The Rise of American Iron, 1720–1860

No one in North America had made much use of the continent’s iron resources before the arrival of Europeans. The Inuit fashioned knives by setting hammered-out pieces of native and meteoritic iron from Greenland into ivory handles, and American Indians colored themselves with hematite. They did not smelt ore. Martin Frobisher’s 1576–78 expeditions, which briefly ignited European interest in the mineral resources of the New World, led to nothing. However, other adventurers in North America found plenty of wood and ore suitable for their European ironmaking techniques. The Spanish in the Southwest probably used bloomeries to supplement the iron they brought with them. Scholars have yet to explore the documentary and archaeological record of their work, and the history of American ironmaking still begins in the colonies along the Atlantic coast.

The adventurers who came to Virginia in 1607 intending to exploit the abundant New World natural resources saw possible profit in making iron for export to England. They dispatched a cargo of ore in 1608 and probably had a bloomery operating two years later. However, when they began building an integrated ironworks (a blast furnace and finery forge) in 1621 at Falling Creek, near present-day Richmond, Indians killed most of the artisans, and the adventurers abandoned their project. Virginians found better economic opportunities in agriculture, and for the next hundred years they made only small amounts of iron for their own use with bloomery forges.

When the Massachusetts Colony encountered financial difficulties in the 1640s, John Winthrop Jr. went to England to raise
capital and hire skilled workers for an ironmaking venture. Winthrop and his fellow proprietors intended to smelt pig, pour castings, fine bar iron, and slit nail rod that they could export to Britain. They chose a poor site for their first blast furnace, near Braintree, abandoned it, and moved their enterprise to Saugus. Here in about 1647 they completed works they called Hammer­smith with a blast furnace, finery, chafery, and slitting mill (Figs. 3-1, 3-2). Although they made iron successfully, the Saugus proprietors entangled themselves in financial and legal difficulties and had to close their works in 1652. Some eight years later Winthrop made another try at industrial ironmaking, this time in New Haven, Connecticut. Here the proprietors overestimated the amount of ore nearby, found their operating costs excessively high, and had to abandon the project about 1680. This ended the initial American attempts to enter the world market for iron products.

Most colonists found iron ore close enough at hand to supply their immediate needs. Artisans among them learned smelting skills and built bloomery forges. After the citizens of Taunton, Massachusetts, started a forge in 1656, other communities in southern New England undertook similar ventures. Colonists in the middle and southern states gradually followed the New England example, first at Tinten Falls, New Jersey, in 1682 and then, in the early eighteenth century, in Maryland and Pennsylvania. Archaeologists have yet to examine the remains of these early ironmaking ventures.

In the first decade of the eighteenth century, English manufacturers found Swedish iron cheaper than that made in Britain. When King George got Parliament to restrain trade with Sweden in 1717, many manufacturers decided to invest in American ironworks. At the same time, colonial entrepreneurs discovered that population growth in America and termination of the seventeenth-century Indian wars had enlarged the home market for iron goods. The revival of colonial ironmaking that they initiated shortly before 1720 started an American iron industry that became important enough to provoke British regulation in 1750. Colonists in the middle Atlantic states pursued this new economic opportunity more vigorously than New Englanders. Many colonial proprietors of ironworks started in the 1730s and 1740s prospered to the point where they could enlarge and improve their equipment. If they began with a bloomery, which required little capital, they would add a blast furnace and begin casting hollow ware and pigs. By converting their bloomery to a finery, they could make bar iron from their pigs. Later, they might add a slitting mill to make nail rod.

In initiating their industry, ironmasters along the East Coast had placed their works where they had convenient access to fuel, ore, water power, transportation routes, and established communities. Many of them used phosphorus-rich bog ore that did not yield the best grade of iron. Additionally, they found most
of the bogs too small to support much expansion of production. The next generation of ironmasters began locating forges and furnaces near deposits of high-grade ore, even if these were in inconvenient or remote locations.

In the second quarter of the eighteenth century, Americans established themselves as major suppliers of pig and bar iron to British manufacturers, and by 1775 they were the third-largest iron producer in the world. During the Revolution, they produced cannon, shot, and the metal needed by makers of small arms. When the war was over and the states were united, they had in place a basic industry that could supply the iron needed by entrepreneurs, such as Eli Whitney, who began making machinery and metal goods in factories. Ironmasters also joined settlers moving westward and made the metal products that frontier communities needed. When explorers opened the western rivers to commerce, these ironmasters turned to larger markets. Meanwhile, in the East, artisans adapted European innovations to American conditions, often changing them substantially. In the eighteenth century everyone had used much the same technique. Now ironmasters in a given district might run modern installations with new techniques while their neighbors still profitably used the old methods at venerable furnaces and forges. While in the eighteenth century most ironmasters had made the same range of products, in the nineteenth both individual works and entire districts began to specialize in particular products.

Ironmasters organized their works around specific natural and economic resources and the cultural preferences of their communities. Ore, fuel, and water resources and natural transportation routes dominated the physical differences between ironmaking regions. The profits of local merchants or manufacturers might provide the capital proprietors needed in one region, while in another they might have to turn to distant investors. Near the frontier, ironworks customers would be neighboring farmers, woodsmen, miners, and millers. In other regions they could be entrepreneurs engaged in secondary manufacturing that drew on primary iron production. Additionally, an ironworks proprietor needed to accommodate the cultural preferences of his neighbors and his artisans, including their attitudes toward industrial work and vocational specialization, willingness to accept innovations, and tolerance of the environmental consequences of ironworks. Combinations of these factors defined ironmaking districts (Fig. 3-3).

Americans steadily enlarged their transportation and communication links and thus diminished regional differences. Canals, railways, and better roads delivered raw materials to producers and carried products to distant customers. A reliable banking system helped capitalists assemble the financial resources ironmasters needed to enlarge and improve their works, adopt new techniques, or exploit previously unused resources. American artisans easily moved to regions with new opportuni-
The North American ironmaking regions in the Northeast, shown on this map, were distinguished by their natural and economic resources and by cultural preferences. Key: 1, Southeastern Massachusetts; 2, Salisbury (in Connecticut); 3, New Jersey–New York (spread along the Hudson River and Lake Champlain); 4, Coastal Plain; 5, Piedmont; 6, Anthracite (embracing the Delaware and Susquehanna Rivers); 7, Juniata; 8, Potomac; 9, Western Maryland; 10, Shenandoah (between the Potomac and James Rivers); 11, Appalachian Plateau (along the Allegheny and Monongahela Rivers); 12, Hanging Rock (in Ohio and Kentucky). Note that the piedmont and anthracite districts overlap and that the Potomac and Shenandoah districts are contiguous.

ties and brought with them the techniques and expertise they had learned.

MID-ATLANTIC CHARCOAL-FUELED IRONMAKING

Proprietors who started ironworks in the embayed coastal plain district had abundant, easily mined bog ore and convenient access to shipping. By 1682 Lewis Morris had a furnace and finery forge at Tinton Falls, New Jersey, operating on a grant of 3,500 acres. The Maryland legislature encouraged adventurers in ironworks with acts in 1719 that allowed ironmasters to acquire land by condemnation and with a 1721 law exempting ironworkers from highway labor. In 1722 a company of British adventurers built a blast furnace and converted an old bloomery in North East into a finery, forming the Principio works. Prin-
cipio, located near the head of Chesapeake Bay, inaugurated a new era of American ironmaking. The proprietors later invested in an additional blast furnace on Augustine Washington’s land at Accokeek in Virginia. In 1736 the company had a furnace, mine, store, gristmill, and plantation at Accokeek; a forge and plantation at North East; and a furnace, forge with two fineries and one chafery, store, gristmill, and blacksmith shop at Principio. Principio and the Baltimore Company, started by Maryland investors in 1731, were the largest American ironmakers in the years before 1760.

In Delaware John Bull began ironmaking with a bloomery on White Clay Creek, New Castle County, in 1722. In the second half of the eighteenth century, Philadelphia investors financed expansion of the industry into the indirect process with the Mitchel and Deep Creek blast furnaces that smelted bog ore from Delaware and adjacent eastern Maryland. Delaware colonists owned the Unity Forge in Sussex County, a large bloomery with associated gristmill and sawmill at the head of the Nanticoke River. These entrepreneurs used ports on Chesapeake Bay, abundant woodland, and nearby ore to build a concentration of colonial ironmaking serving an export market. Some proprietors made iron with charcoal fuel in eastern Maryland until late in the nineteenth century.

Across the Delaware, New Jersey entrepreneurs enlarged the iron industry in two directions from its seventeenth-century nucleus in Monmouth County. Some ironmasters exploited the extensive deposits of bog ore in the wetlands and barrens along the coast, building blast furnaces and forges. Others began to develop the rich deposits of magnetite ore in the north with bloomeries and blast furnaces. In a burst of entrepreneurial vigor, merchant Charles Read of Burlington, with partners from Philadelphia and New York City, bought more than 10,000 acres of forest and wetland in southern New Jersey and put up the Etna, Taunton, and Batsto blast furnaces and Atsion Forge between 1765 and 1768. Read and partners, acting as “latchkey entrepreneurs,” built complete plants, which they then sold to others ready to operate. The artisans at these New Jersey ironworks made up isolated, nearly self-sufficient communities that remained prosperous into the early nineteenth century. By the 1830s the advantage of their convenient seaports no longer outweighed the low cost of mineral fuel enjoyed by ironmasters in other regions, and the furnace and forge communities withered. James Wood of Delaware was an exception: he designed a new form of shovel that could be formed in a rolling mill. James and his son Alan leased an 1814 slitting mill on Red Clay Creek to develop the rolling machinery to make shovels. In 1832 they moved to larger facilities in Pennsylvania, and in 1844 Alan returned to Delaware to make imitation Russian sheet iron with a process patented by John and William Wood in 1842.

Pennsylvanians had no ironworks until Thomas Rutter built
3-4. The Hopewell Village National Historic Site preserves the ironmaster’s house built between 1800 and 1828 (left) and the 1771 blast furnace, which is surrounded by the rebuilt casting shed (with bell tower) and charging bridge. Charcoal was stored in the sheds adjacent to the charging bridge. A succession of proprietors made castings and pig iron here between 1771 and 1883.

a bloomery, Pool Forge, near Pottstown in 1716. In about 1724 Rutter and Thomas Potts started the Colebrookdale Furnace in Berks County. By 1730 other entrepreneurs had ten additional forges and furnaces in operation, usually financed with shares held by as many as nine families. Recent immigrants from Britain managed most of the new works. They bought slaves and recruited indentured servants from Germany and Ireland. The proprietors found drunkenness among furnace and forge crews such a problem that they convinced the provincial assembly to prohibit the sale of liquor or the operation of public houses within three miles of any ironworks. By the 1760s Pennsylvanians had established themselves as the leading iron producers in North America. Except for Peter Grubb’s Cornwall furnace (started in 1742), they had built their ironworks within forty miles of Philadelphia. Cornwall furnace and the Hopewell Village National Historic Site (Fig. 3-4) are relics of the early industry in eastern Pennsylvania.

Although eighteenth-century entrepreneurs who began iron-
works on the piedmont had better ore resources than their colleagues on the coastal plain, they had to overcome the difficulties of inland transportation by road and river. The proprietors of the Oxford furnace in New Jersey, built between 1745 and 1755, carried their metal down the Delaware in Durham boats to Philadelphia. The finers at Valley Forge regularly received wagonloads of pigs from Warwick furnace eighteen miles away, and they had some pig that had been carried twenty miles down the Musconetcong valley, sixty-five miles on the Delaware, and twenty-three miles up the Schuylkill. Few canals or railroads ever reached the piedmont's charcoal-fueled ironworks, which remained dependent on wagon roads.

Most piedmont-district Pennsylvanians had water privileges barely large enough to support one furnace or forge. They had to disperse their works in isolated communities, such as Hopewell, where artisans also undertook production of food and of fodder for their numerous draft animals. They could not include the gristmill and sawmill often associated with charcoal-fueled ironworks elsewhere. Some historians have described these communities as self-sufficient “iron plantations.” Actually, the Hopewell artisans worked within an extended network of commercial and social relations. They exchanged services with other works, got their ore from three different mines up to five miles away, sent stoves down the Schuylkill to Philadelphia, and sent pig to at least twenty-seven different forges (Fig. 3-5).

THE NORTHEAST

Entrepreneurs contemplating an ironworks in northern New England or eastern Canada had to balance the advantages of abundant forest and water power against modest ore deposits and the long distance to major markets. Initially, colonists in southeastern Massachusetts, Rhode Island, and eastern Connecticut smelted bog ore in small bloomeries. After 1725 they began enlarging their enterprises with blast furnaces so that they could cast hollow ware. By 1731 these New Englanders had at least six blast furnaces, nineteen bloomeries, and a slitting mill and nailery.

At about this time, the French colonists in Quebec first began to take interest in their iron resources. In 1729 Poulin de Francheville, a Montreal merchant, requested the right to exploit the bog iron ore, forest, and water power at a site near Three Rivers. The successive proprietors of the Forges of Saint Maurice started by Francheville experienced many of the difficulties of operating a colonial works that had defeated New Englanders at Saugus and New Haven seventy years earlier. In the nineteenth century Canadian entrepreneurs built some ten blast furnaces in Quebec, four in Ontario, and four in the Maritimes. Among them, only the proprietors of the Grantham Iron Works in Drummondville, Quebec, managed to remain in production for more than a decade. Some failed because they made
Map showing the rivers in southeastern Pennsylvania and the numerous forges (solid circles) within a twenty-five-mile radius of Hopewell Furnace in 1858. The Schuylkill ran through Reading and joined the Delaware at Philadelphia. Low stream gradients in the piedmont district of Pennsylvania limited available water power. This forced ironworks proprietors to keep their works small and dispersed. Artisans at Hopewell Furnace, on the upper reaches of French Creek, hauled ore from three mines (crossed hammers and gads) and delivered pig iron to the neighboring forges for conversion to bar iron. They shipped their main product, stoves, to Philadelphia on the Schuylkill River.

bad iron; others gave up when they had consumed the conveniently available ore or fuel. The proprietors of the Woodstock, New Brunswick, furnace lost their works in a furnace gas explosion shortly after starting up in 1848. Canadians later built a substantial steel industry from roots that were independent of their earlier, charcoal-based ironmaking.

New England entrepreneurs had to build a railroad to the Katahdin blast furnace they located in the wilderness fifty miles north of Bangor, Maine, in 1846 (Fig. 3-6). They specialized in pig for car-wheel foundries and, later, for open hearth steelworks. By repeatedly modernizing their plant and finding new markets for their iron, the proprietors kept this isolated furnace operating until 1890. They kept abreast of improvements in technique by investing in a chemistry laboratory and by hiring Ernst Sjöstedt, a graduate of a Swedish mining school, to improve their ore preparation technique. However, with modest ore resources and no secondary industry nearby, most Maine and New Hampshire investors found better uses for their capital in forest products than in ironmaking.

With the Granger blast furnace established in 1791 near Cen-
fer Rutland, Vermont, entrepreneurs added pig iron to the bar iron that smiths had been making at bloomery forges for several decades. They later built some twenty-odd furnaces in the state. Vermont ironmasters helped start an industrial region along the shores of Lake Champlain. They crossed the lake to get the rich iron ores of the eastern Adirondacks. With the opening of the Champlain Canal in 1823, they had a route to the new industrial centers on the Hudson river and Erie Canal. They adopted the American bloomery process for bar iron and shipped pig and bar to manufacturers to the south. Burlington iron founders cast the forge plates and hammers for several of the Adirondack forges. However, Vermont ironmasters did not develop a special product niche that would sustain them when they faced increased competition from other regions. By 1870 Vermonters had retreated to shipping kiln-made charcoal by rail to ironworks in southern New England.

Ironmakers in the district of Rhode Island and southeastern Massachusetts, with natural resources similar to those in the north, had neighbors who were creating the nucleus of American manufacturing. About 1654 the gifted mechanic Joseph Jenks left Hammersmith and built a forge (probably a bloomery)
3-6. The proprietors of the Katahdin Iron Works, Maine, built their first blast furnace in 1846; they rebuilt it in 1874 and enlarged it in 1877 by inserting an iron shell into the stack to increase its height and adding a bell-and-hopper top. This view shows the furnace before the 1874 rebuilding, with a charging bridge leading to the charcoal storage sheds, hot-blast stoves on top of the stack, and the blowing engine house in the foreground. (Courtesy of Robert Vogel)

Rise of American Iron
3-7. This map of the central part of the Salisbury district in the mid-nineteenth century shows mines (crossed hammers and gads), blast furnaces (open circles), and finery forges (closed circles). Only the forge sites that archaeologists have located are shown; many others remain to be found. The furnaces and forges in this district all used water power. The streams were part of the Housatonic drainage basin, except that at Ancram, which flowed to the Hudson.

ists and merchants, these proprietors did not participate in the new manufacturing enterprises favored by New Englanders.

Mechanics and entrepreneurs in New England created a demand for a new class of products when they began manufacturing precision-made metal goods in the early years of the nineteenth century. In addition to castings and forgings for
machinery, they needed reliable supplies of uniform iron and steel. In 1798 Forbes and Adam sold Eli Whitney a tilt hammer and other iron parts for the machinery in his new armory, a supply of rolled iron, and a stock of gun barrels. Other Salisbury ironmasters specialized in serving this market and established themselves as the principal suppliers of barrel skelps (gun iron) to the Springfield, North, and other armories in the Connecticut Valley as well as the Harpers Ferry Armory in Virginia. They reached out to other demanding customers when they supplied the consistently uniform bar iron needed for mechanized production, as at the Collins Company, where artisans ran Salisbury iron through E. K. Root’s new axe-forming machines. Then, as the market for their high-quality wrought iron weakened, the Salisbury ironmasters concentrated on smelting pig iron, which they cast into railroad-car wheels. The forges in the Salisbury district, and some of their associated communities, declined while a few blast furnace proprietors continued smelting into the twentieth century.

3-8. Salisbury adventurers built this blast furnace in 1804 on Mount Riga in northwestern Connecticut, just north of Lakeville. Successive proprietors ran it until 1856, hauling ore to the furnace from mines 1,000 feet below to take advantage of the wood and water power on the mountain. At their forge, located a few hundred yards downstream, they specialized in making gun iron for the national armories. When the proprietors closed the forge and furnace, the artisans, who had never established other enterprises in the community, left, and the mountainside reverted to forest. Today there are no aboveground remains of the water-power system or the buildings associated with the furnace. (Photograph by William Sacco)
3-9. Map of the New Jersey–New York district, showing bloomery forges (small circles), blast furnaces fired by charcoal (marked by an x), furnaces fired by anthracite (large circles), rolling mills (triangles), and foundries (squares). Not all works are shown. The district had magnetite ore, abundant forests, and water power; by 1830 it was criss-crossed by canals. The Delaware and Hudson Canal extended to the Pennsylvania anthracite fields. Railroads later followed the same routes as the canals.
3.10. Remains of Josiah Pierson’s slitting mill and nailery in Ramapo Village, New York, survived more than a decade after closure of the works in 1854. By 1798 Pierson had ninety-six nail-cutting and -heading machines operating here. The works were abandoned after the dam in the water-power system burst. Three stacks with dampers stand at the heating furnaces; remains of a helve hammer and two flumes that supplied waterwheels are visible in the ruined building. (Courtesy of Robert Vogel)

The New Jersey-New York ironmaking district, which extended from northern New Jersey through the Adirondacks to the Canadian border (Fig. 3-9), had rich magnetite ores, some with low phosphorus, and water-borne transportation on the Hudson river and its associated canals. Smiths began bloomery smelting magnetite from the Suckasunny (or Dickerson) mine in Randolf, New Jersey, in 1710. By 1770 Peter Hasenclever had a network of blast furnaces and finery forges operating in the Ringwood area. Artisans at the nearby Sterling Iron Works made the links and fittings for the Revolutionary War chain across the Hudson River at West Point. Others set up slitting mills and naileries (Fig. 3-10).

Shortly after 1780, artisans in northern New Jersey developed their own form of bloomery for smelting their rich magnetite ores. Then, early in the nineteenth century, they improved the thermal efficiency of their bloomery hearths by preheating...
3-11. This photograph of Windham Forge in New Jersey, taken about 1890, shows that the owners had adopted the highly efficient American bloomery technique: the pipes for preheating the air blast are just visible in the partially collapsed brick forge stack. The stack in front with its damper still stood, undamaged, when the photographer visited the site. The flume and pitch-back wheel that drove the blowing engines are in the foreground, and the waterwheel for the stamp mill used to crush ore is visible in the background. (Courtesy of George P. Sellmer)

the air blast (Fig. 3-11). Bloom smelters in northern New York later adopted and refined the New Jersey techniques. Levi Higby and George Throop had initiated iron smelting in the Adirondacks in 1801 with a bloomery at Willsboro, New York, where they made anchors weighing up to 1,500 pounds. After the state opened the Champlain Canal in 1823, out-of-state entrepreneurs came to the region to make bloomery iron and later pig iron for national markets from the region’s rich magnetite ores. At Ironville in 1831, Allen Penfield and Timothy Taft pioneered enrichment of their ore by magnetic separation. They and other bloomery proprietors built reputations for making superior iron; engineers soon preferred their product for critical applications such as suspension-bridge wire. After 1850, crucible
The J. and J. Rogers rolling mill in Au Sable Forks, New York, an important supplier of high-grade bloomery iron in the mid-nineteenth century, had just been destroyed by fire, a constant threat to wooden buildings, when this undated picture was taken. The disaster exposed the heating furnaces and mill engine with its flywheel to the photographer's view. A cam shaft for three water-powered hammers rests at the edge of the ruin. Houses of the village stretch up a hillside that today is forested. (Courtesy of Robert Vogel)

Steelmakers adopted Adirondack bloomery iron as their starting material because of its low phosphorus content. Many, like the proprietors of the J. and J. Rogers Iron Company, developed mines, ore separators, bloomery forges, and rolling mills (Fig. 3-12). These entrepreneurs used a combination of particular natural resources, sophisticated bloomery technique, and a continuing market for low-phosphorus wrought iron to remain in business through the nineteenth century.

Entrepreneurs at Troy had access to Adirondack ironworks, western markets, and Pennsylvania anthracite via the Champlain, Erie, and Delaware and Hudson Canals. Albany investors had hired Henry Burden to manage their new ironworks on the Wynants Kill at Troy in 1822. Burden designed and built a rolling mill for the Springfield Armory in 1829 and soon after developed the rotary puddle-ball squrezer and his famous horseshoe-making machinery. He combined his geographical advantage and metallurgical skills to build the Troy mill into the Burden Rise of American Iron 71
3-13. A 60-foot-diameter waterwheel built in 1851 (said to have been the world’s largest) powered the machinery in Henry Burden’s ironworks in Troy, New York. This photograph was taken shortly before 1914, when the abandoned wheel collapsed. A group of Albany investors had acquired the water power of the Wynantskill for a nailery, and they hired Burden as their superintendent. He used New York’s canal system to assemble raw materials for puddling iron and developed self-acting machinery for making horseshoes as well as nails. (Courtesy of the Smithsonian Institution)

Iron Company, one of the nation’s leading puddling works. His giant, 1,200-horsepower waterwheel remained a landmark into the twentieth century (Fig. 3-13).\(^4\) His neighbors, the proprietors of the Albany Iron works, rolled the iron plates for the U.S.S. Monitor in the Civil War. Immediately after the war, they hired Alexander Holley to perfect the American version of the Bessemer process.

Once the Morris Canal opened in 1831, New Jersey mine owners could adopt the smelting techniques developed by Pennsylvanians and build large, anthracite-fueled blast furnaces like those at Stanhope (Table 6-1). Abram Hewitt bought Hasenclever’s Long Pond site in 1853 and built anthracite-fired blast furnaces to supply pig for his Trenton Ironworks.\(^4\) Across the border in New York the Parrots, proprietors of the West Point Foundry, smelted iron for their famous Civil War cannon at the Greenwood No. 1 charcoal-fired blast furnace that was built in
1811, enlarged in 1825, and closed in 1871. They built the adjacent No. 2, or Clove, anthracite-fired furnace in 1854 and ran it until 1885 (Fig. 3-14). In the Adirondacks, ironmasters in Crown Point, Port Henry, and Lyon Mountain built large blast furnaces fueled with anthracite brought in on the canals and later by railroad. The Witherbees of Port Henry pioneered nationally important innovations in blast furnace practice.

PENNSYLVANIA AFTER THE REVOLUTION

Pennsylvania settlers began moving west after the Revolutionary War into the Pennsylvania valley-and-ridge province. The Juniata district presented formidable transportation barriers and lim-
3-15. This map of the Juniata district, Pennsylvania, shows the numerous blast furnaces (solid circles) and finery forges (open circles) operating in 1858. Here only the largest streams, the Susquehanna and the Juniata (which joins the Susquehanna just above Harrisburg), cut through the mountain ridges; smaller streams made the trellis pattern within the valleys. Juniata ironmasters avoided the ridges and located their forges and furnaces in the valleys, where they had roads and water power.

ited agricultural opportunities, but it had valuable ores, water power, and abundant forests (Fig. 3-15). Ironmasters began exploiting these resources in 1785, when George Ashman and his partners set up Bedford Furnace and Forge near Orbisonia. Like their Yankee colleagues in the Salisbury district, they built blast furnaces, finery forges, and rolling mills to make high-value products worth the cost of carriage out of the region. They could raft iron down the Juniata or Bald Eagle Creek and the West Branch of the Susquehanna River during spring freshets to reach eastern markets. They shipped wrought iron to Pittsburgh by bending the bars into U shapes and turning them over the backs of horses or mules. Pennsylvania completed its Main-
This photograph of Cove Forge on the Little Juniata River, taken about 1870, shows the pitch-back wheel with its flume and tail race, the building housing the finery hearths and helve hammer, and (on the right) the refinery building. A pipe bringing blast air to the refinery runs between the buildings. Children are playing on the steelyard in the foreground. The forge was built in 1808 to refine pig iron made at nearby blast furnaces. In the 1850s the works had two forge fires, a refinery, and a helve hammer. By the time it closed in 1880 it had been rebuilt several times and was the last finery operating in Blair County. By 1990 only the ironmaster’s house and barn and three workers’ houses remained on the site. (Courtesy of the Smithsonian Institution)

line Canal through the Juniata district in 1835, and the West Branch Canal reached Curtin ironworks in 1838, providing reliable routes to both eastern and western markets.48

Unlike their counterparts in New England, Juniata ironmasters relied heavily on family connections to carry on their business. In 1812 John Royer built Cove Forge (Fig. 3-16); he then joined with his brother Daniel to build Springfield furnace in 1815 so that Daniel could supply iron to John’s forge and Samuel Royer’s nearby Franklin Forge.49 Juniata ironmasters also developed strong personal and commercial ties to Pittsburgh entrepreneurs. One of the most prominent Pennsylvania ironmasters, Dr. Peter Shoenberger, inherited his father’s Juniata forge at Petersburg, built in 1804, and began adding works of his own, starting with the Rebecca furnace in 1817. He built a rolling mill in Pittsburgh in the 1820s to process Juniata blooms. Also unlike the Connecticut Yankees, Juniata ironmasters modern-
ized their forges and achieved higher fuel efficiencies in fining than anyone else. By supplying the highest grades of wrought iron, the Royers kept Cove Forge operating until 1880. However, Juniata entrepreneurs never developed much secondary industry, and as demand for charcoal-made iron faded, so did the iron-making communities. Pennsylvanians gained a high reputation for their Juniata iron. These ironworks supplied rolling mills and steam-engine works in Pittsburgh with wrought iron billets until entrepreneurs in that city established their own blast furnaces.

The Schuylkill navigation, opened in 1825, allowed piedmont innovators to undertake anthracite-fueled puddling and smelting. Some of them failed to grasp the geographical possibilities of the new fuel and transportation systems, and built coal-fired blast furnaces at the same rural sites they had been forced to use for their water-powered, charcoal-fueled works. (At the late date of 1853, the Hopewell proprietors built an anthracite-fired furnace, which they soon found uneconomical to operate in their location.) Their more astute neighbors concentrated rolling mills and blast furnaces along the Schuylkill navigation. Completion of the Lehigh (1830) and North Branch (1834) Canals and the Eastern Division of the Mainline Canal (1833) allowed investors to create the “anthracite ironmaking” district that included the eastern part of Pennsylvania’s valley-and-ridge province (Fig. 3-17). With the canals (and later railroads) to bring in ore and fuel, and using blowing engines powered by steam, investors could put their furnaces and rolling mills in communities where other entrepreneurs manufactured metal goods and residents were willing to accept the industrial presence as a wealth-producing alternative to the hardships of rural life.

Furnace proprietors in the anthracite ironmaking district dominated American production of pig and wrought iron for three decades because their fuel source happened to be near the industrial center of the United States. Then they faced increased competition from smelters using bituminous and coke fuel in the west and also from steelmakers. Some, like the managers of the Bethlehem Iron Company, who ran a large iron rail mill, changed over to steelmaking with ore and fuel brought in by rail. Others, like the owners of Danville’s Montour works, the largest American rail mill in the 1850s, did not adopt steel. Instead, they shifted to other wrought iron products and managed to keep their mill going into the first third of the twentieth century. Activity at the Montour works diminished gradually, and its rollers and heaters shifted into other lines of work, as did ironworkers in communities such as Allentown, Easton, and Scranton when the furnaces and rolling mills closed.

**APPALACHIAN PLATEAU**

When they reached the northwest Appalachian Plateau, ironmasters first exploited its wood, water power, and river transportation routes and then turned to its coal and natural gas. They
3-17. This map shows the locations of Pennsylvania’s anthracite-fueled blast furnaces (solid circles), rolling mills (open circles), and anthracite fields (striped areas) in 1858. Since coal-mine owners had canal transportation available by the time ironmasters learned to smelt and puddle iron with anthracite fuel, those who adopted steam power for their blowing engines and rolling mills could concentrate their works along transportation routes rather than disperse them at water privileges. With few exceptions, they chose not to put ironworks in the coalfields.

began smelting with blast furnaces, like the Eaton furnace built in 1804 on Yellow Creek, about a mile and a quarter from the Mahoning River, near the present-day town of Struthers. They built finery forges like the one on Mosquito Creek (now the site of Niles) in Ohio. A few years later artisans at the Eaton furnace began experimenting with a natural resource unique to their area, the Mahoning Valley splint coal. However, it was another forty years before Ohio and Pennsylvania ironmasters began to use raw coal in their blast furnaces on a regular basis.

By 1820 Pennsylvania’s Fayette County, established in 1783, had more charcoal-fired blast furnaces than any other county in the state, as well as numerous forges. Here in 1816 Isaac Meason ran the first American puddling furnaces at Plumstock,
Artisans began smelting cold-blast iron in 1846 at Olive Furnace in Ohio's Hanging Rock district. They kept the mules they needed for hauling ore and charcoal in the stable below Buckhorn Hill (where the photographer stood) and built their houses on the slopes surrounding the furnace. Olive Furnace was abandoned about 1910. The village of Olive Furnace is on State Route 93, fourteen miles north of Ironton, Ohio. (Courtesy of the Smithsonian Institution)

and county residents soon dominated cokemaking. In western Maryland John Alexander and Philip Tyson had initiated American iron smelting with coke at Lonaconing in 1839, while at Mount Savage investors built America's first rail mill in the 1840s. Because they lacked the natural transportation routes Pennsylvanians had, they were unable to sustain these early initiatives.

Ironmasters in the Hanging Rock district of Ohio and Kentucky achieved a national reputation for the quality of their product, one that they maintained through the nineteenth century. John Means, John Sparks, and James Rodgers started the district with a blast furnace completed in 1827. Over the next fifty years, ironmasters built some sixty furnaces to smelt the Hanging Rock ores (Fig. 3-18). Because their furnaces were isolated, the proprietors and artisans built communities for themselves at the furnaces, scattering names such as Scioto Furnace, Ohio Furnace, or Junior Furnace on maps of southern Ohio.

Unlike the ironmasters of the Juniata and Salisbury districts,
who converted much of their pig to bar in finery forges, those
in the Hanging Rock district built no forges. Instead, they used
the Ohio River to send their pig iron to foundries and rolling
mills in Pittsburgh, Cincinnati, and other river towns.\textsuperscript{56} Hanging
Rock ironmasters adopted hot blast promptly, beginning with
the proprietor of the Vesuvius furnace, William Firmstone, who
added stoves in 1836. Following the 1844 initiative of the propri­
etor of the Pine Grove furnace in Lawrence County, most Hang­
ing Rock ironmasters began banking their furnaces on Saturday
night so their artisans would not have to work on the Sabbath.\textsuperscript{57}
In the 1880s they still ran open-top, stone stacks blown by steam
power. They raised steam in boilers with waste heat at the furn­
cace tunnel heads. The Ohio ironmasters preferred charcoal
made by traditional methods. At least one of them imported
charcoal from Kentucky and used an elevator to charge his fur­
cace. Some experimented with new techniques: the proprietors
of the Alice blast furnace tried the Ferre system of smelting by
dividing the upper part of their furnace stack into segmented
chambers where the furnace gases were supposed to roast the
ore and calcine the limestone. They soon rebuilt the furnace
along conventional lines.\textsuperscript{58}

Pittsburgh ironmasters used the Allegheny and Ohio Rivers
to get pig iron from the northwest Appalachian plateau and
Hanging Rock districts, the Monongahela to bring coke from
Connellsville, and the Mainline Canal to get Juniata iron blooms.
By 1879, 34 rolling mills (with 774 puddling furnaces and many
Danks and Siemens furnaces), 8 blast furnace plants (with 15
furnaces), and 16 steelworks lined the riverbanks in Pittsburgh
(Fig. 3-19). In and around Pittsburgh and Johnstown, the steel
industry reused most of the sites of early blast furnaces, pud­
dling mills, and crucible steel works. Industrial continuity here
left little of the fabric of the early iron industries intact.\textsuperscript{59}

THE SOUTH

Aspects of its culture, including slavery and the inferior social
position accorded individuals engaged in industry, defined the
American South. Through the early decades of the nineteenth
century, Virginians led southern pig iron production, while iron­
masters in eastern Tennessee, many using bloomeries, made
much of the region's bar iron. In the 1840s Virginians built
puddling works and took over a larger share of the bar iron
trade, while proprietors of new blast furnaces in Kentucky and
Tennessee made more of the pig (appendix B). Entrepreneurs
in Pennsylvania and Ohio who used coal fuel and had good
transportation systems put southern ironworks at an increasing
disadvantage in national markets during the 1850s. Expensive
transportation in the South more than offset any advantage that
southerners may have had in lower labor costs from their slave
labor.\textsuperscript{60} Because Kentucky did not join the rebellion, and be­
cause the Union Army advanced into Tennessee early in the war,
the Confederacy soon lost the largest segment of its primary iron industry. After the Civil War and Reconstruction, southerners rebounded: in the 1880s they operated some of the largest, most efficient, charcoal-fired blast furnaces in the United States. A large merchant pig iron industry was established around Birmingham, Alabama.  

The industrial aspirations of northerners met the traditions of southern culture in the Potomac and Shenandoah districts. The Great Valley west of the Blue Ridge, which extended from south-
ern Pennsylvania through Maryland into Virginia, offered the settlers who reached it both good farmland and the resources for ironmaking. German settlers from Pennsylvania first entered the valley in central Maryland in about 1730. Major-General Edward Braddock's defeat in 1755 exposed them to Indian attack, and they abandoned the lands west of South Mountain until after the peace of 1763. When they returned, they used the limestone valleys for farming and the sandstone mountain ridges with their associated iron ores and forests for ironmaking. By 1775 ironmasters in central Maryland had a primary iron industry in what had been frontier land only fifteen years earlier. Among them was William James, who began building Antietam furnace about 1763 in what is now the town of Mount Aetna, Maryland, and had it in blast a year later. Archaeological excavation of the site uncovered the stack, crucible, and wheelpit. The furnace was a small one, 12 feet square at the base with outer walls of rough limestone, not battered. The crucible would hold at most about 800 pounds of iron. The excavators found fragments of pigs, one marked “1762,” fragments of pots, decorated stove plates, and casting debris. They concluded that Daniel and Samuel Hughes, who operated the Antietam furnace, made cast items for the local market and pig for conversion to bar iron at their forge on Antietam Creek seven miles northwest of the furnace. (The water power at the furnace site would have been insufficient to operate a forge hammer.)

The Potomac River made the shortest route from the coast to the Northwest Territory. George Washington and other leading Virginians wanted industry along the Potomac; Washington believed that the city named after him could only be a true national capital if it were also an industrial center. Washington joined other investors in founding the Potomac Company in 1785 to build canals around the river’s rapids and to clear its channel of obstructions. In their largest project, the proprietors built a canal to bypass the Great Falls and supply water power to an industrial community. John Potts and William Wilson drew water from it for an ironworks. They began operations sometime before 1793, were probably still working in 1804, and were out of business by 1828. Archaeologists uncovered the remains of a stone building with foundations of three hearths. They found pigs, fragments of cast products such as stove plates and hollow ware, forged bars bearing hammer marks, and slag. Potts and Williams fined pig and poured castings, probably using iron brought down the river from furnaces such as the one at Antietam.

In the 1830s some entrepreneurs wanted to establish manufacturing with water power along the Potomac. The district's ironmakers provided the necessary primary metals: in 1827 the Antietam Iron Works at the mouth of Antietam Creek made castings for machine tools ordered by John Hall for his Harpers Ferry rifle works. The partners later added a nail factory and
rolling mill to their works. They built up a community that in­
cluded a limestone crushing mill, spinning mill, hemp mill, flour 
mill, shingle works, sawmill, cooperage, stoveworks, and woolen 
mill. They built a new blast furnace that used coke and char­
coal fuel in 1845, a few years after completion of the coke-fired 
blast furnace at Lonaconing, Maryland. They got coke from the 
western Maryland coal field via the Chesapeake and Ohio canal. 
However, they failed to make the uniform, high-quality iron 
needed by the armory; the managers at Harpers Ferry had to get 
this material from the Juniata and Salisbury districts. Despite a 
brave start, few of the district’s entrepreneurs prospered. Merr­
ritt Roe Smith’s analysis of the fate of the government armory 
at Harpers Ferry shows the cultural factors that lay behind the 
demise of industrial ventures here.

About 1720, at the same time that British merchants revived 
colonial ironmaking by organizing works in Maryland, Alexan­
der Spotswood built a blast furnace at Germanna, about ten 
miles above Fredericksburg. Later Baltimore capitalists helped 
spread ironmaking into the piedmont. Settlers moving into west­
er Virginia got the iron they needed for tools and implements 
from ironmasters like John Donelson, who built a bloomery at 
Rocky Mount in 1773. By 1809 his Washington ironworks had 
19,000 acres of timber and farmland, and thirty-eight slaves. 
In 1837 eighty-three slaves did everything except manage the 
works. During the 1840s competition from less expensive metal 
made in the North with mineral fuel forced the owners of the 
Washington works, who had never cultivated customers beyond 
their immediate locality, to gradually contract their business.

The German, Scotch, and Irish settlers from the North who 
moved up the Shenandoah started the longest lived component 
of primary Virginia ironmaking when they bypassed bloomeries 
and set up furnaces and forges after 1760. Unlike the pro­
prietors of the Washington ironworks, many Shenandoah iron­
masters developed a new market for their products. They sold 
their pig iron to the new puddling and rolling mills that Virgin­
ians built in the Richmond area in the 1840s. Joseph Anderson 
of the Tredegar ironworks believed that one essential compo­
nent of his success was the superior pig iron he bought from 
certain Shenandoah Valley furnaces. He willing paid $60 a ton 
for Catawba iron, three times the price of ordinary grades.

As settlers moved into the northeast corner of Tennessee in 
the 1790s, entrepreneurs among them constructed bloomery 
forges to supply basic iron products. Because of the expense of 
bringing manufactured goods to this mountainous region, forge 
proprietors could sell their high-cost, locally made iron profit­
ably until better transportation systems allowed merchants to 
buy iron elsewhere. Settlers in eastern Kentucky considered the 
Bourbon furnace, built in 1791, important enough to have the 
militia called out to protect the works against Indian attacks sev­
eral times between 1792 and 1794. When the treaty with Spain
opened the lower Mississippi to trade, the Bourbon ironworks proprietors were able to expand their enterprise by shipping their products to New Orleans for sale. They abandoned the Bourbon furnace as obsolete in 1822 and shifted their operation to a newer, larger furnace. Other frontier entrepreneurs built bloomeries, furnaces and forges in Estill, Wayne, and Montgomery Counties early in the nineteenth century.

Only a decade after pioneers began ironmaking in eastern Tennessee, artisans moved into central Tennessee, finding sites for more substantial ironworks. Once they crossed the Appalachian divide, they could ship their products to eastern markets by way of the Mississippi River and New Orleans. Some achieved substantial technical skills. Richard C. Napier, who built Turnbull Forge in 1815 on Turnbull Creek, twenty-five miles west of Nashville, had some of his iron tested in 1826 at the Springfield Armory. The superintendent reported it “to be equal in quality to any found in commerce, and only inferior in refining to the best warranted Salisbury Iron.” By the 1820s entrepreneurs had solidly established ironmaking in the Cumberland Valley, particularly in Montgomery and Dickson Counties; before the panic of 1837 they had twenty-five furnaces in blast. New Orleans buyers particularly liked the superior heat resistance of sugar kettles cast in this region of Tennessee.

The development of the Tredegar works in Richmond, Virginia, illustrates how proprietors of American rolling mills used the newly opened canals and railway systems to assemble raw materials and ship products to distant customers, and how southern entrepreneurs encountered difficulties unlike those their northern competitors faced. The James River and Kanawha Canal connected Richmond, a seaport at the falls of the James River, with mines twelve miles upstream that could supply coal suitable for puddling and for melting iron in foundries. Canal boats delivered pig from Botetourt County in the Shenandoah Valley, where as early as 1810 ironmasters had twenty-eight forges, sixteen blast furnaces, and eight bloomeries, all fueled with charcoal. John Clarke drew on these resources when he established his Bellona Foundry at the edge of the Richmond coalfield. By 1830 he had made Bellona one of the principal suppliers of cannon to the U.S. government. Next, Richmond entrepreneurs chartered the Belle Isle Manufacturing Company and Cunningham’s rolling mill to puddle and roll iron on sites at the falls of the James River.

In 1837 the owners of Cunningham’s mill and the adjacent Virginia Foundry Company in Richmond merged their works to form the Tredegar Iron Company. By 1843 they had established a reputation for the quality of their products that allowed them to sell in New York and New England. Tredegar artisans used seven puddling furnaces and a merchant mill to make railroad
iron (flat bars, usually 2.5 x 0.5 inches) and axles as well as rods and angle bars. The owners of the nearby Belle Isle works specialized in nail making. Through their sales to Bellona and Tredegar, some Shenandoah ironmasters had built reputations for the superior quality of their pig that allowed them to sell it to foundries as far away as Boston. By 1860 the Tredegar proprietors in Virginia, with eighteen puddling furnaces and two rolling mills, operated at a node of a trading network that moved pig iron and coal to Richmond from the west, bought anthracite-made pig iron from Pennsylvania, and sold wrought iron products along the Atlantic seaboard.

In 1854 the East Tennessee Iron Manufacturing Company, operator of Eagle Furnace in Roane County, built the Bluff furnace (blown with steam power and hot blast) on the Tennessee River at Chattanooga, where it could bring in ore from its mines sixty miles upriver. At this time ironmasters were investing in
furnaces located near supplies of coking coal, as in western Maryland. In 1860, when a rail connection made it possible to bring coal from Raccoon Mines, James Henderson supervised the rebuilding of the Bluff furnace as an iron cupola stack designed to use coke fuel. He successfully blew in the new furnace. Archaeologists excavating the site found evidence that the second furnace campaign ended when the furnace staff could not stop a breakout through the hearth walls. This, together with the difficulties of maintaining steady work in the face of the political excitement among the artisans in November 1860, led Henderson to abandon the furnace. Confederate forces removed the blowing machinery, and by 1864 soldiers had destroyed the works. However, the war left Chattanooga with the nucleus of a new iron industry. In 1864 the federal government brought John Fritz to Chattanooga to supervise construction of a new rolling mill to rework old rails for rebuilding captured railways. After the war, private owners began railmaking here.

Although pioneer ironmakers in Virginia, Maryland, Delaware, and New Jersey used the resources of the coastal plain, in the southernmost states they began in the piedmont, reached by settlers a decade before the Revolution. Upon the outbreak of war, the legislatures of both the Carolinas and Georgia offered substantial bounties to persons who would establish ironworks. John Wilcox had a bloomery in operation and had started to build a furnace on a branch of the Deep River in Orange County, North Carolina, in 1776. His difficulties with the furnace illustrate the problems often encountered by adventurers attempting to establish in frontier country an industry that depended on a high level of technological expertise. Wilcox had no experienced artisans. When his crew blew in their furnace, the hearth stones failed. After repair, they found that they did not have enough water to sustain operation of the blowing engine during much of the year. Then, a great freshet in June 1780 damaged the furnace beyond repair. Despite such troubles, several families successfully operated substantial ironworks serving local markets in the Carolinas and Georgia, reaching the peak of their prosperity in the 1840s. A few, better placed in the regional transportation system, had significant industrial works by the time the Civil War began. Jacob Stroup, a Pennsylvanian, established the Etowah forge in 1837 in Bartow County, Georgia. He started with a bloomery and gradually enlarged his works. Some time before 1849 he replaced his finery with a puddling works, Etowah Rolling Mill, where he employed several hundred hands, making railroad iron as well as machinery needed by local agriculturalists. By 1859 Etowah had 9 puddling furnaces, 3 trains of rolls, 3 nail machines, and 1 hammer, all run by water power, and some 500 hands at work.

Alabamans had one small blast furnace and a few bloomery forges built when the state was admitted to the Union in 1819. Although the legislature appointed Michael Tuomey state ge-
ologist in 1848, it did not appropriate funds for his work until 1854. Tuomey recognized that Alabama had large deposits of the coal, ore, and limestone needed for ironmaking in one district. However, at the start of the Civil War, Alabama had just seven charcoal-fired blast furnaces along with some bloomery forges, most built by immigrants from Pennsylvania. Horace Ware of Massachusetts put the state’s first rolling mill into operation at his Shelby Iron Works in 1860.

The Confederate government invested heavily in new ironworks, particularly in Alabama. The Union Army destroyed most of them in early 1865, and postwar recovery was slow. A. W. North of New Britain, Connecticut, undertook reconstruction of the Shelby Iron Works with northern capital in 1867. He built a large, efficient, charcoal-fired blast furnace plant that operated until 1923. However, the future of ironmaking in the South lay in the coal and iron ore deposits found in a diagonal band that extended southwestward into central Alabama. Industrialists incorporated the new city of Birmingham in 1871 and built the first of many blast furnaces within the city limits, the Alice, in 1880. J. W. Sloss, a native Alabaman, started smelting iron with fuel made from the large deposits of coking coal near Birmingham when he organized a company to build the Eureka blast furnace at Oxmoor in 1876. In 1882 he established the Sloss furnaces in Birmingham.

Although agriculture dominated their politics and culture, southerners made iron wherever they found ore and water power in the years before 1861. They built bloomery forges and small blast furnaces in the uplands, and in regions with better transportation they adopted puddling and rolling mills. When economic opportunity beckoned, southern ironmasters adopted the same methods used in the North, as at Tredegar and the Etowah rolling mills. They and their artisans achieved technical expertise comparable to their northern competitors, as when artisans at the Shelby Iron Company rolled the iron armor for the C.S.S. Tennessee, the most successful of the Confederate ironclads. However, southern ironmasters increased the proportion of slaves among their artisans while simultaneously trying to maintain the closed social system of the plantations, thereby severing the communication between artisans and managers that contributed so much to the success of other American entrepreneurs.

LAKE SUPERIOR

When Michigan appointed Douglas Houghton, an 1828 graduate of Rensselaer Polytechnic Institute, state geologist in 1837, he began to explore the Upper Peninsula for mineral resources. After Houghton drowned during a storm on Lake Superior in 1845, William A. Burt carried on the explorations. Burt, troubled by large magnetic-compass deviations, designed a sophisticated sun compass. His reports of magnetic anomalies near
Negaumee attracted prospectors, who soon located the rich ore of the Marquette Range.

American entrepreneurs interested in the northern Michigan district faced the problem of developing rich iron resources in a remote area (Figs. 3-21, 3-22). They first tried bloom smelting (for which their ore was suitable) with charcoal made from their adjacent woodland. The Jackson Mining Company brought in bloomers from New York to set up a forge on the Carp River in 1847; other pioneers built three more on the Dead River near Marquette, which they ran until 1858. Although these adventurers had rich ore, abundant wood, adequate water power, and skilled artisans, they encountered difficulties with the severe climate and the lack of roads to the mines.

After the mining companies built road and railway connections to Marquette, and after the Sault Canal opened in 1855, entrepreneurs could choose between shipping ore to ports on the lower lakes, smelting it near the mines with charcoal, or bringing coal fuel in to their ironworks. They tried all three. L. D. Harvey of East Stockbridge, Massachusetts, completed a charcoal-fired blast furnace for the Pioneer Iron Company at Negaunee in 1858. The proprietors finally abandoned it in 1893 to make way for a larger one. Between 1865 and 1875 other entrepreneurs built seventeen large, modern blast furnaces in north-
Ironmasters first smelted ore from the Marquette Range (striped area) at bloomeries (triangles) placed along the rivers and then turned to charcoal-fired blast furnaces (circles). Experiments with an anthracite-fueled blast furnace (square) and a bituminous-fueled furnace and puddling works (diamond) in Marquette proved unprofitable. A dense network of rail lines (not shown) moved ore, fuel, and iron.

ern Michigan, all but three fired with charcoal. In the East, ironmasters had to place their blast furnaces along the rivers they used for power or transportation. Michigan proprietors avoided this constraint with steam-powered blowing engines and railroads to deliver ore and haul away their iron. Also unlike many of their eastern colleagues, they did not bother to manage their woodlands for continuous yield. Instead, they got charcoal from distant vendors by rail after they had consumed the woods near their works. Although they had large, modern furnaces, many Michigan ironmasters followed the practice of their colleagues in Ohio and central Pennsylvania and banked their furnaces on Saturday nights so that their artisans would not have to work on Sundays.89

When investors built Marquette’s Grace furnace in 1872, they intended to run it on imported anthracite. Within two years it proved uneconomical. In 1896 the owners of the Gladstone Pioneer furnace had it designed to run on either coke or charcoal; they found they could recover the extra cost of using charcoal by selling wood alcohol made with effluent from their charcoal kilns.90 As late as 1890 the Board of Trade and Citizens Association of Marquette were assembling data to prove that it was more economical to bring coal north than to ship ore south.91 Experience showed, however, that it was cheaper to ship the ore to furnaces near fuel than to ship fuel to northern Michigan.
Making steel proved a particularly difficult problem for American ironmasters through the first two-thirds of the nineteenth century. When they converted bar iron to blister steel, manufacturers found it inferior to the Sheffield product. Manufacturers of edge tools and mechanisms such as gunlocks wanted crucible steel, and they used imported metal. English steelmakers retained their American market through vigorous sales efforts. They provided technical advice, presented customers with gifts, and, most important, supplied superior quality, reliable metal. The Sheffield steelmakers succeeded through their control of the best Swedish iron, access to coal and the special clay needed to make crucibles, and their experienced, stable work force. Steelmaking remained an art where experience counted for much and formal metallurgical knowledge for little. Others found it difficult to duplicate this success because artisans could not transfer techniques that depended on experience and specific materials unavailable elsewhere.

Americans attempted to break the Sheffield dominance of the crucible steel supply. In 1832 William and John Garrard, men in their early thirties who had arrived from England ten years earlier, began making crucible steel in a two-pot furnace they set up in Cincinnati. Information on this enterprise comes from William Garrard’s reminiscences, written fifty years later, and from James M. Swank’s examination of samples that the Garrards had saved. Swank found the steel to be good. However, the Garrards did not make much of it. In the next twenty years, some Pittsburgh blister steelmakers tried the crucible process without much success.

The proprietors of the Adirondack Iron and Steel Company made a sustained effort to produce steel, beginning in about 1835. They believed, wrongly, that their ore would make iron particularly well suited to steelmaking. When Joseph Dixon undertook management of the company’s steelworks in Jersey City and supplied it with graphite crucibles in 1848, the Adirondack artisans began to make commercial quantities of cast steel. However, it “was not for many years of uniform excellence” and did not displace the Sheffield product. Americans needed another fifteen years to make good crucible steel consistently.