The Story Of Ironmaking Bloomery Forges At Picatinny Arsenal

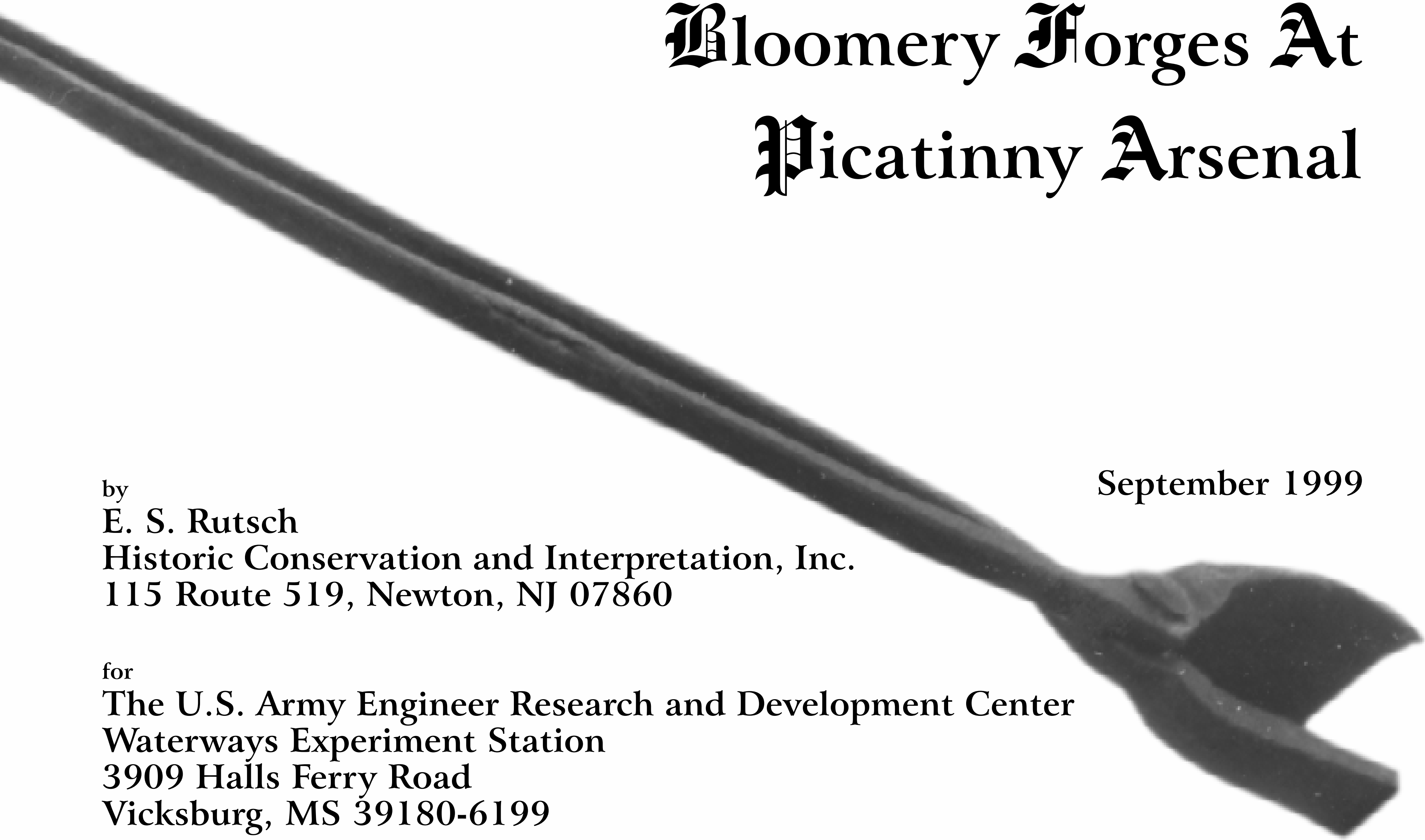

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FIGURE 1. Middle Forge Tools Monument - Hand tools, forge hammerhead, and anvil base found when the Army rebuilt the Aetna or Middle Forge's Dam in the early 20th century. This formed today's Picatinny Lake. The monument is located at the Arsenal Administration Building

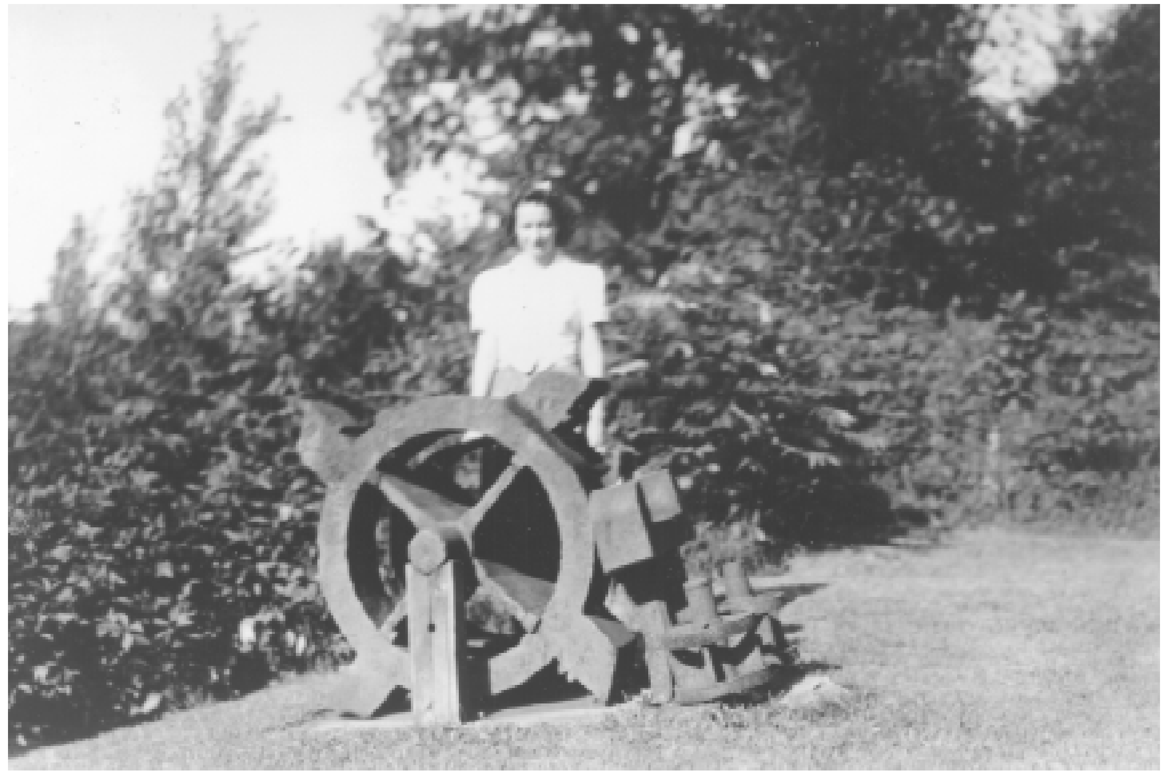

FIGURE 2. Iron forge parts taken from the Denmark Forge site when the pond's dam was enlarged by the Army in the early 1900s. Included is the combination iron cam ring and gudgeon that lifted the forge's heavy hammer helve (Clyde Potts photo collection, 1936-38).

Acknowledgements

A good deal of the document gathering that went into this project was accomplished by my colleague Brian Morrell, who prepared the annotated bibliography that is associated with our research. Our work and its products were carefully improved by the attention and encouragement of Dr. Frederick L. Briuer of the U.S. Army Engineer Research and Development Center Waterways Experiment Station (WES) in Vicksburg, MS. The initial concept and organization of this project was the work of Roselle Henn, a supervising archeologist with the Corps of Engineers in the New York City Regional Office.

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Edward Rutsch

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This is the story of ironmaking at Picatinny Arsenal, a story of a very special place and some of the ways its people and environment have interacted and developed. It would be fair to say that this is a record of man's hand on the land. It is also one part of the story of how people changed as they successfully adapted their Old World methods to the New World environment. From this adaptation a new culture grew, was successful, and has flourished. So, this is part of the story of how we became different than the people we came from. It is a story that illustrates an aspect of how we have become Americans.

The Picatinny Arsenal tract of land was valuable to our historic forebears because of its abundant forest and iron ore. In order to exploit these two resources, a number of other obstacles such as the scarcity of local productive farmland, a decent transport system, and the scarcity of skilled labor, had to be overcome. This is also a story of that struggle.

Because some historically accurate but generally obscure ironmaking terms are used, a glossary has been prepared for the reader's use and is presented after the text. In addition, since this general synthesis is based on a number of detailed historical sources, a selective bibliography of such materials is also presented for those who wish to pursue the subject in greater depth.

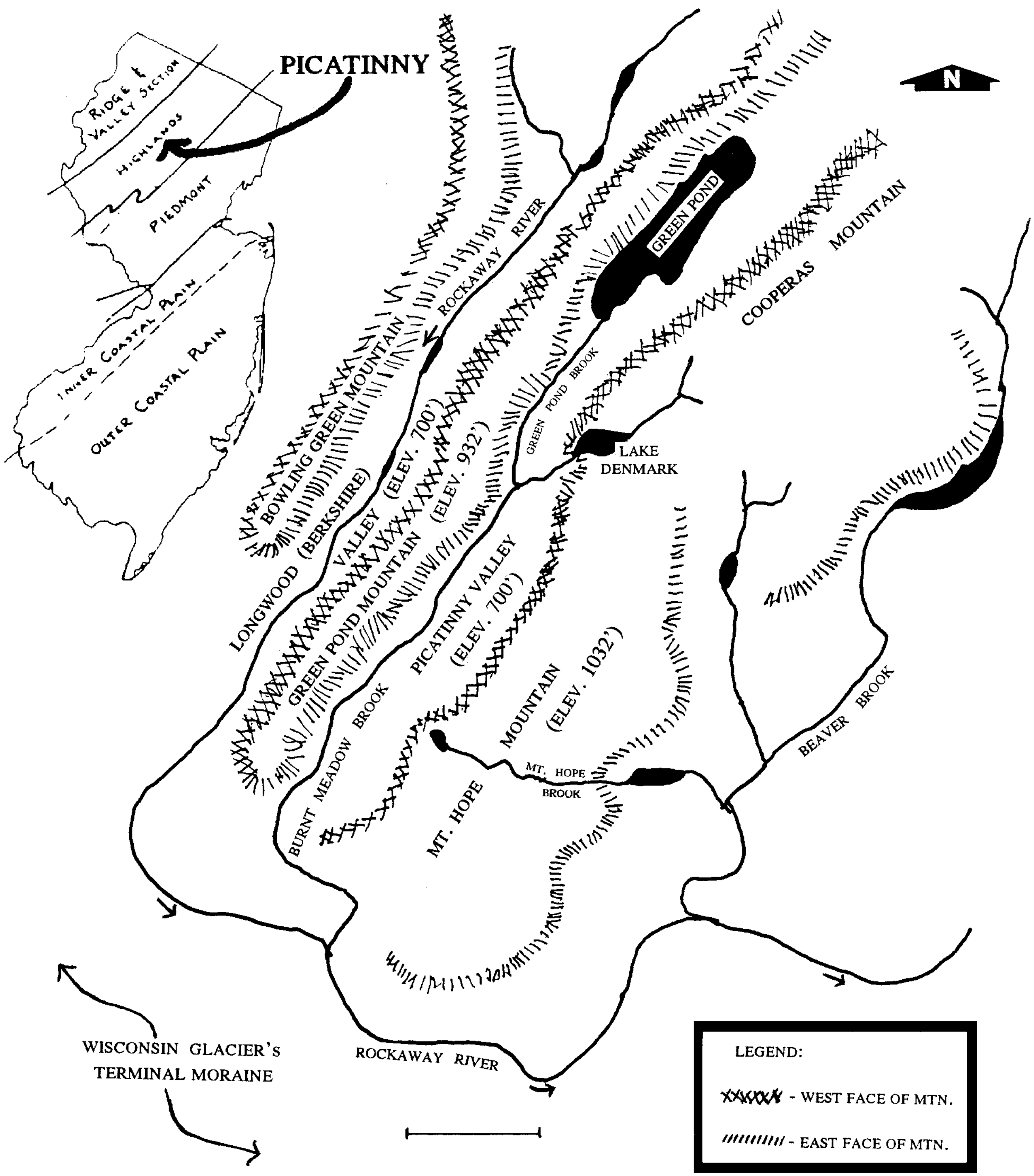


FIGURE 3. Physiographic map of New Jersey. The small diagram on the left shows New Jersey's five physiographic regions. Both diagrams show the Highlands, part of the Reading Prong of the New England Uplands, and the approximate location of Picatinny Arsenal (Wacker 1975:3).

The Natural Setting

Picatinny Arsenal is located in “the Highlands” physiographic region of northern New Jersey. The area is part of a prong of the New England Uplands that extends southwesterly from Bear Mountain, NY, to Reading, PA (see Figure 3). The North Jersey Highlands region with its stone walls, small farms, and villages is much like the rural areas in the New England states that are located to the northeast along a very old and worn chain of mountains.

This rugged landscape was created by glaciers that formed during the Pleistocene epoch. Also known as the Ice Ages, this period ended approximately 10,000 years ago. Then temperatures became so cold that massive sheets of ice, or glaciers, covered much of North America. It is known today that there were four separate glacial ice periods. Glaciers associated with each period, estimated to be at least a mile thick, moved south, grinding down the mountains and pushing a tremendous amount of dirt and stone.

The last, or Wisconsin glacier, came as far south as Picatinny Arsenal. As the glacier moved, it ground and reduced stone to a mixture of gravel, sand, and clay known as glacial till. The glacier’s terminal moraine, a massive deposit of glacial till, formed at its southernmost reach. This massive deposit of rocks, gravel, and sand is called the glacier’s terminal moraine. The land north of the moraine, where Picatinny Arsenal is located, lost almost all of its soil through the process of scraping and gouging. But as the massive glacier retreated, the streams emanating from the melting ice left wave-like deposits of loose till. Today travelers are on the terminal moraine of the Wisconsin glacier when they take Interstate 80 or NJ Route 46.

European Settlement

European settlement of northern New Jersey was strongly influenced by the glacier, with distinct differences in settlement and land-use patterns to the north and south of the terminal moraine. These differences in the cultural landscape of Morris County above and below the Route 80 corridor are still apparent. Initial settlement in northern New Jersey was concentrated in the coastal areas below the glacial moraine where the soil had not been scraped away. This was because the vast majority of colonists were farmers and the accumulated soil could be broken to the plow once the forests were cleared.

A COLONIAL EVALUATION OF A HIGHLANDS AREA SIMILAR TO PICATINNY

In the 1760s, the East Jersey proprietors had a 6,000-acre furnace tract surveyed on the Pequannock River just northeast of Picatinny. The surveyors reported that the land was generally well-timbered, but mentioned two features of interest. First, an estimated 500 acres were too rough to grow trees and so had to be considered barren. Second, in the entire piece of land, they found no more than 50 acres of plow land. The surveyors also reported several good-sized swamps. This tract, called Charlotteburg by its new masters, did serve as the fuel source for a blast furnace and a multi-fired forge of the same name.

More can be learned about this ironworks by reading or by riding north on NJ Route 23 from the Smoke Rise area to where the ironworks was located (the town of Stockholm). The tract along the valley is now reforested watersheds and in that way, must be like the colonial landscape. Note the lack of farmland and imagine Charlotteburg and Oak Ridge reservoirs as cedar swamps. The rough land still has no trees. Consider the Pequannock as the major potential power source in the area. Finally, by erasing the highway and railroad remains from the mind’s eye, the presettlement landscape can be recreated.

ESTIMATES OF CHARCOAL USE IN COLONIAL IRONMAKING

During the 1700s the smallest and most common iron smelter in the North Jersey Highlands was the two-fire, one-hammer bloomery forge. Statistics on raw materials used, labor employed, iron produced for specific forges, and the iron region in general are very hard to come by. However, the primary records of the colonial ironmakers give a much clearer idea of the amount of charcoal that was required by a bloomery forge, and the land needed to produce it.

From the records studied to date, it is estimated that 400,000 bushels of charcoal would be needed in order to make 100 tons of good quality wrought-iron "merchant bars." The wood needed to produce this fuel would come from 250 acres of timber at least 20 years old. Cutting woods every 20 or 25 years was called coppicing and young trees were the best size for colliers to char. Like slash-and- burn agriculture, a new section was harvested every year and then left to grow up again for 20 years. To cut 250 acres per year for 20 years, a charcoal tract of 5,000 acres would be necessary. In addition, the tracts, which also included the farm and forge pond, produced construction timber and heating fuel. Timber production was also subject to soil fertility, climatic variations, and fires. By the 1800s most local ironmakers purchased at least part of their fuel or had the fuel produced by contractors who secured ax men, teams, and colliers to work on what they called "jobs" of 50 acres each.

Settlers tended to avoid the Highlands region north of the terminal moraine because there was little fertile soil in this glaciated area. Europeans who traveled into the region were keen to find anything that could be traded profitably with Europe, however. These individuals searched for natural resources, the most eagerly sought being gold and precious gems, while they made their living trading furs with the Native Americans.

New Jersey Highlands Iron Industry

The most important resources discovered in the Highlands were iron ore and timber. These were the raw materials for making iron, and they played a major role in the permanent settlement of the Picatinny Arsenal region. Colonial ironmasters moved on to what is now the Picatinny Arsenal Tract to exploit its abundant resources, and three ironmaking establishments, referred to as forge farms, were developed on Burnt Meadow Brook.

Resources

Iron ore, timber for charcoal, and water power for driving machinery were the resources needed to produce iron. All three of these resources were readily available in the Highlands area. Initially high quality iron ore deposits lay close to the surface, so that they could be easily mined. The region's timber, which could not be shipped to coastal markets because the roads were either too poor or nonexistent, was available to produce the charcoal which, when burned with iron ore, produced iron. Before this iron could be sold or used to make tools, however, it had to be beaten with hammers that were driven by water power.

Iron Ore

While the early explorers never found gold or precious gems, they did find seams of a very rich iron ore called magnetite. These seams were located on the scoured hillsides or at points where geological faults had cracked the underlying stone, and lay exposed ready for easy mining (see Figure 4). The rock holding the iron ore seams was folded or twisted sideways so that the seams were on an almost vertical slant. As Morris County was settled in the mid-1700s, local rich deposits of magnetite iron ore were among the first resources to be tapped through mining and smelting.

Charcoal Fuel

The northern Highlands region, like most of the North American Atlantic coast, was covered in forests. Unlike those in the more fertile coastal area, these forests were not cleared because of the lack of suitable farmland and the difficulties in transporting forest products to market. As a result, local ironmasters had abundant supplies of wood for making the charcoal needed to fuel the intensely hot smelting fire that turned ore into iron.

The Highland forests were intensively managed by the ironmasters to produce charcoal. After the first trees were cut, the forests were allowed to regrow into stands with trunks at the base of the trees less than 10 to 12 in. in diameter. Larger trunks were not desired because they had to be split. Forest tracts were cut on a 25-year rotation that allowed for a more regular return from the forest than would have been the case if only mature trees were used.

The slender trees were cut into 4-ft lengths and split only if necessary and then were sledded or hauled to charcoal kilns for charring (Figure 5). The cooled charcoal was much smaller in weight and volume than the original timber. Specially built coal wagons were used to haul the charcoal to the ironworks.

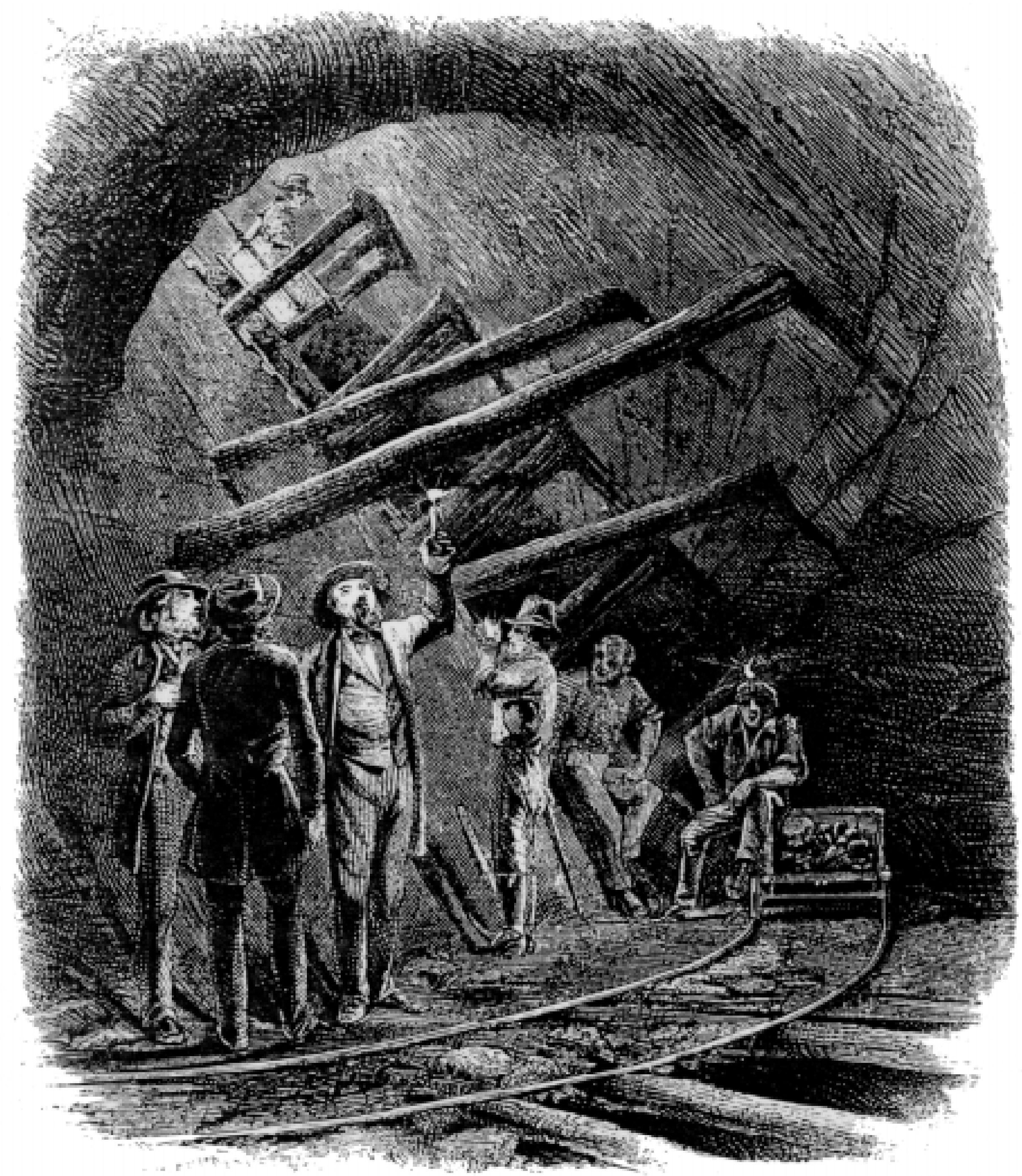
Water Resources

Iron is produced when iron ore is burned with charcoal. The resulting mass of hot iron, however, is full of impurities, or slag. This slag has to be removed to produce a high quality product, and this is accomplished by beating the mass with a hammer at a forge. Before the steam engine became widely used in the middle of the 19th century, the mechanical power that drove the hammer was supplied by water. Ironworking establishments were located at rapids or waterfalls where the energy of the falling water was powerful enough to turn a water wheel. The water wheel, in turn, generated the power needed to operate the forge's hammer.

The Highlands had excellent hydropower potential for powering the ironmaker's machinery. Originally the region had several natural lakes and small swamps that were drained by brooks, streams, and small rivers that enjoyed many natural waterfalls. At locations where the fall of water was sufficient, early ironmasters built dams to impound the stream and erected water wheels to drive the hammers and other machinery needed for iron operations.

The Picatinny Forge Sites

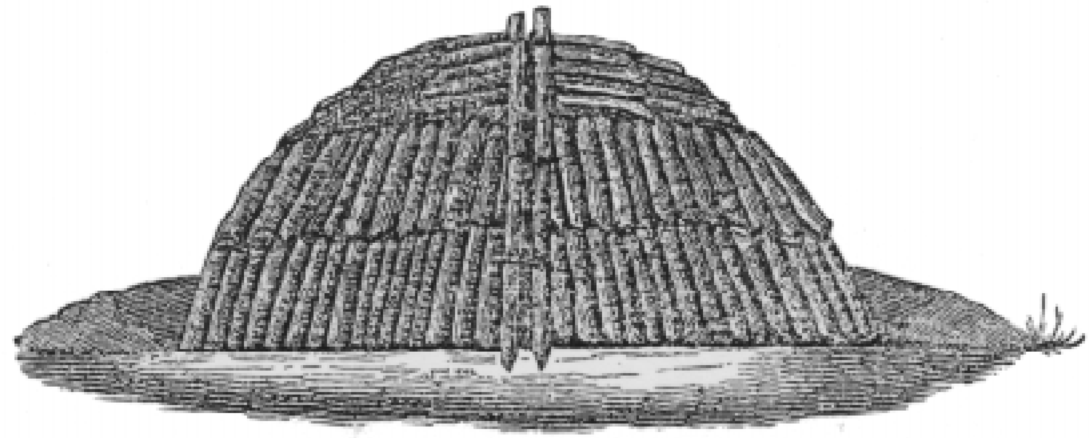
The first ironmakers moved on to the Picatinny Arsenal property by the middle of the 18th century. These ironmakers erected bloomery forges, the smallest but most frequently built and economically successful ironmaking units in New Jersey. Three forges were built on Burnt Meadow Brook, a tributary of the Rockaway River. (Burnt Meadow Brook is often confused with its tributary stream, Green Pond Brook.) (see Figure 6).



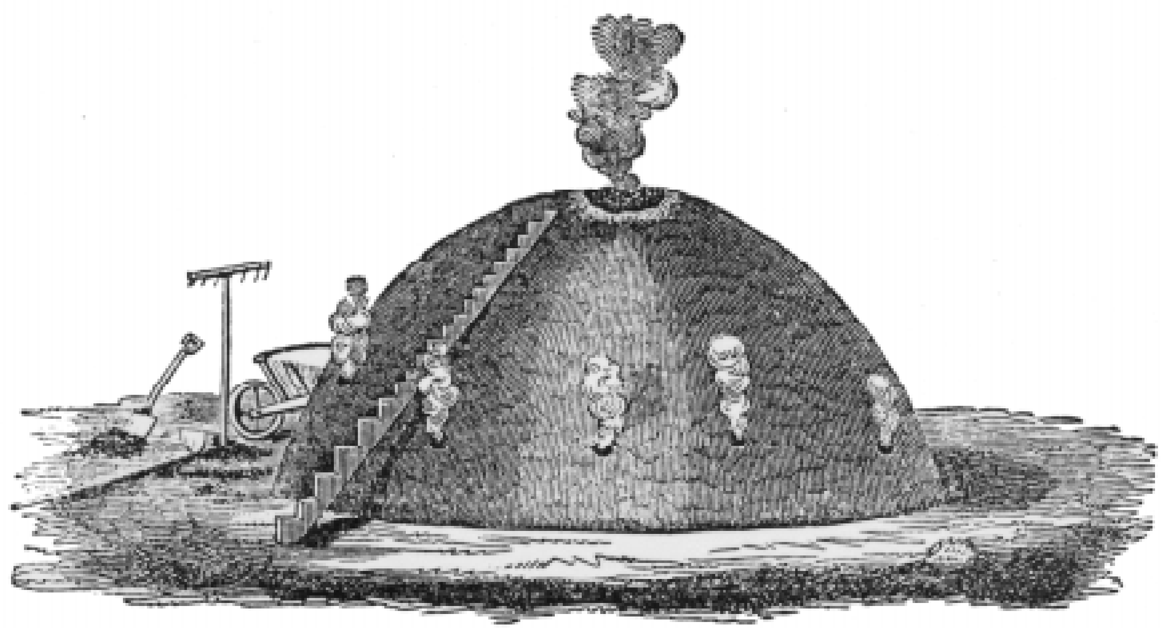
GALLERY IN BYRAM MINE.

FIGURE 4. A gallery, as illustrated in this 1859 rendering of the Byram Iron Mine, was formed when the slanting vein of iron ore was mined between the adjoining "country rock." The left wall was called the "footwall" and the right was the "hanging wall." Note in the upper left, the ore car or "skip" being lowered down on tracks laid on the footwall (Harper's New Monthly Magazine 1860:592).

FIGURE 5. Charcoal was made in a kiln located in the forest tract near where the wood was being felled. The top view shows how the 4-ft lengths of wood were stacked on the kiln site. Wood had to be split if it was too large, but by cutting the woodlands once every 25 years or so, trees of about the right size were produced. Note the center chimney in the pile. The lower drawing shows the charcoal kiln when covered with loose soil mixed with organic material such as leaves and peat moss. The fire was kept smoldering with a draft from holes in the kiln cover around its base. The apertures and the center vent could be manipulated to adjust to wind changes and rain. After 4 or 5 days, the kiln was extinguished and after cooling for several days, the charcoal was removed. The colliers burned several kilns at once and tending each at its own stage of production required them to stay in close proximity for the entire time (Overman 1850:105-106).



Setting the wood for charring.



Making charcoal in heaps.

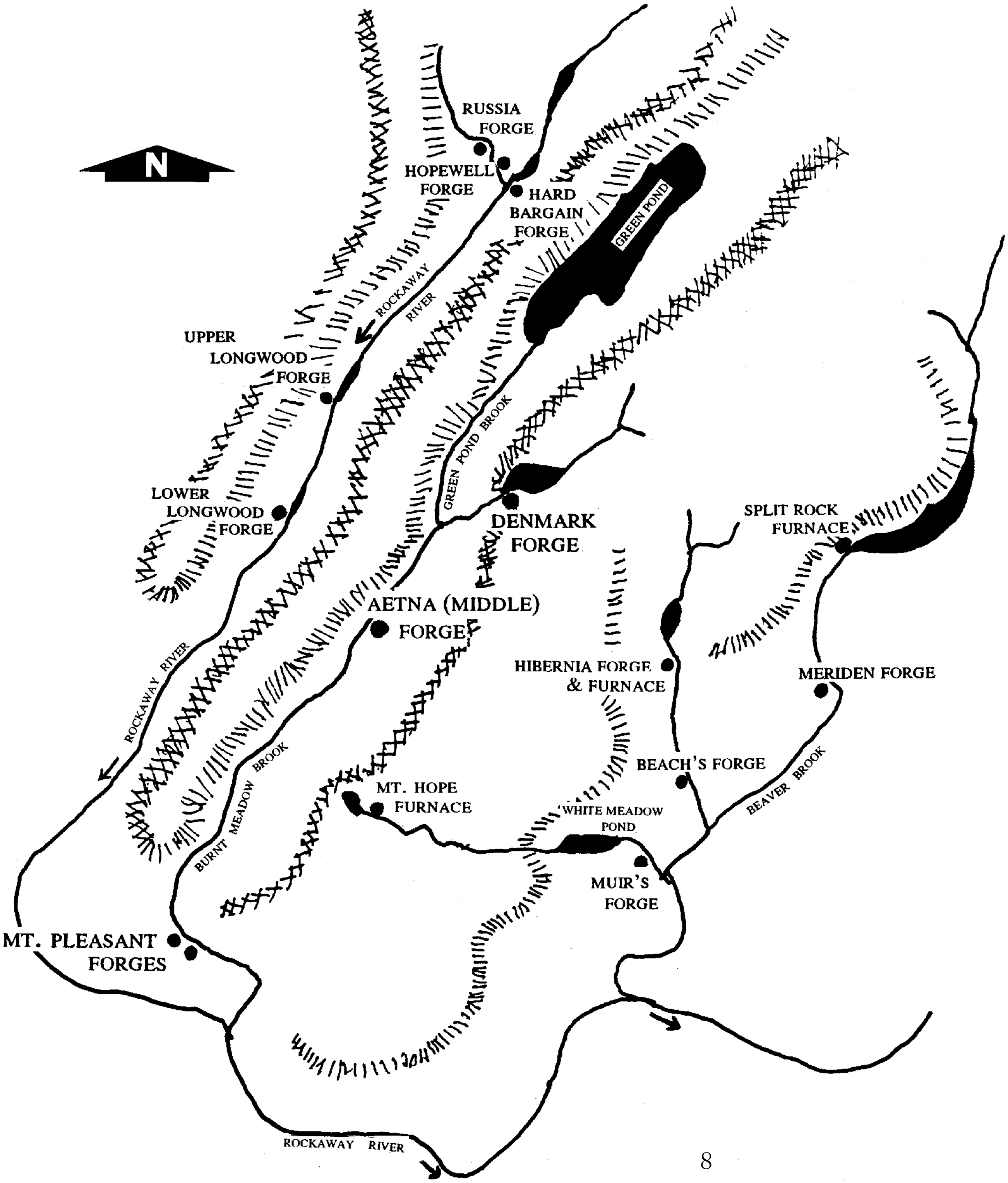


FIGURE 6. Gordon's map of 1828 shows Picatinny's forges labeled as Mt. Pleasant, Aetna (Middle), and Denmark. Note that the surrounding ironworks of the Dover Iron District are marked with a cross for a forge and a starred circle for a furnace. There are not many roads, and reports from the time reveal that those that did exist were very rough to travel over. The poor roads increased the costs of transporting materials in and out of the area, spelling failure for some charcoal ironmasters (Gordon 1828; Scale: 1" = approx. 9,000 ft.).

Mt. Pleasant Forge

The lowest forge site on Burnt Meadow Brook, and certainly part of the largest forge farm settlement, was Mt. Pleasant Forge. Today the site is partly covered by NJ Route 15 near the Gulf gas station located right after the exit from Interstate 80. The area retains its name, as can be seen on the old schoolhouse along the road to Richard Mine and Mt. Hope. Established around 1750 by Jacob Ford, Sr., Mt. Pleasant contained two forges, a substantial iron mine, a charcoal tract, and farmland. The forgemasters ran a public house (tavern/hotel) on the turnpike, and a store. A gristmill and a sawmill were also operated, using excess power generated by the water mill, a typical arrangement where other mechanical operations were developed to take advantage of excess power generated by the dam and mill. All of these activities remained in operation till around 1850. Along with these buildings, there was the forgemaster's house and the tenant houses for the forge's workers.

Middle or Aetna Forge

The next forge up Burnt Meadow Brook was Aetna or Middle Forge, which was built in 1749 by Jonathan Osborn (see Figure 6). This forge site is at the outlet of today's Picatinny Lake, then a dammed forge pond. The forge site remains were partially obliterated when the Army Corps of Engineers rebuilt and enlarged the dam and lake in the 1930s. Some artifacts, including the anvil base and some forge tools, were found and saved as part of a commemorative monument now standing in front of Building Number One on the Arsenal grounds (see Figure 1).

Denmark Forge

The third forge on Burnt Meadow Brook was Denmark Forge, which stood below the dam on Denmark Lake, its forge pond (see Figures 6 and 7). This forge was also built around 1750 by Jacob Ford, Sr. Today the site is in the least developed part of the Arsenal. These circumstances have made it possible to identify a number of individual features of the forge farm's operation. These include roads, house and farm field sites, some as-yet-unidentified forge building sites, as well as at least one of two sawmill sites known to have been operated by the

BLAST FURNACES

By the time of the Revolution, several iron blast furnaces had been built near Picatinny Arsenal. They were the Charlotteburg Furnace to the northeast, Hibernia Furnace to the east, and closest of all, the furnace built on the Mt. Hope tract that was purchased from the Fords by the Swiss ironmaster John J. Faesch.

Blast furnaces were far larger and produced much more iron than bloomery forges. In a furnace, iron ore underwent the same chemical reaction as it did in a forge. However, in a furnace, the iron was melted and the impurities floated to the top of the liquid iron and were removed. This produced a very pure iron that was then drained out of the furnace and allowed to cool.

The product, cast iron, was different than wrought iron in some significant ways. While the cast iron produced by the blast furnace had less slag or impurities, it contained about 4 percent more carbon than wrought iron, making it too brittle to be worked by a blacksmith. The liquid iron could be cast in sand molds to form finished products, such as cannon balls and camp kettles, as well as lumps of unrefined iron called "pigs." The pigs could be shipped to a special iron forge where they were reheated and then beaten and worked under a forge hammer into merchant bars of good wrought iron. The local bloomery forges were adapted to make wrought iron from cast-iron pigs.

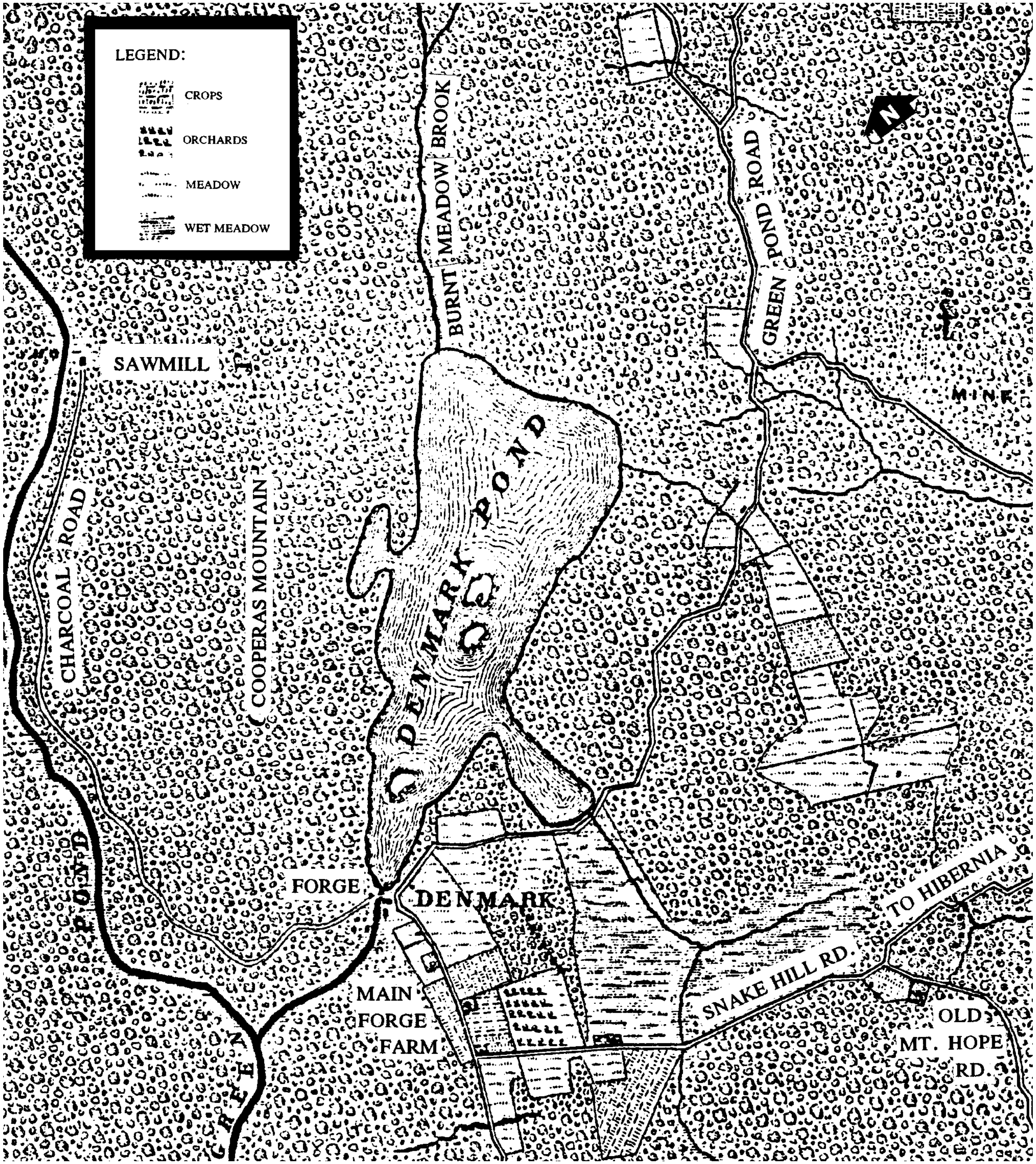


FIGURE 7. Map of a portion of the Denmark Forge tract or property showing the forge on Burnt Meadow Brook, the forge pond, and the road up Green Pond Brook to a sawmill. The road between Copperas Ridge and Green Pond Mountain is thought to be the way charcoal was brought to the forge. The map also shows the extensive farm with indications of an orchard, wet and dry meadows, hayfields, and cropland. The small dark squares are the forgemaster's house, barns, and tenant houses (Hopkins 1868; At 140 percent of the original, the scale on this map is approximately 1in. = 1/4 mile).

forge. The forge site itself was built on a natural fall of water, with the dam built on the bedrock of the falls in a constricted portion of the brook's course. This allowed a small dam to hold back a large pond of water, which supplied a battery of energy that could power machinery in times of low water.

Forge Layout and Operations

Although bloomery forges were the smallest type of ironworking establishment in New Jersey, they were still large-scale operations. The forge owned or controlled several thousand acres of timber, farmland, and mines. The center of operations consisted of the forge, headquarters, housing, and stables, which were located at the water power site. All the tasks required to assemble the raw materials, make the iron, and then get it to market were coordinated by the owner of the forge or his manager.

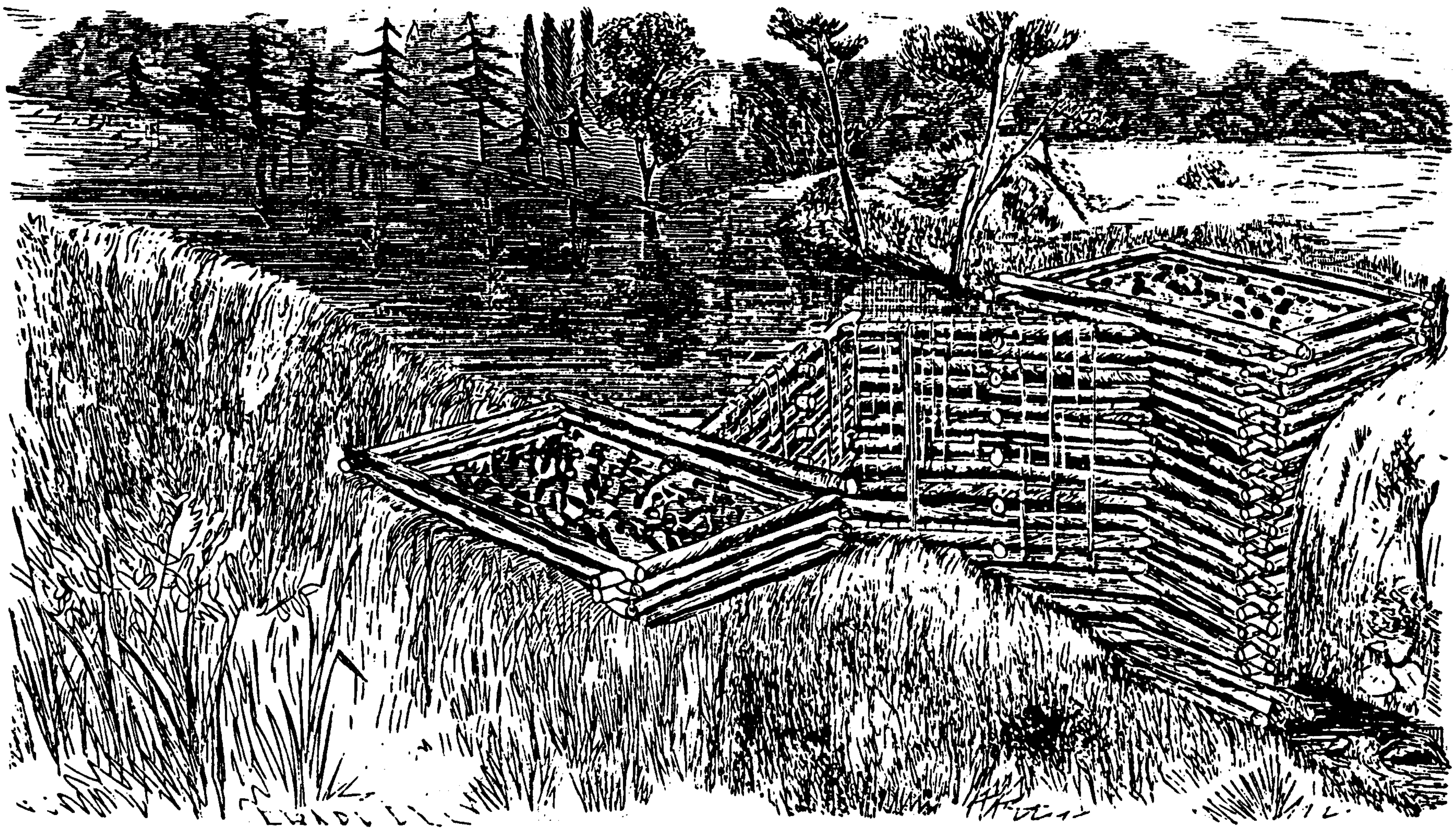
The Forge

As already stated, the forge was located at a water power site. Water power was developed where a stream bed dropped in elevation over a relatively short distance, like at a rapids or a waterfall. A small dam would then be built at the bottom of the falls to hold back a large pond of water. The water in the pond supplied the energy to power machinery, even in times of low water. In many cases, the dam was constructed of timbers notched at the ends to form "cribs" that could be filled with loose stone (see Figure 8). From the dam to the forge or sawmill site, water was led through a channel called a headrace to the water wheel. A larger wheel could be used by placing it in a "wheel pit." The water was then drained back to the stream in a tailrace.

Several types of water wheels were used to develop power under various heights of waterfalls. This height is called the head of water. For its size and width, the overshot wheel was the most powerful water wheel. It was more powerful than either the breast wheel, used under lower heads, or the least powerful undershot wheel, designed to work under the lowest heads of all.

The water wheels were built of wood shaped with carpenter's tools and in part fastened together with rods, bolts, and nails made on the spot by the blacksmith. A forge could be set up with only a few cast-iron objects that had to be purchased and hauled to the site. These objects included the water wheel gudgeons (see Figures 2 and 9), the bellows and forge hammer cam rings, the hammerhead, and the anvil (see Figure 9).

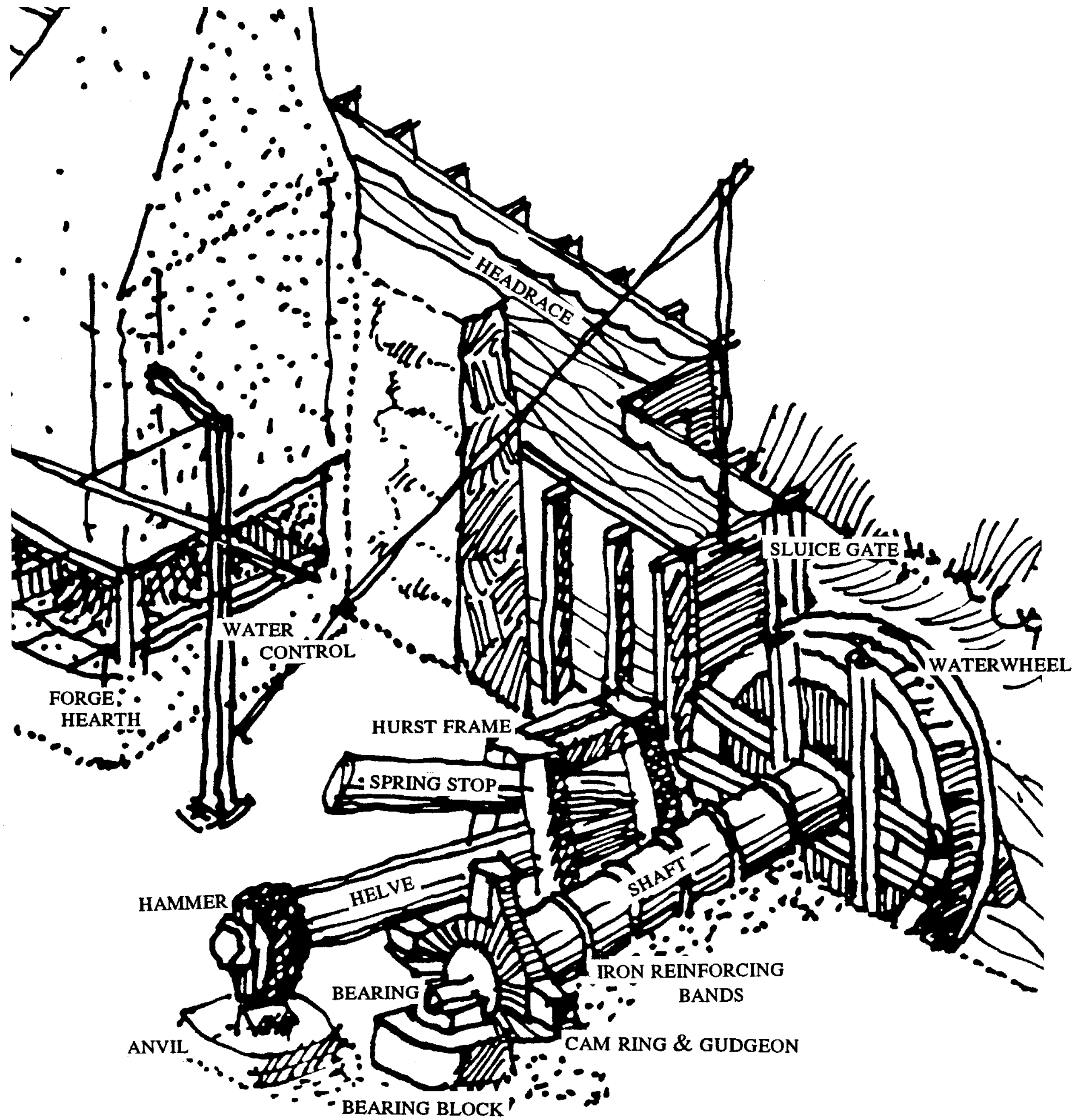
Bloomery forges had two water wheels. One wheel powered the leather bellows that supplied the two forge fires with the oxygen blast needed to get the charcoal fire hot enough, while the second operated a heavy hammer used to beat the iron (see Figure 10). Workable iron was obtained when the oxygen in the air blast and carbon in the charcoal reacted and formed carbon monoxide. This gas then reacted with the heated, but not melted, oxide iron ore removing oxygen and leaving metallic iron. The hot iron particles were gathered into a glowing mass or bloom, which was beaten into wrought iron under the blows of the forge hammer.



A CRIB DAM.

FIGURE 8. Using logs notched together, cribs filled with stone made quick dams of locally available materials (Leffel 1881:22).

FIGURE 9. Each cam of the ring on the water wheel shaft lifted the helve of the hammer up until it hit the spring stop. This would bend the spring stop. After the cam rotated and passed, the hammer was freed to fall by its own weight. This movement was accelerated by the spring stop straightening back into shape. The butt of the hammer helve was fixed into a hurst frame in a way that allowed the helve to swing freely (Hildebrande 1993:61).



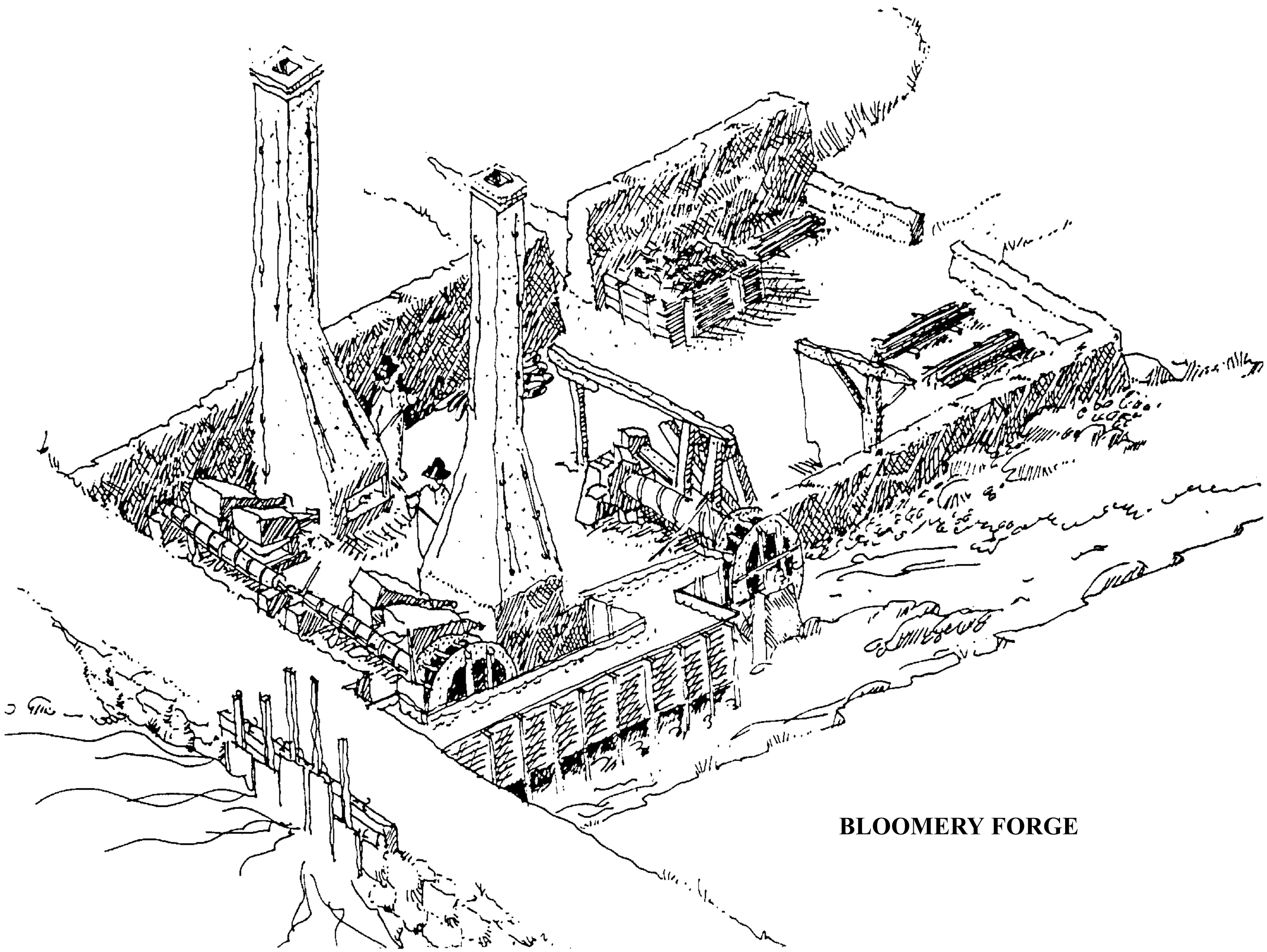


FIGURE 10. This Swedish bloomery forge is much like the Picatinny bloomeries. It shows the forge hammer and its water wheel, as well as the water wheel powering both of the leather air bellows at the rear of each of the forge hearths. The cams on the water wheel shafts lifted the hammer and closed the air bellows (also see Figure 9). The wrought iron produced, often called bar iron, had slag incorporated into the metal. In composition it had a low carbon content and therefore was quite workable. It was the best iron a blacksmith could use and could even bend cold without breaking. The piles of bar iron or merchant bar product, which squared around 2 in. on a side and 14 ft long, can be seen stacked in the rear of the forge building (Hildebrand 1992:57).

Forge Farms

In addition to the land needed for the forge, iron ore mines, and timber for charcoal, the successful ironworks also needed a farm. This was because, except for the water wheel-powered machinery, ironmakers of 250 years ago did all work with the power of their muscle and of their draft animals. The need for a farm came from the need to feed the draft animals, both horses and oxen, that were employed in almost every task at the ironworks. Developing hay fields was critical in keeping animals fit and working through the winter.

The region's only potential farmland was distributed in small patches in stream valleys containing a few open, usually wet, meadows and some deeper glacial till that, while not fertile, could at least be called "plowland." These patches are located where they are because of the way the sand and stone left behind by the glacier eroded. As the ice retreated, the till eroded from the hillsides, leaving unplowable boulder fields behind. The washed-down material clogged the valleys making wet meadows, suitable for growing hay, and clayey soils along streams wherever they were blocked. The till was not eroded from the broader rounded ridge tops, however, and these were the areas on the forge farm that could be plowed. The ridge tops are also where the stone walls and old farm fields associated with the iron industry lie.

The pace of life around an ironworks was not only regulated by the machinery, i.e. "you must strike when the iron is hot," but also by year-round farming activities. At times when the men and animals were needed for farm work such as haying and harvest, all hands would attend to the work of the farm, banking the forge fires for awhile. Farming time came in the summer because, as is well known locally, farming in North Jersey is "three months of hurry and nine months of worry."

Products

The main product from these forges was wrought-iron merchant bar (see Figure 10). These bars were 14 ft long and about 2 in. wide on all four sides. Their weight varied with their thickness, but throughout Europe and America such bars represent the standard unit of manufactured iron. Their size and weight made them about right to be loaded or carried by a single worker.

Local forge records list the sale of merchant bar, also known as common bar, in addition to what is believed to be a more carefully made bar of superior quality and cost that was called "machine bar." Besides this product, iron tire metal for wagon wheels and plowshare molds that strengthened the working point on farmers' wooden plows

LABOR

When looking at the surviving charcoal forge and furnace account books, it can be seen that approximately half of the labor force around one of these iron-works was teamsters. A quarter of this work force cut wood and prepared charcoal. A final quarter included about equal numbers of miners and iron smelters.

The situation of labor in Highlands ironworks changed over time, but generally skilled year-round labor lived in housing supplied for their use and received part of their pay in commodities from the farm and an associated store. Rates of pay depended on skills, with only a few forge workers, miners, and colliers receiving better than laborer's wages.

How well ironworkers were compensated when compared to other workers in the region at given times is as yet poorly understood. More careful historical analysis of the data waits to be done.

THE AGRICULTURAL POTENTIAL
OF IRONWORKS FARMS

Advertisements in early newspapers for Highlands ironworks often stressed the availability of natural meadows and plow land. On April 4, 1804, the Ringwood Iron Works was advertised for sale. The long description of the virtues of the ironworks starts with a description of the iron plantation's farmland:

> *"...about six thousand two hundred acres of land, of which there is upwards of six-hundred acres cleared; two hundred and fifty acres of good meadow, which is now regularly mowed; besides a large quantity of land capable, with little expense, of being converted into excellent arable land and meadow..."*

Claims for valuable cleared land with a furnace tract were also made for Mt. Hope. Here the richest iron mine in the region was treated with less importance than the "Great Hunting Meadow," a large expanse of open grassland, though always too much of a bog to plow.

In 1770 Jacob Ford advertised his 6,000-acre Mt. Hope Plantation as having "400 acres of meadow...100 acres well cleared ... extraordinarily good for hemp and grass...the chief part of the whole meadowland being cleared and drained." The advertisement also claimed that there was "130 acres of cleared upland in good order..." and that the orchard had "600 apple trees of the choicest fruit."

Farmland in forge tracts was also considered very important, as the 1818 advertisement for Picatinny's Denmark Forge tract of 3,000 acres points out that besides the forge, sawmill, and the houses for workmen, there was a considerable amount of tillable land and meadow.

were forged out. Some rods were hammered out into thin sheets that were split into nail rods or stock. The rods were used to make nails and spikes not only by blacksmiths, but also by farmers who were looking to make a bit of cash during the winter months.

Records show that the forgemasters sold most of their bars in Dover to merchants who either paid in cash or gave credit for supplies that the forgemasters could then distribute to their workers as part of their payment. Unfortunately, iron is relatively cheap, but it requires a great deal of money to produce, so that the forge still had to stay in business when the demand for iron was low, and the prices down, so it could pay its debts. If credit with the merchants got overextended because of poor iron prices, they wound up owning the forge. The only way to avoid this was to make as much iron as could be sold during times of good prices. Conversely, when iron prices were low, ironmasters cut expenses by not hiring day laborers or teams and by relying heavily on their farm for sustenance. They could mine ore and make charcoal supplies for the time when iron prices rose. To be successful, the operation had to stay flexible enough to harvest the maximum from the iron business when prices were high and not go bankrupt each time the price was low.

Iron and the American Revolution

The Revolutionary War threw the Highlands iron region into confusion and danger. After the Americans' successful attack on Boston drove the Royal Garrison away, the British returned with a large army of regular soldiers and German mercenaries in a large and powerful fleet of warships. After the fall of New York, the area between New York and Philadelphia saw much of the conflict during the next 4 years. New Jersey saw more than its share of war. The ridges of the Highlands became the Continental Army's redoubts, as well as their source of supply, especially of the iron so essential to the army. Cut off from most European sources of arms and munitions, the American ironmakers were pressed into manufacturing everything from cannonballs to camp kettles.

With the new government's shaky financing and the Continental Army's drain on labor, making munitions for the Continental cause was a taxing business. Two sets of documents throw light on the situation. One author was Samuel Hodgdon, a deputy commissioner of stores for the Continental Army. In his letters are orders to John Faesch at Mt. Hope for iron cannonballs and other munitions to be sent to the artillery. The second set of documents are letters written to Hodgdon by Faesch, ironmaster of Mt. Hope Furnace and the Picatinny forges, as well as by others that were cooperating with him to fulfill government orders. The first set of documents gives information on products and production schedules, while the second set discusses payment. Faesch appealed for payment in kind. For example, if money was not available, commodities such as grain, flour, and beef were requested to keep the iron communities fed and working.

The Continental officers' comparisons of the quality of products and methods used by various ironworks in the Highlands are fascinating. It is known that several ironmasters' ironworks failed during the war. Several ironworks are known to have failed during the war because they either could not keep their labor force intact, their product up to the quality required, or could not obtain payment. The correspondence also mentions problems of gaining exemptions for the ironworkers from recruitment into the Armed Forces. Robert Erskine at Ringwood raised a militia company from his workers to defend his furnaces in Passaic County, but ultimately he could not keep his ironworking force intact. The same problem was faced by other forge and furnace masters of the Dover area.

The Continental Army took prisoners of war, but did not have the resources to keep them. Therefore, they paroled German mercenary prisoners who were willing to work for a living. The soldiers, referred to as Hessians, would essentially be free men if a bond was paid for each. They received wages above their room and board. Faesch secured 35 of these Germans, brought them to Mt. Hope, and put them to work chopping wood for charcoal. After the war, Faesch insisted on being

THE REVOLUTIONARY WAR'S EFFECTS ON THE REGION'S IRONMASTERS

The Revolutionary War created both political and military turmoil for the region's ironmasters. Entire ironworks changed hands as Tory ironmasters had their lands confiscated. The Denmark Forge, located on the Arsenal property, was returned to Joseph Ford, Sr., who held the mortgage, while the Andover Iron-works were operated by the U.S. Government. Ironmasters' political sympathies were also closely scrutinized. An associate of Moses Tuttle, Mt. Pleasant's forgemaster, reported that the complaints made by Tuttle against government policies were based on econmomic, not political, motives. In fact, Tuttle had only said that he wished New Jersey would adopt more positive policies toward iron manufacturing such as he had heard existed in Virginia.

Ironmasters had to defend themselves and were not safe from the tragedies of war. Both Mt. Pleasant and Mt. Hope ironworkers were called to serve in the militia that was being raised to defend against the British incursion in New Jersey, which had started at Elizabeth and quickly led to the battle of Springfield. Colonel Jacob Ford, Jr., who was a local militia commander, operator of a potentially strategic gun-powder works, and, with his father, mortgage holder on most of the local ironworks, died from illness contracted on duty in the winter. His young widow and their children shared their Morristown mansion with General Washington and his military family when their house was headquarters of the Continental Army during the winter cantonment at Jockey Hollow. Visitors can view this house in Morristown National Historic Park.

OPERATION OF AN IRON FORGE IN 1820

As part of the fourth U.S. census in 1820, a full-scale National Census of Industry was taken county by county in every state. The report includes comments made by the Mt. Pleasant forgemaster, then Joseph Hoff. These comments reveal how a successful ironmaster managed in periods of economic depression. The original text has been edited and the lines that have been changed are bracketed.

> *"At the present time it hardly pays the expense we have to pay out for making iron. [In 1820, he was only receiving $72.50-$75. per ton of iron.] Whereas in times past where iron generally sold from [$100 to $110 prior to 1814, $115 in 1814, and in 1815 at $140] per ton the demand was good [and we] could make a reasonable profit." [Note the good iron prices coincide with the War of 1812. Demand and cost of iron go up during wars.]*
>
> *"At present [I] could not afford to manufacture without the aid of my farm and having timber of my own, which by means of the iron business is turned into supplies for laborers and stock for the forge. [I] own about 500 acres of farm and timber land[.] Also an iron mine could[,] if sufficient encouragement [was] offered[,] make 40 tons annually."*

The essential fact is that in good economic times, ironmasters made as much iron as possible; in poor times they reduced their labor force, fell back on their farm, and held on until the price of iron made their works profitable again.

reimbursed for the bonds he had paid to the government. This led to some confusion and slander, but once paid, all but seven Hessians with American wives returned to Europe.

Iron in the Early 19th Century

After the Revolutionary War, ironmasters of the Highlands had a hard time competing with iron from Great Britain. The War of 1812 improved their ability to compete because the British naval blockade kept British iron products out of the American market. This eliminated British competition, which sharply raised price and increased demand. These were the last good times for the Highlands ironmaking industry in the pre-industrial age, however.

The American industry had a good start on making iron after the War of 1812. Congress encouraged its manufacture by placing tariffs on foreign competitors' products. Laws that allowed companies to set up businesses as corporations also improved the American industry's ability to compete, because they allowed investors to risk money in an ironworks corporation without risking all their property and capital.

Technical Improvements: Hot Blast, Canals, and Railroads

Times were changing and new methods of ironworking were introduced, many of which had already been used successfully in Europe for many years. One such innovation was the heating and drying of the air blast before it was sent into the furnace. This hot-blast system reduced the amount of fuel needed to get the required heat. Highlands ironmasters not only adapted the hot-blast system at their furnaces, but also experimented with it at their forges. Another innovation was to work cast iron in puddling furnaces and then roll it into wrought iron, thus avoiding the laborious hammer work. This method was especially useful in rolling iron beams that were to become the I-beams, rails, and nails of the Industrial Revolution.

Of all the successful experiments, however, the most important was learning how to use the fossil fuels of the northeastern Pennsylvania anthracite coal fields. North Jersey iron interests, spurred on by the lower fuel costs, invested in construction of the Morris Canal. The Morris Canal was a bulk-carrying canal system that connected the Highlands iron region to the Delaware River and the Lehigh Valley Canal, both of which then led up into the Scranton, Pennsylvania, coal region.

The Morris Canal, which crossed the ridges and valleys of the Highlands on the terminal moraine in Morris County, signaled the end of iron production in the Highlands. Although a few anthracite furnaces were built, the rest of the New Jersey iron region slowly turned from making iron to producing iron ore, which was then carried west on the canal and smelted in the Lehigh and Delaware River Valleys. The canal's transportation system was completed by the construction of a number of short mine or mineral railroads that brought iron ore from the Highlands mines to the canal and/or the main rail lines (see Figure 11).

The building of the canal and railroads led to new ways of making a living in the Highlands. Forgemasters began to exploit their forest lands for timber as well as charcoal. Cutting railroad ties, mine props, barrel heads, staves, and hoops, as well as lumber began to become more important. The railroads also connected the Dover area with the growing metropolitan regions to the east, with their large markets for fresh milk and produce. Much of this produce was cooled and shipped on ice. While the region was not rich farm country, its relatively cold weather and many ponds were fine for harvesting ice, which could be stored until the following summer in insulated buildings without undue melting. The rail connections soon attracted summer visitors who were happy to leave the city for the healthy environs of the Highlands. The crystal-clear forge ponds were excellent for swimming and soon the stops on the rail line were used by patrons of summer boarding houses, hotels, and cottage communities.

End of Iron Smelting in the Highlands

The section of the Wharton and Northern Railroad through Picatinny Arsenal was opened in 1887, but only after the forges had stopped work. No large mines had been found or developed on Picatinny lands, but ore from north and east of the Arsenal was brought out on its tracks. A minor but at least periodically economically viable product of local iron mining during the 19th century was the processing of dyes made from iron ore with a high sulphur content. The product was called copperas and is remembered by the name of one of the main ridges where its mine and works were located at the northern end of the Arsenal (see Figure 6).

As the forges and local furnaces closed, most of the lands of the Dover Iron District were purchased by multi-state iron and steel-making corporations who were interested in obtaining ore from the most productive and richest iron mines. Wrought iron was no longer being made, having been superceded by cheaper steel-making processes such as the Bessemer convertor and the open hearth steel furnace that made steel in ever-more-prodigious amounts. The large furnace tracts

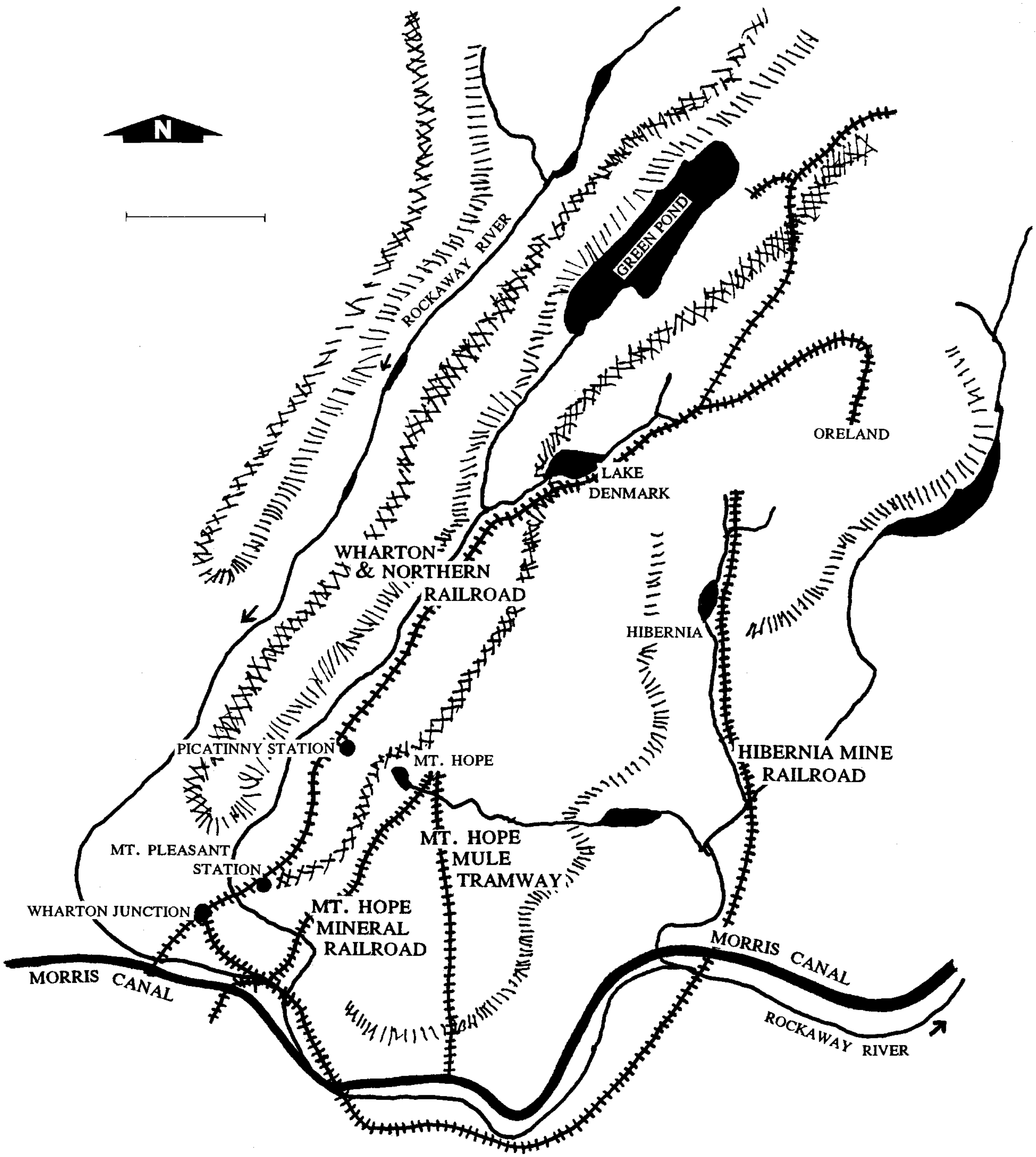


FIGURE 11. The Wharton and Northern Mineral Railroad's routes and stations in the Picatinny Arsenal area. Note similar spur lines to the Mt. Hope and Hibernia Mines. The main lines and the Morris Canal used the glacial moraine to cross the ridges in an east-west direction just as Interstate 80 does today (Lowenthal 1981:112; No scale).

were purchased along with the mines, but the farm and timber products of the land's surface were inconsequential to the new owners. In addition, the 20th century saw steelmakers shift to western iron ores or foreign ore because of the ease of Great Lakes or ocean transport to the coal fields. By the Second World War boom times, only a few of the largest, most productive Dover area mines were still active. After the war, these closed as well.

The Forge Tracts Today

Picatinny Arsenal, first called the Dover Powder Depot, was first established in 1868 close to plants that manufactured black powder used in the iron mines. The three forge tracts in the sparsely settled Burnt Brook Valley made up the bulk of the lands that are today Picatinny Arsenal. In a larger sense, these forested nonagricultural regions of New Jersey, such as the Highlands and the Pine Barrens, have not physically changed as much as the rest of New Jersey because the large forge and furnace tracts were bought and held intact as watershed and reservoir areas. As a result, many state parks and forest lands in these regions share a beginning as iron tracts. In addition, New Jersey installations of the Federal government, such as Fort Dix, McGuire Air Force Base, and of course Picatinny Arsenal, are all located on old iron tracts.

The automobile and the resulting mass exodus from the cities are putting great pressure on these forest lands to be developed into new suburbs. Conversely, an educated public is keenly aware of the causes of pollution and the folly of suburban development without regard to the landscape and environment. Citizens are presently involved in trying to assure that future New Jerseyans will remember that the regional planning in vogue around 2000 A.D. was more than a code label for development.

Glossary

Blast Furnace - a large vertical furnace in which iron ore is smelted into a molten form. The blast refers to air that is introduced under pressure to the base of the fire. The resulting product is cast iron.

Bloomery - a hearth in which iron ore is alternately heated to a near molten state and then beaten under a hammer to remove and incorporate the slag. The product is wrought iron.

Breast Wheel - a water wheel in which water is introduced at about one quarter to one third from the top of the wheel.

Cast Iron - the product of a blast furnace that is often cast into intricate shapes in molds. It is brittle with little strength and cannot be welded.

Charcoal - charred wood that is used as fuel and produces a hotter fire than raw wood.

Charcoal Kiln - a specially constructed covered pile of wood that is charred rather than burnt, in a reduced oxygen atmosphere, thus producing charcoal.

Collier, Colliery - a skilled operator of a charcoal kiln and the locations where several kilns were burnt at once.

Copperas - an iron ore that is rich in iron sulphate from which dyes for cloth were made.

Coppice - woodlands cut every 20 to 25 years for charcoaling.

Culture - a mix of distinct recipes that human groups employ in operating their society.

Cultural Resources - places and things from the past that people find significant to their present and future.

Foot Wall - the slanted lower wall of country rock beneath a mined seam of iron (see hanging wall).

Forgemaster - the operator of a bloomery forge.

Glaciated - areas that have been subjected to and modified by the movement of glaciers.

Gudgeon - a cast-iron extension of a wooden axle that provides a more efficient and longer-lasting bearing.

Hanging Wall - the slanted upper wall of country rock above a mined seam of iron (see foot wall).

Head of Water - the height that water falls in making power.

Head Race - the channel of water leading from the dam to the water wheel.

Hot Blast - the technique of heating and drying an air blast before it is introduced to a blast furnace.

Ironmaster - operator/owner of a blast furnace and/or forge.

Limonite - bog iron; a limited rich ore found in the sands of the coastal plain.

Machine Bar - a local term for a more expensive wrought-iron bar that was a special product of the Highlands forges.

Magnetite Iron Ore - the hard-rock iron ore found in the Highlands that is noted for its magnetic qualities.

Merchant Bar - an average-priced but salable-quality wrought iron bar that was the major product of Highlands forges.

Mt. Hope Hydropower Project - a hydroelectric project based on the use of pumped storage. Also sponsors the Mt. Hope Conservancy, a developing museum of Highlands iron.

Nail Rod or Stock - strips of wrought iron that are slit to form the basis of hand-forged nails and spikes.

Overshot Wheel - water wheel in which water falls on top of the wheel; the most efficient type of water wheel.

Physiographic - descriptions of broad regions of the landscape.

Public House - a tavern and/or hotel.

Puddling Furnace - a furnace used in the process in which wrought iron is made from cast-iron pigs and passed between rollers, rather than beaten under the hammer.

Slash-and-Burn Agriculture - a farming method in which a new field is cleared and farmed until it is no longer fertile. It is then allowed to regrow with forest for a number of years until it can be used again.

Tariff - a system of duties levied either on imports or exports.

Terminal Moraine - a band of deposited loose sand, rocks, and soil marking the furthest extent of a glacier.

Till - glacial debris; stones, gravel, sand, and soils left as the glacier retreated.

Timber Crib - a wooden structure, often notched together, into which stones were placed, producing a strong and heavy structure of local materials. Much used when building in water (dams, docks, bridge abutments, and the like).

Tract - a parcel of land larger than a lot and smaller than a township.

Undershot Wheel - water wheel in which water comes in contact with the blades at the bottom of the wheel. The least efficient wheel, but can be adapted for low heads of water.

Wisconsin Glacier - the name for the last of the four great glacial periods. It is also the glacier that created most of the prominent remains of our present landscape.

Wrought Iron - iron ore heated until it is soft and then beaten under a hammer. Until the 1820s, local wrought iron was made under a hammer (see bloomery) either directly from iron ore or by working up cast iron (indirect method). From 1820 until steel captured the entire market, the puddling process (see puddling furnace) was the most widespread process used.

Suggested Reading

The bibliography that follows includes documents that are cited directly in the text of this booklet as well as others that are suggested for additional research and reading. In compiling the suggested bibliography, the author has tried to include documents that are either in print or, if out of print, are likely to be in the local history sections of most Morris County libraries. Jack Chard's interpretive pamphlet (1995) contains a very serious bibliography focused on historic iron technology. Brian Morrell's bibliography (1996) covers all the primary documents on Picatinny Arsenal research. The locations of the primary documents are noted in his survey. This bibliography will be available as a publication in conjunction with this interpretation.

Besides written history, several local historic preservation organizations address the sites and artifacts of the iron industry in the Highlands and elsewhere. These include the following:

- The Mount Hope Conservancy.
- The New Jersey Canal Society.
- The North Jersey Highlands Historical Society.
- The Society for Industrial Archeology - the local chapter of which is the Roebling Chapter.

In addition, Morris County and many local communities have historical societies in which the history of local ironmaking is much appreciated.

Bining, Arthur Cecil

1973 *Pennsylvania Iron Manufacture in the Eighteenth Century*. 2nd ed. Pennsylvania Historical and Museum Commission, Harrisburg, PA.
Professor Bining's work is a classic in the study of the history of iron in America. The salient factors he has discerned in Pennsylvania history are a good counterpoint to the experiences in New Jersey.

Boyer, Charles S.

1931 *Early Forges and Furnaces in New Jersey*. University of Pennsylvania Press, Philadelphia.
Long out of print, this document can be found in older and larger libraries. It is New Jersey's only state-wide survey of historic ironmaking sites. Though its reporting is uneven and occasionally contains errors, it is a very handy reference that is used frequently.

Chard, Jack

1995 *Making Iron and Steel, The Historic Processes 1700-1900*. 2nd ed. The North Jersey Highlands Historical Society, Ringwood, NJ.
This booklet is the culmination of a great deal of work by a trained metallurgist in providing short, clear interpretations of various historic ironmaking processes. Chard's general bibliography contains the balance of what is currently available in general history and iron studies. Buy this booklet!

Harper's New Monthly Magazine

1860 "Artist-Life in the Highlands," Vol XX, No. 119, pp 577-598. "Among the Nailmakers," Vol XXI, No. 122, pp 145-164. Reprinted by the Canal Society of New Jersey in 1994.
These articles illustrate Morris County iron mining, the Morris Canal, and the Boonton Furnace with its associated nail works. The drawings are superb and the new reprint is well done. The illustrated description of the "puddling" process of ironworking is one of the few known presentations of this industrial process.

Lowenthal, Larry

1981 *Iron Mine Railroads of Northern New Jersey*. The Tri- State Railway Historical Society, Dover, NJ.
Besides the history of these specialized railroads, a good bit is presented about the iron mines and furnaces in the late 19th and early 20th centuries. Especially well-illustrated with period photographs.

Morrell, Brian H.

1996 *An Annotated Bibliography of Documentary Reference Materials Relating to the Picatinny Arsenal Area Ironworks and the Historic Iron Industry of Morris County, NJ*. Historic Conservation and Interpretation Inc., Newton, NJ. February.

Munsell, W. W.

1882 *History of Morris County, New Jersey.* W. W. Munsell & Co., New York.
This standard history available in all Morris County libraries contains a good bit about the iron industry, the various iron works, and the leaders in the iron business over time. Handy to use as a baseline for any Morris County historical study.

Ransom, James M.

1966 *Vanishing Ironworks of the Ramapos*. Rutgers University Press, New Brunswick, NJ.
This out-of-print book should be available in most libraries. It is the best integrated and researched book in existence on the subject. Its focus is on the Passaic County, NJ, and Orange County, NY, area, though it does give a lot of information on Morris County as well. It sets a standard for present-day efforts.

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1936-38 Collection of negatives of Lake Denmark and Lidgerwood Estate. On file at Morristown-Morris Twp. Library.

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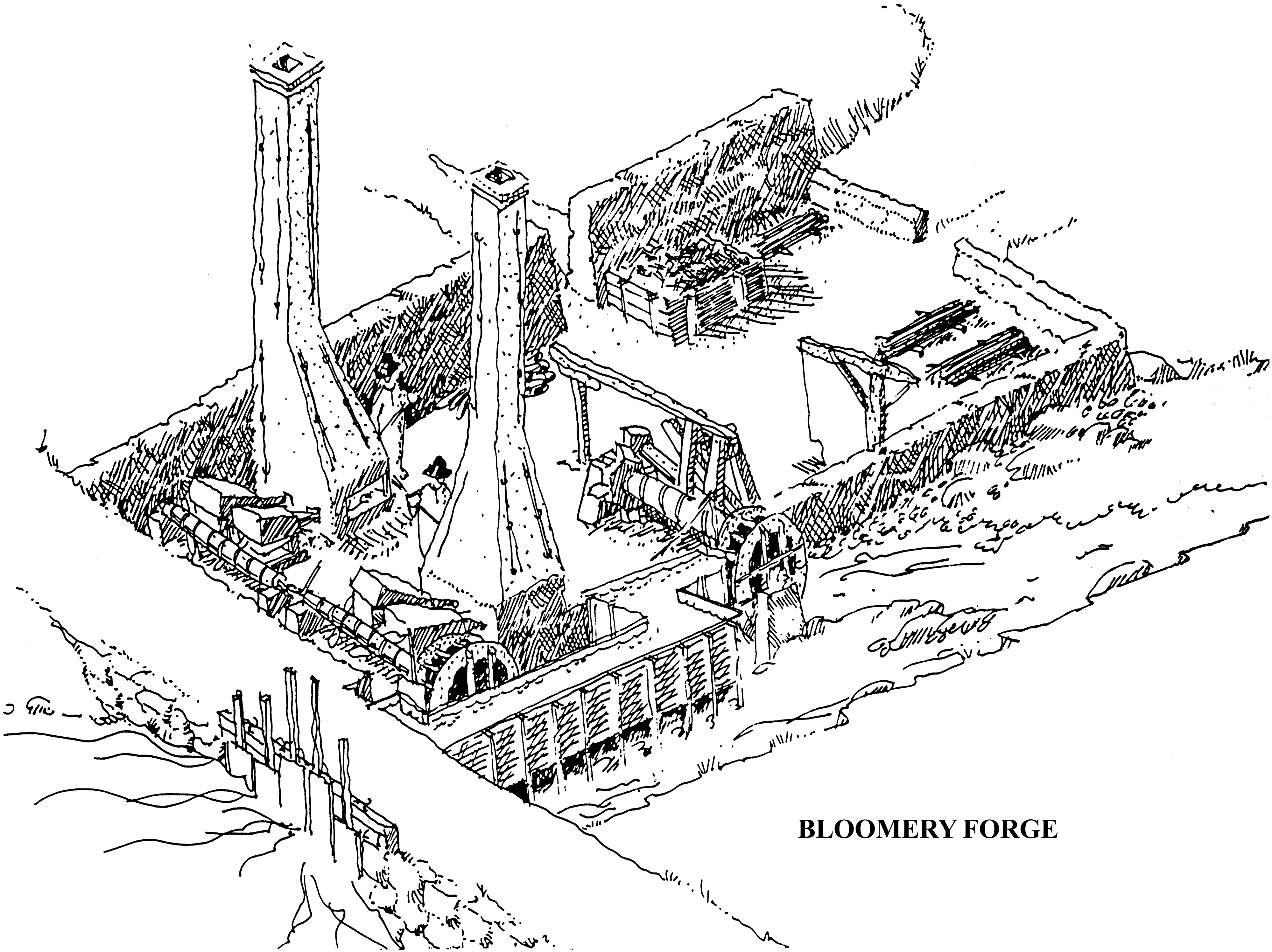

BLOOMERY FORGE