

PRELIMINARY ARCHAEOLOGICAL EXAMINATION OF OHIO'S FIRST BLAST FURNACE: THE EATON (HOPEWELL)<sup>1</sup>

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*Abstract.* The Eaton (Hopewell) Furnace located near Struthers, Ohio was built in 1802-1803. The first blast furnace west of the Alleghenies and the first industry of any kind in the Western Reserve, it went out of blast circa 1808 due to a combination of factors and fell into ruin. Historical sources on the Eaton are scarce and informational sources are vague, but archaeological excavations carried out in 1975, 1976, and 1977 have led to some interesting findings concerning early blast furnace operations. Subsequent chemical and metallurgical analyses of furnace artifacts and specimens provided insights into the level of efficiency of the operation and the quality of the raw materials, products, and byproducts. Foremost among these findings is the fact that the Eaton's use of bituminous coal in combination with charcoal was the earliest use substantiated in the New World.

OHIO J. SCI. 80(2): 52, 1980

The Eaton-Hopewell Furnace (33MH9) is located in Yellow Creek Gorge just 200 m downstream from manmade Lake Hamilton in Mahoning County, between the cities of Struthers and Poland, two suburbs of Youngstown, Ohio. It lies midway up a steep slope with an incline in excess of 45 degrees. The slope soil is classified as Dekalb very stony loam, 25% to 50% slopes (DkF), characteristic of very steep valleys in Mahoning County (Lessig *et al* 1971, p. 78).

The furnace, built in 1802-1803, was the earliest blast furnace west of the Alleghenies and the earliest industry of any kind in the Western Reserve. It operated with only one major interruption until about 1808, when, due to a combination of factors including an inefficient blast process, a shortage of readily available hardwood for charcoal, and an accidental blow-out, it went out of blast. Very little is known about the operation years. What few accounts I have found written in local histories (Butler 1921, p. 658) are somewhat repetitive (even in their errors), suggesting that they were gleaned from the same primary and insubstantial source.

Prior to excavation, very little of the furnace was observable and, like the re-

mainder of the site, was either destroyed or buried under 175 years of erosional overburden. Only the tuyère arch and a small 1.75 m rim segment of the inner chimney of refractory sandstone were visible. Evidence, including old photographs, indicated that little more of the furnace than this was exposed for at least the last 75 years. The cover vegetation was so dense with elm, sycamore, wild grape, sumac, and poison ivy that it took 4 full days just to clear the area for gridding.

Excavations covering 3 seasons were carried out by a crew consisting of 15 Struther's High School seniors, 5 university archaeology students and recent graduates, and a more or less steady supply of university volunteers. The site was divided into 7 major excavation zones, 4 of which were of prime importance. This division served 2 purposes: it allowed for simultaneous sampling and investigation in different areas of the site, and it facilitated deployment of the field crew over the relatively restricted and precarious land area.

#### FURNACE ZONE

The Furnace zone consisted of the furnace structure itself and the fill within its perimeters. Overburden often reached a depth of more than 2 m. Because of

<sup>1</sup>Manuscript received 30 January 1979 (#79-8).

the striking visual remains and great local interest, continuous efforts were made to clear this zone. The end of the first season saw almost the entire furnace

structure uncovered to its full remaining size. Excavation revealed the remains of the entire bosh area and firepot or hearth, measuring 180 cm in height from

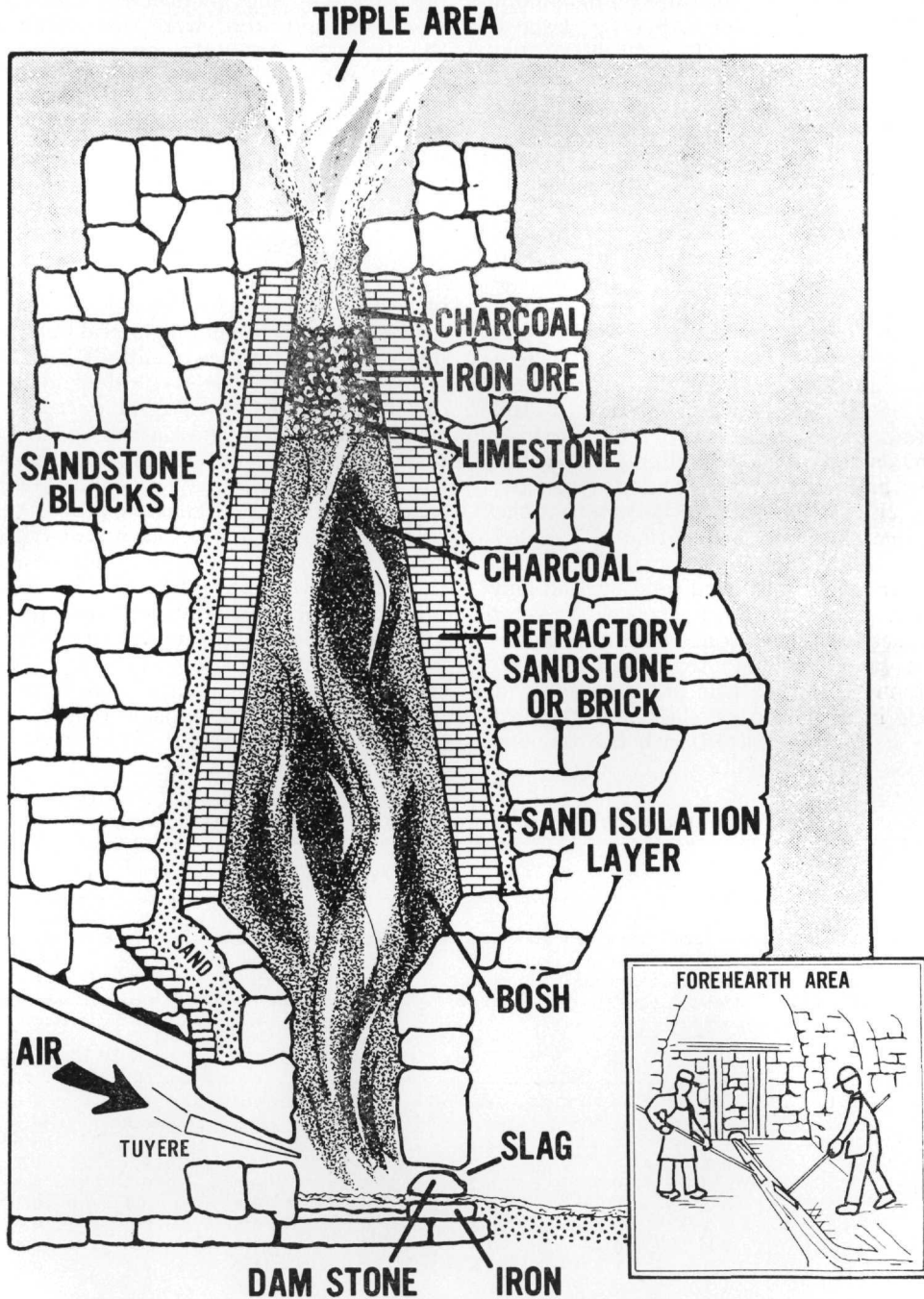


FIGURE 1. Schematic drawing of a typical early 19th century blast furnace.

base to bosh and varying in width between 1.7 m and 1.9 m. The bosh, which is the widest point of the furnace and the structural feature that allows for the support of the charge, measured a maximum of 2.7 m in diameter. (See fig. 1 for a schematic of a typical early blast furnace.) Based on these specifications, an estimated production rate of 2 to 3 tons of cast iron per day seems reasonable.

The inner chimney lining was made from shaped blocks of refractory sandstone that were cemented with a hard mortar colored to a brick-red. Examination of this mortar showed a constituency quite similar to that of the samples of sand and soil analyzed from the site (table 1). In a laboratory experiment, red sand from the hearth opening (Sample 2) was mixed with water and baked. This process resulted in the creation of a friable concretion not as hard as but not very different from the color and texture of our mortar sample. This finding leads us to believe that the furnace builders expeditiously welded their sandstone blocks together with mortar made from local sand or mud and water. The intense heat and pressure produced by the furnace operation hardened and colored the mortar. The chimney interface was patinated with a thick incrustation of slag, and the tap hole itself was clotted with the remains

of the furnace's last cast, a part of which upon cessation of the blast had been allowed to cool within the firepot. Remains of the cast, which consisted of a pudding-like conglomeration of charcoal, slag, ore, and iron, were discovered in the form of a long runner extending from the tap hole some 4 m out onto the casting floor. The runner was covered with 100 cm of erosional soil. This finding suggests that the incompletely cooked cast erupted onto the casting floor as a result of a furnace lining failure.

#### FURNACE WALL

The outer furnace wall was composed of large hand-chiseled blocks of native sandstone, some weighing several hundred pounds. The furnace was built into the gorge slope with the natural sandstone cliff constituting an integral part of its construction. The insulating space between the heavy outer wall and the refractory inner chimney was filled with sand that was subsequently oxidized to a bright red-orange by the intense heat generated by the furnace. This sand, though dramatically different in color, proved to be quantitatively and qualitatively identical to samples taken from other areas of the site (table 1). These sands were local in origin and resulted from weathering and erosion of the contiguous sandstone cliff. When the fur-

TABLE 1  
*Dry sample analysis of Eaton-Hopewell sands and mortar (percent by weight).*

CONSTITUENTS	<i>Samples and Sites</i>						
	1. yellow sand outer brick chimney on south arc of furnace	2. red sand hearth opening	3. grey/black sand hearth opening below red sand level	4. red sand outer brick chimney on south arc of furnace	5. grey sand overburden from area of hearth opening	6. grey sand casting floor area Zone A unit N <sub>2</sub> /W <sub>5</sub>	mortar between refractory sandstone blocks of inner chimney
Fe <sub>2</sub> O <sub>3</sub>	0.5	1.7	1.1	.08	.08	1.0	1.8
SiO <sub>2</sub>	84.0	81.0	84.0	81.2	81.2	83.0	86.0
Al <sub>2</sub> O <sub>3</sub>	7.0	6.8	5.9	7.2	7.6	6.2	8.0
CaO	0.3	0.3	0.2	0.3	0.2	0.2	0.3
MgO	0.3	0.3	0.2	0.3	0.2	0.3	0.6
MnO	0.1	0.1	0.1	0.1	0.1	0.1	0.1
TiO <sub>2</sub>	0.5	0.5	0.3	0.7	0.6	0.4	0.5
Na <sub>2</sub> O	1.2	0.4	0.6	1.2	1.0	0.8	0.6
Loss on Ignition	1.0	1.8	3.2	2.0	1.7	3.4	0.5
Moisture	0.3	0.7	1.2	1.2	9.6	7.8	--

nace subsequently collapsed, the oxidized sand spilled out over the immediate casting floor area and served as a clear red demarcation between the lower cultural levels on which it sits and the post-1808 sandy loam overburden on top of it.

CASTING FLOOR (ZONE A)

Zone A was the designation given to the relatively flat and featureless area immediately adjacent to and south of the furnace. It was determined to be

the casting floor, the place where the raw molten iron or *loupe* was set into various molds. This zone represented the area of maximum furnace activity. The entire zone measured approximately 14 x 18 m in area and was cleared to a depth of between 10 and 100 cm revealing a flat sandy floor. The top several centimeters contained a heavy concentration of rock spalls and fragments. Within this spall level were found several artifacts shaped like large, thick dog biscuits

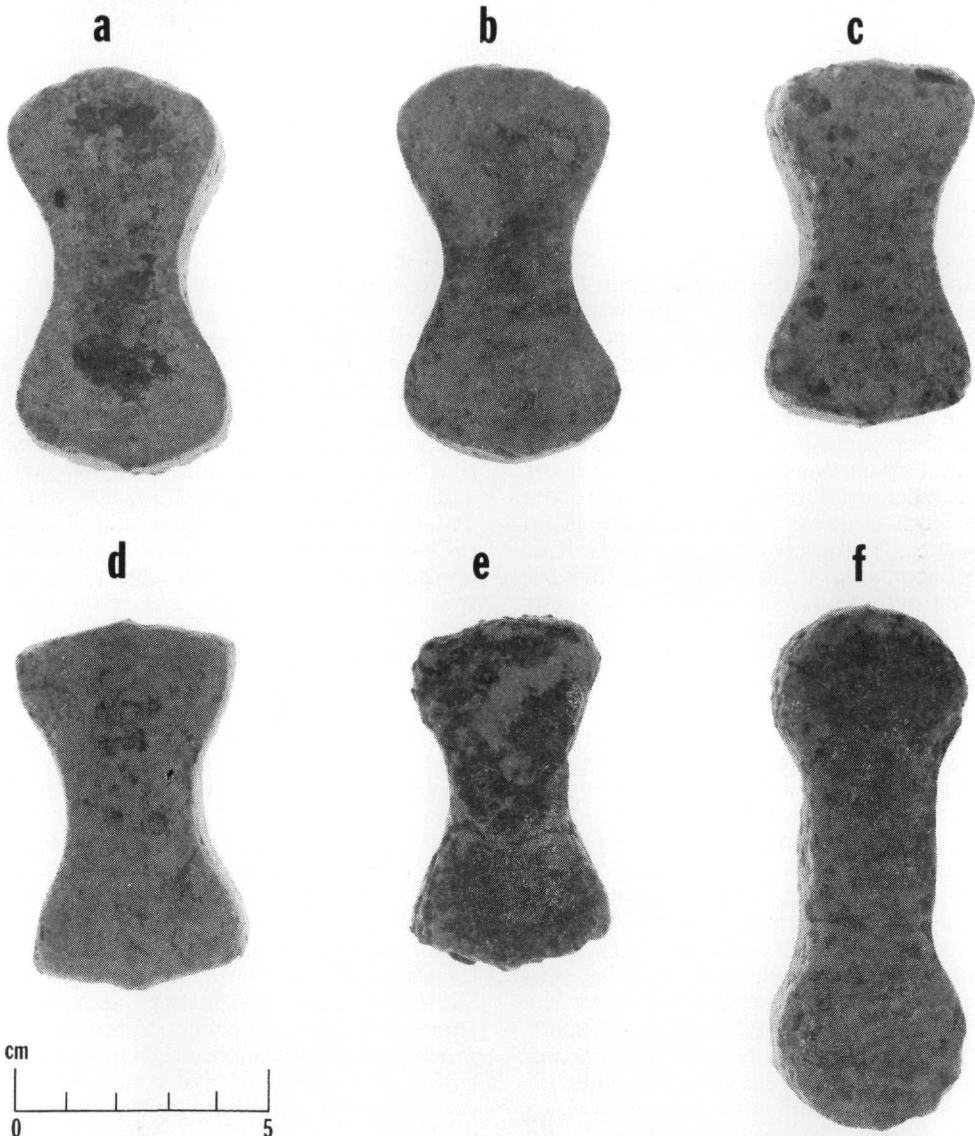


FIGURE 2. Hydraulic mortar bricquets recovered from the site indicate post-1907 activity.

(fig. 2). These artifacts were determined to be bricquets used for testing the tensility of hydraulic mortars (American Society for Testing and Materials 1963, p. 505). These devices were used by engineers during the construction of Hamilton Dam and hence were ideal dating indicators for the spill level as modern or post-1907. The spalls themselves could well represent the result of energies put to the finish-shaping of the enormous sandstone blocks used in the dam. While no evidence was found of a casting floor shed in this area, such a structure would have been a necessity because even the smallest amount of precipitation coming into contact with the molten iron would cause a violent reaction.

Most of the artifacts that were found came from *Zone A*. These included stove parts, fireback fragments, fragments of assorted heavy iron tools, spikes, heavy pins, staples, utensil pieces such as Dutch ovens, trivets, and pans; and byproducts of the manufacturing process including sprues and scrap iron. Some artifacts were so encrusted with rust that identification was impossible. Several artifacts were made from wrought iron and must have been brought to the site from elsewhere because there is no evidence, historical or archaeological, of the Eaton's having a forge or facility for their production. One of these wrought iron artifacts was a large staple that may have been part of the casting shed. The more ubiquitous items included chunks of slag and kidney ore. Two basic methods were used to clean these artifacts: (1) more delicate pieces were cleaned by electrolysis; (2) the hardier, bulkier artifacts were muffled and sandblasted. This is a new, efficient and far speedier process (White 1976).

Less than 30 cm below the sand level, we found an extremely rocky talus level composed of huge slabs and blocks of sandstone that had, through the centuries, detached themselves from the cliff side. Apparently, the furnace builders created the necessary flat casting floor by filling and covering the talus interstices with sand until a level working surface was achieved. Immediately southeast of the flat casting floor was a

massive slag heap that sloped steeply from the perimeter of the casting floor to the creek level 11 m below. A cut made into this slag heap at its top revealed evidence that the furnace had undergone some major repair and relining during its use. Relining was done in a piecemeal or patchwork manner rather than by a complete overhauling. Fragments of discarded refractory sandstone were found sandwiched between layers of slag and cinder. The slag heap probably served as the general disposal area for all discarded material.

#### OTHER ZONES

*Zone B* was the designation given to a small terrace roughly 6 x 6 m in area located about 8 m downslope east from the furnace mouth. It was here that the original mechanism for supplying the blast was located. Excavations revealed a stone wall or footing and an almost square, flat sandstone slab floor measuring 160 x 158 cm along its sides. This structure was all that remained of the blowing shed or wheelhouse. The overshoot wheel turned in the area between the walls and raised and lowered the bellows that rested atop the square slab floor.

The least investigated of the major excavation areas was *Zone C*. This is the designation given to the tippie area approximately 10 m up the cliff face from the bosh. Work was undertaken here to determine what we could about the charging process. We found more fragments of kidney ore, charcoal, and coal in this area than we had anywhere else on the site. This is as it should be, since it was from this spot that the charges of fuel, iron ore, and flux (limestone) were supplied to the furnace. The abundance of high quality bituminous coal in this zone led us to believe that the Eaton (Hopewell) used a combination of charcoal and raw coal as fuel. Chemical analysis of the cast irons by scientists at Youngstown Sheet and Tube company and other laboratories supported this conclusion because the finished iron contained larger amounts of sulfur than expected with simple charcoal reduction, i.e., between 0.060% and 0.22% by weight (White 1978). This fact tends to reduce the effectiveness of

those arguments by historians and archaeologists who proclaim that archaeology cannot add anything of a hard factual nature to our knowledge of our historical past. No extant record of the Eaton (Hopewell) mentions this use of charcoal in combination with raw coal; in fact, coal used in this manner was the earliest reported for the New World (White 1978).

#### ANALYSES

The Eaton (Hopewell) coal was analyzed and found to be of a relatively efficient, high grade, and bituminous type, averaging out as 4.06% ash, 38.04% volatile material, and 52% sulfur. By comparison, the Eaton (Hopewell) charcoal ranged between 1.94% and 7.30% in ash content, between 40.02% and 44.58% in volatile material, and between 0.01% to 0.02% in sulfur content.

Eaton (Hopewell) iron ore is a variety known as *kidney* or *reniform ore*, getting its name from its physical characteristics, i.e., it is generally kidney-shaped and reddish brown in color. Extremely dense, it occurs in both pockets or layers and as float material in Yellow Creek. While higher quality iron ore exists (today the mills use taconite pellets with 60–65% iron), the Eaton (Hopewell), with its ferrous oxide ( $\text{Fe}_2\text{O}_3$ ) between 47.9% and 58.6%, is considered good especially for its time.

The most ubiquitous byproduct of the ironmaking process is *slag*, which is the lithic material created when the limestone flux mixes with impurities or non-ferrous materials in the iron ore. This slag, less dense than the molten iron, floats on the iron and is skimmed off and discarded. Old ironmasters had a maxim: "Take care of the slag and the steel will take care of itself," which exemplified the importance of this phase in the operation. Low viscosity and high sulfur-removing capacity are the prime characteristics of blast furnace slags (Muan and Osborn 1964, p. 148). The Eaton (Hopewell) were relatively consistent in this desulfurizing ability, having between 0.30% and 0.50% sulfur. As is characteristic of blast furnace slags, the thermodynamically stable oxides of magnesium

(MgO), aluminum ( $\text{Al}_2\text{O}_3$ ), silica ( $\text{SiO}_2$ ), and calcium (CaO) were present. Slag colors included blue, green, glassy black, and turquoise. The content figures were roughly comparable for each of the different colors. Analysis of Eaton (Hopewell) slags indicated that the furnace was run at a temperature between 2150 °F and 2250 °F (1177–1232 °C) (White 1977). As a point of comparison, modern furnaces work at approximately 2800 °F (1538 °C). Earlier blast furnaces did not get respectively cooler as there is a minimum effective temperature for ironmaking of 2200 °F (1204 °C).

We have learned a considerable amount about early iron production in an area that prides itself as one of the world's largest steel producing centers, but this is only a preliminary report and many questions still remain. Classification and analysis of the artifacts and specimens from the site is almost completed, as is the final site report containing more complete descriptions of site settings, geology and archaeology. Undoubtedly, publication of our final monograph will serve to raise even more questions, but archaeology can answer some hard questions about those periods and aspects of our historical past traditionally neglected by the record keeper and the historian.

*Acknowledgments.* I am indebted to Youngstown Sheet and Tube company for its contributions of time, equipment and expertise. The highest thanks must be reserved for Frank Galletta, research engineer, without whom much of the analyses could not have been done. Financial support for the project came from the Gund Foundation, the Youngstown State University Graduate Research Council, and the Struthers Board of Education.

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