BLUFF FURNACE
ARCHAEOLOGY OF A NINETEENTH CENTURY BLAST FURNACE

by
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April 1982
ACKNOWLEDGEMENTS

The research reported in this manuscript is unique in several respects. Industrial archaeology in this country is still in its infancy, and an intensive study of a historic iron works is an unusual undertaking, particularly in the South. The site itself provided numerous surprises and challenges, but the least of which was the presentation to Bluff Furnace of Chattanooga, Inc., by the Jeffrey L. Brown Institute of Archaeology 

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The research reported in this manuscript is unique in several respects. Industrial archaeology in this country is still in its infancy, and an intensive study of a historic iron works is an unusual undertaking, particularly in the South. The site itself provided numerous surprises and challenges, not the least of which was the fundamental problem of how to uncover the archaeological remains in an effective yet safe manner. Our biggest surprise, however, has fortunately proved to be a pleasant one. It involves the remarkable interest and encouragement for our research that has emerged across a wide cross-section of individuals and organizations in Chattanooga and throughout the state. As will become apparent in this report, without the combined energy and involvement of these supporters, the project would never have reached a successful conclusion. We will make an attempt to identify those who have contributed to our efforts, but we recognize that we will never be able to sufficiently express our gratitude for their support.

In no particular order, organizations and companies that have made major contributions to the project include Bluff Furnace of Chattanooga, Inc.; the American Foundrymen's Association; the Association for the Preservation of Tennessee Antiquities; the Lyndhurst Foundation; Campbell Construction Company; Chattanooga Coke and Chemical Company; Hensly-Schmidt, Inc.; U.S. Pipe and Foundry Company; the City of Chattanooga; American Cast Iron and Pipe Company; Don J. Phen Landscaping; Combustion Engineering; the Hunter Museum; James Wilson
Individuals who have assisted the project are literally too numerous to mention. A partial list of those deserving special recognition includes the following:

In the last five years, Jim Werner has devoted most of his energies and abilities to planning and implementing the progress of the Bluff Furnace project. As President of Bluff Furnace of Chattanooga, Inc., he has managed to light a fire under everyone involved in the project, and his guidance has provided continuity and direction over the years, as it will continue to do so in the years to come.

Steve Campbell is the person most responsible for transforming Bluff Furnace from being a nice idea into a significant industrial archaeological site. Without Steve's continuous help, the site would still be a patch of green next to Riverfront Parkway. He provided us with heavy machinery, a skilled operator, maintenance, and supplies throughout the project; he was a constant source of advice during the excavation and stabilization of the site; and he was and is a friend to us all. In many ways we are fortunate to have worked with him.

Kendall Morton was extremely generous with his time and support. His contributions ranged from coordinating the project publicity to spending his weekends with a chainsaw, helping to remove the timber at the site. He also personally conducted the UTC field school students on a tour of the Chattanooga Coke and Chemical Plant, of which he is manager.

Sam Rogers has been involved with the project since its inception in 1977 and has donated much time and expertise to the cause. He has
been especially helpful in developing the concept of Bluff Furnace as an interpretive park and in clearly defining the steps needed to reach this goal.

As treasurer of Bluff Furnace of Chattanooga, Inc., Hal Torok has kept a steady hand on the financial complexities of this project. He has also been a constant source of encouragement and at times has provided a much needed sense of practicality to the proceedings.

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Finally, we dedicate this report to the memory of Jeffrey L. Brown. It was he who discovered the site, recognized its importance, and most importantly, communicated his enthusiasm for Bluff Furnace to others. We share in that enthusiasm with all those who knew him.

R.B.C
M.E.W.
N.H.
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Results of archaeological and documentary research relating to the Bluff Furnace Site (1854-1860), a hot-blast iron furnace in Chattanooga, Tennessee, are presented. Research objectives for the project were defined as (1) establishing the coherent nature of the archaeological remains, (2) defining distinct activity areas at the site, (3) identifying the industrial processes that occurred there and determining their relative efficiencies, (4) establishing the local and regional significance of the operation in an industrial and economic sense, and (5) realizing the educational potential of the site. Data applicable to meeting these objectives were generated from the synthesis of archaeological and documentary lines of evidence.

Major structural components of the early charcoal-fueled and later coke-fueled periods of the site were exposed during the excavation, including the base of a coke-fired cupola containing an in situ iron salamander. Analysis of by-products and pig iron samples indicate the operation was capable of producing a high quality finished product, though in a somewhat inefficient manner. In comparison to other blast furnaces in the United States at mid-nineteenth century, Bluff Furnace is seen as an innovative industrial enterprise in a regional perspective.
1. INTRODUCTION

Site Background

Since its discovery in 1977 by the late Jeffrey L. Brown, the Bluff Furnace Site in Chattanooga, Tennessee, has been the focus of a number of research activities. This report documents archaeological and historical research carried out at the site primarily during the summer and fall of 1981 and the winter of 1982 by the Jeffrey L. Brown Institute of Archaeology, University of Tennessee at Chattanooga. Supported in part by a gift from the Tennessee Chapter of the American Foundrymen's Association and principally by a grant from the Bluff Furnace of Chattanooga, Inc., excavation was carried out at the site in order to

1) determine the extent and condition of the archaeological remains present;
2) determine the physical structure of the site through definition of specific activity areas;
3) recover evidence of site function, particularly the industrial processes that may have been employed at the operation;
4) evaluate the historical significance of Bluff Furnace on local and regional levels; and
5) derive educational benefits from the study of the archaeological and historical data.

The Bluff Furnace was recognized as an important archaeological site in the Chattanooga-Hamilton County Landmarks survey completed in April 1977 (Chattanooga-Hamilton County Regional Planning Commission 1977:26). Consequently, when plans were begun to replace the Walnut...
Street bridge the furnace remains had to be taken into account in consideration of possible adverse construction impact (Tennessee Department of Transportation 1977:5-6).

The archaeological remains of Bluff Furnace were first encountered by Dr. Jeffrey L. Brown of the Institute of Archaeology, University of Tennessee at Chattanooga, while conducting reconnaissance of impact areas associated with proposed alternate routes for the Walnut Street bridge replacement. Under a contract with Hensley-Schmidt, Inc., Brown conducted test excavations at the furnace site from April 25 to May 6, 1977. In addition to documenting exposed features on the rock bluff and in an erosional ravine that ran through the site, Brown also excavated five test pits, demonstrating the presence of furnace features beneath fill of modern origin.

A summary of the initial test excavations was written by Brown in 1977. *Exploratory Archaeological Excavations at the Bluff Furnace Site* (Brown 1977) was printed with funds provided by the Chattanooga Chapter of the Association for the Preservation of Tennessee Antiquities which, impressed by the archaeological as well as historical potential of the site, commissioned Hensley-Schmidt, Inc., to prepare a Master Plan for a proposed development of the site as an historical park.

Interest in the site continued to grow and in 1978 the Bluff Furnace was determined to be eligible for inclusion on the National Register of Historic Places. The American Foundrymen's Society became actively involved in the project and began raising funds to support continued archaeological exploration of the site. In December 1978, the City of Chattanooga, which owned the site, granted permission for further testing on the site.
Dr. Brown conducted an archaeological field school at the Bluff Furnace site in the summer of 1979, concentrating primarily on the furnace base in the area at the base of the bluff. This testing confirmed the need for more intensive excavation techniques, in particular, the use of heavy machinery to remove substantial accumulations of overburden obscuring most areas of the site. It was recognized that an organized, concerted effort would have to be made to further explore the site.

In May 1980, the site was formally listed on the National Register of Historic Places. At the same time, the American Foundrymen's Society presented a money gift to the Institute of Archaeology for use on the Bluff Furnace project. Later that year, Bluff Furnace of Chattanooga, Inc., was chartered by the State of Tennessee as a non-profit organization formed to promote archaeological exploration and thence development of Bluff Furnace as an historic site. Efforts began immediately to raise the funds necessary to conduct an intensive excavation at the site as well as to make the required legal arrangements with the City of Chattanooga, which owned the site proper, and the State of Tennessee, which owned access to the site and adjacent areas under Riverfront Parkway.

By using donated materials and with the cooperation and assistance of the City, the storm sewer outfall that had eroded a channel through the center of the site was diverted around the site, opening the way for further exploration of the area. The University of Tennessee at Chattanooga then assumed a lease on the site as an archaeological field station, and plans were made to conduct a seven-week archaeological field school on the site in the summer of 1981. Additionally, funding
for a continuation of the archaeology under a contract format with the Institute was sought. Ultimately, a grant from the Lyndhurst Foundation to Bluff Furnace of Chattanooga, Inc., provided the necessary funds.

Following preliminary brush-clearing by volunteers, heavy machinery donated by local contractors for use at the site was engaged in removal of overburden on the site. The archaeological field school was conducted at the site from June 24 to August 13, followed by the contract excavation from August 31 to October 14, 1981. After the completion of the season's testing, the site was stabilized for the winter while the data retrieved was analyzed by the archaeologists and planners.

**Research Design**

Prior to the initiation of field work, a number of research objectives were established by the authors. These objectives were aimed at addressing explicit questions concerning the Bluff Furnace site that were regional as well as site-specific in scope. The research objectives fall into three problem domains, as summarized below.

**Problem Domain: Site Content, Structure, and Function**

The initial research objective was to determine, through excavation, the extent and condition of the physical remains of the ante-bellum furnace complex. Despite encouraging results reported by Brown (1977) from earlier test excavations, there remained the distinct possibility that much of the site had been destroyed by natural and/or man-made forces. For instance, the location of the site on a steep slope may have contributed to erosion and consequent displacement of the site's structural features. In addition, major land-altering activities
associated with the documented destruction and re-use of the site during the Civil War era, construction of a turn-of-the-century domestic structure directly on the site, construction of the adjacent Walnut Street bridge in 1891, and construction of Riverfront Parkway with its attendant utility and sewer lines just west of the site are all examples of cultural forces potentially destructive to the archaeological record. In one instance, the destruction was real rather than potential: a storm sewer outflow associated with Riverfront Parkway created an erosional gulley that cut through the casting shed area of the furnace site.

Inspection of stratigraphic profiles created by the erosional gulley and by a pipe trench dug by the City of Chattanooga during relocation of the storm sewer revealed the presence of over two meters of redeposited fill material in separate areas of the site. This observation tended to confirm our expectations concerning the occurrence of past land-altering activities in the immediate site area, and served to underscore the possibility of adverse affects to the archaeological materials.

In view of these considerations, determining the existence of archaeological remains associated with the 1856-1860 blast furnace operation constituted a primary research objective during the project. The primacy of this goal is seen in the dependence of the other research objectives on establishing the presence of intact, interpretable archaeological remains at the site. Data applicable to this initial objective is derived exclusively from extensive, large-scale archaeological excavation. Although such an approach necessarily proceeds at the "discovery phase" of research, which is aimed at
delineating and defining an unknown archaeological data base (Deagan 1978:25; Lewis 1977:158), a higher level can be achieved in addressing additional research objectives.

Having first established the existence of the archaeological remains, the second site-specific research objective was to define archaeologically the distinct activity areas at the site. Inspection of historical photographs, documentary descriptions, and preliminary archaeological data generated from test excavations indicated the presence of the following activity loci at the site:

1) A **charging deck**, where charging of the blast furnace took place; this occurred at the top of the bluff. Evidence of auxiliary buildings, machinery mounts, and charging materials also would be expected to be present in this area.

2) The **furnace area**, adjacent to and at the base of the bluff. According to our interpretation of preliminary documentary data, foundation elements and/or basal portions of both the charcoal furnace and the coke-fired cupola furnace were expected to be located in approximately the same area next to the bluff. Heavy deposits of primary refuse resulting from the furnace operation were also expected for this area.

3) The **casting shed**, where the molten iron from the blast furnace was routed and sand-cast into sows and pigs. Documentary information, data derived from Brown's test excavations, and the extant foundations appearing in the erosional gulley indicated that substantial limestone foundations for the walls of the casting building were present west of the furnace area.
By-products of the final casting process, such as sprue fragments and splash iron, were also expected for this area, as was some evidence of sand casting beds.

4) A **power plant** for supplying the blast to the furnace. Detailed information as to the type and size of steam engine used is unavailable, but its suspected location can be derived from a contemporary photograph.

5) A **slag pile** adjacent to the furnace. Small amounts of slag had been noted by Brown next to the casting shed. The most logical place to dispose of this unwanted material would be directly downslope from the furnace complex.

Applicable data in the definition of activity loci at the site consist of (1) contemporary descriptions, illustrations, and photographs of Bluff Furnace; (2) accounts of mid-nineteenth century blast furnace technology, processes, and practices; and (3) archaeological data concerning site structure and content. This third data class would consist of evidence of structural features and associated artifacts which would be expected to exhibit functional variability according to the type of activity practiced in each area. Data retrieval techniques employed in meeting the first objective are also relevant to our second objective.

Coupled with the question of site structure is that of site function. In order to assess the archaeological and historical significance of the site, it is necessary to determine what processes were carried out there. As standardized methods for reducing iron ore in a hot blast furnace were yet to be fully developed and followed in
the 1850s, the processes employed and their relative efficiencies in producing iron at Bluff Furnace were questions considered to be worthy of investigation. Site structure data for each activity area was expected to provide evidence of the processes used and the level of technology that was obtained. Documentary descriptions of the furnace operations would provide complimentary data. Analysis of samples of fuels, slag, ore, and finished iron collected from the site would provide at least a rough estimate of the relative efficiency of the operation.

Problem Domain: Local and Regional Significance of Bluff Furnace

The second problem domain we have defined concerns establishing the importance of Bluff Furnace on a local and on a regional level. On the question of local significance, we have conducted documentary background research aimed at delineating the seminal role of this iron-producing operation in Chattanooga's early industrial development. General historical information on the East Tennessee Iron Manufacturing Company and specific documentation on the composition, character, and chronology of the operations of the company and furnace has been reviewed in an attempt to meet this research objective. Determining the possible importance of the site in the industrial landscape of the ante-bellum South constitutes another research objective. This objective can be approached through comparison and synthesis of documentary information on mid-nineteenth century iron-making methods and techniques with the site-specific archaeological and documentary data generated from the previous research objectives. Unfortunately, as Charles B. Dew has observed, "a thorough history of the Southern iron industry during the nineteenth century is badly needed" (1966:332). Despite a dearth of
research on this subject, determining the place and significance of the site with respect to contemporaneous iron producing technologies can be attempted on the basis of data presently available.

Problem Domain: Educational Potential of the Site

The final set of objectives defined for the Bluff Furnace project were aimed at realizing the educational potential of the site. This could be attempted in several ways. For instance, the site could be used as a field station for a UTC-sponsored archaeological field school, as was done by Brown in 1979. Involvement in the excavation would allow students enrolled in the 1981 field school course to receive intensive instruction and experience in archaeological field methods under direct supervision by Honerkamp and other qualified Institute personnel. As part of the course requirements, the students also would participate in documentary background research on various facets of the development of the early iron industry in Chattanooga.

Direct educational benefits to be derived from the project were not limited to UTC students. An aggressive publicity campaign by Bluff Furnace of Chattanooga, Inc., undertaken as field work was in progress, was expected to maintain high media visibility for the project. In conjunction with a program of presentations and tours of the site, it was hoped that the publicity would inform a wide sector of the general public about the progress of the research, and more importantly, about the reasons for undertaking such research. This would result not only in an increased awareness and appreciation by the local community of the importance of the Bluff Furnace Site in particular and the iron industry in general, but also in wide-spread community support for the project.
Finally, it was anticipated that excavation of the Bluff Furnace site would result in the recovery of information and features that would eventually become part of an interpretive exhibit highlighting the development and significance of the iron industry in Chattanooga and the nation. Archaeological remains uncovered at the site could be stabilized for exhibition purposes, with the site itself becoming part of an historical park. Considerable, long-term educational benefits could thus ultimately be derived from the Bluff Furnace project.
2. HISTORY OF BLUFF FURNACE

A review of primary and secondary documentary references relating to the site's history was undertaken in order to generate data useful in addressing the research objectives outlined in the last section. Information derived from this documentary line of evidence was considered to be particularly applicable in establishing the importance of Bluff Furnace in both the local and regional economic and industrial development during the ante-bellum period.

The East Tennessee Iron Manufacturing Company and Bluff Furnace: Historical Perspective

In compiling this history of Bluff Furnace and the East Tennessee Iron Manufacturing Company we have worked largely from accounts of the enterprise given by such secondary sources as Govan and Livingood's The Chattanooga Country, 1540-1976 (1977), Lewis' Cravens House, Landmark of Lookout Mountain (1961), Wilson's Chattanooga's Story (1980), and Livingood's Chattanooga: An Illustrated History (1980). Armes' The Story of Coal and Iron in Alabama (1910) proved to be useful, as were the earlier works by Swank, History of the Manufacture of Iron in All Ages (1892), which provides the basic account of the Bluff Furnace, and Lesley's Iron Manufacturer's Guide to the Furnaces, Forges and Rolling Mills of the United States (1859).

Moreover, we have endeavored to rely, where possible, on primary historical documentation, that is, contemporary records generated by the participants in the enterprise. These primary documents include articles of incorporation filed with the state legislature, land deeds.
filed at county registers offices, and other legal or period documents. Many observations presented in the secondary sources such as local or regional histories simply could not be substantiated with primary documentation. Some of these unsubstantiated observations are presented for examination. While our search for primary documentation cannot be considered exhaustive, sufficient data has been gathered and examined to present a reasonably comprehensive historical framework into which the archaeological site of Bluff Furnace can be fitted.

The East Tennessee Iron Manufacturing Company was chartered by an act of the Tennessee Assembly on November 27, 1847, "for the purpose of manufacturing iron, machinery, and implements; and all articles composed in part of iron, steel and wood;" (State of Tennessee 1848:47-48). The capital stock was set from $20,000 to $250,000, and the affairs of the company were to be managed by a board of directors, five in number, elected by the stockholders, with a president elected from the board. The articles of incorporation did not list the members of the company, but noted that William Williams, William Swan, Samuel B. Boyd, Thomas C. Lyon and Robert Cravens were commissioners authorized to subscribe the capital stock of the company. The first business of the company, of record, was the purchase of a two-acre tract of land on the south side of Chattanooga from Benjamin R. Montgomery on February 27, 1850 (HCDB 8:209). The tract was east of the Western and Atlantic Railroad line, and was the site chosen for the foundry and machine shops that were to transform pig iron into manufactured items. On July 6, 1850, Robert Cravens conveyed to the company, for unspecified considerations, a one thousand acre tract of land in Roane County on White's Creek "including Eagle Furnace, saw and grist mill, forge and workshops" (RCDB L-1:93).
This conveyance, evidently (but not expressly) in exchange for stock in the company, also included an iron ore bank situated near White's Creek Island.

Cravens' Roane County iron manufacturing complex and ore bank were apparently the first operating asset the company acquired. Cravens had been producing pig iron and casting household iron wares at the White's Creek location for many years (Lewis 1961:204). Eagle Furnace had been built in 1839 (Lesley 1859:82-83). Cravens had also built an experimental blast furnace, called Eagle No. 2, in 1844. Built of brick and operated for only a year, Eagle No. 2 had failed to produce suitable iron (Lesley 1859:83). The nature of Cravens' experiments at the furnace are unknown.

Samuel Johnson sold to Robert Cravens, in exchange for twenty shares of stock in the East Tennessee Iron Manufacturing Company, 500 acres of land on the Tennessee River in Roane County in January, 1851 (RCDB S-1:107). The deed to the property made provisions for access to the river and boat landing privileges; further

...should Cravins ((sic)) or his assigns erect a Blast Furnace on the same he or they shall have the privilege of the use of such ground adjoining the furnace and over the line as may be needed for wasting slag, stacking metal and castings and such necessary room as may be wanted in connexion ((sic)) with the Furnace ...

Evidently neither Cravens nor the company carried out plans to construct more furnaces in Roane County, as there were more felicitous locations down river.

In 1851 Cravens moved to Chattanooga, encouraged by the presence there of the newly-completed Western and Atlantic Railroad. With rail and river communications through Chattanooga, as well as local ore, coal
and timber resources, the prospects for iron manufacturing in the city looked quite favorable (Lewis 1961:204). On April 19, 1851, the company purchased the tract of land at the foot of the rock bluff on the south bank of the Tennessee River. This small triangular parcel, bounded by the bluff, the river and the right-of-way of Lookout Street, was purchased from Jane Henderson (HCDB 8:408). On this parcel were the lower elements of Bluff Furnace to be later constructed.

The foot of the rock bluff, where Lookout Street originated, was a busy area. From there westward along the south bank of the river barge traffic landed. A swing ferry, anchored at the lee end of Chattanooga (now McClelland) Island, plied across the river, connecting the north and south shores. Not only did the rock bluff present a natural location for the erection of a blast furnace, but it stood at a key point in the transportation system of the area (Figure 2-1).

Evidently the East Tennessee Iron Manufacturing Company was not alone in its interest in the mineral resources of the Chattanooga area. J.P. Long, in the transactions of the Iron, Coal and Manufacturer's Association of Chattanooga, reminisced that

> The first effort looking to iron manufacture was made about the year 1850. A Mr. Hollister, a practical iron master, visited this place about that time, made an examination of the ores and the coal around here, and was delighted with the prospects. He succeeded in raising a company with the necessary capital, went North and perfected his plans and specifications, and on his way back took sick and died at Charleston, which broke up the enterprise. Shortly after, the Foundry and Car Works of the East Tennessee Iron Manufacturing Company was established ... (Long 1880:18).

The East Tennessee Iron Manufacturing Company continued its plans for the exploitation of local resources.
The capital stock of the company was raised to a maximum of $1,000,000 by an act of the Tennessee Assembly on February 21, 1852 (State of Tennessee 1852:270). In April of that year the company made a land purchase in the bluff area from the town commissioners (HCDB 28:284). The transaction included Lots 1 and 2 on Bluff Alley, Lots 1, 3 and 5 on High Street, and Lots 2, 4, 6 and 8 on Lookout Street, according to the original town survey. This land acquisition encompassed what would become the upper levels of the furnace site and its southern and western approaches.

Land purchases by the company continued. In July, 1852, Farish Carter sold various parcels of land to the company in exchange for $50,000 in corporate stock (HCDB 10:76). In the following month, James A. Whiteside sold to the company, for cash, a tract of land on South Chickamauga Creek known as the Deering Mills property (HCDB 10:62). Many of the properties acquired may have been simply corporate investments, but properties such as wood lots to provide furnace charcoal, and ore and coal banks (or leases on the same) were purchases necessary to the basic enterprise of the company.

By 1853 the foundry erected by the company on Market Street was in operation. An advertisement in the Chattanooga Gazette beginning in April, 1853, announced that the foundry was

... prepared to execute orders of every description of cast, wrought Iron or Brass Work, at short notice and in the best manner. We are prepared to manufacture chilled railroad car wheels of the very best quality and freight cars of any description. Also, all other descriptions of cars or railroad columns, still and caps of any pattern desired for buildings. Also saw and grist mill castings of the latest and most improved kinds, Hotchkiss' water wheels, gin and crane gear, shafting pulleys and hangers, etc. (in Govan and Livingood 1977:165)
In January, 1856, the company leased its foundry and machine shop to Eastman, Lees and Company, a firm composed of John W. Eastman, Jonathan Lees, and Thomas Webster (HCDB 11:376). The lease, intended to be in effect for five years, evidently terminated by 1858, for in May of that year the East Tennessee Iron Manufacturing Company issued bond for title to the property to Thomas Webster and R.D. Mann. The original bond for title, which set up a schedule of payments for the property, was badly damaged and only partially transcribed in the county records (HCDB M:266). The final warranty deed for the foundry, although also damaged, set the date of bond for title as 1858, and by 1871, the date at which the warranty deed was filed, the conveyance had evidently been completed (HCDB 21:669). In a transaction in July, 1858, between John B. Whiteside and the company, there is reference to "the old stable" on the foundry property (HCDB 13:382), indicating that the company maintained its own transportation facilities.

It was in 1854 that the construction of the Bluff Furnace was completed, although it apparently was not "blown in" until 1856 (Lesley 1859:83). Until that date, it was evidently the Eagle Furnace complex in Roane County that provided the foundry and machine works in Chattanooga with pig and wrought iron bars. A company steamboat was in operation on the Tennessee River (Govan and Livingood 1977:166), presumably transporting not only pig iron but raw materials to be used at the Bluff Furnace. At the heart of the Roane County operation was Eagle Furnace, described by Lesley in his Iron Manufacturer's Guide to the Furnaces, Forges and Rolling Mills of the United States (1859:82-83):
The company had also constructed a bloomary forge (for refining pig iron into wrought bars) at the Roane County complex. Lesley (1859:204) described the forge as

404. Eagle Bloomary Forge, No. 2, situated on White's Creek, at Eagle Furnace, owned by the East Tennessee Iron Manufacturing Company, R. Cravens agent, Chattanooga, managed by S. Hardbarger, Eagle Furnace, Roane County, East Tennessee, built in 1855, has 1 bloomary fire and 1 hammer driven by water, and made in 1856 about 7 tons of bars.

 Apparently the forge that was part of the Eagle Furnace complex when it was purchased in 1850 by the company had been replaced with the above-described bloomary forge No. 2. There is no mention in the two quotes given above that the Roane County complex was still casting domestic wares.

At the time of Lesley's compendium, which was printed in 1859, the newest addition to the company's working operations was Bluff Furnace:

284. Bluff Steam Hot-blast Charcoal Furnace, owned by The East Tennessee Iron Manufacturing Company, R. Cravens agent, Chattanooga, stands in Chattanooga, on the Tennessee River, under the bluff, three-quarters of a mile north from the railway station and thirty-eight miles by railway northwest of Dalton; was built in 1854, 10 1/2 feet across the bosh by 40 feet high, but made nothing until 1856 in about thirteen weeks of which year were made about 172 tons of metal.
out of fossil dyestone ore from Jackson's bank sixty miles up the river, near the dividing line between Roane and Meigs counties, three miles south of Eagle Furnace. The bituminous coal of the Raccoon Mines, now leased and worked by the Etna Mining Company, can be brought to the furnace by railway; it is excellent for coke, and some thoughts are entertained of turning the present furnace into a coke furnace (Lesley 1859: 83).

The Tennessee Assembly chartered the Etna Mining and Manufacturing Company on March 2, 1854, "for the purpose of mining and vending stone coal and other minerals, smelting and manufacturing the same" (State of Tennessee 1854:593-611). Commissioners appointed to subscribe the capital stock of the company were Robert Cravens, David Rankings, Erasmus Alley, Ker Boyce and James A. Whiteside. Early in 1857, the Etna Mining and Manufacturing Company granted to Robert Cravens, in trust, the exclusive right of mining coal on a 320 acre tract of land on the east side of the summit of Raccoon Mountain, and "of taking therefrom a supply for not exceeding two blast furnaces and one Rolling mill to be located at or in the vicinity of Chattanooga" (HCDB 12:527-528). The agreement specified that Cravens was acting in trust for the benefit of J.P. Boyce, James A. Whiteside, Ker Boyce and himself, lessees of the tract. The small tract was apparently within an 18,000 acre tract being leased to the Etna Mining and Manufacturing Company by J.P. Boyce, James A. Whiteside and Robert Cravens. The document indicates that at least some of the coal was intended to be coked, perhaps in anticipation of the use of that fuel at Bluff Furnace.

The first pictorial representation of Bluff Furnace appeared in Harper's New Monthly Magazine in 1858, and illustrated the furnace in its charcoal-fired configuration (Figure 2-2). The view shows that the furnace itself was a typical square stack of stone at the lower levels.
Figure 2-1. Ross' Landing, from *Picturesque America*, ed. by William Cullen Bryant (1872:68).

Figure 2-2. Bluff Furnace in the charcoal period, from *Harper's New Monthly Magazine* (1858:289).
and brick above. The double chimneys on the top of the furnace at the charging deck level indicate that the hot-blast stove was situated at the top of the stack and was heated by waste gas from the furnace. The view depicts a ramp from the river to the charging deck, and it was apparently up this ramp that barged-in ore from Jackson's Bank was hauled to the furnace top. The casting shed or house, also of heavy stone construction, adjoined the furnace structure.

The conversion of Bluff Furnace from a charcoal- to a coke-fired furnace was evidently accomplished in 1859 under the management of James Henderson from New Jersey (Govan and Livingood 1977:168). Some sources (e.g. Long 1880) suggest that the furnace was leased to Henderson, although no lease agreement has actually been located. Giles Edwards, another experienced iron maker from the North, arrived in Chattanooga in June, 1859, to oversee the conversion of the furnace (Armes 1910:175).

By May, 1860, the conversion was complete. The new furnace (Figure 2-3) not only sported a new cupola-type stack, but the charging deck level of the plant and the hot-blast stove had also been modified somewhat. The indifferent success of the furnace after conversion is summarized by James M. Swank in his History of the Manufacture of Iron in All Ages (1892):

In 1859 the limestone stack was torn down by the East Tennessee Iron Company, of which James Henderson, of New York, was the manager, and a new iron cupola stack, 11 feet wide at the boshes, was erected in its place, and Raccoon coke was thereafter used as fuel. The new furnace was blown in in May, 1860, but owing to a short supply of coke the blast lasted only long enough to permit the production of about 500 tons of pig iron. All the machinery and appointments worked satisfactorily. The furnace was started on a second blast on the 6th of November, 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
The working life of the Bluff Furnace appears to have ended, then, in December, 1860, after the furnace had "chilled" and with the departure of its manager, James Henderson.

In the Standard History of Chattanooga, Tennessee, edited by McGuffey (1911), there is a passage that reads "At the outbreak of the war, Capt. "Bill" Jones, representing Northern capital, operated a large blast furnace near the south end of the Tennessee River bridge. When news of hostilities reached Chattanooga, Captain Jones closed down the plant and went North" (McGuffey 1911:174-175). This would seem to refer to the Bluff Furnace, although there was no Tennessee River bridge until Federal troops constructed one in 1864. No connection between Jones and Bluff Furnace has been made, and the quote above seems to be derived from a confusion of names and events. Armes (1910:176) relates a quaint, romantic story concerning Jones, his fiance and Mrs. Giles Edwards, but also notes that "when he (Jones) could not get a job in the iron works he set up a saloon and a pool and billiard room ..." William R. Jones was to become a principal figure in the United States Steel Corporation, and the quote in McGuffey may have come from an imaginative effort to connect Jones with the iron industry at an early date.

As to the disposition of the works at Bluff Furnace after the abandonment of the enterprise there is some doubt. The most often quoted source on this period is Swank (1892), who noted:

In the summer of 1862, before the Union troops took possession of Chattanooga, the machinery of the furnace was removed to Alabama by Giles Edwards, who used it in the equipment of a small charcoal furnace near the site of the present town of Anniston. This furnace was active for about two years. The stack of
the furnace at Chattanooga was used by the Union troops as a lime kiln, by whom it was subsequently torn down (Swank 1892:290).

A photograph, presumably taken in 1864, illustrates the character of the site after all but the iron stack had been removed (Figure 2-4). The stone from the furnace buildings was apparently used in the construction of the military bridge across the Tennessee River, which replaced an earlier pontoon bridge built by the Union troops (Figure 2-5).

The account of the dismantling of the furnace cited above in Swank seems to be quite specific about the details of the movement of the furnace equipment. In Ethel Armes' *The Story of Coal and Iron in Alabama* (1910) there is no mention of this move. Armes (1910:173,177) states that

> No sooner had the Bluff Furnace been put into working order than in March, 1862, at the request of Judge Lapsley of Selma, whom he had met in New York, Mr. Edwards came into Alabama, and reconstructed the Shelby Iron Works.

Not only does this account suggest that the Bluff Furnace was in operable condition in 1862, but also that it was not removed by Giles Edwards. In 1862, Horace Ware (who had started the iron works at Shelby), Lapsley and others formed a new company at Shelby, rebuilt the earlier installations, and produced iron armor plate and other war materials for the Confederacy (Armes 1910:177).

In an article in the Chattanooga News for August 27, 1891, a former Chattanooga iron maker reminisced about Bluff Furnace and noted "the furnace that we made the iron with was removed to Shelby, Ala., during the war ..." This account also provided other details, although sometimes muddled. It stated that the furnace was owned by Henderson and Gleason of New York, that Edward Giles was general manager, and that
Figure 2-3. Bluff Furnace in 1860, from a photograph in the collection of James W. Livingood. The key facilities in this view are the iron cupola stack at center left, and the hot-blast stove at center right.

Figure 2-4. Bluff Furnace in 1864, from a photograph in the collection of the Institute of Archaeology, University of Tennessee - Chattanooga. This view shows the base of the truncated cupola behind the cast-iron arches of the stack support columns. Most of the walls of the casting shed had been removed, and a temporary wooden building erected to serve the lime-making activity at the site.
David Caldwell was furnace manager. We have found no evidence that Henderson or any of his associates actually purchased the furnace.

For whatever reasons, it is clear that the Civil War put an end to operations at Bluff Furnace. Disposable equipment at the furnace would have consisted of elements like the blast machine, internal components of the hot-blast stove, steam engines and boilers, general hardware and gearing, and recyclable fittings and fixtures. In the event that the equipment was not carried south prior to the Federal occupation, it would certainly have been salvaged by the occupying army, which converted Chattanooga into a marshalling area for the Atlanta campaign.

The contest for control of East Tennessee by Union and Confederate forces undoubtedly diminished the viability of the East Tennessee Iron Manufacturing Company. Several members of the enterprise had died by 1863, including Ker Boyce in March, 1854, Farish Carter in July, 1861, and James A. Whiteside in November, 1862 (McGuffey 1911:35-36). In Augusta, Georgia, on the 23rd of April, 1863, the stockholders of the company met and agreed to a division of most of the corporate assets. James P. Boyce, both as an individual and as the executor of Ker Boyce, received all of the property of the corporation with the exception of a parcel known as the Johnson Tract (HCDB 15:429-430). The conveyance included numerous tracts of land but most particularly the Bluff Furnace in Chattanooga and the Eagle Furnace in Roane County. Cravens, as president of the company, executed the settlement.

The affairs of the East Tennessee Iron Manufacturing Company after the Civil War are largely unknown. In July 1886 the company issued another deed to James P. Boyce, correcting errors in the 1863 transaction (HCDB 48:409). At that time, Cravens was still signing as
president. In October, 1889, the company quit-claimed the Deering Mill place on South Chickamauga Creek to the trustees of Ker Boyce's estate (HCDB 75:83). At this date, Tomlinson Fort was president of the company. This is the last transaction of the company uncovered in our research.

The site of Bluff Furnace passed from the hands of J.P. Boyce and the heirs of Ker Boyce to several individuals and companies in the course of the late nineteenth century. Lot 12, the lower triangular section of the site bounded by the river, the bluff, and Lookout Street, passed to the Chicago Lumber Company in October, 1886 (HCDB 49:700), and three years later to S.M. Winchester (HCDB 76:91), who promptly sold the lot to P.W. Beech (HCDB 75:218). After a quick sale to C.B. Finley (HCDB 150:123), half interest in the lot went to E.S. Finley in September, 1892 (HCDB 123:249). In May, 1899, Lot 12 was subdivided into north and south halves by the Finleys and sold to the owners of the adjacent and upslope lots on Bluff View Avenue, Lots 11 and 10, respectively (HCDB T-6:71). In 1899, C.A. Raht owned Lot 11 (adjacent the river), and R. Pritchard owned Lot 10. Lots 10 and 11 became housesites during the last years of the nineteenth century, and it was sometime between 1889 and 1904 that a small house was built on the former charging deck level of Bluff Furnace. This structure, at the rear of Lot 10 and at the edge of the southern one-half of Lot 12, is depicted on a hand-colored postcard of 1905 shown in Figure 2-6. The structure was of 1 1/2 story height, resting on a full basement cut partially into the slope of the hillside. This structure, and others along the adjacent Lookout Street right-of-way, was condemned in 1970
Figure 2-5. The bluff vicinity during the Federal occupation in 1863, from F.W. Dorr's map, "Chattanooga and Its Approaches," (Dorr 1863). On this military plan the iron cupola stack is referred to as an "iron chimney," and apparently served as a benchmark.

Figure 2-6. The bluff in 1905, from a color postcard by the Rotograph Co., New York. At center right is the dwelling constructed on the former charging deck level of the furnace.
and subsequently demolished as part of the construction of Riverfront Parkway.

Introduction

In order to appreciate the place of Bluff Furnace in the history of the American iron industry, and in particular, its role in the introduction of new technology into the Southern iron industry, some understanding of technical matters concerning the smelting process is necessary. The interrelatedness of the archaeological remains of the furnace is also dependent on our understanding of the technology available at the time of its construction.

The following discussion of iron smelting in the mid-nineteenth century is derived largely from two period documents, namely Frederick Dorman's The Manufacture of Iron, in all its Various Branches (1836), and, from a British perspective, William Fairbairn's Iron: Its History, Properties and Processes of Manufacture (1858). These two documents provide a detailed view of iron smelting in the 1830s and 1850s. The technical data in these volumes is balanced by the more historically oriented observations of James M. Snook in his History of the Manufacture of Iron in All Ages (1890). Later blast furnace technology has been summarized by R.E. Bowron in The Principles, Operation and Products of the Blast Furnace (1918), and although this data is from a much later period, it has been useful in providing historical perspective on mid-nineteenth century practice.

Iron smelting was, and still is, one of the primary industries of the American economy. The blast furnace, with its attendant machinery and auxiliary structures, was a complex plant engaged in an intricate operation sophisticated not only from a purely mechanical/structural
3. IRON SMELTING AT THE MID-NINETEENTH CENTURY

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The following discussion of iron smelting at the mid-nineteenth century is derived largely from two period documents, namely Frederick Overman's *The Manufacture of Iron, In All Its Various Branches* (1854) and, from a British perspective, William Fairbairn's *Iron; Its History, Properties and Processes of Manufacture* (1865). These two documents provide a detailed view of iron smelting in the 1850s and 1860s. The technical data in these volumes is balanced by the more historically oriented observations of James M. Swank in his *History of the Manufacture of Iron in All Ages* (1892). Later blast furnace technology has been summarized by J.E. Johnson in *The Principles, Operation and Products of the Blast Furnace* (1918), and although this data is from a much later period, it has been useful in providing historical perspective on mid-nineteenth century practice.

Iron smelting was, and still is, one of the primary industries of the American economy. The blast furnace, with its attendant machinery and ancillary structures, was a complex plant engaged in an intricate operation sophisticated not only from a purely mechanical/structural
engineering standpoint, but from the chemical and physical processes entailed in smelting iron ore.

In the following section we have attempted to summarize the iron smelting process used at blast furnaces in the middle of the nineteenth century. We have broken down the process into three major sections. First, the raw materials used in smelting are described; secondly, the physical plant of the blast furnace; and thirdly, the dynamic process of smelting itself, in which the raw materials and the physical plant interact.

**The Raw Materials**

**Fuels**

Fairbairn (1865), Overman (1854), and Johnson (1918) discussed fuels that have been used in iron production in Europe and the United States, including dried wood, peat, raw coal, coke, and charcoal. Of these, only raw coal, charcoal and coke were in general use at the mid-nineteenth century by the iron industry. Fuels used in the iron smelting furnace consisted mainly of carbon, hydrogen and ash (non-combustable material). In the presence of excess air (in the tuyere zone) the combustion of the fuel (combination of oxygen with the elements of the fuel) yielded basically carbonic acid and water. The carbonic acid combined with the excess carbon of the fuel to become carbonic oxide which acted in the iron reduction process.

Two types of raw coal, also referred to as stone coal, have been important as blast furnace fuels: anthracite and bituminous coal. Anthracite had about the same chemical composition as coke since it was derived from bituminous coal from which the volatile matter had been
driven off under geologic conditions of heat and pressure, creating a close-grained, valuable fuel. Johnson cited three disadvantages of anthracite as a blast furnace fuel (1918:184-185). The ratio of surface area exposed per unit weight was much less than with coke (a smaller amount can burn per square foot of hearth area); thus, furnace output was smaller. Anthracite had a tendency to spall (break down) in the furnace, obstructing passageways through which the gases ascend. The high density of this fuel also increased resistance to the blast. As such, Johnson stated that anthracite furnaces were characterized by "slow driving and small outputs, high pressure, and a strong tendency to become scaffolded and work irregularly" (1918:185). Due to its restricted occurrence in the United States (eastern Pennsylvania), anthracite as a fuel was limited in importance to those areas where it was abundant and economical.

Good quality (low in tarry substances) bituminous coal was an important blast furnace fuel in areas where it was abundant and inexpensive. The drawbacks of bituminous coal for use in iron smelting included its density and the presence of tarry constituents, resulting in a slow rate of combustion and blockage of gas passages in the furnace (Johnson 1918:185-186). Use of raw bituminous coal was mainly confined to southern Ohio where evidence has been found of its use in admixture with charcoal (White 1978).

The process of charring wood to produce charcoal, as well as coal to make coke, involved the burning of the material just long enough to drive off the volatile matter contained therein. Access to air was then prevented so that the unburned, almost pure carbon remained as charcoal.
or coke, respectively (Overman 1854:102-103). In both cases, charring produced the clean, efficient fuel required for iron smelting purposes.

The manufacture of iron required a strong, compact, heavy charcoal (Overman 1854:114). Johnson considered it an almost ideal furnace fuel, being free of sulfur and containing only small quantities of ash consisting of lime and alkalis which acted as flux in the furnace (1918:183). The drawbacks of charcoal as a furnace fuel included difficulties of wood supply, a lower physical strength than coke, and a lower percentage of fixed carbon. Due to the first two considerations, charcoal furnaces were usually small. In spite of the low fixed carbon percentage, Johnson stated that the fuel consumed per ton of iron was less when using charcoal than when burning coke during the mid-nineteenth and early twentieth century (1918:183).

Overman (1854) discussed several methods for the charring of wood to produce charcoal. Heaps (or kilns) and charring ovens were the most important for supplying fuel for the mid-nineteenth century iron smelting industry, both yielding high quality fuel. A heap measuring 30 feet (9 m) in diameter and 10 feet (3 m) in height contained approximately 20 cords of wood. The pile of tightly packed wood covered with wood chips and soil was allowed to burn for 12 to 18 hours, and cool 3 to 4 days before removing the charcoal (Overman 1854:104-108).

The closed oven allowed for security against stormy weather, which would often disrupt the charring procedure previously described. Although varied in form, char-ovens at the mid-nineteenth century generally approximated 12 feet (3.7 m) in width by 12 feet (3.7 m) in height by 50 feet (15.3 m) in length, and had a capacity of 50 to 60 cords of wood. Approximately 48 hours after kindling, the oven was
cooled for at least three days before drawing the charcoal (Overman 1854:110-113).

The yield and quality of the charcoal produced depended, in part, on the qualities (age, season and dryness) and type of wood charred. Soft-wood (pine) charcoal was less important than hard-wood (hickory, birch, beech, etc.) charcoal as furnace fuel, the former being lighter and softer (Johnson 1918:183). Other factors being equal, 100 pounds of wood produced approximately 20 pounds of charcoal (Overman 1854:116).

A high-grade coking coal was important for the production of iron. It must release its volatile matter during the distillation process, and have a low phosphorus and sulfur content. Phosphorus was not removed during the coking process and may have caused a high-phosphorus (non-Bessemer) iron to be produced (Chapman 1953:30). The Bessemer process was a method, developed in 1856, for making steel by blasting compressed air through molten pig iron, thereby burning out excess carbon and many impurities (Fairbairn 1865:141-143). Coke was the chief source of sulfur in iron.

A good quality coke was described as being silvery and compact, containing essentially fixed carbon and ash, with as little bitumen and sulfur as possible (Overman 1854:129; Johnson 1918:158). A compact, or "hard" coke with well developed cell structure and hard cell walls has the physical strength to withstand crushing in the furnace and has greater resistance to solution caused by carbon dioxide in the ascending gas current in the furnace (Johnson 1918:170,173). It is, therefore, superior to "soft" coke. These qualities of coke depend on the characteristics of the coal and the management of the coking method employed (Overman 1854:129; Johnson 1918:13-178).
Fixed carbon is the only useful component of the coke as a fuel and, according to Johnson, ranged between 85% and 90% in ordinary good blast furnace coke (1918:170). The sulfur- and silica-bearing ash were removed during smelting by a fluxing agent. Although some bitumen was necessary to cement the mass of coke together, the tarry constituents of the coal were almost entirely destroyed by the coking process and, therefore, not present to block the passage of ascending gases in the furnace (Johnson 1918:158,169).

The yield of coke per unit weight of coal varied with the type of coal and the coking method employed. In general, the less bitumen contained in the coal, the higher the yield, with a range of 55% to 75% being cited by Overman (1854:130). Fairbairn indicated that a 30% to 50% yield could be expected for ordinary coal coked in "heaps", while a 50% to 75% yield could be expected from closed ovens (1865:39).

Although Fairbairn indicated that the use of closed ovens was the more economical method for charring coal, Overman stated that "iron masters who require a good article, burn coke in the open air" (1854:123). He condoned the use of coke produced in ovens only if the coal to be charred was initially free of sulfur and very brittle (free of bitumen), as the closed oven method did not generally allow for the introduction of steam into the burning mass to aid in expelling these constituents, nor for easy regulation of the fire (1854:129-130). Overman described three coking methods as being important in the production of coke for iron making at the mid-nineteenth century. These are in heaps, rows, and ovens, of which he preferred rows.

The charring of coal in heaps was similar to charring wood in heaps, only with smaller piles. A heap fired in the morning was
smothered with coke dusts by evening (leaving the chimney open) and yielded usable coke by the second or third day. The draft of the open chimney circulated moist air which aided in expelling hydrogen and sulfur. This method produced a strong, coarse coke, but it was not as free of sulfur as that produced in rows due to the larger mass of coal which inhibited air circulation (Overman 1854:119-121).

The preferred method of charring coal, according to Overman, was in rows up to 100 (30.5 m) feet long, 7 feet (2.1 m) to 8 feet (2.4 m) wide, and 3 feet (.9 m) high (1854:121-122). Overman's preference for this method was based on the following reasons:

1) only a small amount of coal was on fire at any one time;
2) there was a large area of contact between the coal and the moist ground surface, allowing for maximum air circulation; and
3) the row arrangement retained heat longer, allowing the steam produced to vaporize the sulfur (1854:122).

Overman described several types of ovens but stated a preference for the simple design of a double oven in use near Pittsburgh, Pennsylvania. This rectangular oven, built of stone or common brick, contained two oval hearths approximately 5 feet (15 m) in diameter and 30 inches (76 cm) high (75 to 80 bushel capacity). Ten to twelve hours after the coal was kindled, the oven was allowed to cool for 8 to 10 hours before removal of the coke (Overman 1854:123-125).

Iron Ores

Iron ore, as it is mined, consists of the oxides of iron and gangue (foreign) material. Several characteristics were important in
determining the suitability of ore for use as a raw material in the blast furnace. These were (1) iron content, (2) foreign materials present and, (3) particle size, density and moisture content (Chapman 1953:27-28). The higher the iron content of the ore, the greater the yield of metallic iron per unit weight of ore. The three most commonly used ores were hematite (red), limonite (brown), and magnetite (magnetic); with maximum theoretical iron contents (by weight) of 70%, 59.8%, and 72.4%, respectively. Limonite and hematite ores were fairly widespread in their distribution, while magnetite ores were generally not found in the southern United States outside of isolated areas of North Carolina and Virginia (Chapman 1953: Map 2).

The most common gangue material of mined ores was silica which must, for the most part, be removed by the fluxing agent in the blast furnace. Sulfur was not as important an impurity in iron ores as it was in the coke used as fuel. The quantity of phosphorus in the ore may be critical as it had an affinity for iron and was not removed during smelting. Limestone was commonly part of the mined ore and had a beneficial role as a flux in the furnace. If the percentage of lime equaled the combined percentages of silica and alumina, the ore was considered "self-fluxing" (Chapman 1953:29).

The particle size, density, moisture content, and magnetic properties of ore vary tremendously between types and effected the smelting techniques, as indicated in the following sections.

In 1918, ores classified as hematite constituted the source of more than 80% of the iron produced in the United States (Johnson 1918:189). Lumped into this category were ores showing variability in water content, color, hardness, crystallinity, particle size and impurities.
The value of these ores for use in the blast furnace depended strongly on their physical structure. Although hard, lumpy ores allow the passage of furnace gases with less resistance than fine and soft ores, they were less reducible. Soft ores, characterized by high reducibility and a plastic nature, were less likely to be blown from the top of the furnace by the gas current than were fine ores, and thus, were highly valued by the early twentieth century iron smelting industry (Johnson 1918:189-190).

The term limonite was applied to a variety of abundant ores (limonite, goethite and turgite) which were hydrated oxides of iron (containing water in the crystal structure). Although the purity of limonites varies, they are generally low in sulfur but may be high in phosphorus. Limonites were valued as blast furnace fuels for their high reducibility (Johnson 1918:187-188).

Magnetite, the most pure of the iron ores considered, exhibits a highly magnetic nature. Being more dense than limonite or hematite, magnetite resisted reduction in the furnace, thus slowing the process and increasing fuel consumption (Johnson 1918:190-191,197). Overman indicated that the mid-nineteenth century iron producing technology had not entirely overcome the problems associated with the use of this ore in the iron smelting blast furnace (1854:19).

According to Overman (1854), all iron ore should have been "roasted" before use in the blast furnace. The main object of calcining the raw ore was to oxidize the ore, thus expelling elements detrimental to the quality of the iron product and/or the workings of the furnace. The undesirable substances driven off during calcining included sulfur, phosphorus, chlorine, arsenic and other elements. The additional
beneficial result of this process was to produce a higher oxidation state and, consequently, better working in the furnace (Overman 1854:39, 47-48).

At the mid-nineteenth century there were basically three methods for roasting ores: in ovens, piles, and rows. The choice of method used depended upon the qualities of the particular ore. Preliminary preparation of the ore for all consisted of breaking it into blast furnace size pieces of two to three inches (Overman 1854:39).

Limonite and hematite ores were considered suited to roasting in ovens of a design similar to that of a blast furnace. Fuel (charcoal, coal or coke) was placed in the furnace with the raw ore and the whole kindled. An oven of 50 ton capacity was expected to yield approximately 30 tons of roasted ore (Overman 1854:40-42).

Overman (1854) suggested that the roasting of ores in heaps was perhaps the most common method and one yielding excellent results if well managed. It served well for limonite and hematite ores, and also for magnetite ores if carried out over a longer time period (six to eight weeks as opposed to ten to twelve days).

After calcining, the ore was generally put through a screen to remove any foreign material.

Fluxes

A flux was employed in an iron producing blast furnace to promote the separation of the iron from its oxides. The main fluxes used by the mid-nineteenth century iron industry included lime, clay, and silex (Overman 1854:68).

Limestones and dolomites (magnesium limestones) are extremely abundant and desirable fluxing materials. They generally produce a slag
which was considered optimum by Overman, that is, slightly more fusible than than the iron itself, thus readily effecting the separation of the iron from the other constituents of the ore (1854:68,230). Clay was applied as a flux where siliceous ores, which tended to yield weak metal, were smelted. Ferruginous clay (red clay), blue clay, and clay ironstone adequately fluxed the siliceous material and were thought to improve the strength of the metal (Overman 1854:230-231). Silex, in the form of siliceous slate or shale, was used in the smelting of calcareous and argillaceous ores. By separating out the excess calcareous and argillaceous (clayey) material, a silex flux aided in the production of good quality grey iron (Overman 1854:71-72,230-231).

The Furnace

The furnace may be thought of as simply a crucible in which ores, fuel and fluxes were mixed and combusted under a pressurized air blast. Iron liberated from the ore was collected at the base of the furnace and, while molten, was tapped out of the hearth of the furnace into molds. The loci of activity at the furnace were at the top, where raw materials were loaded and where hot waste gases were vented, and the base, where the molten metal was tapped and where the blast was admitted into the furnace. The basic component of the furnace was the stack or masonry shell in which the reduction of the ore took place. Much machinery and appurtenances attended the stack, which was nothing more than a container.

Because the stacks of furnaces built at the mid-nineteenth century were from 30 to 60 feet high, it was ordinary practice to situate the stack at the foot of a bluff or hill, often enhancing the relief by
cutting into the hillside to create a base for the footings of the stack. A charging deck or platform, from which raw materials were loaded into the furnace, was constructed from the hillside to the furnace top. At the base of the stack, where the molten metal was tapped, a level working area was created for the tapping operation and sand beds for the pig iron molds. In all, sharp relief in the terrain where the furnace was to be situated was desirable as long as the topography allowed easy transportation of raw materials to the charging deck of the furnace and removal of the finished pigs from the casting level.

The stack had to be situated on firm, well-drained ground. The drainage was particularly important, for if moisture penetrated the hearth, the cooling effect rendered was a considerable impediment to the operation of the furnace (Overman 1854:153). The form of the stack varied with the experience and preferences of the ironmaster and the ores and fuels used in the production of the iron. In all cases, the interior of the stack or chamber was circular in plan, and in profile was narrow at the top, thence broadening near the lower portions to its widest point, called the boshes (Figure 3-1). Below the boshes the chamber constricted sharply, forming a sloping shelf which, while the furnace was in operation, carried the weight of the burden or the load of the furnace. Beneath this angled shelf, the chamber narrowed to a truncated conical or cylindrical section running to the very base of the furnace. This was the hearth area of the stack. Above the floor of the hearth were the tuyeres, the apertures where the blast entered the chamber. On one side of the hearth, an aperture in the lining was formed between an overhead timpstone and a damstone beneath (Figure
Figure 3-1. Front view and section of a charcoal furnace. The form of this masonry stack is typical of most furnaces at mid-nineteenth century. In the section at right, taken from front to back of the hearth, we see the bridge to the tunnel head or top of the furnace, and at the base, below the hearth, a section through the buried blast pipe (Overman 1854:155,152).
3-2). Through this aperture the molten metal was tended. It was through a fire-clay plugged hole in the damstone that the molten metal was periodically tapped.

The typical charcoal-fired furnace of the mid-1800s was, on the exterior, a massive stone construction, reinforced with iron restraining bands or tie rods. Its form was that of a truncated pyramid. At the base of the shell, where the tuyeres entered the hearth and where the metal was tapped out, the outer lining of the stack broke into arches, providing access to the hearth and tuyeres. Where economical, brick was often used in the place of stone.

The chamber of the stack was lined with fire-brick above the boshes, and generally with sandstone or some other refractory stone below. While many varieties of stone possessed refractory or heat-reflecting characteristics, the lining of the hearth also had to resist chemical combination with the molten iron and slag generated by the smelting process (Overman 1854:452).

There were innumerable variants of the form and dimensions of the pyramidal stack furnace, adapted to specific conditions and production requirements. A major departure from the traditional massive masonry structure was the cupola furnace.

The Cupola Blast Furnace

The cupola-type blast furnace stack was so named for its resemblance to the tall, cylindrical form of the foundry cupola in which pig iron was remelted for casting into finished forms (Overman 1854:162). It differed from the traditional massive truncated pyramid of masonry in that it was typically circular in plan and more slightly built. Frequently, the exterior of the stack was revetted with iron
boiler plate, forming either a truncated cone or a cylinder in profile (Figures 3-3,3-4).

In the west it became customary early in the sixties to erect the most modern furnaces upon cast iron bed plates raised some distance from the ground and supported on a cluster of pillars of the same material so close together that trusses were not needed. Upon this base was built the furnace proper, consisting of a shell of boiler iron enclosing the brick interior, as is the custom today (Clark 1949:76).

Fairbairn (1865:59) presented a slight objection to the furnace due to its greater heat loss out the often thin shell of the stack, but noted "it has met with very general adoption" in the British Isles. Somewhat earlier, and from the American point of view, Overman (1854:163) suggested that such round stacks were troublesome and suited only for limited purposes. Echoing Overman, Weitzman states that "the cupola furnace was never widely used in the United States, as it was expensive to build, consumed more fuel than a square stack, and always broke its binders" (1980:166).

The Blast Machine

The blast or forced air current which permitted rapid combustion and high temperature in the smelting process was, at the mid-nineteenth century, commonly produced by some kind of cylinder and piston arrangement working as an air pump (Figure 3-5). The cylinder-and-piston units were usually multiple and could be either single or double acting (in the latter case, pumping air on both the strokes of the piston). Vertical cylinders were preferred over horizontal ones, which tended to wear unevenly on the down side of the piston. Because the air output of the cylinders was produced in pulses, regulator or receiver tanks collected the individual outputs of the
Figure 3-2. Section through the hearth of a furnace, from Overman (1854:159). A- bottom stone  B- damstone  C- hearth  D- tuyere stones  
E- topstone  F- tuyeres  G- timpstone.

Figure 3-3. Section and front view of a cupola blast furnace, at the Great Western Works, from Overman (1854:163).
Figure 3-4. Front view and section of a coke furnace, Hyanges, France, from Overman (1854:177-178). This furnace, designed for the use of coke as a fuel, resembled a cupola in that its stack was circular in plan and slightly built. Not revetted with iron plate, the masonry wall of this stack was ringed with iron binders. The stack was supported by cast iron columns, closely resembling the base of the Bluff Furnace after its conversion to coke.
pumps. Within these receivers were buoyant pistons which, reacting to changing air pressures by moving and thus increasing or decreasing the volume in the tank, levelled out the air blast leaving the receiver.

Another form of the blast machine was the rotary fan (Figure 3-6). The blast of the fan was continuous and even, and as such required no regulator tanks. The fans ranged from simple paddle-bladed affairs to more complex air turbines. These types of devices came to replace the cylinder and piston air pumps in the late nineteenth century.

The blast machines were powered either by waterwheels or similar hydraulic devices such as turbines where water power was available, or by steam engines. Customarily, the blast machine was not situated far from the furnace, as long blast conductors or pipes diminished the power of the blast through frictional loss (Overman 1854:426). The power of the blast ranged from about three to five pounds per square inch, at the tuyeres (Fairbairn 1865:59).

**Tuyeres**

Tuyeres were the apertures through the lining of the furnace through which the blast was forced into the burden of the furnace. They were situated around the hearth just above the floor level of the hearth. In early cold-blast furnaces, the tuyeres were simply fire-clay lined openings, but with the advent of the hot blast and its destructive effect on the lining of the tuyeres, metallic water-cooled tuyeres were introduced (Overman 1854:417).

Overman (1854:201) suggested that one or two tuyeres sufficed for a cold blast furnace, where the blast pressure was relatively high. In a hot blast furnace, where blast pressures were relatively low, multiple
Wooden cylinder bellows.

Figure 3-5. Wooden cylinder bellows blast machine. This example of a piston-and-cylinder air pump featured single-acting air pistons (d) feeding a receiver tank in which bouyed a regulating piston (y). Air egressed the receiver through pipe c. The mechanism could be powered by steam or water.

Common fan.

Figure 3-6. Rotary fan blast machine. Unlike piston-and-cylinder blast machines, rotary fans such as this featured a continuous blast and as such required no receiver apparatus. In general, the mechanism was less bulky and mechanically more simple than bellow-type air pumps.
tuyeres were desirable in order to obtain the proper distribution of the blast through the burden.

In form the metallic tuyere in use at the mid-nineteenth century was that of a truncated cone, although it could be cylindrical. Water cooling was effected by circulating fresh water through the tuyere by means of a water jacket arrangement or through a spiraled conduit integral with the tuyere shell (Figure 3-7). In both arrangements, fresh water was introduced at the nose of the tuyere where temperatures were hottest, and egressed at the mouth.

**Blast Pipes**

The blast, whether hot or cold, was delivered to the furnace from the blast machine through pipes of cast or sheet iron. The pipes could be buried around the hearth of the furnace or suspended above the working floor of the hearth. In the case of hot blast applications, attention to the pipe fittings and mountings was important, as expansion of the metal under the heat of the blast strained pipe connections (Overman 1854:415). Sharp bends in the blast pipe were to be avoided, as such angles diminished the force of the blast.

**Blast Nozzles**

Feeding off the main blast supply pipe which often surrounded the hearth were connector pipes for each of the tuyeres. At the end of these individual pipes were sheet iron nozzles, gently tapering to their ends. In practice, these nozzles were inserted into the tuyeres, then sealed in with fire clay. The nozzles were adjustable, allowing the force of the blast to be regulated. The noses of the nozzles were

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cleaned of accumulating slag with pokers often integral with the nozzle construction.

The Hot Blast

The process of preheating the air before it entered the furnace under blast was first patented in Great Britain by Neilson in 1828. In the 1840s, the use of the hot blast became common practice in American furnaces. The benefits of the hot blast were many. Anthracite coal, which was difficult to burn in comparison to charcoal or bituminous coal, but which also contained fewer impurities than bituminous coal, could be readily burned under a hot blast (Fairbairn 1865:39). Combustion of the fuel in the burden of the furnace was facilitated, enhancing fuel economy. The question of economics, however, revolved around the manner in which the blast was heated.

There is no direct savings in fuel in cases in which the air is to be heated by separate fuel, but only in cases where it can be heated by the waste heat of the furnace itself, or by some other means (Overman 1854:435).

The hot-blast oven or stove was usually a brick containment structure with cast iron pipes feeding in and out air which was already under blast (pressure). Inside the brick shell or oven, feeder pipes on a horizontal plane were connected with arched pipes running vertically between (Figure 3-8). Waste gas from the top of the furnace was vented in beneath these arched pipes and egressed through a chimney at the top of the stove. The waste gas from the furnace warmed the air in the cast-iron piping to around 500 degrees, Fahrenheit (260 degrees, Celsius) (Overman 1854: 435).

There were many variants of the hot-blast stove, but all worked basically on the same principle: heat exchange between hot waste furnace
Figure 3-7. Metallic, water-cooled tuyere, from Overman (1854:419). The type shown here is the water jacket variety, where fresh water ingressed through line A at the nose, circulated freely through the hollow lining of the tuyere, and was drawn off through the egress line B.

Figure 3-8. Hot-blast stove, from Overman (1854:430). In this variety, commonly situated at the top of the furnace, hot waste gas is vented in at lower right, warming the air circulating in arched pipes connecting ingress and egress pipes. In this view, the arched pipes are shown end on.
gas and fresh blast air. Rarely were separate fires maintained to heat the stoves or ovens. Hot blast ovens could be placed at the top of the furnace, receiving hot waste gas directly from the tunnel head, although the often high temperature of this gas had adverse effects on the piping of the oven. A more desirable alternative was possible:

Where the steam which drives the blast machine is generated at the top of the furnace, as is generally the case, it is advisable to place the air-heating stove at the end of the steam boilers; for there is sufficient heat left, after the flame has passed under the steam boilers, to heat the blast to any degree which may be considered profitable (Overman 1854: 441-442).

The waste gas could first be used (indirectly) to power the blast, then to heat it.

The hot blast was generally delivered at the tuyeres with relatively less pressure than at cold blast furnaces, the preheating having enhanced the combustion of the fuel in the burden rather than the force of the blast (proportionally speaking). The ascending column of hot air in the stack had the effect of coking, to a degree, stone coal fuels and of calcining the ores in the burden, both operations which were normally undertaken to purify fuel and ores prior to loading in both hot and cold blast furnaces. The higher temperatures in the hot-blast furnace allowed less fusible ores to be smelted and enhanced the formation of slag in the hearth. As Fairbairn stated

... it appears to us, that although the hot-blast has enabled the manufacturer to smelt inferior ores, cinder-heaps, and other improper materials, and to send into the market an inferior description of iron, this is no reason for its rejection, but rather an argument in its favor (Fairbairn 1865:79).

The hot blast, then, effected a major change in furnace practice during the second quarter of the nineteenth century. Not only could
more types of ores be smelted, but the high temperatures enhanced the amount of metal extracted and the rate of extraction. Economy was obtained by recycling the waste heat of the furnace to heat the blast. The use of anthracite coal as a fuel was greatly facilitated by the introduction of the hot-blast, and this was to change the geography of the iron-smelting industry which prior to 1840 had been dominated by charcoal iron production (Swank 1892:352-365).

The Smelting Process

Introduction

The smelting process was a complex operation involving physical, chemical and thermal processes taking place within a controlled mechanical and structural environment. The principal structural element in the operation was the furnace stack, really nothing more than a chimney lined with heat-resistant materials. Pressurized air, sometimes preheated, was admitted into the chamber of the stack at the tuyeres, where its heat and pressure accelerated combustion of the fuel. The liberated heat, in concert with the chemical activities of the flux, reduced the ore, separating iron from its mineral matrix. The heavy molten metal drained into the bottom of the furnace hearth, and the by-products, fused together in the form of slag, floated on top.

The purely physical processes involved in the smelting largely concerned the passage of hot gases (from the combustion of the fuel) upward through the burden of the furnace. The free passage of these gases was important, for if obstructed, the combustion of the fuel would diminish under a loss of furnace draft. Fuel and ore that was chunky, with numerous interstices through which gas could flow, was thus
preferred over smaller-sized fuels and ores. In many cases, finely broken fuels and ores were simply blown out the top of the stack and into the pipes of the blast equipment.

The blast itself had to be controllable and uniform, for if it ceased at the wrong time or could not be regulated, the furnace could chill or overheat, an expensive proposition in either case. The water-cooling systems that preserved the metallic tuyeres of most furnace at the mid-nineteenth century also had to function reliably.

A key concern in the management of the blast was the regularity and consistency of the supply of raw materials. The continuousness of the smelting operation was in large measure responsible for the economy of the operation, since cold furnaces had to be brought up to temperature before casting could actually begin, and when shut down for repairs had to be "blown out" carefully. When in full operation, every part of the furnace, blast machine and raw material supply had to act in concert to avoid costly down time.

General Chemical and Thermal Considerations

To form a coherent picture of the chemical and thermal properties of the materials and gases within the blast furnace at different points during the smelting process, we will outline the changes which took place in the descending raw materials and the ascending gas column.

The Descending Raw Materials. Johnson (1918:139-151) divided the changes which the raw materials underwent into four main segments relating to four main zones within the blast furnace: 1) drying and warming, 2) reduction of the ore, decarburization of the stone, and some solution of coke, 3) incipient fusion and early stages of slag formation and, 4) the final reduction of the ore and separation from the slag.
In the region immediately below the stock line (the top of the charge), the incoming raw materials were warmed and dried by the ascending gases. In passing through the second zone (the zone of reduction), the ore and the carbon monoxide produced during the combustion of the fuel reacted in such a way that oxygen was removed from the ore and incorporated into the ascending gas as carbon dioxide. As the oxygen content of the ore was diminished, the remaining quantities required a higher heat and greater carbon monoxide concentration to be released. These conditions were achieved during the slow descent through this the second and longest stage of the iron smelting process.

It was in this zone that part of the carbon dioxide of the limestone flux was driven off by heat. This carbon dioxide dissolved a small amount of fuel in this zone, producing carbon monoxide for reduction of the ore but also depriving the system of heat and fuel to a small extent (Johnson 1918:13-15).

The zone of incipient fusion and preliminary slag formation was located near the top of the bosh where materials passed from being in a pasty state to a fluid slag. The ore began to melt, forming a siliceous slag with the iron oxide which flowed down over the lime and coke. As the temperature increased, the remaining iron oxide was reduced and replaced by calcium oxide and magnesium oxide from the limestone flux. Near the tuyeres, the coke, ash and any excess lime combined with the slag.

The highest temperatures existed within a zone between a short distance above and below the tuyeres, the zone of final reduction of the iron. In this area the slag achieved its final composition as the fuel
released its slag-forming matter and the last of the iron was deoxidized. As the small streams of iron trickled over the incandescent coke, carbon absorption was completed.

The Ascending Gas Column. The gas column in the blast furnace underwent changes in composition, temperature, and in pressure and density (Johnson 1918:151-157). The hot blast entering at the tuyeres was converted into carbon dioxide as it rose through the burning coke. This broke down to carbon monoxide as it was almost immediately exposed to excess carbon of the fuel above the tuyere zone. Water vapor entering with the blast was dissociated and lent its oxygen to the formation of carbon monoxide. Passing through the charge, the carbon monoxide of the ascending gas relieved the ore of its oxygen, thus converting to carbon dioxide. The carbon dioxide produced in this way was attacked by the carbon dioxide released from the limestone and thereby converted back into carbon monoxide which acted further on the iron ore. The top gases consisted primarily of nitrogen, carbon monoxide and carbon dioxide, with varying amounts of other vaporized elements.

Overman stated that the highest temperatures achieved in the iron smelting furnace at the mid-nineteenth century were not beyond 2700 to 3000 degrees, Fahrenheit (1482-1649 degrees, Celcius); the lower limit being set by the fusion temperature of the iron (1854:153). Johnson (1918:229) indicated that in early twentieth century coke practice, the issuing iron and slag ranged in temperature between 2650 and 2850 degrees, Fahrenheit (1454-1566 degrees, Celcius), while Overman (1854:229-230) cited laboratory experiments showing furnace slags fused at 2500 to 2600 degree, Fahrenheit (1371-1427 degrees, Celcius). This, however, was not necessarily the temperature at which it would flow from
the furnace. As indicated previously, the highest temperatures existed in a narrow zone near the tuyeres where the hot blast contacted the burning fuel. The temperature decreased quickly above the tuyere plane and then relatively uniformly from the top of the bosh upward, as the endothermic iron reduction reaction took place.

The pressure of the ascending gas column was highest in the tuyere zone where the blast entered. It quickly dropped due to the physical resistance of the charge. This decrease in pressure was fairly uniform between the bosh and the top of the stack. Johnson stated that "a uniform and regular pressure drop is both the condition and the product of smooth and regular working" (1918:157). In the absence of manometric data from blast furnaces of the mid-nineteenth century, we can only assume that these general conditions probably held true. Data given by Overman indicated that a charcoal blast furnace required 1000 to 2000 cubic feet per minute, and a coke furnace 3000 to 5000 cubic feet per minute blast pressure entering at the tuyeres (1854:401). Fairbairn stated that the blast entered the furnace at 3 to 5 pounds per square inch pressure (1865:59).

**Management of the Blast Furnace**

Upon completion of construction of the blast furnace, the hearth and lining required complete and careful drying. A fire was kindled in the hearth of the closed furnace, and as the temperature was increased slowly over a period of two weeks, the fuel load was raised to the widest part of the bosh. After drying, the furnace was charged with fuel, flux and a light load of ore, with a reduced blast applied. The charge of ore and blast pressure were increased to normal over the first
week of operation, and within three to four weeks, full production of
iron was achieved (Overman 1854:183-186).

The furnace was charged regularly, keeping the stack just full.
Ure (1860:1069) stated that an average of 30 charges were made every 12
hours in British coke practice, each being from 226 to 273 kg of coke,
136 to 273 kg of calcined ore, and 45 to 136 kg of limestone flux. He
indicated that approximately 1815 kg of coke, 2270 kg of calcined ore,
and 907 kg of limestone were required to produce 907 kg (1 ton) of iron
(Ure 1860:1073). Overman stated that 1815 to 2730 kg of charcoal were
required to produce 907 kg of iron with mid-nineteenth century American
smelting techniques (1854:173,195), while Fairbairn's figures for the
Coltness Works in Great Britain show approximately 1680 kg of calcined
ore and 1005 kg of limestone to be required (1865:75). These figures
should be taken as approximations, as the actual quantities of raw
materials required to produce a given quantity of iron depended on their
specific qualities and the characteristics and management of the
furnace.

Overman (1854:194-195) stated a preference for charging fuel, ore
and flux by weight, in that order, and spreading each layer uniformly.
The charges were placed in the top of the furnace by wheelbarrow or by a
suspended hopper from the charging deck level of the operation.

Slag played an important role in the iron smelting process. It
acted to remove the impurities from the raw materials and make them
fusible so that they could be removed from the furnace at the lowest
possible temperature. The temperature at which the slag would flow over
the damstone was called the "free running temperature" of the slag and
was considered the "critical temperature" in the blast furnace. The
Critical temperature of the slag in a charcoal blast furnace was lower than that of a coke-fired furnace (Johnson 1918:199, 203). Varying admixtures of fuels and ores with differing chemical characteristics would create slags with differing free running temperatures.

The major impurity in mineral fuel and ore was silica which acted as an acid in the slag. Alumina, a weak acid, was second in quantity and importance. These and other impurities were converted into a fusible, sulfur-removing slag by the addition of mineral bases (lime and magnesia). The silicates of lime and magnesia made up over half of the slag volume and acted as solvents for other ingredients, such as alumina. There was some iron present in the slag, in the form of FeO, and manganese and sulfur (Johnson 1918:25-29). A well operated furnace at the mid-nineteenth century was expected to produce a "well-glazed", nearly transparent, stony-looking slag with a slight greyish or greenish tint (Overman 1854:203; Fairbairn 1865:61).

The smelting operation was continuous, requiring regular timing of charging, constant attention to keeping the tuyeres cleaned of slag, removal of the slag flowing over the damstone, and the burden settling freely in the furnace. The blast was halted only when tapping of the molten iron required it. Four to five years of successful operation were expected from a blast furnace before restoration work was required (Ure 1860:1074).

**Casting**

The molten metal in the hearth of the blast furnace was usually tapped out every twelve hours. The floor of the casting shed or house was fine sand which, when moistened, could retain the impressions of wooden molds pressed into its surface. Often the molds of pig bars had
raised lettering on them that identified the furnace or iron company, and when cast, the pig iron revealed the embossed lettering. Individual iron bar molds or pigs connected with larger channels or sows which in turn connected with a single channel or runner leading to the hearth.

When circumstances were right, the clay seal in the damstone was broken and the blast suspended. Molten iron poured through the damstone and ran down the runner into the sows and pigs. The drained hearth was quickly cleaned of residual slag and impurities adhering to its walls. The damstone was plugged and the blast resumed. After the cast iron had cooled the pigs were broken off the sows, weighed and carted off. The sows and runners were broken up into irregular pieces, collected into containers, and were also sold. The casting sand was dug up, wetted, and relaid for the molding for the next cast.

Ure (1860:1073-1074) stated that approximately 6350 kg (7 tons) of iron were produced in 24 hours in the form of pigs 0.9 m (3 feet) long, 10 cm (4 inches) diameter, and weighing about 113 kg (248.6 pounds).

Uses of the Final Product

At many furnaces in the nineteenth century, finished products were cast directly out of the metal tapped from the hearth of the furnace. More common, however, was the trend toward specialization in the output of the furnace aimed at producing only pig iron to be refined elsewhere and manufactured into finished products for the consumer market.

Forges, bloomaries, foundries and rolling mills emerged as separate production units although often corporately integrated with a blast furnace. The blast furnace extracted the iron from the ore and produced a final product consisting of pig iron bars and scrap pieces consisting of broken-up sows and splash iron. The pig iron was not a finished
product in any sense except that it was the final product of the smelting process.

The pig iron produced by the blast furnace was of course cast iron, and to a greater or lesser degree was characterized by iron homogeneously mixed with impurities that gave the iron strength but also brittleness and hardness. This type of iron could be remelted in a foundry cupola furnace and cast directly into finished products such as stove plates and pots, but for many other uses it was unsuitable. Many more products required either wrought iron, which could be mechanically shaped and welded to form complex units, or malleable cast iron which could be drilled, lathed and planed in a machine shop. In both cases, the pig iron had to be reconstituted and its chemical and physical structure altered for the desired characteristics.

Wrought iron was cast iron which has been made malleable by the removal of impurities including carbon, silica, sulfur and phosphorus, in a forge or puddling furnace. The main difference between cast iron and wrought iron was that while the former was a homogeneous mixture of iron and impurities, the latter was a mixture of more or less pure fibrous iron with a homogeneous mass of impurities filling in between the crystals of iron, which was removed by working the metal (Overman 1854:305-306). Wrought iron bars were made into useful forms with forge hammers and rolling mill machinery.

Malleable cast iron combined the fluidity of cast iron and the ductility of steel. Cast items produced in the foundry (such as cutlery, harness hardware and iron bars) were exposed to a high heat in an annealing furnace. The combination of carbon from the casting and oxygen from hematite evolved carbon monoxide which was expelled as a
gas. A form of steel was the result. Bars annealed in this fashion were further worked into railroad rails, locomotive and coach parts, and other items requiring fine machining and that would be under tension in use (Sanders and Gould 1976:433-436).

By-products

The most important by-product of the smelting process was the waste gas emitted from the top of the stack. The heat contained in this gas was used in heating the air passing through the hot blast stove and for generating steam to produce the blast and operate other associated machinery. The gases were usually drawn from the stack 3 to 4.5 m (10 to 15 feet) below the top, at a point where they were dry and the blast pressure was yet enough to force the gas into the pipes which carried it to its point of usefulness (Fairbairn 1865:88-91).

Slag was an abundant waste by-product of the iron smelting process. During the mid-nineteenth century its usefulness seemed to be limited to acting as an indicator of furnace functioning.

A salamander was an unintentional by-product of iron producing as it indicated an interruption in the process, leaving the furnace untapped and the iron left to cool in the hearth. Johnson (1918:149) called the salamander "a term covering literally a multitude of sins". The salamander consisted of partially reduced and completely reduced iron, graphite, coke and slag, and created a mass which had to be laboriously removed from the hearth. In the early twentieth century this was at times accomplished by the use of explosives (Johnson 1918:150,340). A variety of circumstances may have led to the formation of a salamander in the hearth of the blast furnace, including cessation of the blast and subsequent cooling of the hearth, a break in the hearth lining causing
the operation to be suspended, and mismanagement of the furnace operation.

The earliest archaeological testing at Bluff Furnace was conducted by Dr. Jeffrey L. Brown of the Institute of Archaeology from April 25 to May 7, 1977, working under contract with Henderson-Schuster, Inc., to assess potential construction impact on archaeological resources in areas proposed for the replacement of the Main Street Bridge. Brown conducted excavations at the site by test pitting the upper levels of the site and by clearing vegetation from its upper levels for exposure. Superficial examination showed evidence of anchor bolts at the bluff top and a pipe chase (groove) in the north bluff face where an apparent counterweight shaft had been located.

A 40-foot ravine cut by water eroding from a cliff lower than Bluff Furnace had cut through the lower level of the site, revealing a massive masonry wall footing and a doorway through the same. This wall was recognized as being the north wall of the casting shed of the Bluff Furnace, suggesting the presence of intact remains beneath many feet of fill displaced over the site by the construction of Riverfront Parkway. Subsurface tests revealed several structural footings and architectural details attributable to the furnace. A slag heap was interpreted as being present on the river bank below the lower level of the site. The data recovered during the 1977 tests was published under the title Explanatory Archaeological Excavations at the Bluff Furnace Site (Brown 1977).

Testing at Bluff Furnace resumed in 1979 as Dr. Brown returned to the site with a UID field school in archaeology and conducted subsurface
4. THE ARCHAEOLOGY OF BLUFF FURNACE

Introduction

The earliest archaeological testing at Bluff Furnace was conducted by Dr. Jeffrey L. Brown of the Institute of Archaeology from April 25 to May 6, 1977. Working under contract with Hensley-Schmidt, Inc., to assess potential construction impact on archaeological resources in areas proposed for the replacement of the Walnut Street bridge, Brown conducted explorations at the site by test pitting the lower levels of the site and by clearing vegetation from its upper levels for inspection. Superficial examination showed evidence of anchor bolts at the bluff top and a pipe chase (groove) in the north bluff face where an apparent counterweight shaft had been located.

An erosional ravine cut by water egressing from a storm sewer drain had cut through the lower level of the site, revealing a massive masonry wall footing and a doorway through the same. This wall was recognized as being the north wall of the casting shed of the Bluff Furnace, suggesting the presence of intact remains beneath many feet of fill displaced over the site by the construction of Riverfront Parkway. Subsurface tests revealed several structural footings and architectural debris attributable to the furnace. A slag heap was interpreted as being present on the river bank below the lower level of the site. The data recovered during the 1977 tests was published under the title Exploratory Archaeological Excavations at the Bluff Furnace Site (Brown 1977).

Testing at Bluff Furnace resumed in 1979 as Dr. Brown returned to the site with a UTC field school in archaeology and conducted subsurface
tests at the base of the pipe chase and at the foot of the bluff's west face, where the furnace base was presumed to be located. Results were somewhat inconclusive, as the depth of modern overburden at the site prevented exposure of large areas at the level of archaeological remains.

The tests by Brown in 1977 and 1979 demonstrated that remains of the furnace were present at the site, although deeply buried in most cases. Further exploration of the site by a UTC field school was planned for the summer of 1981. Despite Brown's death in December 1980, the impetus for the project was not lost.

Organization of the 1981 Excavations

With the formation of Bluff Furnace of Chattanooga, Inc., the archaeological investigation of the site received substantial support, both in terms of funds and in contributed services and equipment. A thorough exploration of the site was dependent upon the extensive use of heavy earth-moving equipment. Also, the scale of a UTC field school was in itself not sufficient to the proposed scale of the archaeology. Consequently, funds were sought and obtained to support a contract excavation at the site to follow the field school.

Initiation of archaeological testing at the site was made possible by the diversion of the storm sewer drain around the projected limits of the site. Secondly, volunteer labor was used to clear heavy vegetation at the site and was followed by professionally-contracted tree cutting which removed the larger trees impinging on the site. Prior to the field school some limited earth moving was undertaken in the area at the foot of the bluff where the furnace base was situated.
Logistical considerations were important factors in the excavation of the site. The terrain at the bluff was marked by high relief: a difference of about 12 m (40 feet) existed between the remains of the furnace base in Operation 1 and the charging deck level in Operation 4. North of the furnace base and casting shed level in Operations 1 and 2 the terrain dropped steeply about 7 m (23 feet) to the Tennessee River. Safety considerations during the excavation of this steeply sloped and broken ground played a role in the conduct of the investigations. Operation of heavy machinery on this terrain proved the need for thoughtful planning and a great deal of caution. Standing profiles over areas to be hand excavated had to be periodically lowered (where consistent with archaeological objectives) to reduce the potential of baulk collapse.

The construction of Riverfront Parkway in the early 1970s resulted in the displacement of several hundred cubic meters of fill over the lower levels of the site. Removal of this overburden on treacherous terrain was a costly necessity greatly facilitated by the donation of the use of several earth moving machines.

A UTC field school consisting of six students under the direction of Dr. Nicholas Honerkamp tested at the site from June 24 to August 13, 1981. After a short interim, a contract excavation under the direction of Honerkamp and R. Bruce Council was conducted from August 30 to October 14.

**Methodology and Field Techniques**

In order to meet the research objectives, a large-scale excavation approach was initiated which was aimed at uncovering as much of the site
as was feasible given the unique topography of the site. This methodology employed heavy earth-moving machinery as well as traditional hand techniques utilizing pick, shovel and trowel. Decisions concerning placement of test units and the removal of overburden were based on a model of site structure that resulted from the incorporation of information from period photographs, contemporary descriptions, and earlier test excavations. As more and more elements of the site became exposed, this model became more detailed and accurate. Eventually, a "positive feedback loop" of combined documentary and archaeological data was created which allowed us to make increasingly accurate predictions as to the placement of at least most of the major features of the site.

A 100% collection policy for most non-domestic iron artifacts was initiated at the beginning of the field work. However, no screening of fill materials was attempted due to the nature of the redeposited fill and subsoil at the site, which consisted primarily of clay and limestone rocks. Materials not subjected to this collection strategy were common brick and fire-brick fragments (which were not collected at all), and fuel, ore and slag fragments which, due to their abundance, were only sampled. All complete common bricks, fire-bricks, splash iron and dressed limestone blocks were retained for future reuse in the reconstruction and exhibition of portions of the site.

The site was divided into four basic excavation areas or operations (see Figure 4-1). Smaller discrete test units or areas within operations were designated suboperations. A field specimen catalog was employed to maintain provenience control on artifact collections from each operation. Features (immovable artifacts such as walls, structural elements, etc.) were numbered in sequences within each operation, as
Figure 4-1. Plan of excavations and features, Bluff Furnace site.
were field specimen numbers. Similarly, suboperations were given letter designations in sequences within each operation. The high relief of the site dictated the erection of six semi-permanent transit stations for vertical control during the course of the excavation. Tied in with a permanent benchmark at the top of the bluff, elevations for all features could be given in absolute elevation above mean sea level. Horizontal controls on high-relief, broken ground proved to be tedious. Transit maps and plane table/alidade plans were prepared integrating the remains exposed in each operation. Features, soil profiles and other subjects were recorded in field drawings and in black-and-white and color photography.

Excavation in most areas of the site was initiated by removal of overburden with heavy machinery. At the start of the field work a Menzi-Muck Climbing Hoe, donated for use at the site by Jones-Haley Construction Co., was used to clear in the Operation 1 area of the site. Later, a conventional backhoe was employed, loaned to the excavation by Campbell Construction Co., which also provided a hydraulic lift early in the project and a dump truck throughout the field work. James Wilson Company, provided a large P&H track hoe for continuous use on the site. Late in the excavation a track front-end loader rented from Durham Brothers was engaged in purely landscaping and terracing activities associated with the archaeology. As noted earlier, excavation of the site without heavy earth-moving machinery would have been impossible.

After machinery removal of overburden under careful supervision, excavation proceeded by hand following natural and cultural stratigraphy. In addition to recovery of conventional artifacts,
special by-product and raw material samples from furnace-associated proveniences were taken for chemical analysis.

**Primary Field Documentation**

Primary documentation of field research included photography, notes, mapping, and recording of the proveniences of artifacts collected for analysis. Seventy roles of black-and-white and color photographs, and 36 planview and profile maps visually transcribed the features and stratigraphy encountered at the site. A field specimen catalog was kept to record provenience information on the 67 field specimens (field-defined minimally discrete contexts). Notes were taken to give a detailed description of all activities and observations on the site.

**Operation 1**

The Operation 1 excavation area consisted of the portion of the lower level of the site bounded west by the erosional ravine, north by the casting shed wall or wall line, east by the west face of the bluff, and southeast by the large stone retaining wall (Figure 4-2).

Functionally, this was the critical area of the furnace operation, as it had contained the furnace, the adjacent contiguous area of the casting shed, and the probable location of the blast machine and hot blast stove. Brown had sunk two test pits in the area in 1977, and had returned to the bluff base in 1979. During the latter season, he encountered deposits attributable to the furnace and suspended his testing due to the depth of overburden, the presence of large, immovable boulders, and the concomittant lack of excavation area at the feature level.
Excavation of the area in 1981 commenced with machine clearing of the overburden in the area between the erosional ravine and the west bluff face. First, profiles in the east bank of the ravine were trimmed and recorded. The outfall from the storm sewer drain south of the Operation 1 area had cut through the principal fill layers associated with the construction and operation of the furnace. Inside the casting shed there was heavy, successive lensing of tan sand and black sand with charcoal, coal and cinder inclusions. The tan sand was easily identifiable as casting sand, and the dark sand appeared to contain not only the debris from wood combustion but also coal (i.e., cinder). The lensing of tan and black fills began at about 198.1 m AMSL on a layer of redeposited fill of limestone, dolomite and orange clay. Prominent at the top of the tan and black lensing was a large deposit of white, chalky substance, later shown to be slaked lime.

Erosion had revealed the north wall of the casting shed, and the outfall from the storm sewer drain egressed the archaeological site through a wide doorway (Figure 4-3). Outside the wall of the casting shed, designated Feature 1, the soil profile (Figure 4-4) showed similarly lensed layers of tan sand and black sand with cinder, although more finely lensed, of less volume, and concentrated in lenses trailing away from the casting shed wall. The outer portion of the profile shown in Figure 4-4 contains what appears to be a deliberate deposit of slag, seemingly having been deposited within a shallow trench excavation. Fill layers deposited during the construction of the furnace are prominent at the base of this profile and demonstrate deposition on a sharply sloped surface. The apparent ground surface level outside the north wall of the casting shed at the base of the first furnace
Figure 4-3. The doorway in the north casting shed wall. Exposed by the erosional ravine, the footings of the casting shed wall reveal the large scale of furnace construction activities. Facing southeast.
depositions was c. 198.0 m AMSL, sloping gradually down toward the river. It is notable that the tan sand and black sand with cinder lenses in the Figure 4-4 profile seem to have been deposited in two broad events, separated by a thick zone of brown silty soil and brick debris. Whether or not this is a reflection of the charcoal and later coke fired periods of the furnace is unfortunately not determinable.

The slag deposit in the east profile of the erosional gulley outside the casting shed was apparently highly localized; the west profile of the ravine revealed no such slag deposits.

Two discrete test pits or suboperations were placed at the foot of the large stone retaining wall, designated Feature 2. Suboperation A was a narrow trench excavated at the base of and perpendicular to the retaining walls. The trench cut through three modern cement and stone retaining walls of knee-height and exposed a furnace period stone wall and associated brick feature. The stone wall, designated Feature 6, ran roughly east-west, and was of dressed limestone. The highest surviving point on the wall was 203.16 m AMSL. The brick feature, designated Feature 7, was not exposed sufficiently to determine its function, but appeared to be a brick footing running roughly north-south.

Suboperation B was situated southwest of Suboperation A and was contiguous with Brown's Pit A from the 1977 excavation. A limestone wall was encountered in the trench and designated Feature 8. Only a small portion of the wall was exposed in the trench, which was cut with a track hoe machine. The wall apparently ran roughly northeast-southwest. The highest surviving point on Feature 8 was 202.81 m AMSL. It is probable that Feature 6 in Suboperation A and Feature 8 in Suboperation B connect, although they are not perpendicular.
to one another. Only further excavation and fuller exposures of these features can clarify their structural functions and associations. Both Suboperations A and B had to be backfilled in order to bring heavy machinery into the furnace base area of the site, north of Suboperation A.

Suboperations in the remainder of Operation 1 had only loose definitions as the excavation on the furnace base was large scale and open in nature. Broadly speaking, Suboperation C was the furnace base proper. Suboperation D was that portion of the casting shed adjoining and to the west of the furnace base to the edge of the erosional ravine. Suboperation E was the area north of the casting shed wall or wall line, and Suboperation F was the area south and east of the furnace base, on a terrace level between Operations 1 and 3. Description of the features in the furnace base area will be made without reference to suboperation.

In clearing the demolition fill associated with the final destruction of the site, and during spoil removal in and around the erosional ravine, numerous examples of furnace brick were recovered. Whole examples were retrieved and stored for possible reuse in reconstruction of the furnace base. A typical example of a furnace fire-brick measured 30 cm long, 11 cm thick, and tapered from c. 17.7 cm at one end to 13.5 cm at the other. There was great variation in dimensions and form in other examples of fire-brick. This variation is attributable to the variation in the form of the lining of the stack and to trimming of bricks to fit around furnace fittings.

Several very large pieces of metal were recovered from the demolition zone over the furnace base. Two large pieces of a concentric ring plate or structural element, shown in Figure 4-5, may be part of
Figure 4-5. Heavy structural cast-iron pieces from the furnace base area.
the tunnel head of the stack. The inside diameter of these pieces is c. 1.48 m (4.86 feet), and may be a dimension close to the diameter of the stack at the tunnel head. This, however, is only speculation. The small diameter of these pieces seems to preclude their being part of the furnace near its base which, as will be shown later, was 2.6 m in diameter.

The principal feature exposed in the furnace area of Operation 1 was the sandstone hearth at the base of the coke cupola, this remainder being the very base of the furnace stack from the level of the tuyeres down. It will be recalled, on the basis of the 1864 photograph of the coke cupola, that the stack of the cupola below the arches supporting the iron shell of the stack was a series of cylindrical sections arranged in the form of an inverted cone. The cupola base, designated Feature 10, was the lowest cylindrical section of the stack.

When first encountered, the cupola base was marked by the presence of a salamander (defined earlier in this report) surrounded by furnace brick and sandstone fragments (Figure 4-6). Portions of the salamander were removed, and when the soil pedestal around the hearth was cleared, it revealed the circular form of the cupola base, about 2.6 m (8.5 feet) in outside diameter. The hearth lining was composed of large sandstone blocks bound at the base with an iron restraining band at least 25 cm high (Figure 4-7). These large blocks shelved horizontally at an elevation of c. 201.1 m AMSL. The tuyeres of the hearth had been set immediately above this seam line.

The remains of two metallic tuyeres were found around the perimeter of the hearth. The spacing indicates that the cupola had been furnished with five tuyeres on 60 degree radials. Following contemporary
Figure 4-6. Initial exposure of the cupola base, Feature 10. Notable in this view is the tuyere at bottom and (beneath the scale) the cavity blown by the tuyere as the salamander cooled in the hearth. Facing west, scale in 10 cm zones.

Figure 4-7. Final exposure of the cupola base, Feature 10. Facing the eastern tuyere, this view depicts the sandstone blocks forming the hearth of the furnace, and the metal restraining band at its base. Facing west, scale in 10 cm zones.
practice, there was probably no tuyere in front of the hearth where the metal was tapped out. The more complete of the two tuyeres was conical in section, with its nose imbedded in the salamander. Unlike the example of the water-cooled tuyere shown in Figure 3-7, in this example the pipe delivering water to the tuyere was carried to the nose in a separate conduit molded into the side of the main section. The egress line spiralled out through the shell of the tuyere. The mouth of the tuyere was 14.5 cm in diameter. Because the nose of the tuyere was embedded in the salamander, its finished length is unknown; at least 45 cm of the tuyere survived.

The circular hearth of the cupola rested within the center of a hexagonal-form stone footing 90 cm in width (Figure 4-8). The west side of the footing, designated Feature 12, was open and only closed at a much lower level with small sandstone slabs. Over these slabs casting sand had been drawn up to the furnace base during the furnace operation. At the corners of the Feature 12 footing were remnants of metal plates that originally had anchored the feet of the cast iron pillars that supported the weight of the lining of the upper stack and its outer iron shell. Behind one corner plate was a small brick pad, Feature 29, which was represented by two courses of a pad, one-and-a-half brick wide. This pad had apparently butted against the inside angle of the corner post, perhaps bracing a broken leg. The spaces between the circular hearth (Feature 10) and the surrounding hexagonal footing (Feature 12) had been nogged with half and whole bricks. In three locations in this space metal plates were noted, perhaps having served as pads for vertical supports of some kind.
Of the actual configuration of the hearth at its front, where, in traditional furnaces, damstone and timpstone would have been situated, we know very little. No information was obtained from period documents that illustrated hearth construction of a cupola type blast furnace. As found, the front of the hearth was marked by the presence, on the north, of a large limestone block situated outside but abutting the edge of the circular hearth. On the south, there were remnants of a brick construction very irregular in form. One half brick in this construction was marked with impressed lettering (Figure 4-9). Between the brick work and the large limestone block was a narrow channel filled with congealed slag.

The form of the salamander in the hearth of the coke cupola and the presence of the irregular brick and stone work at the front of the hearth lead to an interesting conclusion about their formation. When the brittle upper portion of the salamander was removed at the front of the hearth, a more dense, metallic layer of the salamander was left. The salamander seemed to have been confined more or less within the projected limits of the inner hearth walls except in the front of the hearth, where the metallic salamander projected west in a tongue-like formation, past the limits of the circular hearth lining and on top of the large limestone block at the left front of the hearth.

The form of the salamander was troublesome and we considered two interpretations. The first was that the projecting tongue of salamander was formed by its extension into the aperture between timpstone and damstone, where slag (in common furnaces) was drawn out before casting. The sides of the projection were not sharp and well defined as we might expect if the salamander had cooled in this area. Also, it seems to
Figure 4-8. Overview of the cupola base. At center is the circular hearth, Feature 10, and salamander, surrounded by the hexagonal footing, Feature 12, which served as the base for the cast-iron pillars supporting the stack. Facing west, scale in 10 cm zones.

Figure 4-9. Marked brick at hearth front. The manufacturer of this brick, marked "SOUT... MAN...," is unknown. Facing north, scale in 5 cm zones.
have expanded onto the stone situated outside the hearth and not integrated into the structure of the hearth base. A second interpretation seemed more feasible. The lining of the hearth may have given way, releasing the then-molten salamander through the hearth wall until it cooled and solidified. The large sandstone block and brickwork at the hearth front may represent an attempt to revet the front of the hearth during the supposed displacement of the lining. The large limestone block at the left hearth front was covered by the tip of the salamander tongue, suggesting that the repair attempt failed, and that the salamander had breached the hearth lining and cooled outside the cupola base (Figure 4-10).

We suggest, then, that it is probable that the front lining of the hearth at the level of the tuyeres was displaced outward during the last firing of the furnace; that an attempt was made to halt the displacement by revetting the hearth front with stone and brickwork; and that the attempt failed, the salamander having pushed the hearth lining out and cooled upon contact with air. At present, this is our best explanation of the furnace base as we encountered it.

When the coke furnace had been in operation, a working floor of dense, packed coal cinder and clinker surrounded the Feature 10 hearth base and covered the surface of the Feature 12 hexagonal footing. The presence of this floor proved to be quite fortunate, for it provided an archaeological horizon between the precedent charcoal furnace remains and the later coke furnace remains. The floor had been the working floor around the furnace during the coke-fired operation, and sealed beneath it debris associated with the demolition of the charcoal furnace.
Figure 4-10. Front view of the cupola base. At center is the Feature 10 cupola base with salamander. The large stone at center left and brick work at center right may represent repair attempts. Note the possible casting channel in foreground. Facing east, scale in 10 cm zones.
Directly south of the cupola base was exposed the north face and a portion of the west face of a substantial brick wall (Figure 4-11). The brick work in the north face of the wall, designated Feature 27, showed much evidence of modification. It is tentatively suggested that this brick wall was the north wall of a platform upon which set the blast machine of the furnace. No diagnostic construction characteristics were present in Feature 27, however, and it is largely on the basis of period practice that the functional attribution of this wall is tentatively made. Abutting the north face of the brick wall were exposed the decayed remains of a wooden box or trough.

The trough, designated Feature 28, measured 2.78 m by 0.73 m, and was constructed of planks 5 cm thick. One metal tie rod remained in situ at the east end of the box, having apparently served to bind the sides of the trough together. The bottom boards of the box rested on three 20 cm wide studs set into the surface of the cinder working floor. The finished height of the trough is unknown, but exceeded 40 cm. The trough and its associated pipes appear to have been built contemporaneous with the laying of the cinder floor around the hearth (see Figure 4-13).

A large pipe egressed from the east end of the box, emptying into a small wood-lined drain, Feature 11, which ran east and then north around the furnace (see Figure 4-13). Two smaller pipes ran from the south side of the box toward the furnace base. The two pipes entered the box 36 cm to 39 cm above its base. The pipes were bent in a vertical S-curve and ran beneath the cinder work floor to the south side of the cupola base, Feature 10. At this point the pipes turned toward the west, the easterly of the two being angle up toward the vertical. These
Figure 4-13. Detail of Features 22 to 28, south of furnace base. A. Feature 22 - curved brick retaining wall,  D. Feature 25 - remnant of narrow brick footing, roughly parallel to Feature 27. E. Natural rock upper portion of Feature 27 wall, C. Feature 26 - half-brick filler between Feature 25 and Feature 27 wall, closing face of crevice in bluff face, B. Feature 23 - brick pad and wall remnant, appearing naturally.
Figure 4-13. Detail of Features 22 to 28, south of furnace base.
two pipes probably connected with the two southerly water-cooled tuyeres of the furnace, perhaps collecting hot waste water and venting it into the box.

In the bottom interior of the box remnants of congealed slag were noted, many of which displayed smooth impressions such as might be made by tools. It is thought that waste water from two tuyeres was vented into a wooden box to provide a quenching box for tools used to work the hearth.

No other buried pipe work was noted around the furnace base, indicating that the blast pipes and tuyere water-cooling pipes had been suspended around the furnace base above the working level at the hearth. Northwest of the hearth was exposed the remnant of a stone apron or pad, Feature 15. The apron featured a carefully laid border of limestone, from which was recovered an example of a masonry anchor. Apparently the top of the apron either had no surface other than cinder or its brick or stone surface had been robbed away. This apron was evidently a working surface from which furnace workmen attended the hearth, removing waste slag as well as tapping the molten iron.

Directly in front of the hearth, where the molten iron had been tapped for casting into pig iron, was the tan sand fill constituting the casting sand floor of the casting shed. A linear soil feature in front of the hearth, Feature 31, appeared to be a possible remnant of a casting channel from the hearth to the pig iron mold beds (see Figure 4-10). A vertically set iron bolt was present on the north side of the possible casting channel, adjacent to a vertical wooden post. A second vertical wooden post was present south of the casting channel. Linear soil stains beneath the upper surface of the casting sand ran east-west
in close association with the vertical posts. All together, these wooden elements may have been remnants of a wooden stake-and-plank form used to contain sand around the main casting channel leading from the hearth to the pig beds. Similar arrangements are illustrated in Sanders and Gould (1976:27).

In the casting shed adjoining the furnace base we might have expected to find the remnants of the pig mold beds, but the erosional gulley had cut this area completely away. No pig beds were observed in the Operation 1 excavation area. Roughly two meters west of the furnace base we encountered a low pile of what was later identified chemically as slaked lime, a major constituent of mortars and similar cements. As noted earlier, its stratigraphic position indicates that it was deposited after the apparent cessation of casting at the site. (marked archaeologically by successive lensing of casting sand and charcoal-cinder layers). Historically, this corresponds with the reported use of the stack as a lime kiln during the Civil War.

Above the level of the cinder work floor of the furnace we had recovered many samples of coke, slag and other waste or by-products of the furnace operation, all being attributable to the coke-fired period of the site. After documentation of the features above the cinder floor, this surface was removed, exposing the structural underpinnings of the earlier charcoal-fired furnace. Amidst the stone, brick and scrap metal debris, we encountered an example of a large pig iron bar which, due to its presence beneath the coke furnace floor, is attributable to the charcoal period of the furnace.

When the stone and brick stack of the charcoal furnace had been dismantled, only the outline of the north tuyere arch of the furnace was
left intact (see Figure 4-2). The later coke furnace was relocated and centered roughly two meters west of the center of the older charcoal furnace. The charcoal furnace had evidently been equipped with at least one tuyere and very likely two, judging from period practice. If two tuyeres had been employed, they would have been placed on the north and south sides of the hearth. The north wall footing of the charcoal stack, near its base, spanned a distance of 7.8 m, and featured a tuyere arch (at basal level) 3.9 m wide. South of the coke cupola base, little evidence of the earlier charcoal furnace base survived.

The bases of both the charcoal and coke furnaces rested on naturally-bedded ledges of limestone geologically connected with the bluff formation itself. Drill holes on the west face of the bluff confirm that a substantial amount of stone was sheared away from the bluff to create a shelf for the furnace base and behind, a vertical face up to the charging deck of the plant.

Southeast of the furnace base, and connecting the north-south face of the rock bluff with the east end of the brick wall, Feature 27, was an obliquely set massive stone pier, Feature 24 (Figure 4-12). The top of the pier (at 203.13 m AMSL) sat well above the furnace base and was near the bottom of a vertical crevice in the west face of the bluff between the Operation 3 and 4 excavation areas. On top of the pier were situated two pieces of brick work, one of which, Feature 23, appeared to be a higher remnant of the Feature 27 wall line. The other brick construction, Feature 22, appeared to be a curved soil retaining wall built, perhaps, to block up the face of the vertical crevice in the bluff face. Adjacent the Feature 24 pier were remnants of a small brick footing (Feature 25) and an apparent mass of brick filler, Feature 26.
Figure 4-11. Feature 27 brick footing and Feature 28 pipes. The brick work in the face of Feature 27 shows several apparent repairs. The pipes which connected with the Feature 28 wooden trough (removed) are in the foreground. Facing southeast, scale in 10 cm zones.

Figure 4-12. Features 22-24. Brick features 22 and 23 are shown here atop the stone pier, Feature 24, situated southeast of the furnace base. In the foreground is an iron reinforcing frame, perhaps from the hot-blast stove or the brick downcomer from the cupola top. Facing northeast, scale in 10 cm zones.
The brick features on and adjacent to the stone pier, Feature 24, point to a substantial brick wall of considerable height rising from the lower brick wall designated Feature 27.

Operation 2

Operation 2 was defined as that portion of the site west of the erosional gulley through the casting shed. The dividing line between Operations 1 and 2 anchored at the doorway in the north wall of the casting shed and ran south-southeast up the ravine to the storm sewer pipe egress abutment. It should be pointed out that the Operation 2 area was arbitrarily determined by the erosional gulley, a feature not in any way pertinent to the furnace period remains. Nonetheless, the gulley had effectively divided the site and as a practical matter served to subdivide the site into more or less convenient excavation areas.

In the 1977 excavations conducted by Brown (1977) a small unit, Pit C, was placed in the Operation 2 area, exposing the interior of the northwest corner of the casting shed wall and a brick pier. These features will be discussed in more detail later.

The Operation 2 area was deeply buried by fill displaced by the construction of Riverfront Parkway. This fill was removed using a front-end loader late in September and early in October, 1981. The area where fill could be removed was delimited on the west by the concrete storm sewer swale and on the south by the relocated buried 36 inch storm sewer (see Figure 4-1). Technically, the limits of the operation 2 area ran only to the west wall of the casting shed.

For practical reasons, an evenly graded slope was left between the west casting shed wall and the concrete swale, permitting machine access from the overpass area to the lower elevations of the site. The
presence of the relocated storm sewer pipe also dictated the extent to which fill was removed in a southerly direction in the casting shed. Because the grade of the pipe was above the projected casting shed floor level by several meters and the projected length of the west casting shed wall placed the southwest corner of the casting shed beneath the path of the storm sewer, a substantial baulk or soil bank had to be left against the easement of the pipe to keep it in place. As such, it was impossible during our excavations to even attempt to expose the southwest corner of the casting shed.

Thus, while the casting shed walls defined the excavation area on the north and west, the eastern and southern limits of Operation 2 were defined by an erosional gulley and a necessary soil bank (respectively). The final area of the operation was c. 9 m by 9 m.

The erosional gulley defining the eastern side of the operation area had made a natural profile cut through the floor of the casting shed. The first archaeological activities in the area consisted of trimming the banks of the gulley vertically in order to facilitate recording of stratigraphy. From this activity we were able to clearly determine the level of the floor in the casting shed.

On the west bank of the gulley a profile section (Figure 4-14) revealed a brick pad, Feature 2, at the base of a zone of brown sand identified as casting sand. The surface of the pad was at an elevation of c. 198.26 m AMSL, and as finally exposed consisted only of a one-and-a-half brick wide strip (30 cm) 1.5 m long. The pad ran perpendicular to the casting shed wall, Feature 1, and an apparent purposive gap of 34 cm separated the pad from the wall.
Figure 4-14. West profile of erosional ravine inside casting shed.
The function of the Feature 2 pad is unknown. It appears to have rested at the base of the casting sand layer on the underlying redeposited fill zones. There was no suggestion that the pad was a remnant of a larger surface, although the entire feature was never completely exposed.

It should be noted that the sill level in the north casting shed doorway was 196.94 m AMSL, over 1.3 m below the top of the Feature 2 pad. The sill would not have been exposed during the operation of the furnace; the earthen floor of the casting shed was simply carried outside the structure, as indicated in the 1858 Harper's print (see Figure 2-2). On the basis of data from the profile cuts in the erosional ravine and the elevation of the furnace base, the sand floor of the casting shed (at its center) was laid from c. 198 m to c. 198.6 m AMSL, and was drawn up to the furnace base at c. 200.2 m AMSL. This 1.6 m drop between the hearth and the pig mold beds was evidently necessary to propel the molten iron down to the most distant molds of the beds.

Assuming bilateral symmetry, calculations were made as to the length of the north wall of the casting shed. From the junction of the charcoal furnace base, Feature 16, with the casting shed wall, Feature 1, measuring to the east edge of the doorway the distance was recorded as 7.6 m. The doorway itself was 3.0 m wide, and assuming bilateral symmetry, the overall length of the north casting shed wall was proposed to be 18.2 m. Backhoe search trenching in the area of the presumed northwest corner of the casting shed did in fact reveal that corner at the anticipated distance from the furnace/casting shed junction. Brown had, of course, exposed the corner in his 1977 excavations, but few
details of the ground plan of the casting shed could be made at that time.

The northwest corner of the casting shed is shown in Figure 4-15. The stone coursing, as elsewhere, was stepped out below the casting shed floor level. In the interior of the wall corner Feature 3, a brick pad measuring 44 cm by 33 cm, was relocated. As noted earlier, this brick pad had been exposed in 1977. The highest surviving point on the pad was 199.33 m AMSL.

The function of the feature 3 pad is not demonstrable, but it is very probably a pier base for columns supporting the roof of the casting shed. In viewing the 1860 photograph of the Bluff Furnace, we note that the top of the casting shed was evidently flat and as no timber work projected over the top of the walls of the building, the roof surface was evidently recessed somewhat. Interior piers, resting on pads such as Feature 3, may have been employed to support the suggested flat, recessed roof.

On the basis of the 1860 photograph, which clearly shows the west casting shed wall, we determined to locate the main doorway in that wall. Suboperation A was a backhoe pit excavated to attempt to locate the northern threshold of the west doorway. The threshold was, in fact, exposed at a distance of 7.6 m along the west wall of the casting shed. Although somewhat disturbed (Figure 4-16), the threshold was clear. As elsewhere, the Feature 1 wall was finished to a width of 90 cm as the floor level of the casting shed was approached. The width of the doorway could not be determined archaeologically due to the presence of the relocated storm sewer pipe; further excavation to the south was not possible.
Figure 4-15. The northwest corner of the casting shed. Note the step in the stone wall footing, and at left, a modern cast-iron sewer pipe breaching the wall. Facing southeast, scale in 10 cm zones.

Figure 4-16. Suboperation A in Operation 2. Shown here, at center, is the north threshold of the west doorway of the casting shed. At right is a modern cement block wall. Facing north, scale in 10 cm zones.
With an archaeologically determined distance, we were able to scale from the 1860 photograph the approximate length of the west casting shed wall, which was set at 15.03 m or about 49.3 feet. The width of the west doorway was scaled as being approximately 2.94 m or 9.6 feet.

On the basis of direct physical measurement of the north casting shed wall, and the combined exposed and extrapolated length of the west casting shed wall, the casting shed appears to have been a rectangular structure measuring 18.2 m by 15.0 m.

To the immediate east of the doorway was a modern concrete block wall, Feature 4, running north-south. This wall corresponds to an apparent retaining wall shown on a Chattanooga flood control plan dated 1969. The date of construction of the wall is not precisely known, but the concrete blocks were a type introduced in the early 1900s.

Also of twentieth century origin was a 24 inch diameter cast iron drain pipe crossing the west half of the casting shed north to south (see Figure 4-15). Declining toward the river, this pipe, designated as Feature 5, had been set in a pipe trench that breached the north wall of the casting shed.

**Operation 3**

Operation 3 was defined as the upper terrace of the site south of Operation 4, the rock bluff, and southeast of Operation 1, the furnace base area. The Operation 3 area had been occupied by a residential structure built between 1889 and 1904 and demolished prior to the construction of Riverfront Parkway. Northwest of the structure was a large stone retaining wall of modern origin which served as the boundary between Operations 1 and 3 (see Figure 4-1). The sloping ground around the house site had been terraced with a series of knee-high retaining
walls. The large stone retaining wall, designated Feature 2 in Operation 1, marked a drop in elevation from Operation 3 to Operation 1 of over three meters.

The first subsurface testing in the area was undertaken during the 1981 field school excavation. Although the house structure in Operation 3 was not associated with the industrial component of the site, initial excavation in this area was carried out in order to develop the students' knowledge of field techniques in a non-critical section of the site.

Suboperation A was a test pit opened over the northern-most corner of the residential structure, (the long axis of which ran northeast to southwest). Beneath c. 30 cm of recent fill the upper elevations of the house foundations, designated Feature 1, were encountered, as were a brick run-off drain, a stone stairway along the north exterior of the building, and large quantities of early to mid-twentieth century domestic debris. A deep, rubble-filled cellar was present.

During the course of the contract excavations at the site it was determined that for safety reasons the upslope burden on the large retaining wall should be relieved. Consequently, the demolition fill in the house cellar was removed by heavy machinery and discarded. The earthen floor of the house basement was exposed, and grading operations around the house recreated the surface contours of the residence when it was occupied. The exposed features were then mapped and photographed.

The house foundations (Feature 1) defined a rectangular structure 6.15 m by 9.65 m. The wall foundations were of mortared limestone blocks in rubble (random) coursing c. 45 cm thick. The highest surviving point on the wall, still well below the apparent first floor
level, was 213.16 m AMSL. Demolition and subsequent deterioration had reduced all walls of the house, the western walls more so than the eastern. The sills of three small windows were present high in the southeast-facing wall of the house, and a large doorway at basement floor level opened through the northwest-facing wall.

In the surface of the earthen basement floor of the house was exposed a stone wall foundation, Feature 6, running east-west diagonally across the southern-most corner of the house. The stone foundation had been truncated somewhat, evidently by the later construction of the house foundations. The orientation of the earlier wall foundation was such that it was apparently associated with the furnace remains, which generally fell on north-south and east-west axes. A small test pit, Suboperation B, was excavated abutting the wall. This trench exposed a dished brick floor and wall or curb elements, (all designated Feature 7), and a trench disturbance, Feature 11, containing wood remains and postmolds (Figure 4-17).

A search trench, Suboperation D, was cut across the interior of the house basement and exposed, at two levels, brick work attributable to the furnace period (Figure 4-18). At the lower feature level, a native stone ledge was encountered that represented an extension of the west face of the bluff. Continuing this trench outside the house foundations to the edge of the large stone retaining wall, deep fill and large stone debris were encountered in Suboperation C. No coherent features were noted in the trench (Figure 4-19).

A determination was made to truncate the extant northwest-facing wall of the house foundation and to remove several meters of fill between it and the large stone retaining wall 3.2 m to the northwest.
Figure 4-17. Planview of Suboperation B, Operation 3.
Figure 4-18. Planviews of Suboperation D, Operation 3. A. Construction trench for Feature 1, house foundation. B. Compacted mortar and sand surface with small brick and stone rubble inclusions. C. Brick and stone rubble, possible robbed wall trench. D. Compacted brick dust and fine chert debris. E. Robbed wall trench, extension of Feature 9. F. Orange clay with chert debris and charcoal fragments.
Figure 4-18. Planviews of Suboperation D, Operation 3.
Figure 4-19. South profile of Suboperation C, Operation 3. A. Feature 1 - limestone wall foundations from late-nineteenth century house. B. Feature 2 (in Operation 1) - high retaining wall of mortared limestone, late-nineteenth century. C. Black-brown humus layer. D. Black-brown humus and limestone debris, formed by retaining wall shift and/or wall repair. E. Light brown clay with limestone, chert and iron ore inclusions; fill zone post-dating house and retaining wall construction. F. Dark brown clay with chert and iron ore inclusions; fill zone pre-dating house and retaining wall construction. G. Brick and mortar debris from furnace-period construction or demolition. H. Orange clay with limestone fragments; pre-furnace construction fill. I. Large, drilled limestone slabs; detritus from pre-furnace bluff alterations.
Figure 4.19. South profile of Suboperation C, Operation 3.
In the process, the large retaining wall was totally removed. This landscaping removed the unstable retaining wall and reduced the height of standing profiles adjacent the furnace base area in Operation 1. The grade of the site was also brought closer to a furnace period configuration.

The function of the Feature 7 brick work in Suboperation B and Features 9, 10 and 12 in Suboperation D is not clear, but on the basis of the brick and mortar they are clearly attributable to the furnace period (see Figure 4-20). It is assumed that these brick features are elements at the base of the large smokestack shown on the 1860 photograph and situated at the southeast corner of the furnace plant. The Feature 6 stone foundation appears to be the outer foundation wall of the stack, although our search trenches did not locate the outer walls of the base. In both Suboperations B and D, however, was ample evidence of the "robbing" of brick from furnace-period walls. Such recovery of construction materials may be responsible for the absence of other walls attributable to the smokestack base. It is not possible, at any rate, to determine the exact location and size of the stack base. We speculate that the brick floor and curb elements in Suboperation B are inside the base of the stack, and may represent some form of ash disposal chute or basin beneath the firebox of the stack, (which is assumed to have housed boilers for steam generation equipment).

Operation 4

Operation 4 was defined as that excavation area situated at the top of the rock bluff east and above Operation 1 and north of Operation 3. The archaeological treatment of the bluff top, which had been tested by Brown in 1977, consisted of expanding the cleared area to the south and
east. Fill in this area consisted of redeposited soil washed down from upslope. No significant accumulations of artifacts were noted.

The bluff is characterized by horizontally-bedded layers of limestone sloping down slightly toward the south. The top of the bluff in the Operation 4 area is marked by limestone solution pockets and channels, and by terrace-like steps in its surface. Elevations on the present bluff top (cleared in the Operation 4 area) ranged from about 211.9 m to 209.7 m AMSL. As noted earlier, there is a large vertical crevice in the west bluff face at the southeast corner of Operation 1. Near the base of this crevice, in Operation 1, sat Feature 24, a large stone pad upon which was mounted what was evidently a brick retaining wall that closed the face of that crevice.

By comparing Figure 2-1, which shows the general form of the bluff prior to construction of the furnace, with later photographs and the bluff's present configuration, it seems clear that an overhang on the north face of the bluff was cut away, creating a more vertical face. The west face of the bluff was also sheared down along a rough north-south line, creating another vertical face against which the charcoal furnace was set. The top of the bluff adjacent the furnace location was also apparently cut down to create a terrace from the northwest corner of the bluff south into the Operation 3 area.

The top of the bluff adjacent the furnace location contained the remnants of 29 anchor bolts/tie rods set vertically into the limestone (see Figure 4-21). Nine empty holes were also noted, but these may have been the remnants of drilling during the terracing of the bluff top for furnace construction. Iron rods were of two sizes. The larger rods were 3.5 cm in diameter and threaded on the ends to receive bolts. The
Figure 4-20. Suboperation B in Operation 3. Shown here are the various elements of the brick construction collectively designated Feature 7. At right is Feature 6, a limestone wall foundation. Note the stone house foundations at upper right. Facing east, scale in 10 cm zones.

Figure 4-21. Anchor bolts in Operation 4. Shown here are examples of large threaded bolts and smaller rods anchored in the bluff top over the furnace base. Note the doorway in the casting shed north wall at upper left. Facing west-northwest, scale in 10 cm zones.
smaller rods, many broken off near the bluff surface, were 2.5 cm in
diameter. Many of the small and large diameter rods or bolts approached
a meter in length. Most were bent over toward the northwest, suggesting
deformation during a demolition event. The rods were apparently set
into over-size drill holes and fixed by pouring molten iron into the
cavity.

A concave channel in the north face of the bluff had been cut
apparently (but not demonstrably) during the furnace period. This
vertical channel has been called a pipe chase and a possible
counterweight shaft employed when the furnace's ore was hauled to the
charging deck by an inclined ramp from the river. Anchor bolt slots or
brackets were present in the cliff face. It is difficult to demonstrate
whether or not this is a furnace-associated feature, and it may be
related to one of many river gauges situated (through time) along that
area of the bluff.

In summary, removal of fill on, and physical inspection of the
bluff top adjacent the furnace base area revealed iron tie bars and rods
used to anchor the superstructures of charging deck buildings. Evidence
of the modification of the north and west bluff faces, and its top, were
also noted.

Laboratory Analysis

All artifacts recovered during the excavation of the Bluff Furnace
site were removed to the Institute of Archaeology for processing. The
first analytical step involved creating an inventory of the entire
collection. Artifact analysis forms were created which reflected
functional and formal categories into which the domestic and non-domestic materials were separated.

The domestic component of the Bluff Furnace site required analysis forms with categories applicable to artifactual material generated at the household level. These included glassware, kitchenware, personal items, architectural materials, furniture hardware, clothing, bone and miscellaneous items (Table 4-1). Results of the analysis of these materials are presented for future research and will not be incorporated into our discussion of the primary, industrial component at the site.

Non-domestic categories (which included the majority of the artifacts retrieved) distinguished between wrought and cast iron and, within these groups, differentiated fasteners, tools and miscellaneous items (Table 4-2). Numerous examples of raw materials, salamander iron, waste materials and soil material from the productive period of the furnace were sampled and identified.

**Data Inventory: Domestic Materials**

Five proveniences were defined as domestic on the basis of their context. Proveniences 3-1 and 3-A-2 were collections of materials directly related to the house foundation located in Operation 3. Three proveniences (1-A-4, 1-A-5 and 1-F-2) were collected from immediately north of the house and appear to contain debris associated with this twentieth century domestic occupation which found its way downslope into the Operation 1 area. Table 4-1 summarizes the domestic artifact inventory and should be consulted during the following discussion.

**Glass.** The majority of the glass in the domestic proveniences was in the form of modern bottles or bottle fragments. The one item in the other glass category was a whole blue pharmaceutical bottle with a
Table 4-1. Domestic Artifact Groups and Classes, by Operation

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</tr>
</tbody>
</table>
hand-tooled rim and raised lettering advertising; "Bromo-Seltzer, Emerson Drug Co., Baltimore, Maryland" (1-F-2). This bottle probably dates from the last quarter of the nineteenth century (Baldwin 1973:82).

**Kitchen.** Two pieces of a cast iron stove were placed in the kitchen class. The tableware category included a stainless steel knife, fork and teaspoon, and a plated teaspoon. All ceramics from the domestic contexts were modern ironstone and porcelain. Several modern food packaging items were collected including bottle lids and sardine can keys.

**Personal.** Two coins were found associated with the domestic component, a 1962 quarter (3-A-2) and a 1941 penny (1-A-4). The former established a terminus post quem for the demolition of the house structure. Among the other personal items were a piece of bone toothbrush, two pieces of lead pencil, three plastic brooches, a small engraved metal clasp, an ink pen top and two fragments of shoe heel.

**Architecture.** A large amount of modern window glass was found in the domestic context, as would be expected. Architectural fasteners included nuts, bolts, screws, nails and staples. A metal doorknob and a door latch made up the hardware category. Other architectural items included fragments of ceramic bathroom fixtures, a lamp chain, a case lock, pieces of asbestos shingles, linoleum fragments, metal brackets, electrical components and brick tiles.

**Clothing.** This category included buttons of plastic, bone and shell, brass buckles and a clothing snap.

**Bone.** All bone was recorded by weight. Several pieces displayed marks indicating a sawing butchering technique.
Activities. The single item in the construction tool category was a small hand saw blade. Fragments of tortoise shell, mussel shell and a peach pit made up the ethnobotanical class. Other activities were represented by items associated with automobiles, toys, a horseshoe, grapeshot (possibly dating to the Civil War), a gun cartridge, etc.

Data Inventory: Non-Domestic Materials

The majority of these artifacts were derived from non-domestic contexts interpreted as being associated with the period during and immediately after the operation of the furnace. The categories used to organize the bulk of the non-domestic material reflected functional relationships when possible (Table 4-2). However, much of the iron which was retrieved had been cast into forms which were not identifiable due to their broken and corroded state. Many were probably structural elements associated with the furnace, hot blast equipment and other machinery. Other fragments were classified on the basis of formal characteristics since their function in the complex of structures and machinery was not clear from the contexts in which they were found.

Wrought Iron Tools. This category included one hollow-handled, unidentified elongated tool, a rat tail file, a metal sheath for a wooden handle, one-half of a pair of metal-working tongs and a chisel (Figure 4-21).

Wrought Iron Fasteners. Iron rivets from the iron band encompassing the bottom of the hearth of the furnace made up a substantial portion of the wrought iron fasteners retrieved from the Operation 1 area. The majority of the wrought iron nails were found in a disturbed context in the interior of the casting shed. A wishbone-shaped masonry anchor was found imbedded in the Feature 15
apron in Operation 1 (Figure 4-22). Other types of fasteners found are enumerated in Table 4-2.

**Miscellaneous Wrought Iron.** There were a variety of wrought iron artifacts placed in this category, including clamps, wedges, rods, bars, rings, etc. The function of some of these could be determined, while others could only be described. The majority of these items were collected from the Operation 1 furnace area.

**Cast Iron Tools.** Included in this category which may have were a straight peen hammer head (an iron-working tool), an unidentified claw-like piece and an octagonal stone working "point" or drill (Figure 4-22).

**Cast Iron Fasteners.** Cut nails associated with the wooden trough and drain south and east of the furnace hearth made up the majority of items in this category. Cut nails and washers probably derived from the charging deck structures were retrieved from Operation 4, as were cut nails from Operation 3.

**Miscellaneous Cast Iron.** Most of the iron fragments included in this category are from the furnace area (Operation 1) and the charging deck level (Operation 4), and are assumed to have been part of the structure of the furnace itself, associated structures, or machinery housings or mounts. Many were unidentifiable as to function and undiagnostic in form (i.e., Unidentified Structural, Unidentified Flat, Flat with Holes). Others, such as the two large curved structural pieces from Operation 1, three possible slot keys, a flywheel fragment (Figure 4-26), and the four castings illustrated in Figures 4-5, 4-24 and 4-25, warrant further investigation. Thirty pieces of cast iron pipe, most with an inner diameter of 2.5 cm, were found in Operation 1.
Figure 4-22. Iron tools. A. "point" stone chisel (1-E-26); B. octagonal-shafted chisel, on edge (1-8); C. square-shafted chisel, on edge (3-D-7); D. chisel-bladed tool with mounting sleeve (1-1); E. straight peen hammer head (4-1).

Figure 4-23. Miscellaneous fittings. Top: masonry anchor (1-D-55); Center: bolt with threaded ends, square nut and heavy washer (1-C-31); Bottom: joined pipes, 2.5 cm (1 inch) interior diameter (1-C/D-22).
Figure 4-24. Two castings. These castings apparently represent structural iron pieces. The rib/girder form of the right example (context 2-A-3) is repeated, with flaws, in the left example (context 1-C-44), which was recovered in a charcoal-period context. The exact function of the pieces is unknown.

Figure 4-25. Structural cast iron. These three cast-iron pieces represent a class of structural iron equivalent to girders or joists, and were used in architectural/structural contexts at the furnace.
These may have been part of the system for carrying cooling water to or from the tuyeres at the hearth. Included in this total are the pipes which were found running from the Feature 28 wooden box to the furnace hearth.

Some of the iron at the site could not be identified as to its original form because of corrosion and breakage and, thus, was placed in a scrap iron category.

**Cast Pigs.** Four cast pigs, assumed to be products of the furnace, were retrieved from Operation 1 (Figure 4-27).

**Raw Materials.** Substances which were assumed to be raw materials used in the iron smelting furnace or steam generating equipment were sampled. These included charcoal, coke, coal and iron ore. The analysis of the latter three will be discussed in a later section.

**Waste Materials.** Large amounts of slag, green and black, were found in the Operation 1 area of the site and sampled for analysis. Cinder and fused material, such as that derived from burning coal, was found in the furnace area and may have been the product of the steam generating boiler system. Also collected were conglomerate masses consisting of varying amounts of iron, coke, coal, charcoal and slag. Splash iron occurred in Operations 1, 3, and 4. Its association with the furnace and casting area in Operation 1 is evident. The small amount in Operation 3 seemed to be associated with the Feature 7 brick work. As noted earlier, the anchor bolts in Operation 4 were set in oversized holes in the bluff top and anchored in iron. The splash iron from this area may have been the result of this construction operation.

In Operation 1 were found elongated pieces of iron which were rounded along one side, that is, they appeared to have solidified inside
Figure 4-26. Machine parts and fittings. Left: light flywheel (1-C/D-22); Top Center: angle bracket or beam stirrup, on edge (1-C-1); Bottom Center: portion of machine frame (?) (1-C-31); Right: cast iron pipe joint (1-C-44).

Figure 4-27. Pig iron. Top: pig bar, from charcoal-period context (1-C-44); Lower Left: small pig, possibly from coke period (1-1); Lower Right: pig bar fragment (1-C/D-22).
a channel. These, perhaps, set up in and were broken out of the trough leading from the furnace to the sand molds or overflow channels.

The furnace hearth, as it was exposed, contained a salamander, that is, an untapped charge of iron. The top of this mass, which was sampled, consisted of spongy iron, graphite, coke and slag. Unfortunately, this composite material was not amenable to chemical analysis.

**Soil Material.** An area of light brown fine casting sand leading from the hearth toward the casting shed was sampled. It was underlain by a layer of black sandy material with charcoal, and overlain by loamy brown sand. This casting sand channel was bordered on the north to Feature 18 by grey and brown sand containing charcoal, splash iron and a fragment of a large nail or spike, possibly from a wooden trough supporting the sides of the casting sand channel.

Also sampled was the furnace "working floor" material located south and east of the hearth. This consisted of black sandy material with coke, coal, charcoal, slag and fragments of iron. West of the hearth in Operation 1 a mass of soft lime was encountered and sampled for analysis. The results of the analysis are considered in a later section.

**Other.** This category included the domestic components within generally non-domestic contexts such as bottle glass, late Pearlware and stoneware ceramics, sawn and cut bone, and window glass. The personal items group consisted of buttons, a comb and a presumably intrusive 1913 penny found in the demolition fill around the furnace hearth. Seven fragments of an iron kettle found in Operation 1 may have been associated with the iron smelting operation.
The wood samples from Operation 1 consisted of pieces of the Feature 28 wood-lined box and Feature 11 wood-lined drain associated with the working floor around the furnace. "Miscellaneous-Other" items are enumerated in Table 4-2.

**Discussion of Bluff Furnace Artifacts**

In general, the types and distributions of non-domestic artifacts recovered from the site tend to corroborate the structural and functional data reviewed above. Artifacts associated primarily with structures (i.e., cast and wrought iron fasteners) were confined mainly to Operations 1 and 4, where documentary and archaeological evidence indicate structures and machinery were located. These two areas account for 85.1% of fasteners, while Operation 3 contained a relatively high frequency of machine cut nails (19.9% of the total nails). This latter figure is thought to reflect the former presence of frame structures that formed part of the charging deck that extended into the Operation 3 area. A more sensitive indicator of site function than architectural items is the Miscellaneous Cast Iron group, which contains artifact classes that are unambiguously associated with the furnace period of the site. The dismantling of heavy machinery and the cupola itself is assumed to have resulted in the deposition of numerous cast iron fragments near or at the original location of the machinery and cupola. Table 4-2 clearly indicates a non-random distribution of pipe segments, structural pieces, and unidentified cast iron fragments, with 90.2% (or 222) of these fragments collected from Operation 1. The context in which almost all of these artifacts were recovered consisted of demolition fill, which would be expected to have dispersed rather than
preserved the positions of the machine and cupola fragments. Despite this tendency toward randomness, there seems to be a highly localized depositional pattern for these artifact types. Their limited distribution can best be accounted for by in-place dismantling of the machinery and furnace.

The quantification of the raw materials and waste products presented in Table 4-2 indicates high frequencies and weights for Operation 1 almost exclusively. However, no claim can be made as to the representativeness of the figures presented for each operation since these materials were obtained as selective samples rather than a 100% recovery collection.

Chemical Analysis of Special Samples

Selected samples of raw materials, waste materials and cast pig iron recovered from the site were subjected to chemical and physical analysis to determine their characteristics. Analytical data on blast furnace materials and products of the nineteenth century iron industry is not abundant. We have referred to sources available to us with the expectation that future research will yield information comparable to that collected at Bluff Furnace.

Two cast pigs, both from Operation 1 (the furnace area), underwent analysis at American Cast Iron Pipe, Co. The smaller example, approximately 23 cm long, was unprovenienced; however, a second pig, approximately 46 cm long, was removed from underneath the cinder and slag working floor around the furnace and is, therefore, assumed to be a product of the charcoal phase of the Bluff Furnace operation. Both were analyzed for silica, manganese, phosphorus, sulfur, total carbon and
iron. The matrix structure was also determined through a photomicrograph technique.

Six samples of coke and one sample of coal removed from immediately above the cinder working floor of the furnace, are interpreted as being directly related to the coke period of operation of the furnace. All samples were analyzed for volatile matter, fixed carbon, ash and sulfur, by Chattanooga Coke and Chemical Co.

Two samples of iron ore recovered from the Operation 3 area were submitted for analysis to American Cast Iron Pipe, Co. They were tested for insoluble matter, metallic iron, phosphorus, manganese, silica and alumina.

The seven slag samples selected for analysis came from two distinct proveniences. Four black samples were collected from the cinder and slag layer immediately above the working floor of the furnace. These are assumed to be directly related to the coke period of the Bluff Furnace operation. Three other samples were collected from the slag pile north of the casting shed. All samples underwent analysis for silica, alumina, lime, magnesia, manganese oxide, sulfur and iron (in the form of FeO) at American Cast Iron Pipe Co.

A soft, powdery white material was sampled from approximately 2 m west of the hearth in Operation 1. Following the suggestion of Swank (1892:290) that the furnace was used as a lime kiln during the occupation of the Union forces, this material was tested for calcium oxide and magnesium oxide, the main constituents of slaked lime.

The results of the analyses described above are presented in the next section.
Discussion of Chemical Analysis

From the analysis of raw and waste materials and cast pigs collected from the Bluff Furnace site we can get an indication of the operation of the furnace.

Lesley indicated that the ore being used at Bluff Furnace came from an area at the foot of the Cumberland escarpment in which the iron ore is of the Rockwood Formation (Lesley 1859:83; Burchard 1913:74-77). This area was also indicated by Chapman to be significant in Tennessee ore mining (1953:34). Safford (1869) stated that these ores from "dyestone" outcroppings were mined along the entire length of the east edge of the Cumberland escarpment in Tennessee. The Half Moon Island range of dyestone ridges lie in Roane and Meigs Counties near White's Creek where the ore for the Bluff Furnace is purported to have been mined (Lesley 1859:83). In quoting a report to the Chattanooga and Kentucky Railroad, however, Safford said that dyestone ore beds across the river from Chattanooga had been worked by the East Tennessee Iron Manufacturing Company (1869:457). This entire area was considered an ideal base for the iron industry as coal, ore, limestone and sandstone (for hearths) were often found in close proximity and within easy access of transportation facilities (Safford and Killebrew 1904:178).

The Rockwood Formation contained bedded ores of the red hematite variety which tended to be amorphous, red to bluish-black and lustrous, mixed with calcium carbonate, silica, alumina, magnesium carbonate and a variety of minor elements. The "fossil" ore referred to by Lesley may be the calcareous structural variant containing aggregates of fossil organic forms and clay (Burchard 1913:74). Some of the hard varieties contain quantities of lime which act as flux in the blast furnace.
Rockwood ores are considered non-Bessemer grade, containing 0.25 to 0.75% phosphorus (Burchard 1913:77).

The results of tests run on the ore samples from the site are presented in Table 4-3. The silica, alumina and manganese values are within the range expected for Rockwood ores of this type, although there is considerable variation among ores of any one type. It appears from the hematite samples that the Bluff Furnace was smelting ores with a higher metallic iron content than is usually found in these ores. It is also on the high end of the range for iron given by Fairbairn for hematite ores smelted in Great Britain and other parts of the U.S. (1865:25,36).

In Lesley’s description of the Bluff Furnace, he stated that the bituminous coals of Raccoon Mountain were found suitable for coking and a shift to coke was being considered (1859:83). Primary sources also indicate that the furnace may have been supplied with coke made from Raccoon Mountain coal (HCDB 10:62). The Pennsylvanian age Crab Orchard Mountain Group rocks of this mountain contain outcroppings of coal seams, including the Bon Air (also called the Etna seam) which may have been exploited by the Etna Mining and Manufacturing Company for use at Bluff Furnace (Luther 1959:187-199). Luther presents a representative analysis of coals from this seam which we have included with the analysis of the Bluff Furnace coal in Table 4-4 (Luther 1959:201). As indicated in Table 4-4 there is a great deal of variability in characteristics within a coal seam. The Bluff Furnace sample is superior to the average for Bon Air coals in having a higher fixed carbon, and lower ash and volatile matter content. Sulfur is slightly higher than the average but not excessively so. The Bon Air coals, and
the sample from the site, show qualities which would make them good coking coals.

All examples of fuel retrieved from the site are from the coke period of operation. The results of the analysis of these samples are presented in Table 4-5. In all samples, sulfur content falls within the range which, in the early twentieth century, was felt to be acceptable (0.8%-1.5%) (Johnson 1918:169). This is an important factor in the production of low sulfur pig iron such as the examples recovered from the site. The values for ash content appear to be relatively high and associated with lower fixed carbon contents than may have been considered optimal, since fixed carbon is the useful part of the fuel. Without comparable data it is difficult to hypothesize whether the mid-nineteenth century coking techniques could achieve what Johnson in the early twentieth century considered an acceptable blast furnace coke, with fixed carbon between 85% and 90% and ash between 8% and 12% (1918:170).

Using the estimates given by Overman (1854) and Ure (1860) on the quantities of raw materials consumed in the production of one ton (907 kg) of iron (see Section 3), we can calculate the approximate raw material consumption at Bluff Furnace. Lesley stated that during the thirteen weeks in 1856 in which the furnace produced, the yield was 172 tons of charcoal iron (1859:83). Using average values of 2273 kg charcoal and 1975 kg of calcined ore, we calculate that the furnace consumed approximately 390,856 kg charcoal and 339,600 kg ore in producing 156,004 kg (172 tons) of pig iron. A yield of 13.2 tons per week is slightly less than the average reported for charcoal furnaces in East Tennessee and Georgia during this time (Lesley 1859: 81-83).
Table 4-4. Analysis of Coals

<table>
<thead>
<tr>
<th>Specimen</th>
<th>Volatile Matter</th>
<th>Fixed Carbon</th>
<th>Ash</th>
<th>Sulfur</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bon Air</td>
<td>39.4</td>
<td>67.4</td>
<td>23.8</td>
<td>5.1</td>
</tr>
<tr>
<td></td>
<td>24.6</td>
<td>46.4</td>
<td>2.1</td>
<td>0.4</td>
</tr>
<tr>
<td></td>
<td>33.08</td>
<td>54.47</td>
<td>9.75</td>
<td>2.39</td>
</tr>
<tr>
<td>Bluff Furnace</td>
<td>27.13</td>
<td>65.39</td>
<td>7.48</td>
<td>2.61</td>
</tr>
</tbody>
</table>

a Analytical technique:
ASTM titrimetric

b Maximum, minimum, and average values
c Provenience:
1-C-34

Table 4-5. Analysis of Bluff Furnace Coke

<table>
<thead>
<tr>
<th>Constituent</th>
<th>Specimen</th>
<th>#1</th>
<th>#2</th>
<th>#3</th>
<th>#4</th>
<th>#5</th>
<th>#6</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fixed Carbon</td>
<td></td>
<td>87.44</td>
<td>80.00</td>
<td>76.52</td>
<td>86.87</td>
<td>88.72</td>
<td>72.06</td>
</tr>
<tr>
<td>Ash</td>
<td></td>
<td>11.06</td>
<td>18.42</td>
<td>21.18</td>
<td>11.73</td>
<td>9.80</td>
<td>25.25</td>
</tr>
<tr>
<td>Sulfur</td>
<td></td>
<td>0.73</td>
<td>1.28</td>
<td>1.24</td>
<td>1.23</td>
<td>0.98</td>
<td>1.44</td>
</tr>
</tbody>
</table>

a Analytical technique:
ASTM titrimetric

b Provenience:
#1 1-C-34, dull black
#2 1-C-34, grey
#3 1-C-19, silvery grey
#4 1-C-42, dull black
#5 1-C-38, silvery grey
#6 1-C-38, silvery grey
Swank stated that 500 tons of coke pig iron was produced in 1860 before the furnace ceased to operate (1892:290). Again, using average values for raw materials consumed per ton of iron (1815 kg coke, 1917 kg calcined ore and 907 kg limestone), we can calculate the needs of the Bluff Furnace for production of 453,500 kg (500 tons) of pig iron as approximately 907,500 kg coke, 987,500 kg ore and 453,500 kg limestone.

Although no recognizable examples of fluxing material were recovered from the site, it is assumed, given the characteristics of the raw materials, that a limestone flux was employed as was standard practice in the industry. Limestone used as a flux is preferably high in calcium carbonate, low in silica, alumina, sulfur and phosphorus, and of a durable physical nature (Hershey and Maher 1963:13-14). The operators of the Bluff Furnace may have taken advantage of the Chickamauga Limestones which are abundant in the immediate vicinity of Chattanooga and yield a stone suitable for use as a fluxing material in the iron smelting furnace (Hershey and Maher 1963:54).

The results of the analysis of the slag samples from the Bluff Furnace site are presented in Table 4-6. Table 4-7 shows comparable data for slags from other blast furnaces operating during the nineteenth century. Specimens #1-4 (Table 4-7) were collected from the Eaton-Hopewell, a mixed charcoal-raw bituminous coal fueled cold blast furnace which was in operation between 1802 and 1808 (White 1977,1978,1980). Samples #5-14 are from Fairbairn (1865) and Overman (1854) for charcoal or coke fueled hot blast furnaces in Europe. Samples #15 and #16 are from the Great Western, a charcoal fueled cold blast furnace near Dover, Tennessee that operated in the mid-nineteenth century (Raymond Evans:personal communication).
Table 4-6. Analysis of Bluff Furnace Slags

<table>
<thead>
<tr>
<th>Specimen</th>
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<th>Al₂O₃</th>
<th>CaO</th>
<th>MgO</th>
<th>MnO</th>
<th>S</th>
<th>FeO</th>
<th>CaO+MgO</th>
<th>SiO₂+Al₂O₃</th>
</tr>
</thead>
<tbody>
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<td>13.1</td>
<td>30.7</td>
<td>6.58</td>
<td>0.33</td>
<td>0.54</td>
<td>7.27</td>
<td>0.69</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>39.6</td>
<td>13.4</td>
<td>30.1</td>
<td>6.60</td>
<td>0.33</td>
<td>0.56</td>
<td>9.18</td>
<td>0.69</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>41.5</td>
<td>13.4</td>
<td>30.3</td>
<td>5.85</td>
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<td>0.51</td>
<td>7.77</td>
<td>0.66</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>34.3</td>
<td>10.6</td>
<td>25.9</td>
<td>4.49</td>
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<td>0.57</td>
<td>23.7</td>
<td>0.68</td>
<td></td>
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<tr>
<td>5</td>
<td>45.9</td>
<td>14.2</td>
<td>32.3</td>
<td>3.96</td>
<td>1.02</td>
<td>0.10</td>
<td>1.74</td>
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</tr>
<tr>
<td>6</td>
<td>43.2</td>
<td>14.4</td>
<td>36.3</td>
<td>4.05</td>
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<td>0.08</td>
<td>0.99</td>
<td>0.70</td>
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<tr>
<td>7</td>
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<td>0.39</td>
<td>0.12</td>
<td>0.38</td>
<td>0.77</td>
<td></td>
</tr>
</tbody>
</table>

**Specimen:**
- #1 1-C-34; black (glassy)
- #2 1-C-34; black (dull, porous)
- #3 1-C-36; black (glassy)
- #4 1-C-38; black (dull, porous)
- #5 1-E-7; green
- #6 1-E-7; black (glassy)
- #7 1-E-7; black (glassy)

**Analytical technique:** Spectroscopy
Table 4-7. Analysis of Blast Furnace Slags

<table>
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<tr>
<th>Specimen</th>
<th>SiO$_2$</th>
<th>Al$_2$O$_3$</th>
<th>CaO</th>
<th>MgO</th>
<th>MnO</th>
<th>S</th>
<th>FeO</th>
<th>$\frac{CaO+MgO}{SiO_2+Al_2O_3}$</th>
</tr>
</thead>
<tbody>
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<td>1</td>
<td>53.5</td>
<td>14.8</td>
<td>20.2</td>
<td>5.1</td>
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<td>0.3</td>
<td>0.4</td>
<td>0.37</td>
</tr>
<tr>
<td>2</td>
<td>55.3</td>
<td>14.5</td>
<td>19.0</td>
<td>3.3</td>
<td>2.9</td>
<td>0.4</td>
<td>0.6</td>
<td>0.32</td>
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<tr>
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<td>15.00</td>
<td>17.80</td>
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</tr>
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<td>19.30</td>
<td>2.90</td>
<td>3.74</td>
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<td>0.33</td>
</tr>
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<td>40.4</td>
<td>11.2</td>
<td>38.4</td>
<td>5.2</td>
<td>----</td>
<td>trace</td>
<td>3.8</td>
<td>0.84</td>
</tr>
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<td>1.6</td>
<td>0.24</td>
<td>0.63</td>
</tr>
<tr>
<td>7</td>
<td>40.20</td>
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<td>30.00</td>
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<td>1.2</td>
<td>0.57</td>
<td>0.66</td>
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<tr>
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<td>41.64</td>
<td>13.20</td>
<td>35.91</td>
<td>4.21</td>
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<td>1.0</td>
<td>0.11</td>
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<tr>
<td>9</td>
<td>42.94</td>
<td>16.29</td>
<td>31.10</td>
<td>4.16</td>
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<td>0.9</td>
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<td>0.60</td>
</tr>
<tr>
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<td>13.20</td>
<td>20.68</td>
<td>2.93</td>
<td>0.80</td>
<td>0.39</td>
<td>20.83</td>
<td>0.46</td>
</tr>
<tr>
<td>12</td>
<td>51.84</td>
<td>15.21</td>
<td>21.80</td>
<td>4.82</td>
<td>1.16</td>
<td>----</td>
<td>3.73</td>
<td>0.40</td>
</tr>
<tr>
<td>13</td>
<td>40.6</td>
<td>16.8</td>
<td>32.2</td>
<td>----</td>
<td>----</td>
<td>----</td>
<td>10.4</td>
<td>0.56</td>
</tr>
</tbody>
</table>
Table 4-7 (continued)

<table>
<thead>
<tr>
<th>Specimen</th>
<th>SiO$_2$</th>
<th>Al$_2$O$_3$</th>
<th>CaO</th>
<th>MgO</th>
<th>MnO</th>
<th>S</th>
<th>FeO</th>
<th>CaO+MgO</th>
<th>SiO$_2$+Al$_2$O$_3$</th>
</tr>
</thead>
<tbody>
<tr>
<td>14</td>
<td>43.2</td>
<td>12.0</td>
<td>35.2</td>
<td>4.0</td>
<td>----</td>
<td>----</td>
<td>4.2</td>
<td>0.71</td>
<td></td>
</tr>
<tr>
<td>15</td>
<td>58.4</td>
<td>9.10</td>
<td>25.4</td>
<td>2.49</td>
<td>2.10</td>
<td>0.08</td>
<td>1.86</td>
<td>0.41</td>
<td></td>
</tr>
<tr>
<td>16</td>
<td>58.0</td>
<td>7.42</td>
<td>16.1</td>
<td>1.58</td>
<td>4.64</td>
<td>0.05</td>
<td>11.9</td>
<td>0.27</td>
<td></td>
</tr>
</tbody>
</table>

Source:
#1 White (1977:187). Eaton-Hopewell; charcoal-coal; black (glassy)
#2 White (1977:187). Eaton-Hopewell; charcoal-coal; green-turquoise
#3 White (1977:187). Eaton-Hopewell; charcoal-coal; green (glassy)
#4 White (1977:187). Eaton-Hopewell; charcoal-coal; black
#5 Fairbairn (1865:62). Scotland; coke.
#6-9 Fairbairn (1865:99). Great Britain; coke
#10-11 Fairbairn (1865:101). Great Britain; coke; black (glassy)
#12 Overman (1854: 231). Europe; charcoal
#13-14 Overman (1854:231). Europe; coke
#15 Great Western Furnace, Stewart Co., Tennessee; charcoal; blue
#16 Great Western Furnace, Stewart Co., Tennessee; charcoal; milky blue-green
Comparing the values given for the Bluff Furnace slags with those from Overman and Fairbairn we find general consistency. The only exception to this is the greater amounts of iron in the samples retrieved from above the working floor of the furnace at Bluff Furnace. Fairbairn indicated that these black, iron-bearing slags are formed when the supply of coke is insufficient to deoxidize all of the iron and a portion of the iron passes into the slag, giving it a dark black or green color (1865:61). In the case of one of the Great Western samples (#16), the high iron content may have produced the milky blue-green color.

The sulfur removing ability of the slag increases in the order of silica<alumina<magnesia<lime. The desulfurization index (sulfur removing capacity) of a slag can be calculated by dividing the combined percentages of lime and magnesia by the combined percentages of silica and alumina (White 1977:186-187). In general, a higher desulfurization index indicates a higher desulfurization capacity. The indices calculated for the Bluff Furnace slags are consistent with those calculated for other nineteenth century furnaces cited by Fairbairn and Overman. They are considerably higher than the values given for the Eaton-Hopewell and Great Western furnaces. A high lime and magnesia to silica and alumina ratio also leads, up to a point, to a lower slag viscosity and free running temperature. Based on comparisons with Johnson's empirical data on slags with 12% to 15% alumina and 33% to 60% silica, the free running temperature of the Bluff Furnace slags may have been in the range of 1340 to 1370 degrees, Celsius. This is within the range of low critical temperatures considered optimum, in terms of fuel efficiency, by Johnson (1918:200-201).
Following White (1977) we have attempted to determine the temperature of formation of the Bluff Furnace slags. Using the 15% alumina place of the lime-magnesia-silica tetrahedron as presented by White (1977:188) and developed by Osborn and others we find the Bluff Furnace slags falling close to the 1300 degrees, Celcius isotherm. This is, of course, appreciably lower than the slag temperatures of the modern blast furnace (over 1600 degrees, Celcius), but comparable to the temperatures calculated for the Eaton-Hopwell slags (White 1977:188).

The results of the analysis of the pig iron produced at the Bluff Furnace are presented in Table 4-8. Both examples are well within the limits given by Johnson (1918) for a good foundry grade iron. A carbon content of near 4% with a low sulfur content indicates a strong finished product (Johnson 1918:460). Next to carbon, silica is the most important component of cast iron. The silica content of both pigs is well within the range given by Johnson (1%-4%) to produce a good quality grey iron (1918:465). This is supported by the analysis showing a highly pearlitic matrix. Sulfur is a most troublesome element in cast iron, especially that produced with coke as a fuel. It tends to cause shrinkage and cracking of the cooled iron (Johnson 1918:465-466). The sulfur content of both pigs is considerably lower than for the iron described by Overman (1854), including that from charcoal furnaces (Table 4-9). In the case of the larger pig, this is to be expected as we assume it was made with charcoal. A general low sulfur product during the coke operation indicates successful fluxing and furnace management with a coke which we have seen has acceptable, but not particularly low, amounts of sulfur. Analysis of the iron produced at the Eaton-Hopewell furnace in Ohio gives an average sulfur content of
Table 4-3. Analysis of Bluff Furnace Iron Ore

<table>
<thead>
<tr>
<th>Specimen&lt;sup&gt;a&lt;/sup&gt;</th>
<th>Insoluble matter</th>
<th>Fe</th>
<th>P</th>
<th>Mn</th>
<th>Si&lt;sub&gt;2&lt;/sub&gt;O</th>
<th>Al&lt;sub&gt;2&lt;/sub&gt;O&lt;sub&gt;3&lt;/sub&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>#1</td>
<td>7.90</td>
<td>59.03</td>
<td>0.25</td>
<td>0.18</td>
<td>6.06</td>
<td>1.80</td>
</tr>
<tr>
<td>#2</td>
<td>9.00</td>
<td>58.03</td>
<td>0.20</td>
<td>0.49</td>
<td>6.60</td>
<td>2.40</td>
</tr>
</tbody>
</table>

<sup>a</sup>Provenience:  
#1 3-B-5  
#2 3-B-7

<sup>b</sup>Analytical technique:  
ASTM titrimetric

Table 4-8. Analysis of Bluff Furnace Pig Iron

<table>
<thead>
<tr>
<th>Constituent&lt;sup&gt;a&lt;/sup&gt;</th>
<th>Small Pig (1-1)</th>
<th>Large Pig (1-C-44)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Si</td>
<td>0.59</td>
<td>1.34</td>
</tr>
<tr>
<td>Mn</td>
<td>1.60</td>
<td>0.30</td>
</tr>
<tr>
<td>P</td>
<td>1.25</td>
<td>0.83</td>
</tr>
<tr>
<td>S</td>
<td>0.013</td>
<td>0.008</td>
</tr>
<tr>
<td>Total Carbon</td>
<td>3.81</td>
<td>3.94</td>
</tr>
<tr>
<td>FeO (approx.)</td>
<td>92.7</td>
<td>93.5</td>
</tr>
<tr>
<td>Matrix</td>
<td>85% pearlite</td>
<td>88% pearlite</td>
</tr>
<tr>
<td></td>
<td>15% steadite</td>
<td>10% steadite</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2% ferrite</td>
</tr>
</tbody>
</table>

<sup>a</sup>Analytical Techniques:  
Si - ASTM titrimetric  
Mn - ASTM titrimetric  
P - ASTM titrimetric  
S - Leco  
Total carbon - Leco  
Matrix - photomicrograph
### Table 4-9. Analysis of Iron

<table>
<thead>
<tr>
<th>Specimen&lt;sup&gt;a&lt;/sup&gt;</th>
<th>Fe</th>
<th>Si</th>
<th>Mn</th>
<th>P</th>
<th>S</th>
<th>Total Carbon</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>91.42</td>
<td>3.21</td>
<td>trace</td>
<td>1.22</td>
<td>trace</td>
<td>4.15</td>
</tr>
<tr>
<td>2</td>
<td>86.73</td>
<td>1.31</td>
<td>7.42</td>
<td>0.08</td>
<td>trace</td>
<td>4.46</td>
</tr>
<tr>
<td>3</td>
<td>95.81</td>
<td>0.57</td>
<td>-----</td>
<td>-----</td>
<td>trace</td>
<td>3.61</td>
</tr>
<tr>
<td>4</td>
<td>90.57</td>
<td>4.86</td>
<td>-----</td>
<td>-----</td>
<td>0.18</td>
<td>3.38</td>
</tr>
<tr>
<td>5</td>
<td>92.87</td>
<td>3.37</td>
<td>1.23</td>
<td>0.75</td>
<td>0.06</td>
<td>3.27</td>
</tr>
<tr>
<td>6</td>
<td>94.63</td>
<td>1.53</td>
<td>0.50</td>
<td>0.39</td>
<td>0.35</td>
<td>2.60</td>
</tr>
<tr>
<td>7</td>
<td>92.30</td>
<td>2.80</td>
<td>-----</td>
<td>1.30</td>
<td>1.40</td>
<td>2.20</td>
</tr>
</tbody>
</table>

<sup>a</sup>Source: Overman (1854:486-487).

1. Grey iron; Germany; charcoal; hot-blast; hematite ore
2. Grey iron; Germany; charcoal; hot-blast; hematite and spathic ores
3. Grey iron; Silesia; coke; hot-blast
4. Grey iron; France; charcoal
5. Grey iron, Germany; charcoal
6. Grey iron; Scotland; coke; hot-blast
7. Grey iron; Scotland; coke; hot-blast
0.086% (White 1978:392). This is considerably higher than the values for the Bluff Furnace iron and is not surprising considering the low desulfurization indices of the Eaton-Hopewell slags.

Although phosphorus is relatively high in both samples in terms of use for production of Bessemer steel, Johnson stated that "the Southern irons which carry in the neighborhood of 1% phosphorus command a premium for foundry purposes" (1918:468). The values reported here are certainly not outside the range reported for other nineteenth century furnaces by Overman (1854) (Table 4-9). In general, phosphorus tends to increase the fluidity of the iron and cause brittleness when the content is somewhere below 1% and up (Johnson 1918:469).

Conservation Techniques

Items of particular interest as representative of period technology and having analytical and/or aesthetic value were selected to undergo special conservation procedures. The two clearly identifiable cast pigs and several iron structural members underwent sandblasting at U.S. Pipe and Foundry to remove surface corrosion. Other items may be selected for this treatment as the remaining assemblage is reviewed. Smaller iron artifacts have been cleaned in the laboratory by electrolytic reduction. After processing, these were coated with tannic acid and an acrylic polymer sealer to prevent further corrosion.
5. SUMMARY, DISCUSSION AND CONCLUSIONS

Summary and Discussion

Through the combined use of documentary and archaeological lines of evidence, we have attempted to meet the data requirements of the research objectives outlined in the first section. By and large, this attempt has been successful. Synthesis of both lines of evidence has allowed us to establish the presence of most of the major features at the site, including the charging deck, furnace base and work area, attendant furnace features, casting shed, slag pile, and (possibly) an ash pit associated with the documented steam generating system. In addition, several unanticipated features were uncovered, the most noteworthy being the in situ coke-iron salamander situated in the cupola hearth. In many cases, these features were in a coherent interpretable form. Discrete site functions and activity loci were also delineated with reference to site structural data, site-specific documentation, documentation of period practices, and collection and analysis of artifacts.

Through laboratory analysis of archaeological samples we have been able to provide estimations on some of the operating parameters associated with the charcoal and coke phases of the furnace, including the relative efficiency and production quality of the operation. Evidence from the chemical analysis of the raw materials used at Bluff Furnace indicates that it was operating with locally derived materials. The association between the Etna Mining and Manufacturing Company, which was mining coal on Raccoon Mountain, and the East Tennessee Iron Manufacturing Company has been well documented. Thus, we may accept
Lesley's report (1858:148) that the owners of the Bluff Furnace were planning to switch to a coke operation based on coal derived from that area. The Bluff Furnace cokes were shown to have good structural and chemical properties for use in the blast furnace.

The hematite ores used in the furnace appear to have been derived from the Rockwood Formation, which stretches the length of the eastern edge of the Cumberland Plateau in Tennessee. If, as Lesley indicated (1858:83), the specific source lay near the boarder of Roane and Meigs Counties, the ore could easily have been barged downstream directly to the furnace site. From the analysis of ore samples retrieved from the site we can conclude that a high quality of ore was being smelted in the furnace, as compared with ores reduced in other mid-nineteenth century blast furnaces in Great Britain and the United States for which we have comparable information (Overman 1854; Fairbairn 1865).

Both of the above factors played a role in the production of good quality grey foundry iron at Bluff Furnace, comparable to iron being produced in Europe for the same time period (Fairbairn 1865). The pig associated with the charcoal phase of the operation has generally lower amounts of impurities than the unprovenienced example. This suggests that the second pig was produced by the coke-fueled furnace where more impurities would have been introduced by the fuel. There was, however, considerable variability in the amounts of contaminants reported for both charcoal- and coke-pig iron being produced at the mid-nineteenth century, so that any such conclusion about the Bluff Furnace pigs may be spurious. Many factors influenced the quality of iron produced, not the least of which was furnace management.
The only indication we have that the furnace may not have been operating under optimal conditions comes from the slag. Examples from both the charcoal and (possibly) coke phases seem to have good sulfur-removing qualities. However, evidence from chemical analysis and from its physical characteristics, particularly its very dark black and green color indicates that more iron was being lost than was considered acceptable by the industry at that time. Based on the information we have gathered concerning the operation of the furnace, this was likely the result of poor management.

Above all, the analysis of Bluff Furnace materials points out the necessity for comparable data from additional blast furnaces in this region. The controlled sampling and analysis of raw materials and products produced at furnaces in Tennessee, Georgia, and Alabama would provide a data base on which to build a coherent picture of the pattern of technological change in the nineteenth-century iron smelting industry of the South.

Establishing the local and regional significance of the site is a more complex objective than those discussed above in that it involves consideration of many qualitative factors. One question that should be answered is why Bluff Furnace eventually failed as an enterprise. Several opinions are rendered in the literature. Swank (1892:290) suggested that the physical plant of the furnace was working satisfactorily and that national politics and related labor unrest closed the plant. Swank also noted that at least once the short supply of coke had closed the plant, and this problem may have been a contributing factor in the furnace's demise. Although the charcoal furnace had been constructed in 1854, it was not fired until 1856. This
lag may be attributable to procurement problems in raw materials supplies. With the conversion to a new fuel, coke, the supply problem may have become more acute. As suggested in the furnace technology section of this report, the process of preparation of coke was itself an intensive operation. Coking, then, may have been as innovative as the use of coke at the furnace, with similar, concommitant problems or production "bugs".

James Henderson, who was to acquire a reputation as an innovator in the iron and steel industry in the 1860s and 1870s, may have withdrawn his expertise at a critical time. What role Giles Edwards might have played in the closing of the plant (or in attempts to reopen it) are unknown. Both Henderson and Edwards, however, clearly were the persons responsible for conversion of the furnace to a coke-fired iron cupola facility. If for any reason they became disaffected with the operation, this may have been sufficient cause for a closing.

Archaeologically we have evidence to suggest that the sandstone lining of the hearth may have given way during the last blast, leaving a salamander in the hearth. In this condition, the furnace could not have been refired without extensive repairs to the base of the cupola. The chemical analysis of the products of the furnace, and its raw materials and by-products, demonstrate that quality iron was being produced, although perhaps not as efficiently as was anticipated.

On all levels we find evidence of some difficulty with the furnace: with its management, labor relations, technical expertise, and engineering. Individually these problems might have been overcome, but collectively they presented insurmountable problems, especially in the volatile political climate surrounding Chattanooga in November of 1860.
It seems likely that no single factor brought about the demise of the furnace. Rather, the convergence of an array of adverse political, economic, and technical factors at a single point in time is responsible for the end of the operation.

Questions concerning the role that Bluff Furnace played in the industrial and economic development of this region must also be addressed in assessing the site's historical significance. Before the war the South was heavily committed to agricultural pursuits, and this certainly was the case in Tennessee (Belissary 1951:57). The industrial potential of the area was known by men like Robert Cravens, but the degree of exploitation was still small. The Tennessee iron industry in the pre-war era produced pig iron and wrought iron bars for local, restricted markets. This was changing in the decade before the war, largely due to the railroads. As Doster (1964:45) has noted, not only did the railroads greatly expand markets for products and permit shipment of raw materials to new manufacturing localities, but the railroads were also enormous consumers of iron themselves. It was this realization that may have been in the mind of Robert Cravens when he moved from Roane County to Chattanooga in 1851.

Industrialism was still emerging in the South when the Civil War erupted. The economic prospects of East Tennessee in the pre-war era stood in sharp contrast with the situation after two years of war. James A. Seddon, Secretary of War in the Confederate government, complained to President Jefferson Davis in January, 1863, that

The most serious embarrassment to be apprehended in reference to the ordinance supplies is in the deficiency of iron. Before the war nearly all iron-works within the States of the Confederacy had languished or decayed, and from the sense of precariousness in the future and the scarcity of
suitable labor it has been very difficult to establish them in sufficient numbers and on an adequate scale to meet the necessities of war. (U.S. War Department 1900:291)

The South was forced to fall back upon its own limited resources, both material and technical. The Federal blockade of Confederate ports meant materials, machines and labor had to be found from within its borders, and as the siege of the Confederacy wore on, the low level of Southern industrial output became crippling.

In this climate it is not surprising that the stockholders of the East Tennessee Iron Manufacturing Company were liquidating their assets in July, 1863. By that date, all of the company's assets were, or were about to be, in Federally-controlled territory. Chattanooga was occupied by Federal troops in September, 1863.

The occupation of Chattanooga had a curious effect on the economy of the area. Initially, its effect was negative. The Bluff Furnace had, of course, already closed, and Thomas Webster, who had been supplying the Confederacy with iron products and services, had fled with his company south to Selma, Alabama, where he resumed the production of iron goods for the South. S.B. Lowe, who had been constructing the Vulcan Iron Works on the banks of the Tennessee River near Cameron Hill, had abandoned that enterprise and also fled south. The Confederate government had even started construction of a rolling mill about two miles from town, but were forced to "spike" the machinery and abandon the works (see Doster 1964).

Chattanooga stood at the gateway to the Deep South, and its central position in the railway network of the region was well known to the Confederate and Union forces. Chattanooga became a marshalling yard for the Federal campaigns leading to the capture of Atlanta. The occupying
forces launched into a vigorous construction campaign first, however, building innumerable storehouses, mechanics shops, railyard facilities, a waterworks, sawmills, and importantly a rolling mill for rerolling worn rails on the heavily trafficked lines of the Western and Atlantic, and Nashville and Chattanooga Railroads. This rolling mill would later figure prominently in the industrial history of the town.

After the war, the positive effects of that conflict began to be felt in the local economy. Among the Federal soldiers that had campaigned through Tennessee were men like John T. Wilder and Hiram S. Chamberlain, who returned after the conclusion of the war to begin a greater exploitation of the area's mineral resources. These two men formed the Roane Iron Company and at Rockwood in Roane County, constructed the first coke furnace in the South built after the war, in 1867 (Swank 1892:291; see also Chamberlain 1942). Their company acquired the government-built rolling mill at Chattanooga. Swank (1892:291) records that

The first open-hearth steel made in any Southern State was made by the Siemens-Martin process at Chattanooga by this company on the 6th day of June, 1878, and in December of the same year the first steel rails to ever be made in the South were rolled at its works.

In the years following the Civil War, Chattanooga came to enjoy a prominence in the nation's iron and steel industry. Clark (1949:68) noted that the recovery of the Southern iron industry was "speediest and most promising" in southern Tennessee and Alabama.

Swank (1892:292) suggested that Chattanooga's importance rested in part on the rich bituminous coal reserves of the area and also on its excellent transportation facilities. The railroads did much to change the industrial geography of the iron and steel industry, permitting iron
ore and coal to be shipped, in bulk, economically. After the Civil War
coke was to become the principle blast furnace fuel in iron and steel
production.

Peter Temin, in his *Iron and Steel in Nineteenth Century America:*
An Economic Inquiry* (1964), has discussed the shift from anthracite coal
(as raw coal) to bituminous coal (largely as coke) as the dominant fuel
in blast furnaces. He noted that while Southern coal was sulfurous and
was thus less chemically desirable than anthracite coal, when coked the
bituminous coal possessed a good physical structure for use in furnaces
and foundries (Temin 1964:200). As noted in an earlier section,
anthracite deposits were geographically restricted to areas of the
northeast, while bituminous coals were more broadly distributed. Thus,
when the bituminous coals (as coke) came to be relied upon more heavily
for furnace fuel, the geographical distribution of iron and steel output
changed.

**Site Significance**

Bluff Furnace, in its charcoal-fired period, was an ordinary
furnace for its day. The masonry stack was typical, and the
steam-generated blast was a necessity dictated by its location away from
a usable water-power supply. The hot-blast stove had been widely
adopted in this country in the 1840s, and its placement at the top of
the stack where it was heated by exhaust heat was unremarkable.

When the new furnace was constructed in 1859, there were several
innovations incorporated into its design and operation, but apparently
only in the sense that the design was new to the area. Swank (1892:291)
noted that the furnace was the first coke-fired blast furnace in either
Tennessee or Alabama, which were the only "Deep South" states in which an appreciable amount of iron was being smelted at the time. Elsewhere, Swank (1892:371) stated that the furnace was the first coke-fired operation "south of the Potomac region." The use of coke at Bluff Furnace was thus not unique except in a geographical, regional sense.

In rebuilding the furnace in 1859, the hot blast stove was relocated from the furnace top down to or near ground level southwest of the cupola. This movement was part of a contemporary trend and was not particularly avant-garde (Swank 1892:454). The iron cylindrical cupola was perhaps the most novel element of the new furnace plant. Earlier in this report we cited Clark (1949:76), who noted that such furnaces were being constructed in the West in the early 1860s and at that time represented the "most modern" design. As the newest technological component of the reconstructed furnace, the iron cupola stack may have represented the most difficulty to construct and maintain by persons unfamiliar with that type of stack.

In its coke-fired configuration, Bluff Furnace incorporated both standard technology and some innovative elements (Figure 5-1). Its use of coke was new to this region. The iron cupola appears to have been both temporally and geographically novel, with respect to American practice. Certainly the furnace was Chattanooga's first in a long line of iron smelting facilities, and in conjunction with the foundry on Market Street, was the first heavy industry in the city.

Bluff Furnace thus assumes local significance by having laid the foundation for heavy industry in the Chattanooga area. Stockholders of the East Tennessee Iron Manufacturing Company, such as Robert Cravens, James A. Whiteside, Ker Boyce and James P. Boyce, also participated in
Many questions remain about the operation of the blast furnace, particularly in the context of its period of operation. The type of blast furnace used in the Lurgi plant was the Lurgi Siemens-Martin (L-M) design. The charging deck was a critical component of the furnace, used to transport the ore from the charging hopper to the coke layers. The charging deck was suspended from the roof of the furnace, allowing for easy access to the charge. The charging deck was also used to transport the charge from the top of the furnace to the charging hopper, ensuring a continuous flow of charge to the furnace. The charging deck was equipped with a series of hoppers, each designed to hold a specific type of ore. The hoppers were connected to the charging mechanism, which was used to transport the charge to the furnace. The charging deck was a critical component of the furnace, and its operation was essential to the efficient operation of the furnace.
Figure 5-1. Analysis of the 1860 Bluff Furnace photograph.
the early exploration and exploitation of local ore and coal resources. The use of coke in a cupola blast furnace was an innovative experiment for this city and region. Technically, and despite all problems, the furnace was a success, and its failure as an economic enterprise in 1860 in no way diminishes its role as a harbinger of the industrial development of Chattanooga.

Bluff Furnace was a vanguard in the transformation of the Southern iron industry from the restricted production charcoal-fired furnace for local markets, to coke-produced iron and steel at vastly increased production levels. As such, its significance extends beyond the local to the regional level. Although it did not survive the Civil War, Bluff Furnace represented the initial step in Chattanooga's heavy industrial development, presaging this city's rise to its place in the constellation of major American iron and steel production centers.

As of this writing, our third major goal for this project has been only partially achieved. The educational potential of the site can be fully realized only when the results of this and other research in industrial archaeology are made accessible to the general public. Bluff Furnace proved to be a focus of popular community interest during the excavation, with extensive coverage of the field activities being carried out, by newspaper and television media. It is clear that considerable educational benefits would result from the interpretation of the extant archaeological remains in a historical park setting. It is our hope that current efforts toward achieving this goal will be successful. As an interpretive park, Bluff Furnace will once again achieve distinction in Chattanooga by eliciting an appreciation of an important part of our industrial heritage.
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