and Zinc Ores," 74.
32. Anon. "Zinc Mining."
33. Drinker, "Mines and Works," 71-2; Miller, "Lead and Zinc Ores," 75-6; Miller, "Mineral Resources," 349-50; Landis, "Zinc Mining," 62-4 (describes the ore processing flowsheets at the Correll and New Hartman Mines in the greatest detail with a discussion of the use of jigs, buddles, and picking tables).
34. Drinker, "Mines and Works," 71-2; Miller, "Lead and Zinc Ores," 75-6; Miller, "Mineral Resources," 349-50; Landis, "Zinc Mining," 62-4.
35. Nadine Miller Peterson and Dan Zagorski, "Zinc Mining in the Saucon Valley Region of Pennsylvania, 1846-1986," *Canal History and Technology Proceedings* XX (Easton: Canal History and Technology Press, National Canal Museum, 2001), 159 (sale of The President is described).
36. M. S. Childs, "Geology and Development at Friedensville, Pennsylvania," *Mining Engineering* 9 (Jan. 1957): 57; *First Hundred Years*, 25; Miller, "Mineral Resources," 330; Clyde B. White and James E. Bell, "Correll Zinc Mine, Lehigh County, Pa.," U. S. Bureau of Mines, *Report of Investigations 4180*, (Washington, D. C.: USGPO, 1948), 1-8.
37. W. H. Callahan, "The Geology of the Friedensville Zinc Mine, Lehigh County, Pennsylvania," in: John D. Ridge (ed.), *Ore Deposits of the United States, 1933-1967, the Graton-Sales Volume,* v. 1 (New York: AIME, 1968), 95-107; R. W. Metsger, A. H. Willman, and C. G. Van Ness, "Field Guide to the Friedensville Mine of the New Jersey Zinc Company" (Geological Society of America, field guide for Northeastern Section Meeting at Allentown, Pennsylvania, New Jersey Zinc Company, 1973), 7-14; Smith, "Zinc and Lead Occurrences," 82-8, 102-11, 140-9.
38. Childs, "Geology and Development," 58-60. Warren Hastings, "The Friedensville Development," *Mining Engineering* 5 (Dec. 1953): 1214-5; Warren Hastings, F. J. Kane, and F. D. Wright, "Methods and Costs of Sinking a Shaft through a Fractured, Water-bearing Formation at Friedensville, Pa.," U. S. Bureau of Mines, *Information Circular 7680* (Washington, D.C.: USGPO, 1954), 1-18; Mayo Lanning, Coopersburg, PA, personal communication, 2012 (Lanning started work at Friedensville as a mining engineer during the sinking of the shaft and rose to become mine captain).
39. Childs, "Geology and Development," 59; New Jersey Zinc Company, unpublished report, 1960, 1-25; Metsger, "Field Guide," 14-6; Kenneth R. Cox, "Hydrogeological Problems and Their Resolutions at the Friedensville Mine," in: George O. Argall, Jr. and C. O. Brawner (eds.), *Mine Drainage: Proceedings of the First International Mine Drainage Symposium, Denver, Colorado, May, 1979* (San Francisco: Miller Freeman Publications, 1979), 620; Lanning, personal communication.
40. New Jersey Zinc Company, unpublished set of final mine maps from the time of mine closure, 1983; Metsger, "Field Guide," 16; Cox, "Hydrological Problems," 619. The maps were provided by the Upper Saucon Township Office, Coopersburg, PA. They show the full extent of the mine on all levels, the incline extension to the Old Hartman Mine, and the mine shaft design.
41. Hastings, "Friedensville Development," 1215; Metsger, "Field Guide," 17; Cox, "Hydrological Problems," 620. The Friedensville Mine was the wettest mine in North America. The staff of the mine had to be prepared for water emergencies at any time. Cox describes two instances in which severe inflows of water caused parts of the mine to flood.
42. Childs, "Geology and Development," 60; New Jersey Zinc Company, unpublished report, 1960, 16.
43. L. Michael Kaas, unpublished report of summer work experience at the Friedensville Mine, 1961.
44. J. R. Pellett and W. C. Spence, "Milling Practice at the Friedensville Mine," in: D. O. Rausch and B. C. Mariacher (eds.), *AIME World Symposium on Mining and Metallurgy of Lead and Zinc*, v. 1, (New York: AIME, 1970), 467-82; Metsger, "Field Guide," 17; New Jersey Zinc Company, "Horsehead Dolomitic Limestone," undated product brochure, ca. 1970.
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46. Clerc, "Mining and Metallurgy of Zinc," 149; Miller, "Lead and Zinc Ores," 59, 77; Smith, "Zinc and Lead Occurrences," 103.

47. Metsger, "Field Guide," 17; Smith, "Zinc and Lead Occurrences," 103. U. S. Bureau of Mines, *Minerals Yearbook*, v. 1 (Washington, D.C.: USGPO, 1958-83). Production from the Friedensville Mine is estimated from published data and from assumptions regarding average ore grade and mill recovery rates.

48. Bob Sharp, "Land Company Buying Friedensville Mine," *Allentown Morning Call*, 8 June 1984 (describes the purchase of 1,680 acres by Stabler from Gulf and Western); Andrew McGill and Scott Krause, "Stabler's Land Gift to Lehigh Contains Contaminated Mine Refuse," *Allentown Morning Call*, 11 May 2012.

49. Frank Whelan, "U. Saucon Zinc Mine Area has Historic Past," *Allentown Morning Call,* 7 Mar. 1999 (describes the study of the Uberroth Zinc Mine Historic District that was necessary to obtain approval to upgrade the Saucon Valley Parkway); Peterson and Zagorski, "Zinc Mining in the Saucon Valley," 139-62 (covers research necessary for placing the Uberroth Zinc Mine Historic District in Friedensville on the Pennsylvania Register of Historic Places; several remaining historic structures are described).