The Iron Industry Underground
The Archaeology of Historic American Iron Technology

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INTRODUCTION
The traditional date for the founding of the American iron industry is 1622. In that year the English-based Virginia Company of London first attempted to smelt iron in Falling Creek, Virginia.

The hope was that enough iron could be produced both for export to the Old World and to supply the needs of the newly founded Jamestown colony. It was a major enterprise: about 150 experienced workmen were sent to the colony to construct what was probably a blast furnace together with a finery and chafery forge.

While the works were slow to move into production, by late spring of 1622 enough progress had been made for the company to write to the colony of "the good enter- ance with you and the iron works" (Swank 1884: 76). Alas, the letter did not reach its destination: on March 13 and the Falling Creek settlement had been massacred by Indians. All the workmen were killed, the buildings were destroyed, and the workmen’s tools thrown into the river. "And thus ended disastrously the first attempt by Europeans to make iron in America" (Swank 1884: 78).

James Swank is the author of the first and still the most complete history of iron manufacture in the United States. In his introduction he explained that his aim was to "preserve from decay the remembrance of what men have done" in the manufacture of iron" (1884: 56). The archaeologist at iron-working sites has more particularly the goal of retrieving from remnants in the earth that information which has already slipped from remembrance.

In early years excavations on iron manufact- uring sites were primarily designed to gather data for reconstruction or restoration. Such important industrial complexes as Saugus and Hopewell were first excava- ted to locate structures and to elucidate constructional details. Moreover the focus early on was very much on the producing industrial unit—the forge or furnace itself—as in the efforts to locate Charlotte- burg Forge and the Valley Forge. More recently, interest in iron sites has broad- ened to include the whole community structure, the recent work at Long Pond Valley being a good example. Questions such as status differentiation between worker and ironmaster as at Hopewell, identification of ethnic sub-cultures at Catottin, and the role played by ancillary structures, are increasingly being addressed.

Investigation of technological developments has been materially aided by the increasing use of analytical techniques. Analysis of the slag with which every kind of iron-working site is littered can often determine quite specifically the process which produced it, as at Catottin, and also the type of ore being smelted, the flux or additives, the fuel, the operating temperature, and the efficiency of the furnace, as was done for the Eaton (Hopewell) Furnace. Metallurgical and elemental analysis of the metal can identify the type of iron pro- duced, what its mechanical properties were, and how effective it would have been for its intended purpose; and can document alloying, forming and heat-treating prac- tices, as at the Whitney Armory.

In this article, some of the findings of selected excavations on iron manufactur- ing sites illustrate a general survey of the history of the American iron industry in the East.

IRON MANUFACTURE UP TO THE REVOLUTION
Following the demise of the Falling Creek venture, iron making in Virginia seems to have ceased until the 16th century. In the New England colonies, however, an equally ambitious undertaking, also conceived in a spirit of exploitation of colonial resources for the home market, was initially more successful. (John Winthrop Jr., son of the first governor of the Massachusetts Bay Colony, travelled to England in 1641 to pro- mote the interests of New England. He returned having stimulated the creation of the Company of Undertakers of the Iron Works in New England, which was de- signed to encourage and support iron manu- facture in the colony. After initial financial and organizational problems culminating in Winthrop’s removal as director in 1645, an integrated facility, the Hammersmith Works, incorporating furnace and forge, and a rolling and slitting mill, was erected on the banks of the Saugus River, outside Boston. In the 17th century iron was most often produced by the indirect method. In this technique, a blast furnace, usually a truncated pyramid of stone maybe 35 feet high and 30 feet square enclosing a cylindrical hearth, was charged with iron ore, charcoal fuel and limestone flux (to facilitate the creation of a slag). Pig or cast iron was pro- duced, which has a low melting point and is easy to melt and cast into complex shapes, but is brittle and non-malleable. To be used for the production of tools and other items, the iron had to be re- melted by being remelted in a finery forge. The carbon and other undesirable elements would be oxidized and, after consolidation under hammer driven by a water wheel, the result would be wrought or bar iron, as free from carbon as possible, a soft, ductile, malleable substance readily machinable and easily welded.

Both a furnace and a forge were in use at Hammersmith (Fig. 1). As well, a rolling and slitting mill was in operation there, one of the earliest built anywhere and one of very few built in America in the Colonial period. Here bar iron was heated and flattened between rollers, then cut into long rods which could be used for production of nails and other small items by being passed between opposing disc cutters (Fig. 2).

The Hammersmith operation was a sophisticated one for its time, perhaps more so than the needs or abilities of the
undertakers warranted. Little iron was produced and ultimately the operation shut down in a morass of bills and legislation in 1632.

The Hammersmith enterprise is a good example of the strain that was implicit in the Colonial manufacture of iron due to conflicting needs and expectations. Initially this was manifest in the discrepancy between the requirements of the British investors, who were putting up the money for large-scale installations in the hope of producing a surplus of iron to be sold in England for profit, and of the Colonials, whose major concern was production for the local needs. In some cases, simpler, less advanced technology, such as direct production of wrought iron from the ore in bloomery forges, was more suited to the conditions in the colonies, and prospered where the overly ambitious Hammersmith enterprise failed.

In the 18th century the conflict was more direct; the growth of a Colonial iron industry ran counter to British iron interests. A series of regulatory efforts led to the 1750 Iron Act, which encouraged the production of pig and bar iron for export but forbade the erection of slitting and rolling mills, plating mills or steel furnaces. The intent was to induce the Colonists to supply British forges and mills with raw iron and to force them to buy their finished iron tools and hardware from the same, obviously at much higher prices than if produced at home. The Act was widely disregarded, with active collusion on the part of the Colonial governments (who were responsible for its enforcement) in the erection of forbidden steel works and especially naileries, but such attempts at regulation of such an essential commodity contributed to the events leading to the Revolution.

The last attempt before the Revolution to develop American iron exploitatively for British interests was the work of a remarkable entrepreneur, Peter Hasenclever. Arriving in America in 1764 as agent and manager for the London-based American Iron Company, by 1768 he had established a vast undertaking in the Ramapo Mountains of northern New Jersey. At its peak the operation included four blast furnaces—at Ringwood, Charlotteburg, Long Pond and Cortland—seven forges, and two stamping mills (in which furnace and forge cinder and slag were stamped or crushed to extract the iron in them). It employed 500 workmen and had expended nearly £55,000 of the investors’ money while producing only 300 tons of bar iron in a year. The company panicked at the low rate of return on its investment and recalled Hasenclever. Subsequently the properties were managed by Robert Erskine—who was to become George Washington’s chief topographer—but with the onset of the Revolution and its drain on able-bodied men, the works shut down by 1778.

The Revolution of course lent an urgency to the Colonial needs for iron and iron manufactory, particularly cannon and shot and shell. Both Catawba in Maryland and Hopewell, Pennsylvania, iron plantations which began operations at around this time, seem to have been supplying shot to the Continental Army. Hopewell was also supplying cannon but with uneven success. The Superintendent of Ordnance made the disgruntled note in 1778 that “not one of Mr. Bird’s [ironmaster of Hopewell] cannon that were made before I got the plan altered stood the proof” (Sanders and Gould 1976: 152). Casting cannon was the true test of the mould, and the failure rate among early cannon was notoriously high. As General Washington remarked, “It is a melancholy consideration that in these cases we suffer more from our own Artillery than the Enemy” (Mulholland 1981: 129).

Hopewell must have been making some substantial contribution to the war effort, however, as much as Mark Bird was more lucky than Erskine and managed to secure the discharge of his workmen from the militia into which they had been drafted. The importance of Revolutionary period iron production is also illustrated by the fact that the British army razed every American installation they came near, including the most famous forge of all, Valley Forge (Fig. 5).
LIFE ON AN IRON PLANTATION

In the 18th and into the 19th century iron manufacturing generally took place in the context of an iron plantation. The necessity for the blast furnace to be near its raw materials—ore, limestone and especially the acres of woodland needed to produce charcoal to fuel the works—dictated a location far away from settled centers of population. Because of this isolation iron manufacturers had to be self-contained, self-sufficient communities, and included the mansion house, the homes of the workers, the furnace and forge or forges, the iron mines, the charcoal house, the dense woods which furnished the material for making charcoal, the office, the store, the smithy, the sawmill, the blacksmith shop, the large outside bake oven, the barns, the grain fields, and the orchards (Binning 1936: 20).

The ironmaster had to supply all goods and services to his workers, resulting in a semi-feudal organization. Often he owned his workers if they were black or virtually owned them if they were indentured (Fig. 7).

By the same token, however, the ironmaster was often at the mercy of his workers. Experienced iron workers were much in demand and often could behave in a high-handed fashion seemingly without reprisal. The account books and journals which were kept by clerks and ironmasters of furnaces and which provide a wealth of information on the economics and day-to-day tasks of keeping a furnace in blast also detail problems in management-worker relations. The chief clerk keeping the journal for the Lonaconing Furnace in western Maryland makes this laconic note as Christmas, 1837 approached: "The Welshmen are drinking very hard. Steele [in charge of mining operations] thinks it cannot be helped" (Harvey 1977: 23).

An even more extreme case is detailed by the furnace clerk in the Martha Furnace (New Jersey) Diary for 1809:

July 28 Molders all agreed to quit work and went to the Beach.
30 Molders returned from the Beach. J. Venning drunk and eating eggs at the Sitting Mill. Josiah Townsend wanting to fight J. Williamson. Furnace boiled & the metal consolidated in the gutter.
31 Molders all idle.

August 1 This month begins with good weather. Molders commence molding for the first time since they came from the Beach (Pierce 1857: 100).

The New Jersey shore seems to have been as popular then as it is today.

This burial is of an adult black male and was uncovered in excavations on the site of an unmarked cemetery at Catoctin by Mid-Atlantic Archaeological Research, Inc. in 1975. He was almost certainly one of the black slaves who worked at Catoctin Furnace in the late 18th and 19th centuries. Photograph courtesy of Mid-Atlantic Archaeological Research, Inc.

NINETEENTH CENTURY ADVANCES IN TECHNOLOGY

The history of 18th century American iron manufacture was played out against the backdrop of the British attempts at regulation of the industry. In the 19th century the main story is the changing needs of the iron consumer and the reaction of the domestic iron industry to try to meet those needs.

The changes in the technology of iron smelting in the 19th century revolved around the adoption of anthracite and coke as fuels. The greater structural strength of the fuel allowed a greater amount of iron to be charged and smelted in a higher blast furnace. The tall column of ore and a less porous fuel, however, required a stronger blast and, as well, anthracite and coke generally required a hot-blast. These factors necessitated powerful blowing machinery, preferably steam—rather than water-powered, and hot-blast stoves. At the same time the increased heat meant a more impure pig iron might be produced, as more of the impurities were reduced from the ore.

A concurrent change in the refining branch of the industry was the adoption of the puddling furnace in place of the refinery forge.

These technological innovations were all in use in Britain in the 18th century and led to a major increase in the production of both pig and wrought iron. In America these were not accepted until the next century. America did not have the impetus to switch fuels that Britain, which had run dangerously short of woodland for charcoal in the mid-18th century, faced.

Also, while the use of coal as a fuel fostered an increase in production, it did not necessarily mean a better grade of iron; charcoal iron was still the iron of choice for certain products, notably railroad car wheels, up to the Civil War. The histories of specific sites in the 19th century all show an uneasy wavering balance between technological advance and conservatism.

Some ironworks tried to incorporate the new technology before need arose, with little understanding of its constraints, and became overextended and failed. A good example is the Eaton (Hopewell) Furnace near Youngstown, Ohio. The furnace was first operated in 1803, and appears to have been the first furnace in the New World to
John White excavated the Eton Furnace in 1775-1787. The black raised mass extending from the top hole of the furnace near the casting floor in the foreground is the remains of the furnace's last cast and suggests that the incompletely reduced charge burst onto the casting floor as a result of a failure of the furnace lining. Photograph courtesy of John White, Youngstown State University.

The revolver frame seen here, excavated from the Whitney Armory site in 1978 by David Starbuck and studied by a team of researchers from Yale University, is made of malleable cast iron, and was discarded during manufacture. Photograph by William Beccio.

The casting house was the center of the stove foundry which guaranteed Hopewell's prosperity in the 19th century. The floor foundation of stone and iron slabs is seen here in the course of the excavations carried out by Leland Abel in the 1960s; the furnace stack is to the right. Photograph courtesy of the National Park Service.

Use coal as a fuel. Unfortunately, this innovation resulted in a poor quality high-sulfur iron, and probably led to the furnace's demise in 1838 (Fig. 6). A more successful innovation was Eli Whitney Jr.'s replacement of wrought iron with steel for his gun barrels manufactured at the Whitney Armory in Connecticut around the middle of the 19th century. Even more interesting is his use of malleable cast iron instead of wrought iron for the revolver frames. This innovation would have allowed the intricate frames to be cast rather than forged, and would have resulted in a stronger frame as well (Fig. 9).

Hopewell Furnace in Berks County, Pennsylvania, was an important and ultimately successful 19th century iron plantation. While Mark Bird went bankrupt after the Revolutionary War and Hopewell went through a history of changes of ownership and sheriff's sales, it finally prospered after 1820. Cast iron stoves were its primary product and the source of its greatest profit until 1844 when stove-casting was halted (Fig. 10). Like many other old installations, it suffered from competition with the new.
more efficient furnaces built around the middle of the century incorporating the latest technology. The furnace managed to stay in operation for a time, casting charcoal pig iron for specialized purposes, but abortive attempts to upgrade the physical plant by incorporating technological improvements such as steam-power and use of waste gases for heating were fruitless, and it went out of blast in 1883.

Bluff Furnace in Chattanooga, Tennessee was an example of the new breed of charcoal furnaces, built in 1854 with innovations borrowed from the coal-smelting technology, such as steam-power and hot-blast. It was however converted to coke in 1859 and completely modified from a square stone structure to a cylindrical boiler-plate stack (Fig. 12). However, it came to an abrupt and unusual end as described by Swank: "The furnace was started on a second blast on the 6th of November [1860], the day of the presidential election, but political complications and the demoralized state of the furnace workmen were obstacles too great to be overcome, and the furnace soon chilled" (1864: 290). It apparently never was put back into blast.

An iron plantation that followed a similar course to that of Hopewell was Catoctin, in Frederick County, Maryland. The first furnace, a cold-blast charcoal furnace, was erected around 1776 and rebuilt incorporating a hot-blast in 1833. In 1857 the Isabella Furnace was built: this was steam-powered but cold-blast. Finally, in 1873 the Deborah Furnace, a hot-blast coke and anthracite furnace, was erected. Catoctin weathered the exigencies of the industry through the 19th century, experiencing a heyday in the third quarter of the century when it extended over an area of some 11,000 acres and included mines, ore roasters, limestone quarries, the furnaces, and numerous ancillary structures (Fig. 13).

Long Pond, New Jersey, site of one of Peter Hasenclever’s charcoal furnaces, had a brief period of prosperity in the first half of the 19th century but then lay quiet until the demand for iron during the Civil War prompted the erection of two large charcoal furnaces twice as high as the Colonial
charcoal furnaces. Other than in size, however, the Long Pond furnaces retained the older technology, being powered by water throughout their working life (Fig. 14). This activity was also manifested in the building of a series of multi-family company dwellings; in fact, Long Pond in the late 19th century was a very much in the iron plantation model.

The Long Pond Works demonstrate the fallacy of assuming that retention of traditional techniques equates to an antiquated or backward mentality in the operator. The Long Pond Works were owned by Peter Cooper and Abram Hewitt, not inconsiderable names in the history of the iron and steel industry, who pioneered the introduction of the open-hearth steel furnace to the United States. But when Hewitt was evaluating the differential economies of steam and water power, he noted that the use of steam at Long Pond would have added 50¢ a ton to the cost of the iron produced there. In the 19th century, survival was a question of selective innovation and adaptation, and those manufacturers who understood that stayed afloat in the troublesome times, especially those towards the end of the century, as described by a trade journal writer of the 1870s:

The dying out of old furnaces, the building of new ones, the alternate stagnation and activity of every branch of the wrought iron business, the constant and increasing activity of every branch of the steel trade, the substitution of iron for wood, and of steel for iron, the multitude of new types of iron and steel furnaces, direct processes, etc., all struggling for existence at once, furnish a problem for the ironmaster the like of which has not been seen in this generation (Sanders and Gould 1876: 315).

The reason for all this hubbub was, of course, the ascension of steel. The Bessemer converter patented in 1856, and the open-hearth process developed around 1865, for the first time made the manufacture of steel in quantity a commercially viable proposition. It took some time for the manufacturing of steel to become established, but ultimately it sounded the death knell for the manufacture of iron.

**Bibliography**