BIRMINGHAM INDUSTRIAL DISTRICT
Birmingham vic.
Jefferson County
Alabama

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Birmingham Industrial District
Birmingham vicinity
Jefferson County
Alabama

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BIRMINGHAM INDUSTRIAL DISTRICT

THE EARLY METALLURGICAL COAL MINING ERA IN THE
BIRMINGHAM INDUSTRIAL DISTRICT: 1876-1928
&
AN ALTERNATIVE MODEL OF PIG IRON PRODUCER:
THE MERCHANT FOUNDRY IRON BLAST FURNACE OF THE BIRMINGHAM
INDUSTRIAL DISTRICT: 1876-1830

HAER AL-105

Location: Birmingham, Jefferson County, Alabama
Birmingham Industrial District

Significance: The District's prominence as a major producer of foundry iron, cast-iron pipes and steel was due to the presence of all the raw materials needed to make pig-iron within remarkably close proximity.

An unprecedented surge of demand for pig-iron in American in the 1870s and 1880s lured iron makers and entrepreneurs who hoped to exploit this fortunate combination of iron ore, coal and fluxing stone. During the next two decades they built more blast furnaces here than in any other region in the United States except Pittsburgh. To feed their new furnaces, they opened record numbers of coal mines, ore mines and fluxing stone quarries. Major railroad trunk lines and mineral short lines sprang up to tie together the growing industrial complex. Cheap pig iron attracted the nation's largest concentration of cast-iron pipe mills and two major steel mills. It soon became clear that the raw material reserves of the district could not support all the furnaces built during the building boom. Only companies controlling optimally located furnaces and mines could survive.

Republic Steel Corporation's Thomas Works was one of four major iron and steel companies in the Birmingham Industrial District. Led by Woodward Iron, the first company to achieve full vertical integration, four companies pushed the remaining competitors out of business. The Thomas Works was one of the survivors.

Historian: Jack R. Bergstresser, Sr., PhD, 1997. Prepared at the Anthropology Lab, University of Alabama Birmingham
Edited and reformatted to HAER standards by Anne Mason, Collections Manager, 2013.

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THE EARLY METALLURGICAL COAL MINING ERA IN THE BIRMINGHAM INDUSTRIAL DISTRICT: 1876-1928

INTRODUCTION

More than any other factor, coal mining in the Birmingham Industrial District is tied to the rise and decline of the coke fired blast furnace. Following four to five decades of slowly accelerating growth beginning in the late 1830s, the mining industry took off rapidly after 1876 raising Alabama to the ranks of major coal producing states. This rise was triggered by the success of a series of experiments at the Eureka furnaces at Oxmoor during the mid-1870s which confirmed that pig iron could be made in the Birmingham Industrial District. The Oxmoor trials demonstrated the crucial fact that Alabama coal could make coke good enough to fuel the efficient smelting of Red Mountain hematite and local brown iron ore. The blast furnace building boom that ensued following this important discovery was matched by a similar rush to open mines to supply coking coal to fuel the new stacks.

By 1901 over 32 metallurgical coal mines were in production in Jefferson County supplying the 26 coke blast furnaces that had been constructed since 1876. Known as captive mines because their output was to be used by their parent company rather than sold on the open market, they were owned and operated by Sloss Sheffield Steel and Iron, Woodward Iron, The Pioneer works, the Tennessee Coal and Iron Company (TCI), and other iron and steel producers. Driven by this boom, the mineral region of central Alabama matured into a diversified industrial and commercial center which in turn spurred the rise of domestic and steam coal production. The metallurgical mines continued to dominate production however, even though the combined production from all types of mines ranked Alabama annually throughout the twentieth century as the nation's 5th to 6th largest coal producing state. In 1901 for instance, Jefferson County's 32 metallurgical mines alone produced 4,310,084 of 47 percent of the 9,099,052 tons of coal mined in the state.[1]

This ranking was not easily achieved. The coal seams of Alabama were difficult to mine.[2] The Pratt Seam, which yielded the greatest output of metallurgical coal, was thinner than those in other coal mining regions, layered with impurities and broken by geological faults. Other that were thicker, like the Mary Lee Seam which produced the second greatest tonnage, were dissected by even greater layers of shale and other impurities, called partings or "middleman," which posed their own particular challenges to miners.

Despite their willingness and ability to bring the latest mining technology to bear to overcome these inherent geological limitations, Alabama's engineers and operators were forced to create mines that were smaller and less productive than those in other regions. As a result, commercial producers were able only to compete effectively in a few limited markets outside of the state,

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[1] Unless otherwise indicated, mine production statistics come either directly from the *Annual Reports* of the Alabama State Mine Inspector or from a database on the metallurgical coal mines developed from these reports; William Battle Phillips, ed. *Iron and Steel in Alabama*, 3rd, Geological Survey of Alabama, (Montgomery, Alabama: Brown Printing Co., 1912), 152.

[2] Herman Hollis Chapman, *Iron and Steel Industries of the South*, (Tuscaloosa, Alabama: University of Alabama Press, 1953), 176.

including Georgia, Mississippi, New Orleans, and the export trade from the port of Mobile.[3] Such a handicap insured the continued dominance of metallurgical over commercial coal mining up until the decline of the blast furnace industry.

Most studies have assumed that the character of industry in the post-Civil War "New South" was shaped by the region's distinctive economic and social legacy. It has been argued that industry was slower to develop because the South's agrarian background left it bereft of the inclination or aptitude for things mechanical. It has further been asserted that poverty, caused by the destruction of the Civil War, added to the problem by leaving little capital for plant construction or mechanization. Finally, it has been argued that modernization was slow in coming because the transplantation of a new industrial order could not be allowed to proceed unless it was structured to accommodate the existing racial and social hierarchy.

For all these reasons one would suspect that when mines, furnaces and factories arose they would be flimsily constructed, technologically backward, and labor intensive, but a closer look at the metallurgical coal mines of the Birmingham Industrial District suggests that this assessment is only partially true. To be sure the pernicious institution of convict leasing undoubtedly originated, in part, from a desire to carry over the functional equivalent of slavery to the new industrial workplace. Instances also abound of mine operators employing the cheapest alternatives in physical plant and mining practice, and unmechanized mining operations are not uncommon. More common among the mines owned by the large iron and steel producing companies however, are up to date operations, skillfully managed and employing the latest equipment and practices. Still, and particularly early in the District's development, there are cases where limited capital clearly played a role in how a mine was designed. There are other cases of plants that were modern, in every way except that they employed state and county convicts to perform labor intensive tasks. But, if "Southerness" alone is evoked to explain these phenomena, too many anomalies arise because underlying these seeming examples of backwardness lies a much more pervasive, mainstream American motivation: capitalistic rationalism.

The dominant theme of metallurgical coal mining in the Birmingham Industrial District is similar to that in every other mining district in the United States: a very systematic effort to adapt standard American design and practice to local mining and labor conditions. It was the physical limitations and idiosyncrasies of the Pratt, Mary Lee, and other local coal seams of the Warrior field, plus the distinct advantage provided by the state of Alabama in the form of a small but significant pool of coerced laborers—rather than poverty and a philosophical need to craft a unique southern industrial model—that gave the captive metallurgical coal mines of the District their unique character. The imperative to extract maximum profit from an exceptionally difficult and flawed raw material endowment dictated mining and operating strategies, plant design, when and what mechanical options were adopted, and the organization of work in individual mines.

What the following essay is principally concerned with presenting a general historical summary of the metallurgical coal mining industry during the period between 1876 and 1930, it will also present a few selected vignettes that "zoom in" on particular mining operations or groups of mines. These brief examples will attempt to illustrate the way in which early capital limitations

[3] Milton Fies, "Coal Seams of Alabama—Their Output, Analyses, Ash-Fusing Point and Geologic Structure," *Coal Age* 26 (October 2, 1924), 477.

and the convict leasing system, but above all, the physical limitations of the Warrior Field coal seams led to adaptations that made the Birmingham Industrial District unique within the mining industry.

THE GEOLOGY AND GEOGRAPHY OF THE COAL FIELDS

All the coal of Alabama is bituminous. It is found in the Pottsville series of the Pennsylvanian coal seams formed during the early portions of the Carboniferous geological era. This is the same geological section of the Appalachian coal field that contains the Lykens coals of the Anthracite region, the Mercer, or Alton and the Sharon or Marshburgh coals of Pennsylvania, and the Kanawha, New River and Pocahontas coals of West Virginia.[4] While it was once an uninterrupted and relatively flat layer of several hundred feet in thickness, the Pottsville in Alabama was broken up during the Appalachian mountain building period and separated into several sections by faults. The faulting caused a series of anticlinal ridges, extending along a northeast/southwest axis, that now separate the coal measures in the Coosa, Cahaba, Warrior and Plateau fields.[5] With the exception of the Plateau field, which is usually considered to be an extension of the Warrior, all are named for the rivers by which they are drained.[6] The workable seams of coal extend all the way from the northeast corner of the state to Tuscaloosa where the Pottsville disappears beneath more recent Cretaceous and Tertiary deposits.

Due less to the quality of its coal than to the inaccessibility of its seams, the Plateau field is least important of the four fields. While classified as plateau because of its relatively level geological strata, the region is deeply dissected by a series of anticlinal valleys that have cut down well below the carboniferous levels. In most cases, the surviving coal seams outcrop near the top of Lookout, Sand, Raccoon and other mountains within the region. These seams are narrow, often no more than 24 inches thick, and irregular. Because of their elevation above anticlinal valleys, the mines that work these seams are usually connected to their rail links below via long inclined planes.[7]

Early accounts of the quality of the coal claimed that it was useful for a variety of purposes mainly for steam and forge use. Ultimately however, the limited tonnage recovered from the Plateau field came to be used primarily for mixing with other coals in byproduct coke ovens. Its low volatile content, often below 20 percent, is similar to the coal of the Pocahontas field of Virginia and West Virginia and mixes well with the higher volatile coals more typically found in Alabama.[8]

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[4] R. Dawson Hall, "The Coal That Underwrote Birmingham's Industrial Activity." *Coal Age* 26 (October 2, 1924), 477.
[5] Erskine Ramsay, "The Pratt Mines of the Tennessee Coal, Iron and Railroad Company, Alabama," *Transactions of the American Institute of Mining Engineers (*hereafter referred to as *TAIME), vol. 19, 1890-1891: 296-297.*
[6] Chapman, *Iron and Steel Industries of the South,* 56; Henry McCalley, *The Warrior Coal Field,* Geological Survey of Alabama, Special Report Number 1 (Montgomery: Barrett and Co., 1886), 4-5.
[7] Henry McCalley, *Report on the Coal Measures of the Plateau Region of Alabama,* Geological Survey of Alabama, Special Report Number 3 (Montgomery: Roemer Printing Co., 1891), 2; A.W. Evans, "Lahausage Mine, Alabama," *Mines and Minerals* 30 (September 1909), 77 and "Lookout Mountain Coal Measures," *Mines and Minerals*, 32 (June 1912), 654-656.
[8] Chapman, *Iron and Steel Industries of the South,* 57; A.W. Evans, "Coal Washing at Lahauage," *Mines and Minerals,* 32 (February 1912), 391.

Of essentially the same rank, in terms of commercial importance, but much smaller geographically, is the Coosa coal field. This small field is approximately fifty-four to sixty miles long and comprises a total of 345 square miles.[9] It is a long narrow syncline, the Coosa trough that is divided into eight small basins. With the exception of a small section that extends into the southeastern edge end of Calhoun Count, it is located exclusively within the boundaries of St. Clair and Shelby Counties. Over the years, the most wide spread use of Coosa coal has been domestic. Some of its output however, has been devoted to railway steam production and coke making.

The Cahaba field is not much larger geographically than the Coosa but has been immensely more important commercially. It is around sixty-eight miles long, averages nearly six miles wide, and contains a total of approximately 395 square miles.[10] Located in St. Clair, Jefferson, Shelby and Bibb Counties, it is separated from the Coosa field to the southeast and the Warrior field to the northwest by two long faults. With the exception of a portion of its southeastern border, near Montevallo, where faulting has left coal measures completely inverted and dipping back to the southeast at a sixty degree angle, the field is divided into a series of eleven small synclinal basins. Overall however, the topography is rugged and in several locales faults have left portions of the coal seams in individual basins very steeply inclined.

During the Civil War and early post bellum period efforts were made to develop sections of the field sources of coke. By the turn of the twentieth century however, the superiority of Cahaba coal for domestic and steam purposes had been established while the Warrior field emerged as the state's sole source of coking coal as well as its overall production leader.

The Warrior coal field is the largest of Alabama's coal field and, relatively speaking, it's most accessible. Unlike the Coosa and Cahaba fields, it is comprised of only one large basin encompassing a total of 3,500 square miles that fall primarily within the boundaries of Jefferson, Walker, Tuscaloosa, Winston, Marion, and Blount Counties.[11] This basin is divided into two synclines by an anticlinal lift that passes through its middle along a northeast/southwest axis. The coal seams dip only very slightly to the southwest but they are extensively broken by numerous faults creating great difficulty in mining. The coal seam in one mine mentioned in a 1928 article had a displacement of 177 feet.[12]

McCalley indicates that the "coals are in from 2 to 5 regular seams in each of six groups, making in all twenty three regular coal seams."[13] These consist in ascending order of the Black Creek, Horse Creek, Pratt, Cobb, Gwin and Brookwood groups. Since the Black Creek is the lowest of the groups, the outcrop of the Black Creek Seam around the outside edge of the basin is generally considered to be the boundary of the Warrior field. The next group of major importance is the Horse Creek which eventually came to be known as the Mary Lee Group in

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[9] A.M. Gibson, *Report Upon the Coosa Coal Field,* Geological Survey of Alabama, Special Report Number 7 (Montgomery: Roemer Printing Co., 1895), 2; Howard E. Rothrock, *Geology and Coal Resources of the Northeast Part of the Coosa Coal Field, St. Clair County, Alabama,* Geological Survey of Alabama, Bulletin 61, Part 1 (Montgomery: Walker Printing Company, 1949), 3-5.
[10] Joseph Squire, *Report on the Cahaba Coal Field,* Geological Survey of Alabama, Special Report Number 5 (Montgomery: The Brown Printing Co., 1890), 12-13.
[11] Chapman, *Iron and Steel Industries of the South,* 54.
[12] R. Dawson Hall, "The Coal That Underwrote Birmingham's Industrial Activity," 589.
[13] McCalley, *The Warrior Coal Field,* 3.

honor of its most important seam. The Blue Creek and New Castle are the two other important seams in this group of five seams. Lying from 175 to 375 feet above the Mary Lee is the Pratt group made up of the Gillespy, Curry, American, Cardiff, and Pratt Seams. In the western part of the field the Pratt and Cardiff come together to form the Corona Seam which was the main seam worked by a group of mines in Tuscaloosa County. The Pratt, Mary Lee, and Black Creek groups were the principal source of metallurgical coal in the Birmingham Industrial District.

HISTORICAL OVERVIEW

Antebellum Period 1830s-1861

In the decades following statehood, some coal was mined in the Coosa, Cahaba, and Warrior fields. Most was sent by wagon, or barged down river during spring freshets, to such places as Mobile, Selma, and Columbus, Georgia. Other small, primitive mines, often opened by farmers in slack seasons, had supplied coal to local blacksmiths.[14] The total tonnage was so insignificant that it escaped mention in the national manufacturing census taken in 1849.

By the mid-1850s, however, geologists and other explorers had begun to recognize and publicize the potential of the mineral region of north central Alabama. Influential entrepreneurs and citizen's groups pushed the state legislature to commission the building of railroads into the virgin region for a variety of reasons, but particularly in order to facilitate the development of commercial coal mining. The first such venture was the Alabama and Tennessee Rivers Railroad which opened tracks from Selma to a railhead at Wilton near Montevallo, at the edge of the Cahaba Coal field.[15] Encouraged by the first State Geologist, Michael Tuomey, the Alabama Coal Mining Company began to enlarge its mining operation on Pea Ridge near the small community of Dutchtown.[16] The company expanded its preexisting Dutch Pit and Whim Pit and opened the first steam-powered coal mine in the state. Subsequently William Phineas Browne opened a better documented but less extensive mining enterprise near the present-day community of Aldrich.[17]

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[14] "Bituminous Coal," *The American Journal of Science and Arts,* 24 (July 1834), 190-191; Charles Lyell, "Coal Fields of Tuscaloosa, Alabama." *The American Journal of Science and Arts* 51 (May 1846), 371-377; Michael Tuomey, *First Biennial Report of the Geology of Alabama,* (Tuskaloosa [sic], Ala.: M.D.J. Slade, 1850), 78, 83, 88-89, 96; Ethel Armes, *The Story of Coal and Iron in Alabama,* (Facsimile ed. Leeds, Ala.: Beechwood Books, 1987), 48-49.

[15] A good account of the political battles over state support for the opening of the Alabama and Tennessee Rivers Railroad and competing railroad proposals can be found in J. Mills Thornton, *Politics and Power in a Slave Society* (Baton Rouge: Louisiana State University Press, 1977), 350-366 passim.

[16] Michael Tuomey, "To Col. Watrous, President of the Alabama Coal Mining Co.," In *Report of Progress for 1875,* by Eugene A. Smith, Geological Survey of Alabama, (Montgomery, Ala.: W.W. Screws, 1976), 205-212 passim. No written reference to the existence of Dutchtown is known to exist but longtime residents in the vicinity fondly recall the location of the community, which is substantiated by the existence of an extensive assemblage of early-to mid-nineteenth century ceramic fragments and other cultural debris. Moore refers to the general vicinity as the location where the first immigrant coal miners worked in the state. See B.C. Moore, "Longwall at Montevallo has Seen Many Changes," *Coal Age* 33 (October 1928), 617.

[17] Squire, *Report on the Cahaba Coal Field,* 96-102; Truman H. Aldrich, "Historical Account of Coal Mining Operations in Alabama Since 1853," in Report for Progress for 1875, by Eugene A. Smith, Geological Survey of Alabama, (Montgomery, Ala.: W.W. Screws, 1876), 29-30. For an account of the activities of Browns see Virginia Knapp, "William Phineas Brown, Businessman and Pioneer Mine Operator of Alabama, *Alabama Review* 3 (April, July, 1950), 108-122, 193-196 passim.

Civil War Coal Mining 1861-1865

When the Civil War broke out, the Confederate government found itself in desperate need of war materials and launched a concerted effort to spur mining and iron production in the mineral region. It pressed the South and North Alabama Rail Road to extend its track, first from Calera to Helena and later to Brock's Gap. This feat accomplished under tremendous hardship, opened up yet another portion of the Cahaba field. To further encourage coal production, the government offered draft exemptions to slave owners who would provide at least twenty slaves to be used as coal miners.[18] While developed before the Civil War, perhaps the Coosa field's most important era was during the conflict. Operating on orders from the Confederate Nitre and Mining Bureau Major Campbell, "an excellent Scotch miner" supervised mines at Broken Arrow and Trout Creeks which supplied coal to the wartime foundries and shops in Selma[19]

An interesting debate arose during the war between the slave owners, who saw slave labor as "the fundamental proposition of the Confederacy," and white miners who had recently arrived in the state and were unaccustomed to working with coerced laborers. According the John T. Milner, engineer for Red Mountain Iron and Coal Company, owners of the Eureka Furnaces and several other coal mines, the "scientific foreigner or Pennsylvania Yankee" did not understand the "character of the negro" or know how to manage slave miners. Milner claimed that the white miners tended to run slaves away from the mines when

> … a little firmness, a little teaching, a little encouragement and a little good management would have in three months have made his as expert and more reliable than any white miner.[20]

The issue, however, was short-lived, because Union cavalry under General James H. Wilson destroyed most of the state's mines during the closing days of the war.[21]

Immediate Post War Era 1866-1876

In the decade following the war, the Cahaba coal field was the first to resume production, probably due to the fact that it had been so extensively developed during the war. The Cahaba Coal Company established an early monopoly of the coal trade by simultaneously acquiring most of the existing mines near Montevallo and Helena. The company's acquisitions included such properties as the Irish Pitt on Pea Ridge, William P. Browne's mines at Aldrich and the Woodson and Gould operation at the fork of Buck Creek and the Cahaba River near Helena. Tonnage figures for these early post war operations are difficult to establish but Truman Aldrich indicates that the restored and improved Woodson and Gould mine had increased production from its wartime capacity of about seventy-five tons of coal per day to more the 40,000 tons mined

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[18] Aldrich, "Historical Account of Coal Mining," 32-34; Armes, *Coal and Iron in Alabama*, 150; John Milner, Montgomery, Alabama, to Wm. B. Gilmer, Esq. Prest., Red Mountain Iron and Coal Co., 17 March 1864, typescript of letter in possess of Kenneth Panhale, Helena Montana.

[19] Tuomey, *First Biennial Report on the Geology of Alabama,* 75-76; Gibson, *Report Upon the Coosa Coal Field,* 40.

[20] John Milner, Montgomery, Alabama, to Wm. B. Gilmer, Esq. Prest., Red Mountain Iron and Coal Co., 17 March 1864, typescript of letter in possession of Kenneth Penhale, Helena, Montana.

[21] The best account of Wilson's raid is found in James Picket Jones, *Yankee Blitzkrieg: Wilson's Raid through Alabama and Georgia* (Athens, Georgia: University of Georgia Press, 1976). See also Armes, *Coal and Iron in Alabama,* 189-194.

between 1866 and 1870.[22]

Of more importance to the future of metallurgical coal mining in the District however, was the reopening of the Red Mountain Iron and Coal Company mines near Helena. The first of several lessees after the war was F.L. Wadsworth who had opened the Wadsworth or Eureka Mine on the property in 1867. Subsequent operators made a series of improvements to the plant. In 1874 the Alabama Mining and Manufacturing Company leased the mines and sent coal to be analyzed at the Eureka Iron Works where it was found to be suitable for coking. According to Truman Aldrich the company was planning to bring convict miners to enlarge the mine and prepare it to supply coke to the Eureka Furnaces once they were "put into blast." Aldrich went on to say that "the plant here is in many respects, superior to any in the state."[23]

Meanwhile, developments in the Warrior coal field were moving more slowly. By 1875, three or four operations had opened along the Warrior River near the crossing of the Louisville and Nashville Railroad. In 1873 John T. Milner and his associated established the Newcastle Coal and Iron Company.[24] Like the Helena mines, the Newcastle operation would play a role in the Oxmoor experiments by contributing trial supplies of coke. Even before the experiments began the owners of the mine had made coke that Truman Aldrich characterized as being of a "very fair quality."[25] While it had probably been Milner's idea to become a major coke supplier once the pig iron industry became established, the Newcastle coal of the Black Creek Seam proved to be better suited for gas production and steam generation. By 1890 the operation which had earlier employed slave labor, had constructed only six beehive coke ovens.[26]

Developing the Warrior Field 1876-1900

The successful effort in 1876 to make pig iron with coke at Oxmoor set off a rush to locate the best available sources of coking coal.[27] Since it was already well established, the Cahaba field served as the principle source of coal during the trials and for a brief period subsequently. The Watson and Gould Mine and the refurbished plant on the Red Mountain Coal and Iron Company property were called upon because both operations had produced coke during the Civil War and they were the closest of the Cahaba mines to Oxmoor. But the coke proved to be too high in ash and was structurally inadequate for regular furnace use. Except for a beehive oven plant constructed across the river from the Watson and Gould Mine and another, built in the late 1880s at Blockton in Bibb County to supply the Bessemer and the Woodstock Furnaces at Oxford, the

[22] "Alabama Coal Fields," *Birmingham Iron Age,*28 May 1874, 1; Aldrich, "Historical Account of Coal Mining," 35-38.
[23] Ibid, 36.
[24] Saffold Berney. *Handbook of Alabama: A Complete Index of the State,* (Mobile: Mobile Register Print, 1878), 259-260; P.H. Mell "The Coal and Iron Interests of Alabama," *Coal* 1 (December 1882) 390-391; "Warrior, Ala., and Its Coal Interests," *The Colliery Engineer*, 8 (July 1888), 281.
[25] Armes, *Coal and Iron in Alabama*, 258; Aldrich, "Historical Account of Coal Mining," 40.
[26] Berney, *Handbook of Alabama,* 260; "Coke Ovens in the Birmingham District," *Iron Age* 46 (September, 1890), 456.
[27] Armes, *Coal and Iron in Alabama,* 271-282; Edna Kroman, "Unkind Fate Follows Furnace," *Birmingham News-Age-Herald,* 6 January 1929, Sunday Magazine Section 4, 1.

Cahaba field was abandoned as a coke producer.[28]

Hopeful prospectors turned their attention instead to the Warrior field. Their problem was the relatively simple one of discovering the best outcrops within the virgin forested region and opening new mines. The exact chronology of these explorations is difficult to document but John T. Milner appears to have gotten a head start in the race while surveying potential rail routes through the area before the war. His Newcastle operation was probably based upon this knowledge. Two English-born prospectors, Billy Gould and Joseph Squire also played key roles in the early exploration. Gould worked independently while Squire entered into a contract with Truman Aldrich to search within a six mile corridor along the tracks of the Louisville and Nashville and the Alabama and Chattanooga Railroad.[29] These early explorations led to the discovery of the Pratt, Mary Lee and Blue Creek Seams which by 1900 would be fully developed into the District's three principal metallurgical coal seams.

Gould made the big find. Prospecting along the southeastern rim of Warrior field, he discovered that, by remarkable coincidence, the best seam of metallurgical coal in the entire District outcropped right along the fringe of Jones Valley, which was destined to become the center of the blast furnace industry. Iron makers would be able to build their plants in the valley directly atop immense deposits of limestone and dolomite, open coal mines in virtually the back door of their furnaces, and bring in iron ore on a downhill grade from Red Mountain on the opposite side of the valley. With the limited capital he had available, Gould began developing the property. He sunk a small pit where the Pratt Slope Number One would later be opened and began building a pole road from his mine to Birmingham, which lay six miles distant. According to Armes, he named his important discovery the Browne Seam.[30]

The fate of the name chosen by Gould for his newly-discovered seam is indicative of the transition in mindset and geographical perspective that accompanied the success of the Oxmoor experiments and the rapid exploitation of the Warrior field. Gould had intended to honor William Phineas Browne, the iron and coal entrepreneur who had done much to open the Cahaba field to mining during the late-Antebellum and Civil War period. But the days when the Cahaba field and charcoal-fueled blast furnaces were seen as the foundation of Alabama's iron industry were gone and a new set of entrepreneurs were now on the scene. Gould sold out to a group of these new iron and coal developers, including Henry F. DeBardeleben, James Withers Sloss, and Truman H. Aldrich, who envisioned Red Mountain and the Warrior field as the foundation of a new industrial order based upon coke-fired blast furnaces. Antebellum industrialist Daniel Pratt's fortune provided the funds for his son-in-law's, DeBardeleben's, stake in Gould's discovery. In his honor, the Browne Seam was renamed the Pratt Seam and the newly formed mining

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[28] "Alabama, A Letter From the Centre of the Great Coal Fields of Alabama," *Colliery Engineer* 8 (April 1888), 198; Armes, *Coal and Iron in Alabama*, 267; Henry McCalley, *Report on the Valley Regions of Alabama*, Geological Survey of Alabama, Special Report No. 8, Part 1, (Montgomery: Roemer Printing Co., 1897), 381.

[29] For an impression of Milner's expectations for the future of the Birmingham Industrial District and his probable advance knowledge of the Warrior field's potential, see John T. Milner, *Report of the Chief Engineer to the President and Board of Directors of the South and North Alabama Railroad Company, on the 26th of November, 1859* (Montgomery: Advertiser Book and Job Steam Press Print, 1859); Armes, *Coal and Iron in Alabama*, 260, 272.

[30] Armes, *Coal and Iron in Alabama*, 260; Erskine Ramsay, who provides a brief but authoritative account of the old prospector's discovery, states that it would be named the Gould Seam. Ramsey, "The Pratt Mines," 299.

enterprise was named the Pratt Coke and Coal Company.[31]

The new company became the principal supplier of coking coal for the first commercially viable iron making operations established following the Oxmoor trials. DeBardeleben and his associates opened the Pratt Slope Number One in 1879, followed by the Pratt Shaft Number One which was sunk in December 1880 and mined by convicts. Other Pratt mines were opened in rapid succession and the newly-formed community of Pratt City was christened. Swank listed the output of the Pratt Coal and Coke Company in 1880 and 89,500 tons, nearly double the production of the state's second largest producer, the Helena mines. The combined production of these two metallurgical mining operations was 138,850 tons or 43 percent of Alabama's total.[32] Most of this tonnage was made into coke and used in the Alice, Sloss and newly rebuilt Oxmoor furnaces. The individuals involved in these pioneering blast furnace plants were either in some form or partnership with DeBardeleben or had been involved in the Oxmoor trials and they all received coal on very good terms from his company over the next four or five years. The coke was made either at the mines and Pratt City or in ovens at the furnace plants.[33] These rather amicable arrangements continued until around 1886 when the Tennessee Coal and Iron Company absorbed the Pratt Coal and Coke Company, the Alice and Oxmoor furnaces and other properties, and began building the Ensley furnaces.

The new situation forced Sloss to turn elsewhere for coal. Under new ownership and with a new name, the Sloss Iron and Steel Company acquired the mines of the Coalburg Coal and Coke Company, which had originally been opened by John T. Milner in 1879. This allowed the new Sloss management to utilize its own coke after the temporary arrangement with the Pratt mines expired. Coalburg, with its mixed labor force of convict and free miners, also served as a base from which to expand northward along the tracks of the Georgia Pacific Railroad, with which Sloss's new owners were affiliated. By 1893, the company had opened or purchased mines at Brookside, Cardiff, and Blossburg. Many of these early operations were relatively small drift mines that averaged less than 100,000 tons per year.[34]

The Woodward Iron Company formerly of Wheeling, West Virginia had begun developing its own company mines at the same time that it fired its first furnace, Woodward Number One furnace I n1883. Its first two slopes, opened within site of the furnace plant in 1883 and 1887, were initially known as Woodward Number One and Two Mines, but around the turn of the century their names were changed to Dolomite Number One and Two. To further supplement production, the company purchased the shaft mine at Mulga in 1912.[35]

After selling the Pratt Coal and Coke Company, Henry DeBardeleben turned his attention to the Bessemer section of Jones Valley where he and others were responsible for erecting three

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[31] Armes, *Coal and Iron in Alabama*, 260-265.
[32] Alabama, *First Biennial Report of the Inspector of Mines, 1892-1894,* (Birmingham: Dispatch Printing, 1895), 5-7; James M. Swank, *Statistics of the Iron and Steel Production of the United States,* U.S. Department of the Interior, Bureau of the Census (Washington, D.C.: 1881). 886; Mell, "The Coal and Iron Interests of Alabama," 390; Erskine Ramsay, "The Pratt Mines and Coke Plant," *The Colliery Engineer* 8 (January 1888), 136; Neil Hutchings, "Alabama Coal Mining," *Mines and Minerals* 22 (January 1902), 254.
[33] Armes, *Coal and Iron in Alabama*, 273.
[34] "Coalburg, Ala. Coal Mines of the Sloss Iron and Steel Company," *The Colliery Engineer* 8 (February 1888), 153; "A Pennsylvania Miner's Impressions of Alabama," in ibid., 9 (July 1889), 281.
[35] "How Mulga Modernized for Haulage Efficiency," *Coal Age* 57 (September 1952), 78-79; Alabama, *First Biennial Report of the Inspector of Mines, 1892-1894,* 13.

separate furnace plants comprising respectively the Bessemer Number One and Two, the Little Bell and the Bessemer Number Three and Four furnaces. To fuel these new stacks he formed the DeBardeleben Coal and Iron Company, which made the first major effort to develop metallurgical coal mines on the Blue Creek Seam along its outcrop a few miles west of Bessemer. The newly formed company opened the Adger, Johns, and Belle Sumpter Mines in 1889. These three slopes were among the District's largest captive mines. In 1900 they averaged 207,000 tons each, 40,000 tons more per mine that TCI's Pratt mines. When TCI acquired the Bessemer furnace the Blue Creek mines were part of the package.[36]

The Pioneer Mining and Manufacturing Company's Thomas Works, which was purchased by the Republic Iron and Steel Company in 1899, was the last of the major blast furnace companies in the District to establish its own captive coal mines. Although its founder David Thomas, one of the first developers of anthracite blast furnaces in the United States, had begun acquiring mineral lands and other properties in the District right after the Civil War, the company did not open its first mines until the latter half of 1898. The production chart prepared by the State Mine Inspector's for 1899 indicates that these first two mines were Sayreton and Warner. Sayreton yielded 72,000 tons of coal during this first year while the Warner operation had still not come on line. By 1900 however, the Warner Slope had become Jefferson County's largest producer while Sayreton mine set its own precedent, becoming the first large captive mine to tap the New Castle or Mary Lee Seam.[37]

When coal began to flow from Thomas' Sayreton and Warner Slopes the event was significant because it completed the process of acquisition and development that would make all of the four major blast furnace companies in the District nearly completely vertically integrated. Now the organizational structure of each operation included a mining division that would serve as the primary source of its coking coal.

The tonnage produced at the turn of the century by these captive mines alone provides an indication of how rapidly Alabama's coal industry had grown during the 24 years since the success of the Oxmoor experiments in 1876. In 1880 the entire state had produced only 322,934 tons of coal compared to 4,310,076 tons mined by the blast furnace companies in 1901. The Warner mine alone, with its output of 344,357 tons, produced more coal in this latter year than all of Alabama's mines combined in the former.

Expansion of the Warrior Field 1900-1928

Between 1900 and 1928 coal production would continue to increase as the furnace industry systematically phased out its older mines and replaced them with larger, more modern plants. In most urgent need of upgrading was the Sloss coal mining division. The company's early strategy of relying heavily on inexpensive drift mines—probably necessitated by a shortage of operating capital—meant that in 1893 it was dependent on a total of eleven mines for its 865,000 tons of

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[36] Bessemer Land and Improvement Company, *A Circular of Information About Bessemer City, Alabama* (New York: The South Publishing Company, 1889), 8-11; Alabama, *First Biennial Report of the Inspectors of Mines 1900* (Birmingham, Ala.: Dispatch Printing, 1900), 49-53.
[37] Armes, *Coal and Iron in Alabama*, 353, 356; Alabama, *Second Biennial Report of the Inspector of Mines, 1898* (Birmingham: Dispatch Printing, 1898), 15-16; Alabama, *Third Biennial Report of the Inspector of Mines, 1900,* 16-18.

coal. The largest of the group, Coalburg Number Four had produced a respectable 150,000 tons but nine others had yielded less than 100,000 tons each, hardly enough to offer Sloss any of the advantages of economy of scale. Around the turn of the century the company began the transition to fewer large mines beginning with the acquisition of New Found, the District's fourth largest mine in 1900, with an annual output of 230,000 tons.[38] Flat Top was added in November 1902, followed by Bessie around 1906, giving Sloss a complement of three large slopes. New Found began to decline by 1910 and was replaced by Lewisburg in 1925 when Sloss acquired the mines of the Alabama Company.[39]

While Sloss struggled to develop an optimal group of mining operations, its two closest competitors in the merchant foundry iron business; Woodward and the Thomas Works had developed optimal arrangements by the turn of the century. Woodward had an efficient arrangement from the beginning based upon its two large mines located within sight of its furnace plant. The shift to two Dolomite mines moved the slope openings a little further away from the furnaces but did not materially alter the arrangement. To further supplement production, the company purchased the shaft mine at Mulga in 1912. Except for the Little Ben, Short Creek and Sayre Mines that the company operated briefly during and shortly after World War I, these three mines remained the principle source of coking coal for Woodward throughout the period under consideration.[40]

Like Woodward, the Thomas Works attempted to keep the number of mines that it worked to a minimum, focusing instead on large production from two or three mines. Shortly after 1901, however, the company opened the small Thompson mine adjacent to the Sayreton Slope. Later, around 1912, it also opened the three mines at Palos and a series of small drifts at Warner. During World War I the company opened the Risco Mine followed by the Republic Slope developed around 1923.[41]

TCI was able to continue its reliance on the original Pratt mines and those on the Blue Creek Seam until shortly after 1910 when the company turned to the task of developing a new generation of mines. Around 1912 the company opened the Bayview, Docena, and Edgewater Mines a few miles further away from the edge of Jones Valley but still conveniently close to the blast furnaces. By 1915 Edgewater had emerged as the largest producer with 772,226 tons. By this time, TCI had begun to refer to its Pratt mines as the Wylam mines and its second largest producer was a refurbished Pratt Number Eight, now known as Wylam Number Eight which yielded 363,489 tons of coal during the year. Over the next few years the company would gradually phase out its older generation of mines in favor of the new plants which they would expand to include the Hamilton Slope in 1920. This new slope was named in honor of Robert Hamilton, who became TCI's chief authority on coal mining following the departure of Erskine Ramsay around 1900.

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[38] Alabama, *Third Biennial Report of the Inspector of Mines, 1900,* 23.
[39] Samuel H. Lea, "Flat Top Mine," *Mines and Minerals,* 25 (March 1905), 395; "Mergers in Bituminous Coal Fields in 1924 Include Only 30,000,000 Ton OutPut," *Coal Age,* 27 (March 19, 1925), 424.
[40] "How Mulga Modernized for Haulage Efficiency," 78-79.
[41] The approximate chronology of these mines is derived from a database on Alabama coal mines compiled from *Annual Reports* of the State Mine Inspector.

COKE MAKING AND COAL WASHING

Coking

In Alabama beehive ovens, along with a few other notable types of non-by-product ovens, were the principal means for making coke from the time of their introduction around 1876 until around 1913. In the later year, by-product tonnage first exceeded beehive coke production climaxing a trend that had been underway since 1898 when TCI had introduced the District's first by-product coke plant, consisting of four batteries of thirty Semet-Solvay ovens. The transition from beehive to by-product coking had progressed more rapidly in the Birmingham Industrial District than in any other metallurgical coal mining region. Beehive coke making had peaked between 1906 and 1907 when Alabama produced 2,796,399 tons of non-by-product coke in 9,696 ovens.[42] Except for a brief episode during World War II when the Sloss Sheffield Steel and Iron Company reactivated its Lewisburg ovens, 1927 was the last year that beehive coke was made in the District.[43]

The Antebellum and Civil War Period 1854-1865

While the advent of coke making in Alabama is generally associated with the Oxmoor experiments and the birth of the blast furnace industry in Jones Valley, there are several earlier references to the practice. According to Ethel Armes, the first coke was made near Tuscaloosa in 1854 by William Gould. Gould made coke in mounds, following methods similar to those used to make charcoal. The son of a Scots coal miner from Glasgow found a ready market for his coke in Mobile, where is sold in competition with imported Pennsylvania anthracite.[44]

When the Civil War began, the Confederate government encouraged mine operators in the Cahaba and Coosa fields to convert portions of their coal into coke for use by foundries and other industrial facilities at Selma, Mobile, Columbus, Georgia, and elsewhere. Truman Aldrich indicates that coke was produced in the Cahaba field at mines on Pine Island Branch of south Piper, and at mines near Marvel and Gurnee. Coal from the Gurnee area "was found to make an excellent quality of coke… used with great success in casting cannon at Selma." In the Coosa field a Captain Schultz of the Confederate Army made coke which was transported by river and rail to Montgomery and Selma. Apparently all of these operations employed open mounds for making the badly needed war material.[45]

One long established operation, the Alabama Coal Mining Company proposed in May, 1862, to

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[42] The relative size of the District is revealed by comparing this latter figure to the 43,063 beehive ovens in operation in the Connellsville region at about the same time.
[43] William Hutton Blauvelt, "A Description of the Semet-Solvay By-Product Coke-Oven Plant at Ensley, Alabama," *TAIME 1889,* vol. 28 (Philadelphia: American Institute of Mining Engineers, 1889), 578-591; James Saxon Childers, *Erskine Ramsay: His Life and Achievements* (New York: Cartwright and Ewing, Published, 1942), 390.
[44] Armes, *Coal and Iron in Alabama,* 68; Aldrich, "Historical Account of Coal Mining," 32-34. For a brief discussion of the origins of beehive coke making in the Connellsville District see John Fulton, "A Report on Methods of Coking," in *Coke Manufacture,* by Franklin Platt, Second Geological Survey of Pennsylvania, 1875 (Harrisburg, Board of Commissioners, 1976), 55-63; George M. Cruikshank, *A History of Birmingham and Its Environs,* 2 Vols. (Chicago and New York: The Lewis Publishing Company, 1920), 33.
[45] Aldrich, "Historical Account of Coal Mining," 32-33, 38.

build coke ovens on behalf of the Confederate Ordnance Bureau.[46] Company president John Storrs suggested to Socrates Maupin, who had been sent to appraise the lead and saltpeter deposits of the District by the Chief of Confederate Ordnance, Josiah Gorgas that the ovens be built at his mines on Pea Ridge in Shelby County. Storrs offered to build the ovens if the Confederacy would pay for their construction. The company would supply coke until the war's end, at which time it would assume ownership of the ovens. Maupin reported that coal from the Pea Ridge operation already had been coked and tested for metallurgical purposes but stated that the results had not been satisfactory. Apparently the coal was coked in open mounds, because Maupin suggested that better results might be obtained if ovens were used. No records have been found to confirm or deny that the Alabama Coal Mining Company ever built the proposed ovens.

The Beehive Coke Oven Era 1876-1897

The era of the beehive coke oven in Alabama began with the success of the iron making experiments at the Eureka furnaces at Oxmoor. Unfortunately, very little documentation regarding these seminal experiments has survived, particularly concerning what role beehive coke ovens may have played. The postwar entrepreneurs who backed the experiments apparently had initially constructed six Belgian and four Shantle reversible bottom ovens at the furnace plant. The Shantle oven was a modified beehive type, while the Belgian oven was the earliest form of what later became known as the Coppee retort oven. It is likely that neither of these oven types performed well because they do not appear to have survived for long following the experiments that were concluded in the mid to late 1870s. The only known reference to their performance is provided in a U.S. Census report by Joseph D. Weeks that does not mention Shantle ovens but indicates that the Belgian ovens were not successful, and that beehive ovens were erected in their stead.[47]

This suggestion that the first beehive ovens in the District were constructed at the Oxmoor furnace plant is supported by an 1890 *Iron Age* article which provided a detailed list of coke ovens in the Birmingham Industrial District. The article made no reference to either Shantle or Belgian ovens, but lists 100 beehive ovens at Oxmoor.[48]

It is possible, however, that the first beehive ovens in the District were located at the Eureka Company's mines near Helena rather than at the furnace plant. Enoch Ensley, a prominent Birmingham entrepreneur of the period and extremely reliable source, indicated in 1885 that soon after the pronounced success of the Oxmoor trials the Eureka Company shifted to beehive ovens by building a battery of 100 ovens at its Helena mines in the Cahaba coal field. Since, like the furnace, the mines were also named Eureka, it is possible that the *Iron Age* article is actually referring to their location at the site of the oven plant. Another source corroborates the mines as the site indicating that in one three-week period during the Oxmoor experiments, seventeen wagon loads of coal per day were hauled from the Warrior field to Helena, coked, and returned

[46] Socrates Maupin to Lieutenant Colonel Josiah Gorgas, 30 June 1862, transcript in File Record Group 109, National Archives and Records Administration, Washington, D.C.
[47] "Alabama, Its Iron Mountains and Coal Basins," *Birmingham Iron Age* 15 (July 1875), 2; "In the Coal Fields," *Birmingham Age-Herald*, 6 January 1889, 12; Cruikshank, *Birmingham and Its Environs*, 4, ed. Richard P. Rothwell (New York: The Scientific Publishing Co., 1896), 220-222; Joseph D. Weeks, *Report on the Manufacture of Coke*, U.S. Department of the Interior, Bureau of the Census (Washington, D.C.: GPO, 1884), 47.
[48] "Coke Ovens in the Birmingham District," *Iron Age* 46 (September, 1890), 456.

to the Eureka furnaces. This source goes on to say that the Warrior field coal proved so successful that the iron makers built and "expensive battery of patent ovens operated by machinery," apparently beehives, at the furnace plant.[49] These may be the ovens to which Weeks and the *Iron Age* article refer.

What further complicates the issue of where the first non-by-product coke ovens were built is the existence of the ruins of a battery of eleven "English" style rectangular ovens near Helena. There are no historical references to these ovens but they are doubtless early. If they are not of Civil War era origins, they were almost certainly contemporaneous with the Oxmoor experiments. They are a rare example of this type of construction and are probably among the oldest surviving coke ovens in the United States.

One of the most important finding of the Oxmoor experiments was the fact that the coke produced from the coal of Wadsworth and Helena seams in the Cahaba field did not work as well as coke made from Warrior field coal.[50] This discovery shifted the geographical location but not the pave of coke oven construction. Oven construction proceeded as rapidly as the furnace building boom that followed the successful experiments, but most of the new coke batteries were built in the Warrior rather than the Cahaba field. The owners of Alice Number One, the first furnace built following the Oxmoor success, installed a battery of 242 beehive ovens adjacent to the plant to make coke from coal delivered from newly opened mines on the Pratt Seam. Sloss Furnaces followed suit in 1882 by constructing a battery of 242 beehive ovens, which was later enlarged to 285. Soon afterwards, the Pioneer Mining and Manufacturing Company created the District's largest plant by building 910 ovens at its Thomas Furnaces.[51] Between 1880 and 1893, 5,232 beehive ovens were built in Alabama; in 1888 alone, 1,469 ovens were constructed. All were installed either at blast furnace plants or at the coal mines. Sloss-Sheffield, for example, had built or acquired 1,238 coke ovens by 1900: 288 at its City Furnaces; 350 at its Blossburg mines; 214 at Coalburg; 200 at Flat Top; 99 at Brookside; and 87 at New Found.[52]

While the overwhelming majority of the non-byproduct ovens constructed in the District were of the standard beehive type referred to by Frederick Overman as "Pittsburgh Ovens," at least three other designs were built. The earliest of these were the English style rectangular ovens already referenced. The second was the patented Thomas mechanically charged, rectangular oven. Two batteries of this important design were built; a bank of sixty-three ovens installed by the Sloss Iron and Steel Company at Coalburg in 1889, and a bank of 10 ovens built by the St. Clair Coal and Coke Company at Ragland at about the same time. These were possibly the first such

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[49] Testimony of Enoch Ensley in U.S. Congress, Senate, *Report of the Committee of the Senate Upon the Relations Between Labor and Capital,* 5 vols. (hereafter cited as *Labor and Capital), (Washington, D.C.: GPO, 1885), 4, 413;* "Business Item," *Iron Age* 17 (February 24, 1876), 24; Armes, *Coal and Iron in Alabama*, 262; Cruikshank, *Birmingham and Its Environs,* 37; John R. Hornady, *The Book of Birmingham* (New York: Dodd, Mead, and Co., 1921), 63; testimony of Llewellyn Johns in *Labor and Capital,* col. 4, 443.

[50] Ibid., 262; John Witherspoon Du Bose, *The Mineral Wealth of Alabama* (Birmingham: N.T. Green and Co., 1886), 591; Eugene A. Smith, *Report of Progress for 1874,* Geological Survey of Alabama (Montgomery: W.W. Screws, 1875), 41

[51] Kroman, Edna, "Unkind Fate Follows Furnace," *Birmingham News-Age-Herald,* 6 Jan. 1929, Sunday Magazine Sec. 4; "Coke-Making by the Sloss Iron and Steel Company," 271; H.S. Geismer and David Hancock, "Beehive and Byproduct Coke in Alabama," *Coal Age* 3 (June 1913), 879, 882.

[52] John Fulton, *Coke: A Treatise on the Manufacture of Coke and the Saving of By-Products,* (Scranton, Pa.: The Colliery Engineer Co., 1895), 96; "Coke Ovens in the Birmingham District," 456, "Coke Manufacturers in the Connellsville District," *Coal and Coke Operator* 11 (January 1909), 23.

beehive and other non-byproduct coke ovens in the United States. Their cost of operation was greater than that of beehive ovens, however, and no more were built in the District. A block of six Conner ovens were constructed around 1888 by the Corona Coal and Coke Company at its mines in Walker County.[53]

Pennsylvania's influence of the construction and operation of these coke making operations was extensive. Ethel Armes indicates the strength of this connection by citing at least three cases in which leading coke plants were managed by men who had worked and trained in the Connellsville region before coming south. As previously stated, Erskine Ramsay worked for H.C. Frick before taking charge of TCI's mining department, which included 806 coke ovens at the time and also supplied coal to the coke ovens at the Thomas, Sloss, and Alice Furnaces. Louis Minor, a Connellsville native, served as general superintendent of the coke ovens of the Cahaba Coal Mining Company, which supplied coke to Oxmoor and Anniston, F.B. Keiser, a Pennsylvania-born engineer, supervised the layout and construction of the first three Thomas furnaces, where the District's largest single group of coke ovens was built. He had studied the construction and operation of beehive ovens in Connellsville before coming to Birmingham.[54]

Metallurgical Coal Washing

Converting the coal of the Warrior field into coke in beehive ovens was reasonable simple, but insuring that the quality of this product was suitable for blast furnace fuel was probably the greatest single challenge that faced the Birmingham Industrial District during the last decade and a half of the 19th century. Unless it was mechanically cleaned, the impurity-ridden coal yielded coke which occasionally contained the prohibitively high level of over twenty-one percent ash. Fortunately, washing the coal before charging it into the ovens, reduced the ash content in the resulting coke to about five percent. This was lower than some of the best Connellsville coke.[55] Although the process was relatively expensive, the greater thermal efficiency of coke made from mechanically cleaned coal helped offset the higher cost of mining the relatively thin, dirty seams.

According to an article published in 1907 by Samuel Diescher, a member of the Engineer's Society of Western Pennsylvania and developer of one leading model, coal washing was first introduced into the United States at Alspville, Pennsylvania in 1869.[56] But, with the coming of the era of the coke-fired blast furnace, Pittsburgh took a brief, early lead in the practice during the 1870s and 1880s. The first attempt, conducted simultaneously with trials at Joliet, Illinois, and a few other blast furnace plants may have been made at Pittsburgh's Eliza Furnace in a washery built by John J. Endres, formerly an engineer of mines for the Prussian government, who had worked in the Saar region of Germany. At about the same time, Pittsburgh's Clinton, Lucy and Isabella Furnaces also resorted to coal washing, but by the late 1870s western

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[53] J.T. Hill, "Thomas Coking Oven," in *Proceedings of the Alabama Scientific and Industrial Society*. vol. 1, no. 2 (Tuskaloosa (sic): Book and Job Printing Press of Jno. F. Warren, 1892), 90; "Coke Ovens in the Birmingham District," 456; Gibson, *Report Upon the Coosa Coal Field*, 44; "Walker County, Ala., Coal Field," *The Colliery Engineer*, 8 (March 1888), 185.
[54] Armes, *Coal and Iron in Alabama*, 295, 354, 422; Mell, "Coal and Iron Interests in Alabama," 390; Ramsay, "The Pratt Mines and Coke Plant," 136; Hutchings, "Alabama Coal Mining," 254.
[55] William B. Phillips, "Washing Alabama Coal," *Mines and Minerals* 18 (April 1898), 395; Erskine Ramsay and Charles E. Bowron, "Coal Washing in Alabama," *Mines and Minerals* 25 (December 1904), 227.
[56] Samuel Diescher, "Process of Coal Washing," in *Proceedings of the Engineer's Society of Western Pennsylvania*, (Pittsburgh: Engineers Society of Western Pennsylvania 1907), 202-203.

Pennsylvania furnace men abandoned the practice when they discovered that Connellsville's Old Basin coal did not require such treatment. With little impetus coming from this important center of innovation, development slowed. The census for 1880 listed only twenty-eight coal washeries in the entire United States, eight designed by Diescher and twelve designed by Sebastian Stutz, both men operating out of Pittsburgh.[57]

Since it had little choice but to rely on its own less than perfect coal deposits, and since there were no clear examples to follow, the Birmingham Industrial District became a proving ground for American metallurgical coal washing practice in the late 19th century.[58] Several early prototypes were tested. Coal washing became so pervasive that one observer claimed in 1925 that "all methods used for cleaning bituminous coal have been largely brought to perfection in this state."[59] In 1927 Alabama produced over 14.5 million or 61 percent of the 23.5 million tons of coal washed in the United States and the lessons learned helped establish the simple but effective practice, that would become the essence of metallurgical coal washing, of washing the coal in one size, called slack, which was best suited for coking. [60]

The First Coal Washing in Alabama ca. 1876

The first documented coal washing in Alabama, conducted during the mid-1870s, was short-lived. It was performed in conjunction with the Eureka Furnace experiments at Oxmoor. The experimenters constructed a Stutz washery at the Eureka mines near Helena in order to wash coal from several localities in the Cahaba Field prior to coking. The plant was quickly abandoned following the experiments as iron makers turned from the Cahaba to the Warrior coal field for metallurgical coal.

For the next decade, none of the blast furnace companies in the District washed their coking coal. The reasons for this brief hiatus are difficult to document, but they were apparently tied to the belief among many operators that Warrior coal did not require mechanical cleaning. Erskine Ramsay, for example argued that, while washing would undoubtedly improve the quality of Warrior coal, it was questionable whether such cleaning was needed. Ramsay claimed that "Southern coke has been condemned where it was not the fault… when a furnace gets working badly, the furnaceman, to shield himself, will lay blame on bad coke."[61] He questioned whether the improved quality would be sufficient to offset the additional cost of washing, asserting that

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[57] Weeks, *Report on the Manufacture of Coke,* 5' Clarence David King, *Seventy Years of Progress in Iron and Steel* (New York: American Institute of Mining and Metallurgical Engineers, 1948), 46; W.R. Chapman and R.A. Mott, *Cleaning of Coal* (London: Chapman and Hall Ltd., 1928), 180.
[58] John B. Atkinson, "Coke Making in the Western Kentucky Coal Fields," in *Engineering Association of the South, Publication Number 1,* by the Engineering Association of the South (Nashville, Tennessee: University Press Printers, 1891), 30; H.S. Geismer, "Alabama Coal Washing and Cleaning Practice Helps Make Good Metallurgical Coke," *Coal Age* 26 (October 1924), 501; "Blazing the Trail in Alabama," *Coal Age* 33 (October 1928), 642. Another state that was early to devote extensive attention to coal washing was Illinois. See F.C. Lincoln, "Coal Washing in Illinois," University of Illinois Engineering Experiment Station Bulletin 69, 1913.
[59] H.S. Geismer made the claim in an article in which he noted that two major new coal washing processes, the air or dry cleaning process and the Chance sand-liquid method, had recently been introduced in other regions. H.S. Geismer, "Coal Washing Practice in Alabama," *TAIME, 1925* vol. 71 (New York: American Institute of Mining and Metallurgical Engineers, 1925), 1089.
[60] H.F. Yancey and Thomas Fraser, *Coal Washing Investigations*, U.S. Department of Commerce, Bureau of Mines, Bulletin No. 300 (Washington, D.C.: GPO, 1929), 4.
[61] Ramsay, "The Pratt Mines of Tennessee Coal, Iron and Railroad Company, Alabama," 312.

careful beehive coking practice and management yielded a product that compared favorably with the Connellsville article. Whatever the case, demand was so great in the early 1880s that furnace operators could sell all the pig iron they produced regardless of its low quality caused by high-ash coke made from unwashed coal.

Obviously Birmingham would have to resume coal washing as competition intensified and profit margins narrowed. It simply cost too much to make iron from coke with high ash content. An article published in 1912 summer up what had been learned over the preceding two decades: that iron makers could save as much as one dollar per ton on the cost of pig iron for every five percent reduction in the ash content of their coal. Even though Ramsay was still defending beehive coke made from unwashed Warrior coal as late as 1890, experiments with new coal washing systems had been underway for at least five years.[62]

Early Washing Experiments with Warrior Coal ca. 1886-1890

The washing experiments conducted on coal from Warrior Field in the 1880s are not well documented, but apparently the produced mixed results. The Alice furnaces washed coal as early as 1886, proving that coal from the Pratt Seam could be greatly improved by mechanical cleaning. The Woodward Iron Company conducted experiments in a 500 ton per day capacity for nearly a year. The system produced clean coal that coked well, but so much fine coal was lost in the process that the effort was judged a failure. The Coalburg Coal and Coke Company attempted several unsuccessful trails. In the Cahaba Field, the Cahaba Coal and Railroad Company also tried washing but determined that it was too costly.[63]

The Sloss Iron and Steel Company installed the first Luhrig Jig system in America adjacent to its beehive coke ovens at the City Furnaces in 1890. The plant was built by English immigrant Alexander Cunningham, who brought the German invention to the United State and later established a leading mining equipment company in Chicago.

The washery received considerable attention in coal mining journals. More than 200 were already in operation in Europe at the time of the Sloss trials and many more were subsequently installed across the United States. Observers from the Colorado Field and Iron Company traveled to the District to conduct tests at the plant using their own coal. The Colorado Field and Iron Company went on to build a modified version of the Sloss prototype that employed components of the Luhrig process combined with other equipment.[64]

Despite its notoriety, the Sloss City Furnaces washery did not perform well. Contemporary observers attributed the failure to poor design and improper operation but the disappointing performance was also attributable to the fact that the Luhrig system was too complex for the

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[62] David Hancock, "Coal Washing in Alabama," in *Iron and Steel in Alabama,* 3rd ed., by William Battle Phillips. Geological Survey of Alabama (Montgomery, Alabama: Brown Printing Co., 1912), 233.
[63] Henry E. Cotton, "Some Ideas on Coking Coals in the South," *Colliery Engineer* 8 (November 1887), 81; Ramsay, "The Pratt Mines and Coke Plant," 136 and "The Pratt Mines of the Tennessee Coal, Iron and Railroad Company, Alabama," 312.
[64] Ernst Prochaska, *Coal Washing* (New York: McGraw-Hill Book Co., Inc., 1921), 42; R.M. Hosea, "A Description of the Colorado Fuel and Iron Co.'s Washery at Sophis, Colo.," *Colliery Engineer and Metal Miner* 17 (June 1897), 478.

relatively simple requirements for metallurgical coal washing.[65] The first step in the process consisted of running the coal over several screens to separate it into predetermined sizes, based on the types of impurities in the coal and their separation characteristics. A series of jigs washed each coal size separately.

Like all hydraulic washers, jigs worked on the principle that the impurities in coal were heavier than the coal itself. This difference in specific gravity caused the coal and its impurities to separate into discrete layers in a tank of agitated water. If the water was properly agitated, the coal would float while the impurities settled to the bottom of the tank. The clean coal could then be removed separately. The jig, which consisted of a plunger mounted on a shaft, provided the agitation as it moved up and down in the tank. A flat, perforated table submerged near the top of the tank aided the separation process by keeping the coal near the surface while allowing the heavier impurities to sift through the perforations.

Luhrig washers were distinctive because their perforated tables were covered with a layer of feldspar. Since it was intermediate in specific gravity between coal and most of its impurities, the feldspar acted as a filter, retarding the downward flow of coal while facilitating the removal of impurities.[66] As the proponents of the Luhrig washer maintained and as the Colorado Fuel and Iron Company and other users later proved, this complex arrangement could achieve excellent results when properly conceived, designed, and operated.

The Stein washer was another design which was first introduced in the Birmingham Industrial District but was soon rejected because of its complexity. The inventor had personally supervised the construction of his patented washer at Sloss' Brookwood Mine, but his device was based upon the same concept of pre-sizing as the Luhrig and other European coal washers. The new installation was watched closely by mine operators in the District but after only a few years of operation it was replaced by a Stewart jig washing plant.[67]

The close of the Luhrig and Stein experiments marked the beginning of an era that would last until the mid-1920s during which metallurgical coal washing practice would be confined to a very elementary process. Unsorted coal, just as it came from the mine, known in the trade as run-of-mine, could be crushed down to slack and fed directly into the washers. Since no pre-sizing was needed, all that was required to wash slack was a plant containing one or two washing tanks of simple but durable construction and an effective system for recycling water. After being cleaned and drained of excess water, it was ready to be coked. The two designs that epitomized this simplistic process were the Robinson-Ramsay and Stewart Washers.[68]

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[65] Edward C. Pechin, "Iron Making in Birmingham, Alabama," *Iron Age* (July 1894), 6; Phillips, "Washing Alabama Coal," 396; J.V. Schaefer, "Coal Washing," *Colliery Engineer and Metal Miner* 17 (March 1896), 249-253.
[66] G.R. Delamater, "Bituminous Coal Washing," *Mines and Minerals* 27 (September 1907), 64-65; Schaefer, "Coal Washing," 251.
[67] F.M. Jackson, "The Stein Washer," in *Proceedings of the Alabama Scientific and Industrial Society*, Vol. 6, pt. 1, by the Alabama Scientific and Industrial Society (Tuscaloosa: Burton and Weatherford, 1896), 50-54; Fulton, *Coke,* 65-70.
[68] Geismer, "Coal Washing Practice in Alabama," 1092; Hancock, "Coal Washing in Alabama,: 234-235.

The Robinson-Ramsay and Stewart Washers

The first simple system introduced in the Birmingham Industrial District in the 1890s was installed by Erskine Ramsay at TCI's Shaft Number One Mine in 1892. Names the Robinson washer after its English inventor, it was an upward current system that was first used in the United States at a coal mine near Chattanooga, Tennessee. Rather than using a jig and plunger to agitate the wash water, Robinson's device employed an air pump installed in the bottom of a large tank shaped like an inverted cone. The pump sent regular air bursts upward through the water while paddle-like arms that rotated on a vertical shaft in the middle of the cone provided further agitation.[69]

The Robinson washer was well suited for the coal mines of the Birmingham Industrial District. While requiring very little ground space, it could be maintained by only one man who easily was able to handle the entire output of most mines. By inserting this relatively simple and inexpensive plant between their mine portals and beehive ovens, Birmingham's metallurgical mine operators could be assured that they were working with coal as clean as that which Connellsville miners brought out of their mines and simply dumped straight into their coke ovens.[70]

The original Robinson washer had room for improvement however, because it left an accumulation of very fine material, called sludge, in the wash water. Erskine Ramsay provided a partial solution to this problem by adding a sludge removal system. He also made other changes that so improved Robinson's prototype that it came to be called the Robinson-Ramsay washer. After this hybrid was perfected at the coal mines of the Birmingham Industrial District, an agreement was reached between Ramsay and Robinson regarding patent rights and the Jeffrey Manufacturing Company began distributing the improved system throughout the United States.[71]

Ramsay installed the first Robinson-Ramsay washer at TCI's Slope Number Two in 1893 and a second on January 1, 1895 at the Pratt City Coke Ovens. At about this latter date, Sloss installed a Robinson-Ramsay plant at Brookside that washed coal from the Brookside, Cardiff, and Brazil Mines. By the turn of the century the Robinson-Ramsay washers were being used almost universally in the District, but they soon received serious competition from a rival machine, the Stewart washer.[72]

Ellwood Stewart developed his important design in Illinois, but in 1900 he moved to the Birmingham Industrial District and installed his first plant at the Brookwood Mine replacing the Stein washer which had been in operation for about six years.[73] The Robinson-Ramsay washer had found great favor in the District, but it possessed a few disadvantages when compared to Stewart's device. Both washers were reasonable efficient but the Stewart movable jig washer had much more capacity, took up much less floor space, and required much less water. There were

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[69] Childers, *Erskine Ramsay,* 199; Chapman and Mott, *Cleaning of Coal,* 181-199; Prochaska, *Coal Washing,* 53-57.
[70] J.J. Ormsbee, "Notes on a Southern Coal Washing Plant," *The Colliery Engineer and Metal Miner* 16 (September 1895), 27-29.
[71] Childers, *Erskine Ramsay,* 200-202; Prochaska, *Coal Washing,* 53.
[72] Phillips, "Washing Alabama Coal," 396, Ramsay and Bowron, "Coal Washing in Alabama," 230; Ormsbee, "Notes on a Southern Coal Washing Plant," 27-29; Alabama, F*irst Biennial Report of the Inspectors of Mines,* 1892, 7.
[73] Hancock, *Coal Washing in Alabama*, 234; Jackson, "The Stein Washer," 66; Prochaska, *Coal Washing,* 206.

also problems with Ramsay's sludge removal system which carried away excessive amounts of very fine coal. Within two years after Stewart introduced his apparatus, no more Robinson-Ramsay washers were installed. By 1912, twenty-one of the fifty-seven coal washing plant in Alabama utilized Stewart's design. When the non-metallurgical coal mines are excluded from this list, the Stewart machine was almost exclusively the washer of choice.[74]

The simplicity of Stewart's washer so impressed Ernest Prochaska, one of the leading authorities on turn-of-the-century coal washing, that he dedicated his book on the subject matter to the inventor, stating the "Stewart brought about an epoch-making revolution with his machine which held the field for a long time without a competitor."[75] The most distinctive feature of the Stewart washer was the way in which it jigged coal. In most designs, the jigs were attached to plungers that agitated the water in the washer tank. Stewart's jigs were mounted on the perforated screen, to create what was termed the movable screen jig. The invention was so effective that operators mining metallurgical coal in southwestern Pennsylvania copied it as the better grade of Connellsville coal began to play out and they were forced to wash the inferior coal of the Lower Connellsville and Klondike Fields. Known as the "Pittsburgh Jig," it bore a striking resemblance to the design that Stewart had perfected a few years earlier in the Birmingham Industrial District.[76]

As plunger jigs became more refined Birmingham iron makers began to convert to the more versatile systems. Leading designs used in the District included the Elmore, Faust, American, and McNally Pittsburgh varieties. A distinctive feature of this new generation of washers was their two to four jig compartments. The first new Elmore jig washing plant to receive attention in professional journals was put into use at TCI's Wylam Number Eight Mine.

Since it placed such heavy emphasis on coal washing it was only natural that the District became a proving ground for much of the peripheral equipment associated with the process. One such device, the mechanical coal drier was much cheaper to install than older coal drainage bins, which required dewatering elevators and other ancillary equipment. Mechanical drying also made it possible to recover a great deal of the very fine coal that was lost in older drying systems. Two centrifugal coal dryers were installed at TCI's Wylam Number Eight by the American Concentrator Company of Springfield, Ohio in 1914.[77]

At about the same time, Woodward installed a Waddell continuous centrifugal drier at its coal

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[74] Ibid., 234-238. The sludge removal in the early washeries was simply dumped into streams, causing pollution problems and subsequent lawsuits from farmers whose property lay downstream of the coal mines. These lawsuits, along with the increasing cost of coal, probably contributed to the eventual demise of the Robinson-Ramsay washer. See Geismer, "Coal Washing Practice in Alabama," 1089-1092, and L.A. Harding and G.R. Delamater, "Bituminous Coal Washing," *Mines and Minerals* 25 (July 1905), 580-581.

[75] Prochaksa, *Coal Washing,* 32.

[76] Fulton, *Coke,* 114-116. For an idea of the similarities between the movable jig washer developed for use in the Lower Connellsville or Klondike Fields of southwestern Pennsylvania and the Stewart jig, compare the illustration of the former in "Coal Washing," *Mines and Minerals* 27 (February, 1907), 329 with an illustration of the latter in Prochaksa, *Coal Washing,* 199.

[77] Geismer, "Coal Washing Practice in Alabama," 1093-1102; O.H. Bohm, "Coal Washer for No. 8 Mine, Tennessee Coal, Iron and Railroad Co," *Coal Age* 7 (March 1915), 495-496; Robert Hamilton, "Edgewater Mine Produces Large Output of Washed Coal Under Adverse Conditions," *Coal Age* 28 (August 1925), 246-247; W.A. Hamilton, "Jig Washer at Wylam No. 8 Shows High Efficiency," *Coal Age* 33 (October 1928), 637-638; F.E. Butcher, "Drying Washed Coal," *Coal Age* 7 (February 1915), 325.

mines. Woodward's coal drier had recently been developed by Carl A. Waddell, an experimental engineer for the Illinois Steel Company at Joliet, Illinois. The design, which had taken four years to develop, had been perfected in tests conducted at the Woodward washery.[78]

In addition to mechanical driers, mine operators in the Birmingham Industrial District also worked with some of the earliest sludge recovery equipment. One of the most highly regarded of these was an inverted cone sludge tank developed locally by one of TCI's engineers, Robert Hamilton. The sludge cone was a refinement of Erskine Ramsay's original sludge recovery system, which Hamilton designed to remove very fine coal and waste material from water before it was discharged into streams or recirculated through the washery. The large inverted cone tank was placed outside the washery building, giving TCI's coal washing plants a distinctive appearance. A Dorr thickener, another sludge recovery system that gained wider acceptance, was installed at the Republic Steel Corporation's Risco and Sayreton Mines. The Risco installation was the second Dorr thickener used at a coal mine in the United States.[79]

In addition to mechanical improvements, the Birmingham Industrial District ushered in other refinements in coal washing practice, including chemical analysis and the monitoring of cleaned coal and waste material. Mine operators built testing laboratories at their washing plants where chemists were employed to maintain quality control standards. These laboratories generated data that enabled chemists to develop pioneering scientific methods for determining the efficiency of coal washing systems. Using such data, consulting chemist David Hancock wrote a seminal article that appeared in the third edition of William Battle Phillips' *Iron Making in Alabama* in 192, setting forth a systematic method for evaluating the efficiency of coal washers based upon specific gravity analysis. According to H.F. Yancey and Thomas Frasier, who published the first definitive work on coal washing test methods for the U.S. Bureau of Mines in 1927, Hancock's work, along with that of a few other investigators, was regarded as the pioneer research of its type in American and became the foundation for the subsequent work of the Bureau.[80]

SOCIAL ORIGINS

One reason the Birmingham Industrial District kept pace with other American coal-mining regions was because it attracted large numbers of experienced miners and engineers who brought in the expertise that was lacking to the South. The majority came from Pennsylvania, bringing state-of-the-art knowledge to the rapidly developing Warrior coal field. By the late 1880s, if not sooner, Pennsylvania coal miners occupied most supervisory positions at the District's coal mines. One homesick Pennsylvania miner, writing to *Colliery Engineer* in 1888, refers to "our little Pennsylvania colony" at the Helena Mines of the Eureka Company:

> I only wanted you to know that much of the present success of this company here in the coal and coke department, is certainly mainly due to the old Pennsylvania men (Schuylkill countians) who are now in charge of this end of the enterprise.[81]

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[78] Butcher, "Drying Washed Coal," 325; E.A. Holbrook, "The Wendell Continuous Centrifugal Drier," *Coal Age* 7 (March 1915), 456-458.
[79] Hamilton, "Edgewater Mine Produces Large Output of Washed Coal," 246-247; Geismer, "Coal Washing Practice in Alabama," 1090, 1096.
[80] Hancock, "Coal Washing in Alabama," 233-245; Yancey and Fraser, *Coal Washing Investigations,* 33, 53.
[81] "A Letter From the Centre of the Great Coal Fields of Alabama," 198.

An article that appeared in the same journal a few months later reinforced the prominent influence of Pennsylvania miners. It pointed out that every major mining operation in Alabama that produced coking coal was supervised by emigrants from the Keystone State. Henry F. DeBardeleben's mines at Blue Creek were under the charge of James Hillhouse, formerly of Shenandoah, Pennsylvania, who would later become Alabama State Mine Inspector. Peter B. Thomas of Audenreid, Pennsylvania was in charge of the Blockton Mines and coke ovens; Isaac Prince, another transplanted Pennsylvanian, was superintendent of the Coalburg Mines and coke ovens.[82]

England, and particularly Wales, was another major source of technical expertise during the formative years of the Birmingham Industrial District. As previously mentioned, Billy Gould and Joseph Squire who figured so prominently in the discovery of the best coal in the Warrior Field, were British. All the owners and officers of the early Pierce Mine at Warrior were natives of Wales as was Llewellyn Johns who served terms as chief mining engineer at the Pratt Mines, DeBardeleben Coal and Iron Company and the Republic Iron and Steel Company. Welshman Giles Edwards, who built the first cupola-style coke blast furnace in the South at Chattanooga in 1854, was hired by another Welshman, the famed David Thomas, to acquire some of the first property for the Pioneer Mining and Manufacturing Company. Throughout the formative decades of coal mining the overwhelming majority of foreign born participants were British. In 1890, for instance, 1,009 or 68 percent of the 1,490 foreigners employed in Alabama coal mining were from England. By 1900 the percentage of immigrants from Great Britain had increased to 70 percent or 1,112 of the 1,573 foreign born coal industry employees.[83]

Obviously this high percentage of British-born coal miners is an indication that other nationalities were not heavily represented in the work force of the Birmingham Industrial District. In 1900 for example, the country with the nest highest representation in the mining industry was Ireland with 279 or 18 percent. Following Ireland was Austria-Hungary with 189 or 12 percent and Italy with 171 or slightly over 10 percent of the foreign miners.[84]

For the most part coal mining in the Birmingham Industrial District was conducted by native born blacks and whites. Only 8.7 percent of the work force in 1900 was made up of foreigners. Of the total of 17,898 workers, 6,590 were native born whites and 9.735 native born blacks.[85] While a healthy percentage of native whites were from Pennsylvania and other northern states, the black miners who comprised 54 percent of the work force were undoubtedly southern born, probably farm workers fresh from the black belt and other agricultural areas of Alabama. And most blacks who made this sudden and radical change in occupation did not do so of their own free will.

CONVICT LEASING

The one area in which "Southerness" in Alabama coal mining is most evident is in the

[82] "Alabama's Coal and Iron," *Colliery Engineer* 9 (January 1889), 133-134.
[83] Armes, *Coal and Iron in Alabama*, 353-357, 292; U.S. Department of Commerce and Labor, Bureau of the Census, *Report on the Population of the United States at the Eleventh Census: 1890, Part II,* (Washington, D.C.: GPO, 1897), 537; U.S. Department of Commerce and Labor, Bureau of the Census, *Special Reports. Occupations at the Twelfth Census*, (Washington, D.C.: GPO, 1904), 222-223.
[84] Ibid, 223.
[85] Ibid.

composition of the work force and the way in which poverty and traditional attitudes toward race led Alabama first, to adopt convict leasing and retain it longer than any other state and, secondly, to turn over most of this coerced work force to the larger metallurgical mining companies. While convicts made up a relatively small percentage of the work force ,their presence had a profound impact on the course of unionization in the District and led to some unique underground mining arrangements and marketing strategies that both diluted the bargaining position of free miners while enhancing company profits.

The original inducements for introducing the convict leasing system into coal mining soon after the Civil War appear to be a direct reflection of the social attitudes and economic conditions of the South. As Mancini contends, the leasing of convicts in Alabama, the overwhelming majority of whom were black, "was partially a response to the demise of slavery."[86] A clear continuity seems evident in the fact that the first convicts used as miners following the war were leased by the same mining operations and individuals who forced slaves to mine coal during the conflict. John Milner for instance, who had worked slaves at the mines of the Red Mountain Iron and Coal Company at Helena during the war proclaiming their toil to be the "fundamental proposition of the Confederacy," was one of the first two mine operators to employ convicts after the war. The other was the Alabama Mining and Manufacturing Company which leased the Helena property of the Red Mountain Iron and Coal Company and used its convicts to mine coal for the Eureka experiments that tested the viability of smelting pig iron with coke made from Alabama coal. Later, when Henry DeBardeleben and his associates formed the Pratt Coal and Coke Company which supplied coke to all the seminal blast furnace operations in the District during the early 1880s, these New South entrepreneurs with old South ties were quick to take on a contingent of convict coal miners.[87]

If there was a very long strong continuity between antebellum slavery and post war convict leasing because of the entrepreneurs involved, there was an equally strong financial inducement for the state government to perpetuate coerced labor in the metallurgical coal mining industry. At about the same time that New South political leaders discovered that Alabama lacked adequate penal facilities, as well as the funds for their construction, they also discovered that convict leasing could be quite profitable. In 1876, the state penitentiary reported a profit of $14,307.40. During the accounting year that Eureka furnace experiments were underway at Oxmoor, the state earned $4,121.30 from the Eureka Company and $3,014.20, from the New Castle Coal Company while the two private enterprises were busy supplying much of the coal used during the trials. In 1898 Alabama derived 73 percent of its total revenue from convict leasing, primarily from TCI and Sloss Sheffield Steel and Iron Company which, by this time, were paying the state nearly as much for able bodied inmates as free miners received in wages.[88]

At least two studies have contended that one of the greatest advantages of convict labor was its reliability compared to strike-prone free miners. Both of these accounts quote the telling

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[86] Matthew J. Mancici, *One Dies, Get Another* (Columbia: University of South Carolina Press, 1996), 20.
[87] John Milner, Montgomery, Alabama to Wm. B Gilmer, Esq. Prest., Red Mountain Iron and Coal Co., 17 March 1864; Aldrich, "Historical Account of Coal Mining," 36; Alabama, *First Biennial Report of the Inspector of Mines, 1892-1894*, 5-7.
[88] J.L. Lerner, "*A Monument to Shame: The Convict Lease System in Alabama,*" (M.A. Thesis, Samford University , Birmingham, Alabama, 1969), 93; Mancini, *One Dies, Get Another*, 102, 113; Alabama, *Annual Report of the Inspectors of the Alabama Penitentiary, 1877* (Montgomery: Barrett and Brown State Printers, 1878), 17; Alabama, *Second Biennial Report of the Board of Inspectors of Convicts* (Montgomery: Roemer Printing Co., 1898), 19.

observation of TCI President George Gordon Crawford who stated in 1911 that "the chief inducement for hiring of convicts was the certainty of a supply of coal for our manufacturing operations in the contingency of labor problems."[89] Indeed, as time passed many inmates, upon their release, continued to work as coal miners.

Despite its profitability for the state and the advantage that it offered to private companies, convict mining was an extraordinarily dangerous proposition for the inmates. Out of 36 total coal mine fatalities reported in 1893—in the first report of the state mine inspector and after conditions had supposedly improved greatly—10 were convicts. This is a startling 28 percent fatality rate compared to the 0.3 percent fatality rate for free miners. In addition to their excessive number of individual fatalities, some of the worst large scale mining accidents in the history of the state occurred in convict mines. Principal among these was the Banner Mine explosion of 1911 in which around 121 state inmates perished.[90]

A comparison of the Banner and the Praco Mines which were both owned by the Pratt Consolidated Coal Company, the largest independent metallurgical coal mining concern in Alabama, reveals a great deal about the ways in which convict miners served the needs of private companies. As will be shown, when these two mines are discussed in the following group of brief case studies, while convict leasing was a Southern institution, it was far from the "prebourgeois form of coerced labor par excellence"[91] that Mancini believes it to be. In fact, the way that Erskine Ramsay, by this time Chief Engineer for the company, and his associate George Gordon Crawford wove convict leasing into their production and marketing strategy was not prebourgeois at all, but rather very rational capitalism.

CASE STUDIES

TCI's vs. H.C. Frick's Slope Mines

A good way to show how greatly the imperfections of the Birmingham Industrial District's metallurgical seams constrained mining practice is by comparing one of its leading mining operations with a counterpart from the Connellsville District of southwestern Pennsylvania. TCI's Pratt Mines and the mines of the H.C. Frick Coke Company in Fayette County, Pennsylvania are excellent candidates for such a comparison for at least three reasons. First, the Frick Mines, owned by the Carnegie Iron and Steel Company, were the standard for captive metallurgical coal mines in America, while the Pratt Mines played an analogous role vis a vis the blast furnace company mines of the Birmingham Industrial District. Second, the Frick Mines tapped the Pittsburgh seam of Connellsville's Old Basin, which yielded the best coking coal in the United States, while TCI's Mines on the Pratt Seam produced the best coking coal in the Birmingham Industrial District. Third, the two groups of mines were linked by common engineering traditions first through Erskine Ramsay and his close connections with Connellsville then later through the United States Steel Corporation which absorbed both the TCI and Frick operations. Because these linkages probably insured both companies roughly equal access to the

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[89] Ibid., 109; Robert David Ward and William Warren Rogers, *Convicts Coals and the Banner Mine Tragedy* (Tuscaloosa: University of Alabama Press, 1987), 50.
[90] For an excellent account of the tragedy as well as general summary of the impact of convict leasing on labor conditions in Alabama, see Ward and Rogers, *Banner Mine Tragedy*, passim.
[91] Citation for quote missing in original document

latest ideas and technology, it would seem that the differences between their mines might well stem from TCI's need to accommodate ethos and economics on the one hand, or the physical limitations of local coal seams on the other.

Ramsay was perhaps the most notable Pennsylvania coal mining engineer to migrate to the Birmingham Industrial District. His work for TCI from 1886 through 1903 exemplifies the innovativeness and adaptability that imported technicians brought to the South. Before coming to Birmingham, Ramsay had distinguished himself at age eighteen as the youngest mining superintendent in the local mining empire of Andrew Carnegie and H.C. Frick. He drew the plans for Frick's new Standard Mine, which set a world's record for the most tonnage joisted to the surface in a single shift. Later, as superintendent of a group of three mines owned by Frick, Ramsay implemented new procedures that broke company records for beehive coke production. While working at TCI, Ramsay maintained close contact with events in the Connellsville region through frequent correspondence with his father, who was the superintendent of the Frick Mines and a native of Andrew Carnegie's hometown, Dumfermline, Scotland.[92]

When he migrated to the Birmingham Industrial District, Ramsay assumed control of the second-largest group of coke ovens in the United States, ranking behind only those of the Frick Company, and what was probably the largest group of captive metallurgical coal mines outside of Connellsville. The newly arrived mining engineer may have been hampered by TCI's lack of capital, but he still had the freedom to devise and implement a series of significant innovations. Perhaps the most important of these was the Robinson-Ramsay coal-washing plant, a modification of Englishman Robinson's original patent that was widely used in the District.[93] Ramsay also devised a system of flues to capture the waste gas given off by beehive ovens, and burn it to raise steam to power equipment at the Pratt Mines.[94]

In later years, after leaving TCI, Ramsay made a series of improvements in revolving car dumpers used to dump coal and ore. The first model of Ramsay's revolving dump was installed at an ore mine in the Birmingham Industrial District, followed by a second installation at the Jagger Coal Mine. The H.C. Frick Company built a large model of the device at its Lemont Number 2 Mine in the Connellsville District. It proved so satisfactory that several were soon installed at other mines owned by the same firm.[95] Ramsay also invented a sampling machine that mechanically sampled loaded coal cars as they emerged from a mine to determine their rock content. This device was particularly appropriate for the Birmingham Industrial District because its coal seams contained much shale and other impurities. The mechanical sampler allowed the mine operator to keep more accurate track of a miner's daily tonnage, but it also provided the company with systematic records of the quality of product coming from different parts of its mines.[96]

In 1903 the H.C. Frick Coke Company worked twenty-six mines on the Pittsburgh Seam in Fayette County: twelve slopes, nine shafts, and five drift mines. In 1901, TCI operated eleven

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[92] Childers, *Erskine Ramsay*, 8, 76-101 passim.
[93] Armes, *Coal and Iron in Alabama*, 327.
[94] Ibid., 156, 198-199; Procjaska, *Coal Washing*, 53; Chapman and Mott, *The Cleaning of Coal*, 122; Ramsay, "The Pratt Mines and Coke Plant," 136; Charles Bowron, "Waste Heat and Gases From Coke Ovens," *Colliery Engineer and Metal Miner* 18 (January, 1898), 60-61.
[95] H.S. Geismer, "Revolving Dumps at Coal Mines," *Coal Age* 10 (August 5, 1916), 224-225
[96]. Prochaska, *Coal Washing*, 79-84.

mines on the Pratt Seam: eight slope mines, one shaft mine, and two drift mines. The Frick Mines yielded a total of 4,387,271 tons for an average of 243,737 tons per mine while TCI produced 1,920,299 tons, for an average of 173,321 tons per mine, or just over 70,000 tons less than the average Connellsville operation. There was also a significant disparity in the tons mined per man; in a year's time, a Frick miner dug 1,701 tons of coal, 638 more than the 1,063 tons produced by a TCI miner.[97]

The Carnegie Iron and Steel Company Mines were located along a long, narrow syncline near Connellsville called the Old Basin. Connellsville coal was fabled among turn-of-the-century iron makers because it produced almost perfect coking coal. It was almost perfunctory for trade journals of the period to preface the phrase Connellsville District with such laudatory adjectives "the famed" or "the famous" in deference to the quality of its coal. When other districts were discussed, their coal was almost invariable compared to the Connellsville product in order to establish its merit. Because Old Basin coal, which was controlled almost entirely by Frick, yielded the best of this exceptionally fine coking coal, it was considered to be the standard of the industry.[98]

The Old Basin also provided near optimal mining conditions. The Pittsburgh Seam averaged about five feet, nine inches thick. It occasionally contained thin layers of impurities, but these were negligible and detracted little from the coking characteristics of the coal. When notable concentrations of sulphur, phosphorous, and other impurities did occur, they were generally confined to four-to-eight inch layers at the top and bottom of the seam. A miner could simply leave this dirty material in place and remove the cleaner coal in between.[99] The coal itself was soft and fractured in a way that made it break into small cubes when mined. These small, clean cubes were easy to load into a coal car and were ideally sized for charging directly into a beehive coke oven. There natural advantages also made the transition to mechanical mining a logical and easy step once the technology became available.[100]

Partings in the Pratt Seam

While a Pennsylvania miner working the Pittsburgh Seam could count on an uninterrupted sixty-nine inch layer of coal, Alabama miners working the Pratt Seam faced a coal layer that not only was thinner, usually averaging no more the forty-eight to fifty-four inches, but was also riddled with troublesome lenses of impurities known as partings. The coal in the turn of the century Pratt Number Three Mine, for example, was broken into three layers by two slate partings. The top parting averaged from one to two and on-half inches, while the bottom parting averaged about

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[97] Pennsylvania, *Report of the Department of Mines of Pennsylvania, Bituminous Region, 1903* (Harrisburg: Wm. Stanley Ray, State Printer of Pennsylvania, 1904), 280-290, 302-305. Statistics on TCI's Pratt Mines are taken from a data file compiled from the Alabama State Mine Inspector's reports from the years from 1893 to 1950.
[98] Fulton, *Coke,* 10; A.O. Backert, *The ABC of Iron and Steel* 5th ed. (Cleveland: The Penton Publishing Co., 1925), 62-63; F.Z. Schellenberg, "Our Coal," in *Proceedings of the Engineering Society of Western Pennsylvania*, col. 22 (Pittsburgh: Engineering Society of Western Pennsylvania, 1907), 482.
[99] J.M. Camp and C.B. Francis, *The Making, Shaping, and Treating of Steel,* 4th ed. (Pittsburgh: Carnegie Steel Company, 1925), 97; Backert, *ABC of Iron and Steel,* 62.
[100] C.S. Finney and John Mitchell, "The Beehive Oven Era," in *History of the Coking Industry in the United States* (New York: American Institute of Mining, Metallurgical and Petroleum Engineers, 1961), 38; John Aubrey Enman, "The Relationship of Coal Mining and Coke Making to the Distribution of Population Agglomerations in the Connellsville (Pennsylvania) Beehive Coke Region," Ph.D. diss, University of Pittsburgh, 58; Fulton, "A Report on Methods of Coking," 63.

one inch.[101]

An article written in 1916 by Thomas Fear, Superintendent of TCI's Bayview Mine, gives a good idea of the difficulties inherent in mining such coal. Fear carefully described the seam that his miners faced each day:

> …this measure contains a slate parting 2 in. thick about 5 or 6 in. from the top and a second parting, or 'middleman' from 6 to 17 in. in thickness about 18 in. from the bottom. At a number of places there is a soft rash from 1 to 2 in. thick on top of the 'middleman.'[102]

A miner was required to follow a meticulous series of steps to remove the coal from such a seam. Beginning at the top of the seam, he dug the coal with a pick until he encountered the first layer of rash. He then removed the rash separately after which he drilled into the coal directly below the middleman, added very light charges of explosives, and blasted and removed the middleman. In the final step he removed and loaded the bottom layer of coal. The need to follow this laborious regiment in order to get clean coal delayed the transition to machine mining. According to Fear, mechanical cutting equipment would have yielded more coal but the increased cost of washing the extremely dirty product would have offset the increase in tonnage. Clearly the District faced a difficult trade-off that was directly traceable to the physical idiosyncrasies of its coal seams.[103]

Faults

It its layers of impurities slowed the tonnage of Warrior field coal that could be won by individual miners each day, countless geological faults forced engineers to lay out the mines in less efficient ways that slowed production even further. Faults split the geological strata of the Warrior coal field into massive plate-like fragments that were then pushed out of alignment by pressure on the earth's crust. While the Pratt Seam outcropped along a northeast-southwest axis at the edge of Jones Valley, it was split by many faults that ran perpendicular to the outcrop. The vertical displacement along these faults, known as "throw," varied from eight to 130 feet. Because of this extensive disturbance to the once intact coal measure, TCI's Pratt Mines of 1901 were not dealing with once wide, uninterrupted expanse of coal, like the Pittsburgh Seam, but with 19 narrow seams that dipped back to the northwest for several miles into the Warrior field.[104]

Faults restricted the layout of a mine's underground working. Turn-of-the-century coal mines usually employed the room-and-pillar method of mining, which required two principal types of access tunnels: the main haulage slope that extended into the coal seam on a perpendicular line to the outcrop, and headings. Ideally, the headings branched off the main slope at ninety degree angles, but they could follow any angle that provided optimal access to the coal seam. The coal was mined from rooms that branched off from the headings. Coal was collected from these

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[101] Crane, "The Pratt Coal Mines in Alabama," 178.
[102] Fear was describing the American Seam which was very similar to the Pratt. Thomas G. Fear, "Getting Clean Coal," *Coal Age* 10 (September 30, 1916), 541.
[103] Ibid, 542.
[104] Crane," The Pratt Coal Mines in Alabama," 177; Fies, "Coal Seams of Alabama," 478; Hall," The Coal That Underwrote Birmingham's Industrial Activity," 589.

rooms and taken, via the headings, to the main slope, where it was transported to the surface.

The production rate of a mine was proportional to the number and length of its headings. Numerous, short headings were less productive that fewer headings driven to an optimal length because the junction between the main slop and each heading usually served as a loading point were coal was transferred from the heading haulage to the main slope haulage. An excessive number of headings reduced the efficiency of the haulage system by complicating the movement of coal to the surface while simultaneously increasing the frequency of minor breakdowns and disruptions. At the same time, short headings played out more quickly causing a production slow down each time a new heading had to be opened. This problem was further amplified once machine mining began because, in addition to the usual work required to open the new heading, the mining machinery had to be broken down, moved, and set up again.

Mines in the Old Basin required a minimal number of headings because there were few faults in the Pittsburgh Seam. Fewer headings reduced the bottlenecks at the main slope and allowed miners to spend more time digging coal rather the relocating their mining rooms and equipment. TCI could employ relatively fewer long headings because the Pratt Seam was so faulted. Miners could extend their headings only a relatively short distance before the coal disappeared at a fault. They then were forced to choose between closing the heading and cutting an intermediate haulage slope up or down to the adjoining section of the Pratt Seam. In cases where the “throw” of the fault was minimal this was no major problem, but where it approached 130 feet, substantial intermediate hoisting equipment had to be installed.[105]

Whether to continue to work the Pratt Seam with a series of long narrow mines confined to single fault section, or to open new mines that worked several sections simultaneously, connecting each level to a main haulage slope via intermediate haulage slopes, was a crucial question for successive generations of TCI mining engineers.

Accommodating Faults at Pratt Number Three and Edgewater

The haulage systems designed for Pratt Number Three and Edgewater Mines by Erskine Ramsay and his success at TCI reveal a great deal about the nature of metallurgical coal mining in the Birmingham Industrial District. On the one hand, the successive designs of these haulage systems reflect the accommodations necessary to win coal from the difficult geological setting of the Pratt Seam. On the other hand, the innovativeness and relative efficiency of these designs show that engineers here were as adept as any in the country regardless of the amount of capital they had to work with.[106]

Ramsay’s endless rope replaced the original tail rope system at Pratt Number Three. Tail ropes, which were the most common haulage systems used in American slope mines, consisted of two ends of cable attached to a hoisting drum. One end of the cable pulled loaded coal cars to the surface, while the other returned empty care to the base of the slope. A steam engine powered the hoist, which raised the loaded cars while the empty ones rolled back down the slope by gravity. The endless-rope system did not employ a hoisting drum. It consisted of a very long wire rope

[105] Crane, “The Pratt Coal Mines in Alabama,” 178-180.
[106] Hutchings, “Alabama Coal Mining,” 254; “Endless Rope Haulage,” *Mines and Minerals* 21 (December, 1900), 220-221; Erskine Ramsay, “New Endless-Rope Haulage Plant,” *Mines and Minerals* 24 (December 1903), 236-237.

that extended 4,000 feet into the mine, looped around a large return sheave know as a bull wheel, and returned to the surface. The endless rope moved constantly at a slow speed. Loaded coal cards were positioned under the rope, where they were snagged by an overhead latching device and pulled to the surface. There they were detached from the cable, dumped, and returned to the mine in the same way that they had been brought to the surface. Such an arrangement was ideally suited to a long, narrow mine.[107]

Ramsay might well have chosen a tail-rope system, but for two reasons he resorted to the less common endless rope haulage. The first was a specific problem with the Pratt Seam in the vicinity of TCI's Pratt Mines. He described this problem in an article that appeared in the engineering journal, *Mines and Minerals*:

> …the slope opened on the outcrop of the coal and following it down; the grade of the outcrop, of about 15 degrees, flattened considerable, so much so that when the slope had reached a point about 1200 feet from the outcrop, the pitch had reduced to such an extent that the mine cars would no longer drop by gravity into the mines and pull the rope after them.[108]

The second was the shortage of capital available to TCI during its formative years. The endless rope system was not only efficient; it was also cheap.

Scots mining engineer Robert Hamilton who took over at about the time that TCI was brought out by U.S. Steel brought not only the advantage of a new infusion of capital but also a new generation of mining practice and concepts. The company closed some of the Pratt Mines and increased the size of others, giving TCI a more efficient operation in which a smaller number of mines produced more coal. Even so, Hamilton could not completely overcome the need to customize TCI's mines to compensate for the idiosyncrasies of the Pratt Seam. After Ramsay left TCI, the new engineer replaced the endless rope with a tail rope because electric haulage locomotives had become available that could more rapidly assemble coal from the headings to a common loading point at the base of the main haulage slope. The new Pratt system which was one of the first to be used south of the Ohio River, employed four 6-ton and two 10-ton Jeffrey mine locomotives to assemble much more coal in a day than could be hauled in mule drawn cars. With its tonnage increased from about 1,100 tons daily to 2,400 tons the new mine layout was productive enough to support a larger main hoisting engine and the heavy cost of preparing level and well graded haulageways throughout the mine.[109] The more expensive operation, installed in September, 1903, would seem to confirm the fact that capital, once scarce at TCI and elsewhere in the District, was now more readily available, but engineers could still not avoid the need for relatively long haulageways that remained a standard feature of the Warrior field until around the second decade of the 20th century.[110]

Whether to continue to work in the Pratt Seam with a series of long narrow slopes confined to single fault sections, or to open shaft mines that worked several sections simultaneously connecting each level to a main haulage slope view intermediate haulage slopes, was a crucial

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[107] Ramsay," The Pratt Mines and Coke Plant," 136; Hutchings, "Alabama Coal Mining," 254; Crane," The Pratt Coal Mines in Alabama," 177-180; Fear, "Getting Clean Coal," 541-542; Fies, "Coal Seams of Alabama," 473-477.
[108] Ramsay, "New Endless-Rope Haulage Plant," 236-237.
[109] Neil Hutchings, "Electrical and Steam Haulage," 168; C.B. Davis, "Electricity in Coal Mining," *Coal Age* 10 (October 14, 1916), 633.
[110] E.B. Wilson, "Slope Haulage in Alabama," *Coal Age* 10 (August 5, 1916), 221.

question for the next generations of TCI mining engineers. In 1912, Robert Hamilton designed the Edgewater Mine that became one of the first in the District to adopt this latter strategy. The new mine accessed three sections of the Pratt Seams. The first section lay only 275 feet below the surface but a fault had split away the second section and dropped it an additional 172 feet. The mine shaft descended downward parallel to the fault until it intersected the lower section of coal. A rock tunnel connected the upper section to the skip cars of the main hoist. An additional 56 feet of displacement separated one section of the lower layer of coal from the other, requiring an intermediate haulage slope to connect these two areas of the mine. An elaborate and well-coordinated haulage system was required to keep the mine working effectively and a large daily output, well in excess of the early slope mines, was required to make the operation cost effective. Edgewater's first year's output reached only 115,606 tons but by 1924 annual tonnage had increased to 1,159,400 tons.[111] If the Birmingham Industrial District was to continue to produce pig iron it would be forced to develop ever larger and more elaborate mines as the more accessible sections of the Pratt Seam were exhausted.

Drift Mining in the Birmingham Industrial District

Coal could be mined from many different geological settings, employing concepts appropriate to the terrain and adopting equipment and techniques most suitable to a given set of conditions. Pratt Number Three was a slope mine, meaning that its main opening dipped downward at an angle following the inclination of the coal seam. Edgewater was a shaft mine, meaning that its main entry was a vertical tunnel that descended down to a deeply buried coal seam. Not all sections of a coal seam spread across a wide geographic area are this difficult to access, however. At some places in the Warrior coal field the Pratt Seam was nearly flat and outcropped along the side of a hill.[112]

Mines that worked these flat coal seams from their outcrop were called drifts. At the turn of the century it would have been easy to distinguish a drift opening from a slope or shaft mine by the minimal surface plant surrounding the latter. Slope and shaft mines required hoisting engines, usually housed in substantially built structures, head frames, powerhouses where steam was generated and facilities and equipment. Drift mines did not require hoisting plants because their coal could be pulled to the surface by mule or, later, by an electric haulage locomotive. If the drift seam dipped slightly upward, loaded coal cars could even be allowed to roll to the surface by the force of gravity. A person could be reasonably certain that he was seeing a drift mine if he saw an emerging string of coal cars that were pulled by a mule or mine locomotive instead of bring impelled by a wire rope cable.[113]

The simplicity of drift mines compared to slope and shaft mines has led some observers to equate the former with more primitive mining practice.[114] In fact, drift mines could be large, heavily capitalized operations working broad, thick seams of coal such as the Sewell Seam in the New

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[111] Hamilton, "Edgewater Mine Produces Large Output,: 241-242, 245.
[112] A good primer on the general mining practices of the era is William Jasper Nichols, *The Story of American Coals* (New York: J.B. Lippincott Co., 1904).
[113] One of the most comprehensive discussions of the surface plants required to serve different types of coal seams is found in International Library of Technology, *Surface Arrangements at Bituminous Coal Mines* (Scranton, Pennsylvania: International Textbook Company, 1907).
[114] Nichols, *The Story of American Coals,* 136-141.

River Gorge of southern West Virginia. While minimal equipment was required to bring the coal to the surface, the underground works could be highly mechanized, employing the latest mining and loading equipment. The larger drifts of the New River Gorge and the Connellsville District were among the most completely mechanized, highest producing mines in the United States.[115]

Since their startup and operating costs were so low that they could yield a profit in a very short time, drifts could be opened in limited seams expected to play out quickly. Because they could be opened quickly and cheaply, they were usually the first to be exploited in a new coal field. In the Connellsville District, such operations were called "hill top mines" because they usually tapped a seam of coal that outcropped up the side of a hill.[116] The seam ran through the hill like icing in a cake, offering an easily determined total amount of coal that could be tapped quickly and marketed while more elaborate slope and shaft mines were being opened.

Sloss Drift Mines

At the turn of the twentieth century, Sloss-Sheffield operated more drift mines than any other iron company in the Birmingham Industrial District. In 1893, the company worked ten drift operations that averaged 74,000 tons annually. By 1901, the number of individual operations had fallen to eight, but their annual production had risen to 94,000 tons.[117] Their coal became particularly important to Sloss when production at its large slope mines at Coalburg began to wane. The drifts provided a cheap source of coal until Sloss-Sheffield could develop major slopes at Flat Top and Bessie, but by 1920, their coal reserves had been exhausted.

The drift mines in the vicinity of Brookside and Cardiff are significant because they not only illustrate the wide variety of mining concepts that were employed in the Birmingham Industrial District but also because the Brookside Mine in particular shows how expertly imported technicians could adapt practice and machinery to local conditions.[118]

Although they were managed by the same superintendent, the Brookside and Brazil Mines, which were located less than a half mile apart, were radically different types of operations. The Brazil Mines consisted of about twenty openings arrayed along a ravine that cut into a large hill. The mines on the eastern slope of the ravine were known as the East Brazil Mines, while those on the west side were called the West Brazil Mines. Coal was mined by pick and was hand-loaded in the traditional manner. It was brought to the surface at the various openings, and sent down the ravine to railroad cars. The mines were ventilated by furnaces, an ancient but efficient system in small mining operations that did not have complicated underground workings. In 1893, 175 miners worked the Brazil drifts, producing a total of 81,000 tons in 184 working days, or a rough average of about 2.51 tons per day per miner. Operating costs were held to an absolute minimum because there was virtually no surface plant to be maintained and the mine could

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[115] Schellenberg, "Our Coal," 483-484; Bergstresser, "Kay Moor Coal Mine," 3-5.
[116] Enman, "Coal Mining and Coke Making in the Connellsville Beehive Coke Region," 73, 75.
[117] The comparative statistical data in the following paragraphs are taken from a data file compiled from the Alabama State Mine Inspector's reports from the years from 1893 to 1950. For more information on the Coalburg operation see "Coalburg Mines of the Sloss Iron and Steel Company," 153; "Coke-Making by the Sloss Iron and Steel Company," 271; "Pennsylvania Miner's Impressions of Alabama," 281-282.
[118] For an overview of the remarkable variety of mining methods employed in Alabama in response to the variability of its coal seams, see Milton Fies, "Alabama Coal Mining Methods Vary Widely," *Coal Age* 26 (October 9, 1924), 509-512 and "Details of Actual Mining in Alabama Coal Beds," *Coal Age* 26 (October 16, 1924), 537-540.

easily be shut down and reopened as demand warranted.[119]

In stark contrast, Brookside was a fully mechanized operation that included a large tipple, a powerhouse, a coal washing plant, and a battery of 100 beehive coke ovens. The underground workings were as mechanized as those at any mine in the United States. In an era when most coal mines in the country still employed mules to pull coal cars to the surface, Brookside use a locomotive powered by compressed air. Built by the H.K Porter Company of Pittsburgh, the “mole engine” pulled eighteen to twenty cars per trip. Instead of traditional pick mining, which still predominated throughout the country, coal cutting was done by air-powered Ingersoll-Sargent coal cutting machines. The Ingersoll-Sargent “puncher” was one of the earliest and best mining machines available. It was so named because its pick-like cutting head reciprocated back and forth in the coal seam like a jackhammer. The mine was ventilated by a Crawford and McCrimmen fan with a twelve foot diameter.

The surface plant that provided the power for machine mining at Brookside was equally impressive; a well-equipped powerhouse including at least one steam engine, air compressors and other equipment would have been necessary for such operations as these. The coal preparation plant included a Robinson-Ramsay coal washer, and English design imported into the United States and adapted to the coal deposits of the Birmingham Industrial District by Erskine Ramsay. All told, Brookside would have compared favorably with any mechanized drift mine in the United States. It was the epitome of the most modern “hill top mine” of the Connellsville region, and its capital-intensive features contrasted with labor-intensive mines at the nearby Brazil drifts. In 1893, the seventy-five miners at Brookside produced 60,150 tons in 237 working days for a rough average of about 3.38 tons per man per day. This daily per miner production was almost 75 percent greater than output at the Brazil Mines.[120]

The Brookside Mine provides an example of the way in which a series of highly localized characteristics of the Pratt Seam combined to dictate specific mining applications. The amount of coal available in the Pratt Seam, as it lay enclosed like a layer of icing in a cake at the base of the hill at Brookside, was sufficient to justify the use of mechanical coal cutters. The quantity of coal available, requiring twenty or thirty years to extract, justified the use of expensive equipment that could be amortized over a long period of time. The nature of the mine itself in fact, required such equipment; a thin layer of fire clay at the base of the coal seam was a tough, sticky material that was very difficult to remove with a hand pick. At the same time, the coal immediately above the

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[119] James D. Hillhouse, “Table Showing Location, Character and Product of Alabama Coal Mines and Coke Works for Calendar Year, 1893,” (Birmingham, Alabama: Dispatch Printing, 1894); Alabama, *First Biennial Report of the Inspector of Mines, 1898,* 15. For a discussion of the advantages of such small drift mines, see Nichols, *The Story of American Coals,* 136-141.

[120] Alabama, *First Biennial Report of the Inspector of Mines, 1896,* 11-12; Alabama, *Second Biennial Report of the Inspector of Mines, 1898,* 14; Hillhouse, “Table Showing Location, Character and Product of Alabama Coal Mines and Coke Works for Calendar Year, 1893.” For a discussion of the introduction of machine mining and its impact on traditional work relations see Keith Dix, *Work Relations in the Coal Industry: The Hand Loading Era, 1880-1930* (Morgantown, West Virginia: Institute of Labor Studies, West Virginia University, 1977). According to Dix, the first machine mining in American was conducted in 1876, but by 1900 only one-fourth of the bituminous coal output of the United States was machine-mined. Not until 1930 had the industry “practically speaking, full mechanized the undercutting operation.” Dix, *Work Relations in the Coal Industry,* 21. For a recent account of the Brookside Mine and its Robinson-Ramsay coal washing plant, see Lewis Shannon, “Report on the Brookside Coal Main and Bee Hive Coke Oven Site” (unpublished research report, Washington, D.C.: National Park Service, Historic American Engineering Record, 1992).

fire clay was imbedded with pyrite fragments that resisted the saw-like action of chain-driven coal cutting machines. A coal seam with these characteristics was ideally suited for coal punchers.[121] Because these punchers required compressed air, steam engines and air compressors were required. In view of the fact that compressed air would be available if the punchers were employed, it also made sense to install compressed air haulage locomotives, which were not only efficient but also guaranteed that optimal use would be made of the mine's power plant. The Brookside Mine may have been ahead of its time in the Birmingham Industrial District if not in most mining regions, but local conditions combined to make it a very rational operation.

It is clear from the Brookside example, as well as that of the Pratt Number Three that the mining engineers of the Birmingham Industrial District were capable of employing innovative practice when conditions warranted. The fact remained, however, that the mines of the Birmingham Industrial District were not as productive as those in other regions. Their per-miner tonnage rates were below the national average. Furthermore, despite the use of Ingersoll-Sargent machines at Brookside, the District as a whole was slower than other American coal regions to adopt machine mining practice. In 1913, for example, only 23 percent of Alabama coal was cut by machine compared to the national total of 51 percent. The reason lay in the peculiar characteristics of the coal seams located in the Warrior field rather than unwillingness or inability to adopt the latest practice.[122]

Praco vs. Banner: Preindustrial Ethos or Capitalist Profit Motive?

A comparison between the Banner and the Praco Mines provide an excellent opportunity for establishing the true nature of convict leasing. That is: was the practice devised by the ruling elite for the purpose of retaining the racial status quo of a preindustrial, antebellum South or was it the tool of a new generation of capitalist entrepreneurs. These two particular mines are well suited for such a comparison because Banner employed convicts while Praco was worked by mostly white, free miners. Bother operations were supervised by Erskine Ramsay who, after leaving TCI, joined with several associates to form the Pratt Consolidated Coal Company which was, for several years after its founding in 1902, the largest independent metallurgical coal producer in the Birmingham Industrial District. The enterprise grew even larger when it merged with the Alabama By Products Corporation in 1924 after which most of its mines assumed the role of captive mines supplying coking coal to the company's by-product coke plant at Tarrant City.[123]

The organization of work at the two mines as well as the way in which their output was tied into the company's marketing strategy serves as a major caveat to the tendency to assume that the character of coal mining in the Birmingham Industrial District was somehow hampered by a racist, antiquated, prebourgeois ethos that favored labor intensive practice as a means of social control while failing to grasp the advantages of such modern industrial concepts as

[121] Atkinson, "Coal Cutting Machinery," 1-4; "Coal Cutting Machines," *Mines and Minerals* 18 (January 1898): 273-274; "Mining Machinery," *Colliery Engineer and Metal Miner* 18 (August, 1897); 38-39; G.E. Lynch, "Power for Coal Mining Machinery," *Mines and Minerals* 25 (June 1905), 541-542; J.H. Scurfield, "Suggestions on Thin-Vein Mining," *Coal and Coke Operator* 8 (February 1909), 121-122.
[122] Chapman, *Iron and Steel Industries in the South,* 178.
[123] W.C. Chase and M.E. Haworth, "Quality and Efficiency Provided by Praco Preparation Plant," *Coal Age* 49 (1944), 72.

mechanization and skilled labor. To begin with, Praco, which employed free miners, was the most labor intensive of the two operations and by far the least capitalized. Ramsay's intent when he opened Praco in 1907 was to create an operation that would produce maximum profits for a minimum investment. The series of small hillside drifts that comprised the works was more like the company's other small operations such as Arcadia, Crocker, Jett and New Pratt. In these small openings free miners cut and loaded the coal by hand.[124] Since they were driven into a flat or slightly upward sloping seam of coal at its outcrop along the side of a hill, these drifts required virtually no mechanical power for haulage or water removal. Loaded cars could often be rolled from the working face of the coal seam to the surface by gravity, while any water that might be present could simply run out of the mine under its own power. The most expensive structure required was a simple wooden loading tipple.

By stark contrast the Banner operation, worked by convict labor, was a shaft mine. Because of the head frame, large hoisting engine and other equipment required to raise coal up their vertical access tunnels, shafts were the most heavily capitalized of all coal mines. Considered to be the company's "prize mine," Banner was one of the first in the district to install electric haulage, electric coal cutting, and electric lighting.[125] It also featured Ramsay's patented revolving dump, later adopted by leading companies such as the H.C. Frick Coke Company in the Connellsville District of western Pennsylvania.[126]

This paradoxical blend of mining operations; one featuring state of the art mechanization and unskilled, coerced black labor, and the other featuring skilled, free white miners employing labor intensive practices, would seem to be much more a case of shrewd business management than evidence of a lingering, preindustrial ethos. In terms of modern capitalistic profit motive that characterized American coal mining, it made perfect sense.

The Banner Mine was the flagship operation of the Pratt Consolidated Coal Company. A shutdown of its deep, expansive underground works, elaborate haulage and hoisting system, and substantial surface plant could be a costly affair. By employing convict labor, Ramsay not only avoided the problems associated with unscheduled work stoppages, but his company also could continue to produce and sell coal while competitors were embroiled in strikes. The fact that convicts were unskilled was no problem since the coal was cut and hauled mechanically. The inmates need merely to load the coal, a task that ironically, would be replaced by mechanical loaders at about the time convict leasing was abolished in Alabama in 1928. At the same time the low-cost drift mines could easily shut down and their free miners could be laid off and left to their own devices during periods of low demand, then brought back to work when market conditions improved.

CONCLUSIONS

Mine operators in the Birmingham Industrial District faced a difficult challenge in adapting to

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[124] Alabama, *Report of the Inspector of Alabama Coal Mines, Showing the Location of Mines, Character, Production, Employees, etc., for the Year 1907,* J.M. Gray, Chief Mine Inspector (Birmingham, Ala.: Birmingham Engineering Company, 1908), 16, 21.
[125] Armes, *Coal and Iron in Alabama*, 494.
[126] Jack R. Bergstresser, Sr., "Raw Material Constraints and Technological Options in the Furnaces and Mines of the Birmingham District: 1876-1930," (Ph.D. diss., Auburn University, Auburn, Alabama, 1993), 53.

the marginal seams of the Warrior field. They were aware of, and capable of, choosing the latest technology but often new developments could not be quickly and cheaply applied to the Pratt and Mary Lee Seams. For every example such as Brookside, where state-of-the-art applications could be adopted with relative ease, there were other cases such as Edgewater where a very expensive underground layout was required to overcome the faults in the Pratt Seam. Even when operated with optimal efficiency the mine's elaborate haulage and hoisting system would never be as cost effective as one that worked a more forgiving coal seam. Furthermore, even the most conscientious miner could extract only so much clean coal in a day's time when it had to be meticulously extracted from layers of rock and other impurities.

These factors combined to raise the cost of coal mining in the Birmingham Industrial District. Convict leasing could partially offset this cost but eventually the price of employing these coerced workers became as high as troublesome, strike-prone free miners. In the end their main contribution was in allowing operators to delay creating an equitable bargaining process with their workforce. So even though the Pratt Seam was located literally at the back door of their furnaces, local iron makers still produced some of most expensive metallurgical coal in the United States.

Ironically, the seemingly minor fact that Connellsville coal broke down into small cubes while it was being mined and loaded serves in microcosm to epitomize the paradox of metallurgical coal mining in the Birmingham Industrial District. Such cubes were not only more easily loaded, they were also the perfect size for coking. By contrast, the coal of the Warrior field had to be crushed to slack then washed before coking. This need for this additional task meant that more crushers and washers had to be installed at a typical mining operation. Steam power above and beyond that normally required for hoisting was therefore needed. The national Census of Manufacturing for 1910 revealed the consequences and its ultimate irony; the smaller, less productive, more labor intensive mines of the Birmingham Industrial District had more steam power available per miner than those of any other coal mining region.[127]

In 1866, in one of the first extensive discussions of coal mining in the United States up to that time, Samuel Daddow wrote:

> Ignorance may import coolies or buy or breed the negro slave, but intelligence will build the steam engine…The slaves of the South brought poverty, waste, war, and desolation, and never did, and never could have made their masters powerful, influential, and wealthy. They were an element of weakness,---a relic of the barbarous past.[128]

Little did the Pennsylvania mining engineer know that within a few decades intelligent Pennsylvania miners along with Southern entrepreneurs would combine both the steam engine that symbolized northern mechanical prowess, with a modified version of slavery, in the form of convict leasing, to create the largest metallurgical coal mining district outside their own home state. And the motivation for creating this strange, hybrid combination of mechanical power and labor intensity was less a desire to retain a prebourgeois ethos than a purely rational, capitalistic

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[127] U.S. Department of Commerce, Bureau of the Census, *Mines and Quarries,* Thirteenth Census of the United States, vol. 11 (Washington, D.C.: GPO, 1913), 197, 225.

[128] Samuel Harries Daddow, *Coal, Iron, and Oil: Ore the Practical American Miner. A Plain and Popular Work on Our Mines and Mineral Resources, and Text-Book or Guide to Their Economical Development* (Pottsville, Penna.: B. Banner, 1866; Philadelphia: J.B. Lippincott & Co., 1866), 582.

effort to use any means available to wrest maximum profits from a flawed raw material endowment.

AN ALTERNATIVE MODEL OF PIG IRON PRODUCER: THE MERCHANT FOUNDRY IRON BLAST FURNACE OF THE BIRMINGHAM INSUTRIAL DISTRICT: 1876-1930

INTRODUCTION

The coming of the "second industrial revolution" in the United States and the accompanying rise of Pittsburgh, Chicago, and other centers of steel production are reasonable well established facts. Less publicized is the fact that this unprecedented burst of growth was accompanied to a shift to coke-fueled blast furnaces as the principle producers of pig iron; the raw material from which steel is made. The incredible tonnage records achieved during the 1870s at Pittsburgh's Lucy and Isabella furnaces first drew widespread attention to the remarkable productivity achievable in furnaces fueled by the superior coke made from Connellsville coal and operated according to new techniques known as "hard driving." Spurred by the example, American operators rushed to build ever larger blast furnaces capable of exceptional economies of scale which, in turn, facilitated the rapid growth of the iron and steel industry based upon large-batch steelmaking in Bessemer convertors and open hearth furnaces. Newly constructed coke blast furnaces with their large and imposing silhouettes became one of the more noticeable features in the skylines of growing industrial centers.

The mineral region of central Alabama is an excellent example of this phenomenon. During the last two decades of the 19th century, ironmakers built more new blast furnaces in the Birmingham Industrial District than anywhere else but Pittsburgh. By 1880, as historian William Hogan put it, Alabama had become "a new addition to the top ranks of the iron producing states." In 1890, its 45 blast furnaces ranked the state third in the nation behind Pennsylvania with 148 and Ohio with 53.[129]

But the blast furnaces of the Birmingham Industrial District were unique. While the American industry in general pursued a goal of ever larger, hard drive, furnaces producing iron exclusively for steel mills, a group of leading iron making concerns in the Birmingham Industrial District chose to strike out upon a divergent technological path.[130] They launched a decades-long effort, symbolically climaxed in the late 1920s by the construction of the Sloss City Furnaces, to perfect an alternative model of pig iron producer; a smaller furnace, with a correspondingly smaller scale of operations, which smelted a product specially formulated for foundry rather than steel mill use. Typical blast furnaces, including those in the District at Ensley and Fairfield, were integral components of the steel mills which they served. In these operations, blast furnaces and steel furnaces were positioned as close together as possible so that pig iron smelted in the former could be transferred while still molten, and immediately converted into steel in the latter.

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[129] William T. Hogan, Economic History of the Iron and Steel Industry in the United States, Col. 1, Part 2 (Lexington, Massachusetts: D.C. Heath and Company, 1971), 212-212. Iron Age 42 (November 1888): 712. The 1901 Directory of the Iron and Steel Works of the United States, published annually by the American Iron and Steel Association, Philadelphia, indicates that no American blast furnace District other than Pittsburgh constructed more new furnaces during the 1880s and 1890s that did the Birmingham Industrial District.

[130] While the merchant blast furnace industry of the Birmingham Industrial District as a whole has not been written off previously, two works which have focused upon the history of the Sloss Furnaces are: Gary Kulick, "Sloss-Sheffield Steel & Iron," Historic American Engineering Record Report (HAER AL-3), Washington, D.C.: U.S. Department of the Interior, National Park Service, 1976, and W. David Lewis, Sloss Furnaces and the Rise of the Birmingham District: An Industrial Epic, (Tuscaloosa, Ala.: University of Alabama Press, 1994).

Birmingham's foundry iron furnaces were not components of steel mills and were not owned by steel companies. They were stand-alone plants known as merchant furnaces because they produced pig iron for sale by the railroad car load on the open market.[131]

The decision to specialize in a product other than steel proved to be a wise one that resulted in the District growing into the nation's largest center of foundry iron production. In 1915, Alabama's 1.2 million tons of foundry iron amounted to one-fourth of the national total of 4.8 million tons. Over the years, as the blast furnace industry of the state became more and more concentrated around the cities of Birmingham and Bessemer, its share of the foundry iron market grew. By 1940, Alabama annually produced more than 40 percent of the national total[132]

This cheap, abundant supply of foundry iron quickly attracted the attention of cast iron pipe manufacturers who soon began to build their largest and most modern plant in the Birmingham Industrial District. These new installations were some of the country's first large, rationally organized mills featuring the first U.S. applications of the centrifugal process for making cast iron pipe, which consisted of pouring molten iron into a spinning mold.[133]

Now that it possessed not only the foundry iron blast furnaces capable of converting raw iron ore and fuel into pig iron, but also the pipe mills where this intermediate product could be processed into a finished item, the District had matured into a region bearing a close resemblance and similar economic dynamics to the centers of integrated steel production. Although the merchant blast furnaces and the cast iron pipe companies did not begin to consolidate into integrated ownership until the 1950s, their productivity combined with the United States Steel Corporation's operations at Ensley and Fairfield to sustain a growth rate more similar to other major industrial centers than to the largely agrarian southeast in which the mineral region was located. Studies of the southern iron and steel industry by Hollis Chapman, and of the by-product

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[131] The most comprehensive discussion of the concept of a merchant blast furnace is woven into Labor Productivity in the Merchant Blast Furnace Industry, Department of Labor, Bureau of Labor Statistics, Bulletin No. 474 (Washington, D.C.: GPO, 1929), passim. Unfortunately, this account attempts to explain why the merchant blast furnace industry of the United States was in decline at the time and fails to recognize that developments in the Birmingham Industrial District were running counter to this trend. By subsuming data regarding the District within larger statistical summaries of regional and national patterns, the report fails to identify those factors stimulating the growth of the Alabama industry at a time when the industry in general was in decline.

[132] American Iron and Steel Institute, Annual Statistical Report of the American Iron and Steel Institute for 1916 (New York: The American Iron and Steel Institute, 1917), 8; Woodward Iron Company, Alabama Blast Furnaces (Woodward, Ala.: Woodward Iron Company, 1940), 32; J.R. Thoenen and Avery H. Reed, The Future of Birmingham Red Iron Ore, Jefferson County, Ala., U.S. Department of the Interior, Bureau of Mines, Report of Investigations 4988 (Washington, D.C.: GPO, 1953), 48.

[133] There are a number of brief discussions of the cast iron pipe industry in the Birmingham Industrial District, but no comprehensive account yet exists. The best account covering a long time span is Rupert Hicks, The Iron and Steel Industry in Alabama, Alabama Department of Industrial Relations (Montgomery: Dept. of Industrial Relations, 1950). A more technical account is provided by Richard Moldenke in "Cast Iron Pipe Manufacture in the South," Iron Age (September 1924), 687-698. A detailed description of one company's operation is found in United States Pipe's Integrated Operations (Birmingham: United States Pipe and Foundry Co., 1956). For accounts of the technical achievements and historical milestones, see the following brief descriptions: Y.A. Dyer, "Cast Iron Pipe Manufacture in the South," Iron Age 98 (November 1916): 1159-1162; Victor S. Clark, History of Manufactures in the United States Vol. 2, 1869-1893 (New York: McGraw Hill, 1929), 345-348; William Davis Moore, Development of the Cast Iron Pressure Pipe Industry in the Southern States 1800-1939, New Comen Society, American Branch (Birmingham, Alabama: Birmingham Publishing Co., 1939), and Henry Nobel, History of the Cast Iron Pressure Pipe Industry in the United States of America (Birmingham, Alabama: Newcomen Society, 1940).

coke industry of Alabama by Mable Mills show that the Birmingham Industrial District usually equaled and, and perhaps exceeded the national average growth rate, throughout the American era of coke blast furnaces.[134]

Until fairly recently, historical studies have tended to overlook this relatively impressive achievement. The findings of Mills and Chapman were generally unappreciated by writers who, because of two broad biases, were predisposed to assume that the industrial character of the District must have been predisposed to assume that the industrial character of the District must have been comparatively underdeveloped and technologically backward. The first of these biases was perpetuated by students of Southern history who, knowing of the South's antebellum heritage of slavery and a preoccupation with cotton culture, as well as the devastation of the Civil War and subsequent decades of extreme rural poverty, were willing to accept as *prima facie* the notion that industrialization in the region would be inherently inept and undercapitalized.

The second bias derives from historians of the business and economic history of the United States who, as John Ingham has recently pointed out, have tended to equate successful industrial enterprises with "capital-intensive center firms that benefited from economies of scale and were technologically sophisticated." Ingham goes on to state that this bias fostered the notion that "the center firms were progressive and their development was inevitable—all part of a continuing process of industrialization. Small business, on the other hand, was a relic of a premodern, anachronistic past."[135]

If the American steel industry has traditionally been considered to exemplify the essence of capital-intensity and technological sophistication, the massive corporation built by Andrew Carnegie and his associates, represent the quintessential center firm. Since steel production had been considered a primary indicator of success, studies of the industrial development of the Birmingham Industrial District have focused on its early efforts to manufacture this important commodity. The success of these efforts have been judges marginal at best because the principal steel company involved, the Tennessee Coal, Iron and Railroad Company (TCI) did not grow to rival Carnegie's empire, but was later absorbed by that magnet's successor company the United States Steel Corporation. Reasons posited for this presumed failure, have generally been linked, more or less directly, to the economic, social and cultural traditions of the South. Racism, poverty, regional isolation, and a cultural ethos inconducive to industrial development have supposedly played a part in relegating the District to the status of peripheral underdevelopment.

The perception of underdevelopment has obscured the national ascendency of Birmingham's merchant furnaces and pipe mills around the turn of the 20th-century and their persistence throughout the era of American coke-fueled iron smelting, a tenure during which the two symbiotic enterprises commanded a greater share of the national market for foundry iron and cast iron pipe than did Pittsburgh for steel. It has also encouraged many observers to assume that the District lacked technological expertise, and was, in fact, technologically backward. One recent economic study even concluded that since a well-established technical community was

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[134] Mabel D. Mills, Coke Industry of Alabama (University, Alabama: Bureau of Business Research, 1974), 20; Herman Hollis Chapman, The Iron and Steel Industries of the South (Tuscaloosa, Ala.: University of Alabama Press, 1953), 111-139 passim.
[135] John N. Ingham, Making Iron and Steel: Independent Mills in Pittsburgh, 1880-1920 (Columbus, Ohio: Ohio State University Press, 1991), 3.

presumably a prerequisite for industrial development:

> …the South lacked a strong indigenous technological tradition and a 'southern' technical community developing an advanced southern version of new innovations…it was not in a position to make use of the best products emerging from the American machine-tools industry.[136]

Since very little work has in fact focused specifically upon technological features of Southern industrial development it is perhaps better to take this statement as a working hypothesis rather than an established fact. And because of their outstanding record of survivability, the blast furnace plants that were the underpinnings of the foundry iron and pipe making industries of the Birmingham Industrial District provide an excellent case study for evaluating such a hypothesis.

Studies of capital availability and market growth, the origin and nature of the District's labor force, management structure and entrepreneurialism all can illuminate the subject, in fact, it was Gary Kulick's study of the influence of black worker migration and the persistence of labor-intensive sand casting and the Sloss City Furnaces that provided the first acknowledgement that modern, capital intensive practice was also a factor in the District's history.[137] But a focus on specifically on the technological aspects provides the clearest perspectives for understanding the birth and growth of foundry iron blast furnaces. This focus should not be narrowed simply to technicians and machines however, it must also consider technology transferred across national and regional boundaries, particularly diffusion on the intellectual level including the organizational concepts and adaptive strategies that had deep historical roots in the collective knowledge of the iron industry. And it must be considered in its proper context, in terms of the dialectic that occurred between the ideas and machines of the ironmakers and the defining characteristics of mineral resources with which they worked.

There was one outstanding advantage of this raw material endowment; all the ingredients—iron ore, coal and fluxing stone—required to smelt pig iron lay within extremely close proximity to one another.[138] Fluxing stone, both limestone and dolomite, outcropped on the surface of the anticlinal Jones Valley extended through the center of the District. Red hematite outcropped along the slopes and crest of Red Mountain that flaked the valley's southeastern edge. Metallurgical coal outcropped from the Pratt, Mary Lee and other seams that formed the Warrior Coal field which bordered the northwestern edge of the valley. Scattered but reasonably accessible pockets of excellent brown hematite, comprising the largest such concentration in the United States, were spread across central and northern portions of the state. In the narrowest section of the Jones Valley Red Mountain ore, fluxing stone and coal lay within ten miles of one another. This advantage quickly drew the attention of ironmakers and spurred the rapid birth of the District during the last three decades of the 19th-century. It facilitated the formation of efficient, vertically integrated companies capable of very tight control over the extraction and assembly of raw materials and their timely processing into saleable pig iron.

Hidden at first, were numerous paradoxes inherent in these closely juxtaposed minerals that

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[136] Gavin Wright, Old South, New South (New York: Basic Books, Inc., 1986), 79.
[137] Kulick, "The Sloss Furnace Company," passim.
[138] Countless sources refer to the close proximity of raw materials in the District, but perhaps the most convincing account is found in the report of a geologist who actually surveyed these mineral resources. See Henry McCalley, Report on the Valley Regions of Alabama, Special Report No. 8, Part 1, Geological Survey of Alabama (Montgomery: Roemer Co., 1897), 381.

ultimately proved just as decisive as their near proximity in defining the character of the industry.[139] The ore of Red Mountain sometimes contained a sufficient percentage of calcium carbonate to be self-fluxing but it was hard, low in metallic iron, and it required more fuel to smelt it properly. While difficult to convert into pig iron suitable for steel making, it made excellent foundry iron, especially when mixed with judicious amounts of brown ore. The coal of the Warrior coal field required expensive processing before it could yield a suitable coke but it still was inherently softer and less porous than might be desired. Softer, less porous coke would only work well in smaller furnaces. Fortunately, the best foundry iron was produced in smaller batches. The geology of the ore and coal seams proved to be very challenging and capable of decisively limiting the amount of raw materials that could be brought to the surface on a given day. But the lower capacity furnaces required to produce foundry iron from hard ore and soft coke harmonized well with the necessarily lower productive capacity of the mines.

The District was never technologically backward because of its resident practitioners and entrepreneurs were capable, from the very beginning, of attracting manpower, machinery and ideas from such centers of technological innovation as England, eastern Pennsylvania, and the Pittsburgh District. This exchange enable the District not only to perfect a successful alternative model of vertically integrated iron making operation specializing in a grade of pig iron in high demand but also to gradually bring the entire productive apparatus of the companies that survived this adaptive process; the Woodward Iron Company, Sloss Furnaces and the Thomas Works, into harmony with the carrying capacity of their mineral holdings.

The technology of these companies, and by extension the entire industrial district, should be analyzed in terms of the dynamics and internal logic of this unique evolutionary cycle. The equation of capital-intensity, economies of scale, and technological sophistication that defined the steel mill blast furnaces provides an excellent contrast for telling this story.

The following essay is divided into three parts. The first deals with the origins and sources of the technological exchange. This process included much more than the migration of technicians and the purchase of "the best products emerging from the American machine-tools industry."[140] It also included the importation of pre-packaged fully-equipped, blast furnace plants. Most decisively, however, it included the transplantation of complete models of successful ironmaking operations that arrived with the Woodward Iron Company of Wheeling, West Virginia and the legendary Thomas family of Hokendoqua, Pennsylvania transferred entire wings of their operations to the Birmingham Industrial District. At the risk of some oversimplification, it can be asserted that these companies together taught the District the advantages of specializing in foundry iron production while Woodward taught it the more subtle aspects of the seemingly simple concept of vertical integration. The second part of the essay discusses the ways in which some of the more obvious idiosyncrasies of the District's mineral resources which encouraged ironmakers to build smaller furnaces best suited for producing pig iron for foundry use. The final section presents selected events in the historical development of iron making in the District

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[139] While there are numerous accounts of a multitude of problems with Birmingham raw materials, a few good summaries are R.E. Garret, "Raw Material Problems in Birmingham," in Yearbook of the American Iron and Steel Institute, 1948 (New York: American Iron and Steel Institute, 1948), 208-216; Chapman, Iron and Steel Industries of the South, passim; W.E. Curran, "Trend of the Southern Pig Iron Business," in TAIMME, 1938 Vol. 131 (New York: American Institute of Mining and Metallurgical Engineers, 1938), 37-43.
[140] Citation omitted from original report.

compared to similar occurrences in Pittsburgh. The purpose for this comparative perspective is to show how differing experiences with raw materials facilitated the development of large steel mill furnaces in Pittsburgh while encouraging foundry iron production in Birmingham.

THE TECHNOLOGICAL EXCHANGE

Alabama had a technical community that arrived with its first settlers and continued to grow as the state's economy developed. Cedar Creek Furnace in Franklin County, which was the state's first blast furnace when it was built in 1819, provides an early example of the nature of this technical community and the way in which it shaped Alabama's industrial development. Alabama's pioneer industrial historian, Ethel M. Armes, states that, after a few years of unsuccessful performance, Cedar Creek Furnace was sold to Dr. Robert Napier of Tennessee. According to Armes, Napier was associated with two other men, whom she identifies only as Chandler and Peel. Under the new management, "capital was put into the enterprise, improvements followed, and pronounced period of commercial success began."[141]

A clue to the identity of Chandler and Peel is found in a Pennsylvania Geological Survey report that was subsequently published in 1877. It describes the activities of the Oliphant brothers, who owned an innovative furnace company located on the Youghiogheny River, six miles below Connellsville, Pennsylvania. Among Oliphants' many achievements was an early successful attempt, in 1836, to smelt pig iron using coke for fuel.[142] Referring to what must have been the Cedar Creek Furnace in Alabama, the 1877 report makes a revealing statement:

> In 1825, Mr. F.H. Oliphant conceived that the furnace gases might be utilized and, in that year, he advised a firm who were about to build a furnace in Alabama, that the boiler should be placed on top of the stack. The experiment was tried and proved thoroughly successful…[143]

An isolated blast furnace in Alabama was thus among the nation's first to experiment successfully with techniques for using waste furnace gases. The intent here is not to establish a list of technological firsts, but to show that, early in Alabama's industrial history, a working partnership between northern and southern entrepreneurs had already begun to bring the latest technology to bear upon the state's mineral resources.

Interregional cooperation leading to increasingly modern practice continued to occur throughout the history of the Birmingham Industrial District. The Alabama Coal Mining Company, an important enterprise established during the late antebellum period, is a case in point. This firm opened the state's first steam-powered coal mine in the Cahaba Coal Field near Montevallo. Its first two presidents, Daniel Watrous and John Storrs, were both northerners. The steam engine that powered the hoisting engine at their shaft mine was purchased at a company in Wilkes Barre, Pennsylvania. John Hart, the stonemason who laid the foundation for the steam engine, was and Englishman, as was Joseph Squire, a mining engineer who supervised the underground

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[141] Ethel M. Armes, The Story of Coal and Iron in Alabama, facsimile ed. (Leeds, Ala.: Beechwood Books, 1987), 31.

[142] J.J. Stevenson, Second Report on Fayette and Westmoreland Counties, Second Geological Survey of Pennsylvania, 1876, Bulletin KKK (Harrisburg, Pa.: Board of Commissioners, 1878), 212; James M. Swank, Introduction to a History of Iron Making and Coal Mining in Pennsylvania (Philadelphia: James M. Swank, 1878), 71.

[143] J.J. Stevenson, Second Report on Fayette and Westmoreland Counties, 212-212.

operations. The Alabama Coal Mining Company did not survive the Civil War, but many of the technicians who worked there, including Joseph Squire and Billy Could, went on to play important roles in establishing coal-mining ventures that fueled the postwar coke furnaces of the Birmingham Industrial District.[144]

By the time that the blast furnace building boom began in Birmingham in the 1880s, the channels of communication and technological exchange across regional boundaries were already in place. The District may have lacked a tradition of independent invention and an indigenous machine tools industry, but this would prove no serious barrier to timely development. The recent linkage of northern and southern railroads following Reconstruction plus the proliferation of professional trade associations that maintained nationally circulating journals would further facilitate the process of technological diffusion.

Pittsburgh's Contribution

Pittsburgh became Birmingham's main source of ideas, manpower, and machines. The Pennsylvania city was best able to serve this function because its unique mechanical tradition had fostered the growth of capital equipment producers ideally qualified to serve the needs of the entire American coke blast furnace industry. One such supplier of the latest in industrial equipment was the MacKintosh-Hemphill Company. "Mack-Hemp," as the company called itself, traced its origins back to the first foundry in Pittsburgh, which eventually began to manufacture rolls for iron-rolling mills. By the 1880s, the company started to offer package deals consisting of complete rolling mill plants as well as the steam engines that powered them. So important was its role as supplier, technical advisor, and builder to the likes of Andrew Carnegie and Henry Clay Frick that the latter once asserted that MacKintosh-Hemphill built Pittsburgh.[145] Among the leading items in Mack-Hemp's product line was the most crucial class of devices associated with the introduction and development of hard driving practice: the large, powerful blowing engines that provided a furnace's air blast. The blast furnaces at the Lucy and Edgar Thomson Works which were instrumental in the development of hard driving furnace practice, were blown by MacKintosh-Hamphill engines.[146]

Birmingham's experience with the blowing engines manufactured by Mack-Hemp and its principal rival the Mesta Machine Company is one of the better examples of how easily the District availed itself of Pittsburgh's mechanical expertise. As will be shown, several of

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[144] Howard N. Eavenson, <u>The First Century and a Quarter of the American Coal Industry</u> (Pittsburgh: privately printed, 1942), 293-296; Truman H. Aldrich, "Historical Account of Coal Mining Operations in Alabama Since 1853," in <u>Report of Progress for 1875</u>, by Eugene A. Smith, Geological Survey of Alabama (Montgomery, Ala.. W.W. Screws, 1876), 28-32; Michael Tuomey, "To Col. Watrous, President of the Alabama Coal Mining Co.," in ibid, 205-212; Joseph Squire, <u>Report on the Cahaba Coal Field</u>, Geological Survey of Alabama (Montgomery, Ala.: Brown Printing Co., 1890), 95-102; Armes, <u>Coal and Iron in Alabama</u>, 69-155 passim.
[145] MacKintosh-Hemphill Company, <u>Over One Hundred and Twenty Years of Service</u> (Pittsburgh: MacKintosh-Hemphill Company, 1924), 3; MacKintosh-Hemphill Company, <u>Rolling Mills, Rolls, and Roll Making</u> (Pittsburgh: MacKintosh-Hemphill Company, 1953), 38-40.
[146] "Lucy Furnaces, Pittsburgh, Pa." <u>Iron Age</u> 17 (May 18, 1876), 1; "Large Output at the Lucy Furnaces, Pittsburgh," <u>Iron Age</u> 21 (February 28, 1878), 15; American Iron and Steel Institute, <u>Directory of the Iron and Steel Works of the United States, 1882</u> (Philadelphia: American Iron and Steel Institute, 1882), 33-34. The last mentioned source is hereafter referred to as <u>DAISI</u>.

Birmingham's early plants installed blowing engines provided by these two companies.[147] As logistics improved, the time required to obtain these engines shrank to a point at which Birmingham ironmakers could order and install them nearly as fast as their Pittsburgh counterparts. This is a very important fact to remember because it shows that the Birmingham Industrial District possessed the machinery required to operate large, hard-driven furnaces. If they were not lacking the necessary hardware, there must have been other reasons why ironmakers chose instead to build an industry based on smaller foundry iron blast furnaces.

Pre-packaged Blast Furnace Plants

The easy flow of technology from Pittsburgh and other centers of innovation to Birmingham did not end with individual, albeit crucial pieces of capital equipment. By the beginning of the District's building boom, leading engineering firms could be contracted to design and build fully equipped blast furnaces. As part of their package deals, firms such as J.P. Witherow and Company in New Castle in western Pennsylvania and Gordon, Strobel, and Laureau, Ltd., of Philadelphia, also acted as agents for the iron and steel industry's leading inventors and patent holders. This meant that, in addition to the ability to erect custom-design blast furnaces anywhere in the country, they could also equip an installation with the latest machinery and furnace appliances. With such services available, entrepreneurs with sufficient capital and adequate raw materials could establish iron making enterprises in the remotest regions of the United States and still be assured of essential technological parity with their competitors in older, betters established centers of production.

One book promoting the industries of the Pittsburgh District in 1888 included a piece of J.P. Witherow's company, which indicates how widespread the practice of contracting out for the construction of blast furnaces had become. After the Witherow Company's promotional literature proudly underscored the pioneering role of its founder:

> Having made an exhaustive study of the best methods for the economic production of iron and steel, he has achieved distinguished success in the erection of blast furnaces…He carries on every department of the business…and employs a corps of talented engineers and draughtsmen and only the most skillful artificers and machinists.[148]

It went on to list more than fifty furnaces that the firm had erected all over the United States. These included not only one of Andrew Carnegie's world-renowned Lucy furnaces and its closest rival, the Isabella furnaces, but also nine leading furnaces of the Birmingham Industrial District. These consisted of: The Sloss City Furnaces, two furnaces; Alice Furnace Company, one furnace; Mary Pratt Furnace Company, one furnace; Woodward Iron Company, one furnace; Eureka Company, two furnaces; and DeBardeleben Coal and Iron Company, two furnaces.[149] Gordon Strobel and Laureau, Ltd. also was a major contributor to the Birmingham Industrial District's building boom. The Philadelphia firm erected both of the Sloss Iron and Steel

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[147] "Large Orders of Allis-Chalmers Engines," Iron Age 78 (November 15, 1906), 1332; "World's Record in Building Large Engines," Iron Trade Review 54 (January 1914), 204-207; "Woodward Plant Improvements," Iron Trade Review 55 (November, 1914), 908.
[148] Historical Publishers, Pennsylvania Historical Review- Cities of Pittsburgh and Allegheny- Leading Merchants and Manufacturers (New York: Historical Publishers Inc., 1888), 94.
[149] Ibid, 94.

Company's North Birmingham furnaces and all four of TCI's Ensley furnaces.[150] This amounted to at least fifteen, or 63 percent of the twenty-four furnaces constructed in Jefferson County between 1880 and 1900.

Transplanted Furnace Operations

Two northern firms of impeccable ironmaking credentials, lured to the Birmingham Industrial District by its abundant, closely juxtaposed deposits of iron ore, coal and fluxing stone were a second source of newly constructed blast furnace plants.[151] One of these transplants was the Pioneer Mining and Manufacturing Company, an offshoot of an important northern anthracite ironmaking enterprise founded by a Welsh immigrant David Thomas, who is often cited as having introduced the anthracite blast furnace industry to the United States. The Thomas family enjoyed a generation of successful foundry ironmaking after the elder Thomas spearheaded the technological breakthroughs, particularly the use of heated air blast that made iron smelting with Pennsylvania anthracite possible.[152] Thomas visited the Birmingham Industrial District immediately after the Civil War to purchase prime tracts of mineral land and a good furnace site. Recognizing that the foundry iron business was in decline in the North and unwilling to follow other ironmakers into the growing steel industry, the Thomas family moved south in 1886, bringing their unrivaled expertise in foundry iron production with them.[153]

An article appearing on the front page of an 1888 edition of Iron Age presented a glowing account of the Pioneer Company's newly erected Birmingham facility.[154] It was highlighted by a large illustration of the plant's new blast-furnace blowing engines, which had been built by the Port Richmond Iron Works of Philadelphia. The engines were equipped with the latest valves and other accessories and were capable of producing large volumes of air blast with great efficiency.[155] Their installation was supervised by F.B. Keiser, one of the Pioneer Company's leading engineers, who had been in charge of the mechanical and construction departments of twelve northern furnaces before he came south. Keiser's father was a German engineer, foundryman, and inventor who also brought his technical experience to the Pioneer Company, where he served as chief engineer.[156] Just as the Thomas family's anthracite furnaces had once

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[150] "New De Bardeleben Furnace," Iron Age 33 (May 22, 1884), 25; "New Ensley Furnace Plant," 40 (November 3, 18887), 1, 17.
[151] Robert Casey has presented an informative discussion of the role of such firms in the construction of Birmingham furnaces in Robert Casey and Marjorie L. White, "A Look at Thomas, and Alabama Iron Town" Canal History and Technology Proceedings 9 (March 1990), 121-141.
[152] For information about David Thomas and his early activities in Pennsylvania see James F. Lambert and Henry J. Reinhard, A History of Catasauqua in Lehigh County, Pennsylvania (Allentown, Pennsylvania: Searle Dresser Co., Inc., 1914), 46-51; Lance E. Metz, "The Arsenal of America: A History of Forging Operations of Bethlehem Steel," Canal History and Technology Proceedings 11 (March 14, 1992), 233-235; Craig L. Bartholomew and Lance E. Metz, The Anthracite Iron Industry of the Lehigh Valley, Publication of the Center for Canal History and Technology, ed. Ann Bartholomew (Phillipsburgh, New Jersey: Harmony Press, 1988), 1, 20-27.
[153] For a more detailed examination of the role that the Pioneer Mining and Manufacturing Company played in the early development of the Birmingham Industrial District as well as the general influence of northern technicians and companies, see Casey and White," A Look at Thomas," 121-141. In this work, Casey was the first scholar to explore the technology transfer that accompanied the blast furnace building boom in the Birmingham Industrial District.
[154] "Blowing Engines of the Pioneer Mining and Manufacturing Company," Iron Age 41 (April 1888): 553-555.
[155] "Blowing Engines of the Pioneer Mining and Manufacturing Co.," 553.
[156] Armes, Coal and Iron in Alabama, 354.

served as models for eastern Pennsylvania, their new coke-fueled blast furnaces would now serve as models for the Birmingham Industrial District.

The Woodward Model of Vertical Integration

The second northern transplant, the Woodward Iron Company, formerly of Wheeling, West Virginia, quickly established itself in the District by earning impressive profits from its first days of operation in 1882.[157] Woodward introduced the most valuable example that long experience in the ironmaking business could provide: the concept of vertical integration and the advantages of owning not only one's blast furnaces but also the mines and quarries that produced their raw materials and rail system over which they were transported.[158] An article written in 1914 used the phrase "straight line production" to describe the system of vertically integrated holdings and management practices that Woodward had pioneered to maximize its unique locational advantages.[159]

Woodward could set such an example with relative ease because the Birmingham Industrial District offered the best location in the country, and perhaps in the entire world, for the efficient assembly of raw materials. This advantage enabled Alabama-based firms to achieve complete vertical integration before even the largest of steel conglomerates.[160]

When the Great Lakes region became the major source of ore in the North, most of these giant concerns were forced to develop expensive, complicated assembly systems requiring both water and land transport over substantial distances. At the Jones Valley's narrowest point, Birmingham's ore and coal reserves lay only twelve miles apart. Simply by building its own short-line railroad along a line as straight as possible from Red Mountain through the middle of the valley and into the edge of the Warrior coal field, Woodward achieved a quick and uninterrupted flow of coke, iron ore, and fluxing stone to its centrally-located furnaces a decade before Andrew Carnegie and Henry Clay Frick accomplished such results in Western Pennsylvania. For these steel magnates, acquiring iron ore alone was a proposition many times more costly and complex than Woodward's entire raw material extraction, processing and assembly system. To insure access to Lake Superior ore, which was unloaded from large ships at ports along Lake Erie and then shipped by rail to Pittsburgh, Carnegie and Frick purchased the entire Pittsburgh, Shenango and Lake Erie Railroad to expand it to form the Pittsburgh, Bessemer and Lake Erie.[161]

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[157] For the best brief account of the history of the Woodward Furnaces see Woodward Iron Company, Alabama Blast Furnaces (Woodward, Alabama: Woodward Iron Company, 1940). "Good Furnace Work in the South," Iron Age 39 (February 24, 1887): 25.
[158] Armes, Coal and Iron in Alabama, 299-301; F.J. Crolius, "Straight Line Production," Blast Furnace and Steel Plant 12 (June 1924): 264; "Birmingham," Iron Age 37 (March 4, 1886): 31; "Good Furnace Work in the South," 25.
[159] Crolius, "Straight Line Production," 234-237, 264-267, 305.
[160] The effect of locational factors on the variable rates of regional growth within the iron and steel industry is brilliantly analyzed by Kenneth Warren. See American Steel Industry, 1850-1970: A Geographical Interpretation (Oxford, Clarendon Press, 1973), 109-133 passim.
[161] Andrew Carnegie's first attempt at vertical integration occurred in 1881 when he formed Carnegie Brothers and Company Limited, which brought together ore and coal mines in support of his steel mills and blast furnaces. Two months later however, the new company sold the Lucy Furnaces, and as Joseph Fraizer Wall expressed it, "the first venture into developing a truly vertical steel organization had quickly dissolved." Andrew Carnegie (Pittsburgh:

The example that Woodward set for the Birmingham Industrial District was actually more subtle than it appeared at first. The owners of most early ironmaking concerns in and around Birmingham incorrectly assumed that because of ore, coal, and fluxing stone lay so close at hand, simply building their furnaces in Jones Valley would itself insure success. Such persons did not realize that even in such a remarkably favorable location they would still be required to devise highly efficient systems for the acquisition and assembly of raw materials. As competition intensified, many early entrepreneurs failed because they could not obtain adequate supplies of raw materials and deliver them to their furnaces in a timely fashion. The number of enterprises that survived this intense struggle dwindled down to only four companies. These were Woodward; Sloss; the Pioneer Mining and Manufacturing Company, which would ultimately be acquired by the Republic Steel Corporation; and TCI, which would be purchased by the United States Steel Corporation, and discontinue foundry iron production.

RAW MATERIAL CONSTRAINTS AND THE SCALE OF FOUNDRY IRON MAKING

Despite having ready access to the best technology available, and having recognized the advantages of straight line production, foundry ironmakers of the Birmingham Industrial District discovered that smaller furnaces would restrict their merchant plants to a smaller scale of production which would neither provide the capital for, not require, the high degree of mechanization essential to large steel mill blast furnaces.

Raw material constraints lay at the heart of this situation, acting in a variety of mutually reinforcing ways. Three prominent examples will come nowhere near exhausting the subject, but will serve to illustrate this point. In the first place, local ore and coal could on be efficiently converted into foundry iron in small furnaces. These small merchant furnaces could not achieve the same economies of scale as steel mill furnaces and, consequently, could not produce gross profits sufficient to pay for highly mechanized plants. Secondly, the small scale foundry facilities faced technological thresholds, points at which the continuation of optimal productivity necessitated the replacement of a manual with a mechanical process, at much lower frequencies. Finally, because of their relatively poor quality, greater volumes of the District's raw materials had to be fed into a furnace to yield the same amount of metallic iron. A high ratio of ore and coke consumption to pig iron production meant that more capital had to be diverted from furnace plant mechanization to the maintenance of raw material extraction and processing facilities.

The Raw Material Factor in Economies of Scale

High volume production and technological innovation are mutually reinforcing processes associated the economies of scale achievable by very large manufacturing operations. As the steel industry began to grow with unprecedented speed, Pittsburgh was forced by the increasing demands for pig iron from its steel mills to build larger blast furnaces. Such installations in turn required expensive machinery to keep up with their growing output, but increasing capacity

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University of Pittsburgh Press, 1989), 472. For discussions of Carnegie and H.C. Frick's successful efforts, which came toward the end of that same decade, see Hogan, Economic History of Iron and Steel, Vol. 1, part 2, 248-254, and Warren, American Steel Industry, 102-106.

results in greater profits that paid for innovations.[162] In his important treatise on American ironmaking, Joseph E. Johnson described the series of mechanical devices that were introduced in response to the rapidly increasing capacities of Pittsburgh blast furnaces during the last two decades of the nineteenth century. He dubbed this burst of modernization the "Duquesne Revolution,"[163] naming it after Andrew Carnegie's Duquesne furnaces near Pittsburgh, where many innovative machines were first introduced.[164]

The large, highly mechanized blast furnace plants that were so essential for high volume steel production would not have been possible had Pittsburgh's raw materials been no better than Birmingham's. Fortunately for such entrepreneurs as Andrew Carnegie, Connellsville coal possessed chemical and physical qualities that were better suited for use in large furnaces than any other coal in America. The vast reserves of high-grade Lake Superior ore at Carnegie's disposal were equally well-suited to the task. As increasing demand for steel dictated that more pig iron be made, Pittsburgh ironmakers could rest assured that the inherent qualities of their raw materials would never be a barrier to building ever larger blast furnaces.

For ironmakers of the Birmingham Industrial District the situation was much different. Writing in 1931, James Pickering Dovel, vice president of the Sloss-Sheffield Company and one of the men who was most familiar with the characteristics of local raw materials, clearly stated the results of the fuel and ore added to a blast furnace in order to achieve optimum results:

> …the coke must be consumed and the ore completely reduced by the time they have passed the tuyéres. An accumulated excess of either at this point would be fatal to good operation.[165]

Unfortunately, the physical and chemical characteristics of coke made from coal from the Warrior field and the hard, silicious ore of Red Mountain combined to make achieving these conditions an extremely illusive objective in anything other than a relatively small furnace. The coal produced is a soft, low-porosity coke that, because of its tendency to wear down and initiate direct reduction at an early point in its downward passage through the stack, would only work well in smaller furnaces.[166] Speaking from personal experience with similar problems in another district, a veteran northern furnace master succinctly stated the limitations of such coke:

> The extreme softness of the coke evidently made it highly vulnerable to dissolution by CO^2 in the furnace stack. This and excessive abrasion reduced it to

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162 Temin devotes two chapters to the economies of scale, point out several important factors including the impetus to develop large blast furnaces provided by the introduction of Bessemer converters and their immensely greater consumption of pig iron compared to iron puddling furnaces. See Peter Temin, Iron and Steel in Nineteenth-Century America (Cambridge, Mass: Massachusetts Institute of Technology Press, 1964), 153-193 passim.

163 The Duquesne Revolution was a labor saving system that mechanized the delivery of raw materials and delivered them to the furnaces.

164 J.E. Johnson, Blast Furnace Construction in America (New York: McGraw-Hill Book Company, Inc., 1917), 15-16.

165 James P. Dovel, "Economies in Blast Furnace Operation," Blast Furnace and Steel Plant 19 (January, 1931): 118.

166 For an early account of the influence that varying grades of coke had upon the size and efficient operation of blast furnaces, see John Fulton's account in Annual Report of the Secretary of Internal Affairs of the Commonwealth of Pennsylvania for 1874-75, Part III, Industrial Statistics, Vol. 13 (Harrisburg: B.F. Meyers, State Printer, 1876), 233-236. For a later account which benefitted greatly from hindsight, see Roy P. Hudson, The Blast Furnace: Its Raw Materials, By-Products and their Chemical Analysis (Brooklyn, New York: Chemical Publishing Co., 1942), 34-114.

> a small size, favoring 'direct' reduction, which accelerates the movement of the stock, and not sufficient coke reached the tuyéres to maintain the temperature of the hearth. On the small furnaces at the Union and Milwaukee Works this coke, for apparent reasons, gave better results.[167]

The hard, coarse Red Mountain ore aggravated the problem of softness and low porosity. It abraded the soft coke into smaller sizes "favoring 'direct' reduction"[168] and created a higher proportion of fine particles that restricted the upward flow of gases in the stack. These conditions were opposite of those required by a large, hard-driven furnace, and they challenged Birmingham's ironmakers to develop a smaller alternative that would be optimally suited to such limitations. Even as late as the 1920s and 1930s, a typical southern foundry iron furnace was limited to a capacity of between 425 and 475 tons per day.

This small size, however, did not mean that the District's foundry iron furnaces were technologically inferior. This fact was clearly demonstrated in a series of experiments conducted during the 1920s by S.P. Kinney for the United States Bureau of Mines at the 300-ton furnaces of the Central Iron Company at Holt, Alabama. Based on exhaustive comparisons with data compiled by the Pittsburgh and Minneapolis stations of the Bureau of Mines, and utilizing reports resulting from similar work in such places as Pittsburgh and Illinois, Kinney's work showed that improvements were possible in the interior design of both northern and southern furnaces, but gave no indication that the southern installations were significantly less efficient, relative to their size, than much larger furnaces located in other parts of the country.[169]

Mechanical Thresholds at a Lower Scale of Production

Kinney's findings are important because they serve as a note of caution to the easy tendency to view examples of labor intensity within the merchant furnace plants of the Birmingham Industrial District as technological backwardness. The fact that, in terms of smelting efficiency, their furnaces were keeping pace with their steel mill counterparts after nearly a half century of developments in design and practice, is a clear indication that foundry ironmakers were fully capable of mechanization when necessary. It remains then to examine cases where they retained labor intensive practices in order to explain why merchant furnace men in Birmingham could be innovative in some aspects while retaining seemingly obsolescent practice in others. While several factors were undoubtedly involved, one is the simple fact that a judicious blend of labor and capital-intensity was better suited than full mechanization to the smaller scale of production in plants served by smaller, but optimally-sized foundry iron blast furnaces.

American ironmakers did not mechanize simply for the sake of being innovative. If they made

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[167] Herman A. Brassert, "Modern American Blast Furnace Practice," Paper presented at the annual meeting of the American Iron and Steel Institute, New York, New York, 25 May 1917, 15.
[168] Citation omitted from original report.
[169] Kinney recounted carious aspects of his experiments in numerous articles. The most pertinent observations on the question of the effect of coke of furnace operation are found in S.P. Kinney, Composition of Materials from Various Elevations in an Iron Blast Furnace U.S. Department of Commerce, Bureau of Mines, Technical Paper No. 397 (Washington, D.C.: GPO, 1926), passim, and The Blast Furnace Stock Column U.S. Department of Commerce, Bureau of Mines, Technical Paper No. 442 (Washington, D.C.: GPO, 1929), passim. See also D.L. Jacobson, International Handbook of the By-Product Coke Industry (New York: The Chemical Catalog Co., Inc., 1932), 155-156.

the mistake of installing expensive machinery that was not absolutely necessary, they increased the risk of creating an over-capitalized operation, a situation that no less a figure than Andrew Carnegie felt should be avoided at all costs.[170] Instead, iron manufacturers usually waited for a clear financial inducement to mechanize. Such inducements occurred when the daily capacity of a blast furnace reached a critical threshold at which traditional manual practices, such as hand loading, began to require so many men that they became more expensive than mechanical alternatives such as machine-driven loading buckets or skip cars. Joseph Johnson, was well versed in the financial calculation of these crucial thresholds. Speaking of hand loading at northern furnaces after they reached a capacity of about 400 tons per day, he stated:

> The great expense of this method [hand loading] also became more and more obvious as the number of men required increased, and looking at the matter from the financial point of view it was well worth while to make an investment which would eliminate the labor of sixty men while the same investment to eliminate the labor of only twenty men might be a poor one.[171]

Johnson goes right to the heart of the economic factor that determines when a given element in a plant's production cycle should be mechanized. As long as the number of men required to perform a certain task was so low that the manual procedure cost less than a mechanical alternative, the rational response was to retain the labor-intensive practice. Steel mill blast furnaces involved in a rapidly accelerating spiral of growth would obviously reach production plateaus requiring the replacement of man-power by machinery much earlier and more frequently during their course of historical development. Smaller foundry iron blast furnaces, conversely, would reach such mechanical thresholds later and less frequently.

Sand Casting as Rational Response

Undoubtedly the best example of enduring labor intensity is the practice of sand casting which the Woodward and Sloss-Sheffield companies retained until the early 1930s, well over 30 or 40 years after it was abandoned by the steel mill blast furnaces. Sand casting was the earliest means developed for tapping the molten iron from a blast furnace and allowing it to cool and harden into a form that could be readily handled. The accomplish this objective, early ironmakers periodically broke the clay plug sealing the hearth of their furnace and allowed the liquid iron to run through a trough into moulds impressed in the surface of a carefully prepared sand floor. Even during the era of small charcoal blast furnaces, the tasks of breaking and removing the hardened iron and preparing the sand floor in time for the next cast was laborious, but with the advent of high-volume coke furnaces the increasing manpower required doomed the entire process to obsolescence. Steel mill blast furnaces began to abandon sand casting with the advent of the Duquesne Revolution.[172]

Writers supporting the shift, including Edward A. Uehling, the inventor of a mechanical pig casting machine, did much to publicize the notion that operations which did not make the transition were clearly backward.[173] Ironically, Uehling was a former employee of Sloss who had conceived his important invention while working at the company's City Furnaces which may

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[170] Joseph Fraizer Wall, Andrew Carnegie, 322.
[171] J.E. Johnson, Blast Furnace Construction in America, 61.
[172] E.A. Uehling, "Pig-Iron CaSting and Conveying Machinery," Cassier's Magazine 24 (June 1903): 113-33.
[173] Ibid., passim

well have been the last plant in the United States to abandon sand casting in the early 1930s. Uehling had presented his idea to Sloss' management only to have it rejected. Undoubtedly angered by the rejection, the inventor resigned and was soon hired by Andrew Carnegie's corporation whose technical advisors quickly recognized the importance of the casting machine, and installed it at several furnaces in the Pittsburgh area. It soon became a standard feature of large, steel mill blast furnaces in the United States and was widely adopted in central Europe.[174]

Gary Kulik was the first observer to offer an explanation other than backwardness for this apparent resistance to change on the part of the Birmingham Industrial District. Kulik emphasized the importance of the South's vast pool of black labor, arguing that the gradual adoption of labor-saving devices by such firms as Sloss proceeded apace with the increasing rate of Black migration from the South. In Kulik's opinion, the decisions made by Sloss and Woodward, first to adopt a limited degree of mechanization and ultimately to replace sand casting with pig casting machines, came in direct response to an increasing scarcity of unskilled labor.[175] In support of his case, he quoted a statement made by Woodward's managers in 1924 after their company had decided to mechanize its sand casting operations to at least a limited degree:

> The most laborious type of work around the blast furnace is that of the pig iron carrier. As this type of workman is seemingly becoming extinct, in order to prevent serious decreases in production, arrangements are now being made to install mechanical means of handling iron, which is now being handled by hand.[176]

Kulik's argument cannot be sustained until a closer study is made of the availability of such labor in Birmingham during the 1920s. Still, his analysis underscores the fact that the retention of labor-intensive practices such as sand casting was conditioned by rational calculations which appear all the more rational if the slow growth in the capacity of the District's foundry iron blast furnace is considered. Not until 1924 had increasing capacity finally caught up with the sand casting process. The output of Sloss' four Birmingham furnaces since 1900 had increased by 60 percent from slightly over 56,000 tons to 90,000 tons per furnace. Woodward's output had increased by 52 percent from 62,500 to 120,000 tons.[177] This meant that by the 1920s these two companies were drawing considerably more molten iron from their furnaces in a single cast, requiring more workers to break and load a greater number of heavy iron pigs. The problems of removing one cast of iron and preparing the sand beds in time for the next pour had also increased proportionally.

The District's foundry ironmakers had thus reached, in a single component of their operations, a production threshold similar to those which had occurred simultaneously in virtually every facet of the process in large Pittsburgh plants nearly decades earlier which brought about the Duquesne Revolution. Significantly, however, neither Sloss nor Woodward immediately adopted Uehling's invention because many of their customers still preferred sand cast pig iron. Instead, they devised mechanical means of making sand molds and removing, breaking, and loading the

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[174] For a thorough discussion of the Uehling pig casting machine, see Johnson, Blast Furnace Construction, 340-343.
[175] Kulik, "Sloss Furnace Company," 26-28.
[176] Ibid., 27.
[177] DAISI, 1901, 136, 252; American Iron and Steel Institute, DAISI, 1920 (New York: American Iron and Steel Institute, 1920), 319, 390.

resulting pig iron.[178] These methods were somewhat more labor-intensive than using pig-casting machines, but allowed the two companies to handle the increased output of their furnace more efficiently and still cast their pig iron in sand.

The Critical Ratio of Raw Materials Consumed to Pig Iron Produced

The same raw material deficiencies which forced operators to build relatively small furnaces also increased the amount of coke and ore required to make pig iron. The soft coke was consumed so rapidly in a furnace that it gave the Birmingham Industrial District the unwanted distinction of leading the nation in the amount of coke that was expended to produce a ton of pig iron. Just how costly this seemingly small factor could be was illustrated by the experience of Republic Steel Corporation at its foundry iron furnaces in Birmingham. In 1937, Republic operated two furnaces. According to W.E. Curran, Superintendent of Republic's blast furnaces and coke works, each furnace required between 600 and 700 pounds more coke to produce a ton of iron than furnaces in other parts of the country. At this excessive rate of consumption, two furnaces annually producing 320,000 tons of pig iron, would burn 104,000 more tons of coke than installations located in other districts. Since 1/5 tons of coal was needed to make a ton of coke, the company was required to mine an additional 156,000 tons of coal per year to produce an equivalent amount of pig iron. If the average yearly capacity of a typical company-owned mine in 1940 was 735,000 tons, this meant that two and one-half months of each year were spent mining the additional coal required by local blast furnaces.[179]

The District faced a similar problem with its Red Mountain ore. Since it graded only about 35 percent, a ton of ore yielded only around 700 pounds of metallic iron compared to 1000 pounds obtained from Lake Superior ores which graded around 50 percent. This meant that to produce a tone of pig iron Birmingham ironmakers were required to mine approximately 4.78 tons of ore compared to four tons required in northern furnaces. In other words, to supply one of the Sloss City Furnaces during the early 1930s, that produced 425 tons of pig iron in a twenty four hour period, Sloss Sheffield's mining department was required to mine around 330 tons more ore per day than the average northern operation. Conversely, if only 35 percent of the material obtained from a ton of ore was metallic iron, this mean that the remaining 65 percent consisted of sand and other impurities that had to be removed from the furnace as a molten waster material known as slag. Birmingham's ironmakers would have preferred to load less of this low-grade raw material into their furnaces because it was so hard and abrasive that it wore out furnace linings more quickly which meant accounting for increased cost of furnace repair, but instead, they were forced to load more, and consequently devote more time and expense to removing worthless

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[178] George J. Young, "Iron Mining in the Birmingham District," Engineering and Mining Journal 110 (August 1920): 254; "Little Pigs- Little Pigs," Pig Iron Rough Notes (Winter-Spring, 1939): 3-4; Crolius, "Straight Line Production," 266-267, 305; H.E. Mussey, "Blast Furnace Practice in Alabama," in TAIME, 1925 Vol. 71 (New York: American Institute of Mining and Metallurgical Engineers, 1925), 436-452.
[179] Curran, "Trend of the Southern Pig-iron Business," 37-43; Garrett, "Raw Materials Problems in Birmingham," 212-213; J.M. Hassler, "Offsetting Increased Labor Cost in Southern Blast Furnace Operation," TAIMME, 1937, Vol. 125 (New York: American Institute of Mining and Metallurgical Engineers, 1937), 53-55. The figures for blast furnace and mine capacities are compiled from data in the Directories of American Iron and Steel Institute and the state mine inspectors reports for Alabama.

slag, rather than profit yielding pig iron.[180]

Soft coke and hard silicious ore encouraged Birmingham's ironmakers to develop a smaller type of blast furnace for their foundry pig iron operations. Small-scale foundry iron production did not offer great economies of scale that could support the costs associated with a high degree of mechanization. Instead, it dictated a path of technological evolution that was slower-paced and marked by much lower levels of mechanization. This more gradual evolutionary path harmonized well with the smaller scale of mining operations dictated by the Birmingham Industrial District's difficult geological conditions, the slower growth of southern regional markets, an abundant supply of cheap labor, and a cultural ethos conducive to labor intensity. This interrelated web of factors, with raw materials constraints as one of its central elements, ensured that the Birmingham Industrial District's blast furnaces would never reach such a climax as the Duquesne Revolution, but would continue to dominate the foundry iron industry.

DISCOVERING AN ALTERNATIVE TO HARD DRIVING

Any study attempting to place the foundry iron blast furnaces of the Birmingham Industrial District in their proper context within the American pig iron industry must address one fundamental question: why did local ironmakers not adopt hard driving practice, the hallmark of the industry? The experiences of the last three decades of the 19th-century had shown that, for reasons tied to a complex set of limitations inherent in the local mineral resources, economies of scale would be different if not impossible to achieve so the District would never be capable of sustaining more than one or two large steel mills. Paradoxically, many of the same factors that made mammoth, hard-driven blast furnaces and large scale steel production difficult, also presented profitable opportunities for optimally-sized foundry iron companies capable of acquiring strategically placed ore and coal properties then creating an iron making system that struck a fine balance between the carrying capacity of its mines and the production capabilities of its blast furnace plants.

A comparison of selected events in the historical development of Pittsburgh's and Birmingham's blast furnaces shows that differing experiences with their respective raw material resources encouraged the two Districts along divergent technological paths. The first thing shown by such a comparison is the fact that there was little difference between the two Districts either in technological acuity or in a willingness to seek innovative solutions to problems. Ironmakers in the Birmingham Industrial District were generally receptive to innovative practices and the latest technology, provided it was optimally suited to their scale of production. Secondly, it was a series of discoveries about the limitations of their raw materials, as much as any other factor, which inexorably drove them along the path toward small-scale iron production.

The Birth of Hard Driving

During the twenty-three years between 1872 and 1895, Pittsburgh's ironmakers developed the techniques and machines that would become the hallmarks of hard driving practice. On opposite

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[180] F.R. Crockard, "Five Years of Progress in Southern Blast-furnace Practive," <u>TAIMME, 1936</u>, Vol. 124 (New York: American Institute of Mining and Metallurgical Engineers, 1936), 37; Curran, "Trend of the Southern Pig-iron Business," 41; Garrett, "Raw Materials Problems in Birmingham," 209-210.

banks of the Allegheny River, during the 1870s, the Lucy Furnaces, owned by Andrew Carnegie and his associates, and the rival Isabella Furnaces launched an intense race, each striving for hitherto unheard-of levels of daily production. The lead passed back and forth over many months. In 1872 the furnaces were producing 500 tons of iron per week. By 1880, they were producing 1,000 tons per week. The means employed to accomplish these unprecedented yields were surprisingly simple but represented a dramatic break with the past. They consisted of a marked increase in the air blast and feeding iron ore and coke into the furnace as fast as possible in order to operate at maximum capacity. Hard driving wore out furnace interiors more rapidly than earlier methods, but the cost of more frequent relining's was offset by increased yields.[181] This was the antithesis of traditional practice, which emphasized operating at a rate often considerable lower than maximum capacity in order to extend the life of the furnace as long as possible.

Record-setting tonnage taxed the ability of workers to load and unload the furnaces, but the innovations of the Duquesne Revolution enabled them to keep pace with spiraling output. Shifting production during the 1880s and 90s from its Lucy Plant to new furnaces at Edgar Thomson, Carrie, and Duquesne Mills, the Carnegie Steel Company introduced a series of new devices including mechanical top loaders, ladle cars, and pig-casting machines.[182] The era of high-volume pig iron production had begun.

The Eureka Experiments

While the glowing successes of Lucy and Isabella during the 1870s, held the attention of ironmakers around the world, a committed group of entrepreneurs were quietly struggling to bring Alabama's coke blast furnace industry into existence at a small, rebuilt Civil War plant at Oxmoor on the side of Red Mountain opposite the Jones Valley. Unlike their Pittsburgh counterparts who could draw upon lessons learned from years of experimentation and commercial success with lake ore and coke made from Connellsville coal, the Oxmoor experimenters would have to start essentially from scratch. When they began their first post-war efforts to smelt Red Mountain ore with charcoal in the early spring of 1872, the city of Birmingham itself had been incorporated for less than a year, and the Louisville and Nashville Railroad which would become the city's most direct link to most of its future markets, would not be opened until September.[183] Previous attempts to make pig iron from the Red Mountain ore seams in the vicinity of the Jones Valley had been limited to the hastily installed wartime plants at Oxmoor and the nearby McIlwain Furnace. The only experience with coke gained by these charcoal-fueled operations before their destruction by federal cavalry raiders in late March of 1865, was a brief, but apparently successful, experiment at the McIlwain Furnace conducted at the insistence of the Confederate Nitre and Mining Bureau's Captain Richardson Hunt.[184]

The attention drawn to the Red Mountain ore seams by the war effort insured that an iron industry would eventually arrive, but the first efforts to reestablish production after 1865 were

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[181] William T. Hogan, Productivity in the Blast-Furnace and Open-Hearth Segments of the Steel Industry: 1920-1946 (New York: Fordham University Press, 1950), 34; Wall, Andrew Carnegie, 323-324.
[182] Hogan, Productivity, 35.
[183] Armes, Coal and Iron in Alabama, 41, 251.
[184] Woodward Iron Company, Alabama Blast Furnaces, 22-23, 83-84, 106-197; Armes, Coal and Iron in Alabama, 163-169.

sporadic and limited to the use of charcoal. The McIlwain Plant was rebuilt first and operated for a while under the name of the Jefferson Iron Company before lapsing into a cycle of unsuccessful ownership changes and eventual abandonment. The renewal of production at Oxmoor was initiated by Daniel Pratt and his son-in-law Henry Debardebelaben following unsuccessful efforts by a group led by Daniel Troy to elicit northern capital to the project. Pratt and Debardeleben erected two new 25-ton blast furnaces and changed the name of the company from the Red Mountain Iron and Coal Company to the Eureka Mining Company.[185]

Over the next year or so, as participation in the enterprise changed frequently, a series of local entrepreneurs with little or no experience in iron making attempted to operate new furnaces. The first run was supervised by DeBardeleben and ended in abject failure. The Mudd family followed and achieved essentially the same results. While Ethel Armes suggests that DeBardelben's efforts began when the furnaces went into blast in the winter of 1873, Levin Goodrich indicates that a ten week run had been launched earlier, on June 29th of the same year. According to Goodrich, this campaign yielded 633 ¼ tons of pig iron consuming 185 2/5 bushels of charcoal per ton and produced a product that was "difficult to classify and not giving satisfaction as a No. 1 foundry pig."[186]

The company had hired Goodrich at some point during these first early runs in order to establish a more professional grounding for its efforts. The experienced ironmaker from Kentucky immediately began to achieve positive results. He set the enterprise on a learning course over the remainder of the decade that would prove difficult and marred by frequent setbacks, but would be characterized by a ready willingness to innovate when necessary and a heavy reliance on outside expertise and technology. This brief era of experimentation during which the elements of innovation and technological borrowing are strongly evident was a microcosm of the overall history of ironmaking in the Birmingham Industrial District. The discoveries made by its self-proclaimed pioneering ironmakers, about the nature of its ore and coal, foreshadowed the future realization that the District's mineral endowment was ideally suited for smelting in small scale foundry iron plants.[187]

Goodrich's first priority was to conduct a suitable furnace run using charcoal so that the company could make its first accurate assessment of the feasibility of entering the trade as a charcoal foundry iron producer. Concluding that previous failures were due primarily to "improper mining and mixing of the ores,"[188] the new superintendent evaluated the company's ore and coal supplies and learned that the ore deposit on Red Mountain, which had been thought to consist of one massive, homogeneous seam was actually comprised of seven seams of varying richness and composition. At this point Goodrich had columnar samples taken of each ore seam along with samples of coal from the Cahaba field and shipped them to Pittsburgh for analysis by the prominent metallurgist Dr. Otto Wurth.[189]

In the meantime, Goodrich rebuilt the No. 1 Furnace radically altering its interior proportions and installing a cone-shaped furnace-charging device that he had patented in 1871. Like many

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[185] Armes, Coal and Iron in Alabama, 238-242; "Mineral, Agricultural and Commercial Resources of Birmingham and its Vicinity," Iron Age, 21 May 1874, 3.
[186] Citation for quote missing in original document
[187] Levin Goodrich, "Correspondence," 3.
[188] Citation for quote missing in original document
[189] Levin Goodrich, "Correspondence," 3.

similar models introduced at about the same time, the apparatus made it possible to seal the opening in the top of the furnace to prevent the escape of gas. The furnace gas containing a high percentage of carbon monoxide, an excellent fuel, could then be recovered via a flue and used for various purposes including firing steam boilers and heating the furnace blast. Cone-shaped charging devices, known initially as cup and bone feeders and later as bell and hopper feeders, also facilitated better distribution of raw materials in the furnace.[190]

Incorporating its new interior proportions and other improvements, the Eureka No. 1 Furnace began a 10 week run in March 1875. Workers fed the furnace with ore that had been classified and mixed prior to loading and were able to achieve better distribution of the material in the furnace because of Goodrich's new top loader. In addition, they employed the gasses recovered from the furnace top to heat the air blast. The results were a significant improvement over previous performance. The furnace produced 1,010 tons of pig iron during the ten weeks, an average of 101 tons per week at a greatly reduced charcoal consumption rate of 144 2/5 bushels per ton of iron. The quality of the pig iron was also improved to the point that a reasonable percentage of the total product could easily be classified as No. 1 foundry grade.

The Cooperative Experimental Company

Despite these improvements, however, the amount of charcoal required to smelt the silicious Red Mountain ore remained prohibitively high. Based on Otto Wurth's analysis which indicated that the limestone and ore of Red Mountain as well as the coal of the Cahaba field were suited to the task, Goodrich recommended that Eureka Mining Company attempt the production of the coke pig iron. Lacking the capital that would be required to upgrade their furnaces, build coke ovens, and purchase the equipment necessary, D.S. Troy, who had assumed the presidency of the company, appealed to local businessmen for support. Troy proposed the formation of the Cooperative Experimental Company intended to "test the value of Alabama coal in the manufacture of pig iron from the ores of Red Mountain," and received the immediately backing of officials of the South and North Alabama Railroad, including James Withers Sloss and experienced ironmaking families such as the Woodwards and Thomases, who were interested in setting up their own installations in the Birmingham Industrial District, and others.[191]

Under arrangements worked out by the interested parties, The Eureka Company would provide one of its blast furnaces, and the ore and fluxing stone that would be required. Led by the New Castle Coal Company, which would commit 2,000 tons at one dollar per ton, local mining companies were encouraged to provide coal for the experiment. Other investors were expected to put up cash, while the South and North Alabama Railroad would deliver any marketable pig iron produced to George S. Moore and Company, sales agents in Louisville, Kentucky. All totaled, the company raised an initial subscription of $33,000 to modify the existing charcoal furnace at Oxmoor and install the new equipment needed for its conversion of coke.[192]

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[190] Frederick Overman, The Manufacture of Iron in All Its Various Branches (London: Delf and Trubner, 1852), 171; Uehling, "Pig-Iron Casting and Conveying Machinery," 113-133; Goodrich, "Correspondence," 3.
[191] "Experimental Company," Iron Age, 4 June 1874, 3.
[192] Ibid., 3. For accounts of the Oxmoor experiments, see Armes, Coal and Iron in Alabama, 60, 238-265 passim and Edna Kroman, "Unkind Fate follows Furnace," Birmingham News-Age-Herald (January 6, 1929, Sunday Magazine Section 4): 1.

The Experimental Coke and Coal Company spared no expense when it converted the Number One Eureka Furnace to utilize coke. Though designed for charcoal, the stack was well built, no more than two years old, and was readily adaptable to experimental testing with coke. Apparently the most significant modification was the addition of a 15-foot cylindrical iron extension mounted atop the original stone furnace.[193] Interestingly, the first Edgar Thomson blast furnace erected by Carnegie Steel in 1875, employed many of the components salvaged from an old charcoal stack.[194]

Following Otto Wurth's earlier recommendations the experimenters at Oxmoor built a battery of six Belgian or Coppee retort ovens. They also installed a second battery of four innovative retort ovens designed by Lewis Shantle. Shantle's patented design featured unique oscillating bottoms that discharged the coke into an iron truck that passed beneath the ovens.[195]

Despite his claim that "Belgian ovens properly constructed will yield a coke…about, if not quite equal to the Connellsville coke," Wurth's recommendation that retort ovens be used was a tacit acknowledgement that the Birmingham Industrial District would not be able to build furnaces as large as those in Pittsburgh.[196] As far as producing a metallurgical fuel was concerned, the essential feature of retort ovens was their ability to prevent the admission of air that was employed in beehive ovens to assist combustion. Instead of outside air, combustion in retort ovens was supported by the oxygen contained in the coal. While this process facilitated a greater yield of coke per ton of coal, its most crucial advantage was the fact that it produced a harder coke, one of the principal factors effecting furnace size.[197]

Retort ovens also allowed for the controlled removal and reuse of the coke gas, an innovative departure from the more primitive and wasteful beehive coke ovens commonly in use in the Connellsville District which allowed this valuable by-product to escape into the atmosphere. The ironmakers at Oxmoor were thus able to use the combustible gas both to "redden the furnace" (apparently meaning to heat the furnace air blast) and to fuel steam boilers that powered the furnace's blowing engine built by the Webster Company of Chattanooga.[198]

These innovative features of the Oxmoor experiments are a clear indication that the members of the Cooperative Experimental Company were well aware of trends within the industry and capable of drawing upon the latest technology when needed. Another example of this ability is evident in a poorly documented but important episode involving coal washing that occurred toward the end of the Oxmoor trials. Coal washing had only recently been introduced to the American iron industry. John Endres and Sebastian Stutz had placed competing designs on the market and both the Lucy and Isabella Furnaces had used washed coal during the early stages of their rivalry. At sometime around 1877, the Cooperative Experimental Company or its successors became interested in the new technology, and John Milner shipped a load of coal

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[193] Armes, Coal and Iron in Alabama, 262.
[194] Ibid, 238. Bridge, Inside History, 87.
[195] U.S. Patent no. 151, 513, application filed April 8, 1874; Joseph D. Weeks, Report on the Manufacture of Coke, (U.D. Department of the Interior, Bureau of the Census, Washington, D.C.: GPO, 1884), 14, 113. Armes writes that five Shantle ovens were built: Armes, Coal and Iron in Alabama, 259.
[196] Goodrich, "Correspondence," 3.
[197] William Hutton Blauvelt, "A Description of the Semet-Solvay By-Product Coke-Oven Plant at Ensley, Alabama," TAIMME, 1889, vol. 28 (Philadelphia, American Institute of Mining Engineers, 1889), 579-580.
[198] Henry E. Colton, "Iron Making in the South—Hot Blast Charcoal Stacks," Iron Age 15 (June 3, 1875): 5; "Alabama, Its Iron Mountains and Coal Basins," 2.

from his Newcastle Mine to be washed in Stutz's newest coal washing plant, located at the works of John Robson and Son in Pittsburgh's Fourteenth Ward.[199] Milner's agent at the Pittsburgh trial was J.W. Bell of Porter, Bell Can Company, a leading builder of locomotives which had supplied the yard engines employed at the Lucy Furnaces. Porter, Bell and Company had also provided a light locomotive used by the Cooperative Experimental Company to haul iron ore to the furnaces over twenty-pound T-rail track to Oxmoor from the company's mines on Red Mountain.[200] The chronology is not clear on the subject, but at some time just before or immediately following Milner's washing trial, the Eureka Mining Company installed a Stutz jig coal washing plant at its coal mines near Helena.

Goodrich and his staff conducted a complex series of experiments that finally resulted in success in early 1876. Members of the Cooperative Experimental Company then formed a new partnership and immediately replaced the converted charcoal furnaces with two sixty-foot stacks with iron shells and sixteen- and fourteen-foot boshes. In 1886 and 1887, these furnaces were replaced by even larger stacks that were seventy-five feet high, with seventeen-foot boshes.[201]

Scaffolding

The problems of the Experimental Coal and Coke Company invited the scorn of some contemporary observers, but they were actually little different from those encountered by coke ironmakers in other districts. Take for instance, the problem of scaffolding, the tendency of raw materials to cake up and stick to the inside of a furnace wall at some point dangerously high above the tapping hole. If a scaffold became sufficiently large, it could break loose and fall down into the molten iron and slag at the bottom of a furnace, causing many potential problems; it might even cause the furnace lining to break, sending fiery molten iron and slag pouring out with disastrous results. The causes of scaffolding were still a mystery in the mid-1870s, and every furnace found itself occasionally confronted with the problem.[202] When the Oxmooor experimenters suffered the results of a particularly disastrous scaffold, it was portrayed by Samuel Noble, owner of the rival charcoal-fired Woodstock furnaces of Anniston, as an example of inept practice. In his scornful account of the incident appearing in *Iron Age*, Nobel reported that:

> The furnaces scaffolded, then came a mine fall that threw the molten slag iron and burning gases in such quantity as to burn down both furnaces.[203]

Despite Noble's scorn however, the Eureka Furnaces were not the only coke fueled operation beset by occasional scaffolds. They even afflicted the Lucy Furnaces where one scaffold became so severe that it formed a complete arch across the middle section of the furnace. The final solution improvised by Lucy's operators held the potential for consequences as disastrous as those suffered by the Eureka Furnaces but since it succeeded it was characterized as a "novel"

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[199] "Alabama Coke Manufactured at Pittsburgh," Iron Age 20 (September 13, 1877): 3; King, Progress in Iron and Steel, 44-46.
[200] "Alabama, Its Iron Mountains and Coal Basins," Iron Age (September 13, 1877), 2.
[201] Armes, Coal and Iron in Alabama, 261, 262; Woodward Iron Company, Alabama Blast Furnaces, 108; American Iron and Steel Institute, Directory of the Iron and Steel Works of the United States, 1890, (Philadelphia: American Iron and Steel Institute, 1890), 43.
[202] Henry R. Foote, "Chills, Scaffolds and Salamanders in Blast Furnaces," Iron Age 18 (December 28, 1876): 3.
[203] "Cheap Iron Making in the South," Iron Age 33 (May 22, 1884): 9.

remedy:

> A mortar was forthwith procured from the arsenal and they commenced firing shots into the chilled mass… Mr. Skelding put in a large charge of powder… rammed the mortar full of cotton waster, and on top of this placed a large lump of ore weighing about fifty pounds. This novel shot brought down the scaffold…"[204]

Similar Building Booms

Considering that the efficacy of smelting Red Mountain ore with coke was virtually unknown before 1875, the building boom that began in the early 1880s, after only a five year discovery process, was remarkable. This surge of construction equaled in number, if not in capacity, the explosive period of blast furnace building that occurred in the Pittsburgh District at roughly the same time. The Directory of the American Iron and Steel Institute for 1901 indicates that approximately twenty-four blast furnaces were constructed in Pittsburgh between 1880 and 1900, about the same number that were built in Jefferson County during the same time period.[205]

Alice Number One was the first new stack built in Birmingham, going into blast in 1880, and it was followed by Alice Number Two in 1883. The Sloss City Furnaces were built between 1881 and 1883; the Woodward Iron Company erected two stacks between 1882 and 1883; and the Thomas family blew in its Pioneer Furnaces in 1888 and 1890. Several installations were built by other groups, including the four Ensley stacks that were erected by the Tennessee Coal, Iron, and Railroad Company in 1888 and 1889 and five furnaces built by Henry F. DeBardelaben and his associates in and around Bessemer between 1887 and 1890. But the Sloss, Woodward, and Thomas Furnaces are the most important for the purposes of this study because they would survive and grow into the three leading merchant pig iron producers of the District. Eventually these three companies would account for almost one-fourth of all foundry iron produced in the United States, the bulk of which was produced in Birmingham. Most of the other furnaces in the Birmingham Industrial District were soon consolidated by TCI; some of them continued to produce foundry iron for a few decades, but were ultimately modified to make basic iron for conversion into steel. Eventually, they were dismantled and replaced by larger furnaces that U.S. Steel, which absorbed TCI in 1907, built to supply its integrated steel mills at Ensley and Fairfield.[206]

Learning the Subtleties of Location

Both the Pittsburgh and Birmingham districts made early misjudgments about the best locations for their furnaces. Prior to the widespread use of Connellsville coke, the majority of blast furnaces were located along the tributaries of the Monongahela River. As the immense advantages of Connellsville coke became apparent, the logic of locating blast furnaces along the Allegheny River rather than the Monongahela came into question. Not only was the latter

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[204] Bridge, Inside History, 60.
[205] American Iron and Steel Institute, DAISI, 1901, passim.
[206] The best comprehensive source of information about the construction dates, capacities and related data about these furnaces is Woodward Iron Company, Alabama Blast Furnaces, passim. For a good account of the early furnaces see A.S. McCreath and E.V. D'Invilliers, "Comparison of Some Southern Cokes and Iron Ores," in TAIME, 1882, Vol. 15 (Philadelphia: American Institute of Mining Engineers, 1882), 736-805.

waterway more accessible to the Connellsvile region, but its banks also provided relatively larger sections of flat land that would be needed to build integrated steel mills. Within a decade, the Lucy and Isabella Furnaces declined in importance as steel makers built the Edgar Thomson, Duquesne, Carrie, and other furnace plants along the banks of the Monongahela River adjacent to their new steel mills.[207]

Ironmakers also had lessons to learn about optimal locations within the Birmingham Industrial District for coke blast furnaces. The original decision to build the Oxmoor plant on the Shades Valley side of Red Mountain rather than in the Jones Valley reflected the mindset of the charcoal ironmakers of the antebellum era. Their market orientation had been southward toward the fledgling antebellum manufacturing centers that had developed at the fall lines of the state's major rivers. The vast expanse of virgin timberland blanketing the mineral region freed these charcoal ironmakers of transportation routes to the south found a most favorable convergence.[208]

After the Louisville and Nashville and the Alabama Great Southern Railroads linked the Birmingham Industrial District with the industrial markets to the north, the insurance of survival and profit for the coke ironmakers of the New South became a matter of finding those prime spots in the Jones Valley from where the cost of assembling Red Mountain ore and Warrior field coal could be brought as close as possible into perfect balance.

Initially, the Cooperative Experimental Company had tried to use coal from the Cahaba field, located in the southeastern portion of the Birmingham Industrial District. First they hauled coal from mines near Helena to be coked in the Coppee and Shantle ovens at Oxmoor. Later, they built a Stutz coal-washing plant and a battery of 100 beehive ovens at the Helena mines. Because Cahaba coke worked poorly in their furnace, the experimenters began testing coal from mines in the Warrior field. At first, Warrior coal was hauled all the way to Helena to be coked and was then taken back to Oxmoor. Once its superiority over Cahaba coal had been established, the Warrior field became the principal source of fuel for the District's blast furnace industry.[209]

Because the Eureka Furnaces were located south of Red Mountain, they stood at one end of the line between their coke and ore sources rather than at some ideal point near the middle. Ironically, this small locational disadvantage doomed the furnaces that had proven the coke and ore of the Birmingham Industrial District to being marginal producers that ultimately went out of blast for the last time in May, 1927.[210] What ironmakers would learn over the next few decades was that, even though the mineral resources of the District were confined to a remarkably compact geographic area, the survivors would still have to devise extremely efficient vertically integrated operations because, micro-locational factors could have a strategic impact on their profitability.

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[207] For two good accounts of Carnegie's steel mill and blast furnace building activities, see Bridge, Inside History, and Wall, Andrew Carnegie.
[208] For brief, early post-Civil War accounts of the Eureka Furnaces and other holdings of the Red Mountain Iron and Coal Company, see Joseph Hodgson, The Alabama Manual (Montgomery: Mail Building, 1869), 112-117.
[209] Testimony of Enoch Ensley in U.S. Senate, Report of the Committee of the Senate Upon the Relations Between Labor and Capital, 5 vols. (Washington, D.C.: GPO, 1885), vol. 4, 413; John Witherspoon Du Bose, The Mineral Wealth of Alabama (Birmingham: N.T. Green & Co., 1886), 591; Eugene A. Smith, Report of Progress for 1874, (Geological Survey of Alabama, Montgomery: W.W. Screws, 1875), 41; Ernest F. Buchard, Charles Butts, and Edwin Eckel, Iron Ores, Fuels and Fluxes of the Birmingham District, Alabama, U.S. Department of the Interior, U.S. Geological Survey, Bulletin No. 400, (Washington, D.C.: GPO, 1910), 170.
[210] Woodward Iron Company, Alabama Blast Furnaces, 110.

The Woodward Iron Company taught the Birmingham Industrial District this valuable lesson by example, by establishing a model operation featuring optimally juxtaposed properties and carefully articulated management concept. A feature article on Woodward appearing in 1924 in Blast Furnace and Steel Plant, praised the efficiency of the company's system for extracting, assembling, and processing raw materials into pig iron according to the principles of "straight line production." A reprint appearing in another trade journal, Coal Industry, contained a preface that stated the essence of the Woodward concept succinctly:

> The making of iron in the Birmingham District is first, last and always a great material handling business.[211]

Woodward held all of the key elements required for straight-line production. The company owned and managed its own ore mines on the slopes of Red Mountain, coal mines along the edge of the Warrior field and fluxing stone quarries at its centrally located blast furnace plant that stood adjacent to a major rail line near the middle of the Jones Valley. And all of these facilities were linked together by the company's own fully equipped short line railroad, only twelve miles long, that was completely independent of the vagaries of the railroad industry including car shortage, strikes and so on.

The wisdom of Woodwards, strategy of full vertical integration is evident when the company's early experiences are compared with those of others who failed initially to perceive that issues and micro-locational factors could have significant consequences. Take for instance the formative years of Woodward and Sloss Furnaces. As previously stated, Woodward succeeded in paying off its construction costs very quickly and by doing so was able to achieve an extremely efficient operating record that impressed even the editor of Iron Age magazine.[212] The first owners of Sloss simply erected a blast furnace plant without serious consideration of the need for a vertically integrated system that included mines and transportation facilities. Their first supply of coal came not from their own mines, but was provided under contract by Henry DeBardeleben, owner of the Pratt Coal Mines and a former business associate of James Withers Sloss. Ironically, Colonel Sloss had opened the Pratt Mines, but soon sold out to DeBardeleben so that he could focus upon building his City Furnace plant.

By the time its contract with Pratt Coal had expired, the Sloss Iron and Steel Company, now in new hands, had acquired its own mines, but was still forced to rely on the mainline railroads for delivery in an era when car shortages were a frequent occurrence. In addition, the reorganized company suffered continuing problems with ore supply. Because Colonel Sloss had not initially acquired adequate properties near Bessemer, where the richest ore outcropped, the new owners were forced to draw a part of their red ore supply from secondary mines near Irondale where the seams contained a lower percentage of iron, more silicon, and less carbonate of lime. More silicon meant that the ore was harder, posing a variety of problems in the blast furnace. Less carbonate of lime meant that more fluxing stone had to be quarried and added to the ore as it was fed into the furnace.[213]

Although Sloss, Bessemer and Irondale mines were only a few miles apart, the difference in the

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[211] Crolius, "Straight Line Production," 224.
[212] "Birmingham," 31; "Good Furnace Work in the South," 25.
[213] The ore from the prime area of outcrop near Bessemer contained so much carbonate of lime that it was self-fluxing; that is, it did not require the addition of fluxing stone such as limestone or dolomite. Y.A. Dyer," Alabama Iron Mining," Engineering and mining Journal, 111 (January 1921): 180.

quality of their ore translated into immensely different pig iron production costs. For example, when the mines near Bessemer were flooded in 1910 and Sloss had to fall back on its Irondale mines, production costs jumped $1.50 per ton of pig iron.[214] The new owners of Sloss struggled with such problems and eventually achieved a relatively high degree of integration, but were ultimately forced to bring brown ore to Birmingham over a commercial rail line from a large strip near Russellville, more than seventy miles away in northwest Alabama. All in all, the firm that Colonel Sloss had founded paid a continuing long-range price for the fact that he had not been as far-sighted as the owners of the Woodward Iron Company.

In no instance are the consequences of failure to emulate Woodward's straight-line production model more evident than in the case of TCI, which moved into the Birmingham Industrial District in the 1880s and became a subsidiary of U.S. Steel in 1907. The company very nearly went bankrupt during its first years. Mismanagement, stock watering, and undercapitalization have generally been cited as the main causes for the firm's plight, but a major contributing factor was the fact that TCI's blast furnaces were scattered all the way from Oxmoor to Bessemer to Birmingham. The cost of assembling and distributing raw materials to this hodgepodge of furnaces must have greatly narrowed the company's profit margin. After TCI replaced this scattered array with two strategically-located new clusters of furnaces at Ensley and Fairfield, which were within sight of their coal mines and linked to their ore mines on Red Mountain by a company-owned rail line, the company's prospects improved considerably.[215]

The fate of several early companies in the Birmingham Industrial District was sealed by the fact that they were not capable of achieving vertical integration. The Williamson Furnace, built in 1885-1886; the Mary Pratt Furnace, built in 1882-1883; and the Vanderbilt Furnaces, built in 1890 and 1908, are such examples. Perhaps the best example, however, was the furnace at Trussville, fifteen miles northeast of Birmingham. The Trussville Furnace changes ownership numerous times during its three decades of intermittent operation, going into blast only when pig iron prices were very high. Situated at the far northeast end of the workable outcrops of Red Mountain ore, Trussville was one of the worst locations in the District for ironmaking. The poor quality of the ore in the vicinity is evidence of the irregular operating history of the nearby Ruffner and Alfretta Mines. Even worse, the closest coking coals were located at the opposite end of Jones Valley. After going into blast for a final campaign in 1918-1919, the Trussville Furnace was ultimately dismantled in 1933.[216]

Machinery Capable of Hard Driving

Birmingham ironmakers possessed the machinery and appliances capable of supporting hard driving practice because their inferior raw materials could only be efficiently smelted using such modern equipment. Scaffolding, for example, a persistent problem for furnaces using Red Mountain ore, could be avoided more readily by applying high volumes of air blast at temperatures between 1400 and 1700 degrees Fahrenheit. High volumes of very hot air could be achieved only by using regenerative stoves and efficient blowing engines. High blast

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[214] "Sloss-Sheffield Company Passes a Dividend," Iron Age 86 (November 1910): 1153; "Sloss-Sheffield Steel and Iron Company Report," Iron Age 87 (March 1911): 325.
[215] Justin Fuller, "History of the Tennessee Coal, Iron, and Railroad Company, 1852-1907," Unpublished Ph.D. Diss., University of North Carolina, Chapel Hill, 1966, passim.
[216] Woodward Iron Company, Alabama Blast Furnaces, 100, 145-150.

temperatures also helped to restore heat loss that occurred from poor coke. Most importantly, while ironmakers were not able to pinpoint the exact reasons, fire brick stoves worked well with small furnaces making foundry iron.[217]

The need for such expensive equipment forced aspiring furnace companies to spend considerable sums on the construction of their new installations. While critics of the Birmingham Industrial District may have believed differently, more knowledgeable observers realized that sizeable amounts of capital were being invested in its mines and furnaces, even during the early years of its development as an ironmaking center. An anonymous observer, writing in 1888, noted that the most striking feature of the southern iron industry was the "very excellent character of the appliances used." He cited as the reason for this good equipment the fact that:

> Instead of copying after cheap construction, which the people of that section might readily have been excused for doing, with their original lack of capital, they have been inclined to strike out boldly in the direction of radical innovations requiring heavy investments.[218]

James Withers Sloss, one of the foremost entrepreneurs in the Birmingham Industrial District, made a similar claim when testifying in 1883 before an investigating committee from the United States Senate. Sloss, who had been responsible for bringing the Louisville and Nashville Railrod into north-central Alabama in 1871, was prominent in the Eureka experiments, helped open the first large mines in the Pratt Seam of the Warrior field, and founded the Sloss Furnace Company. Its capitalization of $500,000, about half the capitalization for Duquesne in 1886, was still large figure for the time, supported his assertion that he and his fellow investors had "spared neither money nor pains to put this section of the Country."[219] Much of this money went into the kinds of equipment that would have made it possible for local ironmakers to achieve hard driving practice if all other factors had been equal.

Innovative Hot Blast Stoves

One example of the modern equipment used at an early date in the Birmingham Industrial District was the fire-brick hot-blast stove, which operated on the regenerative principle first developed by Sir William Seimens in 1856. Within a few decades after its introduction into the United States from Europe in 1875, the fire brick stove would completely replace older recuperative stoves featuring cast iron pipes. The newer fire-brick stoves cost more than twice as much as the earlier type to build, were more difficult to maintain, and required more ground space, but thy could produce a much hotter blast and quickly proved to be vastly superior to their predecessors for making pig iron with coke.[220]

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[217] For a detailed discussion of the causes and cures for scaffolds, see J.P. Witherow, "Removing Scaffold in Blast Furnaces," in TAIME, 1880-1881, Vol. 9 (Philadelphia: American Institute of Mining Engineers, 1881), 60-71; Foote, "Chills, Scaffolds and Salamanders," 3; "Hot and Superheated Blast," Iron Age 17 (January 20, 1876): 9; "The Cowper Hot Blast Stove," in Iron Age 29 (January 14, 1882), 1.
[218] "Southern Iron Plants," Iron Age 41 (June 14, 1888): 971.
[219] Testimony of James Withers Sloss in Labor and Capital, 4: 279.
[220] For a brief discussion of the regenerative process and its first use of the heating of air for blast furnaces, see Cyril Stanley Smith, "Mining and Metallurgical Production, 1800-1880," in Technology in Western Civilization, vol. 1, ed. Melvin Kranzberg and Carroll W. Pursell, Jr. (New York: Oxford University Press, 1967), 357; for information

The first regenerative stoves in the United States were erected no more than 100 miles from the Birmingham Industrial District, at the Rising Fawn Furnaces in northwest Georgia, near Chattanooga, on June 16, 1875.[221] Rising Fawn's coke-fired furnaces possessed such new technology because they were built by an English firm that included Thomas Whitwell as one of its owners. Whitwell had patented his own version of the hot blast stove, which, he claimed, was a great improvement over the original Cowper fire-brick stove that was the first to use the Siemens' regenerative principle to heat the furnace blast. Soon, Whitwell stoves were widely adopted across the United States. They were placed in service at fifty-nine plants by 1877. In 1880, an article in Iron Age, describing the new, fully integrated four-furnace plant of the North Chicago Steel Company, praised the plant for embodying the "best modern Practice," placing particular emphasis upon its fourteen Whitwell stoves.[222]

For an established blast furnace, the changeover to regenerative stoves was an expensive proposition that could require significant alteration to its existing layout. For this reason, plus the fact that a hot blast in excess of 600 degrees Fahrenheit was not crucial to making good pig iron in anthracite and charcoal furnaces. American ironmakers continued to use recuperative stoves ling past the time of their obsolescence in Europe. The new furnaces of the Birmingham Industrial District, being built for the first time, had no such problems with preexisting plant layouts, and their furnaces would require blast temperatures will in excess of 600 degrees if they were to work effectively using Warrior coke. The choice of the more modern fire-brick stoves therefore, was almost preordained.[223]

A year after their introduction at Rising Fawn, the first Whitwell stoves were built in Pennsylvania. Rather than being adopted at Pittsburgh, they were installed at the Dunbar Furnace ad the base of Chestnut Ridge, about fifty miles away. Even the Lucy Furnaces were not particularly timely in their shift to the new type of hot blast stove. While two Whitwell and two Siemens-Cowper-Cochran models were installed at Lucy Number One at some point after January 1878, Lucy Number Two was still using iron-pipe stoves as late as 1882, at the same time that Colonel Sloss was installing Whitwell stoves at his newly constructed Sloss City

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about the first use of regenerative stove in the United States, see Hogan, Economic History of Iron and Steel, vol. 1, part 1, 28-29.

[221] "Progress of the Hot Blast," Iron Age 16 (February 3, 1875): 1; Swank, Iron Mining and Coal Mining in Pennsylvania, 88; James Bowron, "The Southern Iron and Steel Industry," Iron Age 94 (November 1914), 1127.

[222] Temins states that the Whitwell stove was not widely adopted. This statement is true in the sense that fire-brick stoves of any type were not is use in more than seventy or eighty of the hundreds of furnaces in the United States around 1880. When one excludes charcoal and anthracite furnaces and focuses upon the new coke furnaces being built, however, the proportion of regenerative stoves over the old recuperative stoves greatly increases. The increasing propensity of coke furnaces to select fire-brick stoves begins to show up in the Annual Reports of the American Iron and Steel Institute after it began recording such data in the early 1880s. A lively debate over the relative merit of cast iron versus fire-brick stoves took place in the pages of Iron Age in the late 1870s and early 1880s. John Birkenbine's advocacy of the cast iron stove surely did much to extend its use for a few years after the superiority of the regenerative fire-brick stove was firmly established. See Temin, Iron and Steel in America, 160-161; John Birkinbine, "Suspended Pipe for Hot-Blast Stoves,: Iron Age 17 (May 17, 1876): 15; "Whitwell Hot Blast Stoves," Iron Age 24 (July 17, 1879): 15, John M. Hartman, "A Sketch of the History of Hot Blast Fire Brick Stoves," Iron Age 24 (July 3, 1879): 15; "Cast Iron vs Fire Brick Stove," Iron Age 27 (March 17, 1881): 15; John Birkinbine, "Hot Blast Stoves," Iron Age 27 (March 31, 1881): 15.

[223] "Cast Iron vs. Fire Brick Stoves," 15; Johnson, 191. Hogan stated that the cost difference between cast iron pipe and fire brick stoves was not as great as some early observers thought. See Hogan, Economic History of Iron and Steel, vol. 1, part 1, 29.

Furnace Number One.[224]

Dramatic evidence of the advantages of regenerative versus recuperative stoves for smelting Red Mountain ore with local ore was provided by the experience of the Woodward Iron Company. For some undetermined reason Woodward, which had installed three 17x75-foot Whitwell stoves at its Number One Furnace in 1883, built four iron-pipe stoves for its new Number Two Furnace, which went into blast on January 26, 1887.[225] The output of the newer furnace proved to be much less than that of the older furnace, which had performed so well using Whitwell stoves that it was cited twice in a national trade journal for a "conspicuously good run," when it operated for three years and five months, averaging 50 tons per day, without a shutdown.[226] The difference in productivity using the iron-pipe stoves was so great that, when Woodward planned to take the Number One Furnace offline for repairs in 1889, concern was expressed that the "limited output" of the Number Two stack would force the company to lay off employees at its ore mines, coal mines, and coke ovens, who would then quit. Woodward's solution was to temporarily hook up the Whitwell stoves to their Number Two Furnace so that its output could be raised to a point at which layoffs would not be necessary. Meanwhile, the company hastened to replace its iron-pipe stoves with new Whitwell types.[227]

Powerful Blowing Engines

More decisive than stoves for the development of hard driving practice, however, were large and powerful blowing engines.[228] Although the first blowing engines installed at the Eureka Furnaces and Alice Number One proved to be inadequate, from that point onward all subsequent furnaces in the Birmingham Industrial District installed blowing engines comparable, if not identical, to those employed in Pittsburgh. For example, the two blowing engines installed in the new Alice Number Two Furnace in 1882 compared favorably with the blowing engines that served Lucy Number One. The engines at Alice featured 84-inch air cylinders, 36-inch steam cylinders, and a 54-in stroke, while Lucy's blowing engines had 84-in air cylinders, 35-inch steam cylinders, and a 48-inch stroke. Examples of such progressiveness in the Birmingham Industrial District were

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[224] "Comparison of the Work of Blast Furnaces," Iron Age 20 (December 20, 1877): 15; "The Hot Blast of the Lucy Furnace," Iron Age 21 (February 28, 1878): 15; "The Siemens-Cowper-Cochrane Hot-Blast Stoves," Iron Age 23 (May 1, 1879): 1' "The Genesis of the Edgar Thomson Blast Furnaces," Iron Age 47 (April 23, 1891): 770; DAISI, 1882, 33-34.
[225] Du Bose, The Mineral Wealth of Alabama, 592; Woodward Iron Company, Alabama Blast Furnaces, 155.
[226] "Birmingham," 31; "Good Furnace Work in the South," 39.
[227] Minutes of the Woodward Iron Company Board of Directors, May 10, 1889; W.T. Burt and Company, Wheeling, West Virginia, to Woodward Iron Company, May 10, 1889, Woodward Collection, W.S. Hoole Special Collections, University of Alabama, Tuscaloosa, Alabama.
[228] A description of the Lucy Furnace published in 1876 states that the furnace was still being served by iron-pipe stoves that could deliver only 1 900 degree blast. This date was four years after the Lucy and Isabella Furnaces had begun registering high production figures in 1872. "Lucy Furnace, Pittsburgh, Pa.," 1; Fulton, "Industrial Statistics," 250-251. The issue of what crucial innovations made hard driving possible is subtle and complex. For example, Bridge, in his historical account of the Carnegie Steel Company, places little emphasis on the role of blowing engines, focusing instead upon the proportions and dimensions of the Lucy, Isabella, and Edgar Thomson Furnaces. In 1881 a furnaceman from New Castle, Pennsylvania who had achieved results similar to those of Carnegie Steel's furnaces claimed that it was the Whitwell stoves rather than specific furnace dimensions that made hard driving possible. Bridge, Inside History of the Carnegie Steel Company, 62, 63; W.E. Reis, "The Whitwell Hot-blast Stoves at the Neshannock Iron Works," Iron Age 27 (Feb 10, 1881): 15.

not uncommon; on the very same day in 1906 that the Edgar Thomson Works of U.S. Steel purchased 14 new blowing engines from the Allis-Chalmers Company, the Thomas Furnaces ordered eight engines of the same size and type from the same firm.[229]

Nowhere is the close comparison in blowing engines between Birmingham and Pittsburgh more apparent than in the case of the Woodward Iron Company. When Woodward built its first two furnace plants in Birmingham, its owners installed MacKintosh-Hemphill blowing engines similar to those at the Lucy and Edgar Thomson Furnaces. A generation later, when Woodward modernized its furnace plant, it placed a rush order with the Mesta Machine Company of Pittsburgh for four cross compound horizontal blowing engines. Mesta accepted this order as a challenge to its ability to deliver a product quickly; building the new engines, it placed them on flat cars and shipped them to Birmingham in record time. The speed with which the order was filled so impressed the editors of Iron Trade Review that they referred to the episode in two separate articles.[230]

In terms of furnace construction, major equipment and basic iron making skill, there was no appreciable difference between the Pittsburgh and Birmingham Industrial Districts. When it came to hot-blast stoves, blowing engines and other major capital equipment in particular, the Birmingham Industrial District usually proved capable of acquiring the designs best suited to its needs.

Small, Slow-Driven Foundry Iron Furnaces

Despite their willingness to seek out and employ the latest equipment and practice in their efforts to overcome the limitations of their raw materials, it became apparent from the earliest days that much of the Birmingham Industrial District's future was wedded to small foundry iron furnaces that could not be hard-driven. Even though the Eureka Furnaces had been modified and enlarged twice within their first decade of operation, they still proved incapable of matching the average tonnages of their counterparts in Pittsburgh. By the late 1880s the Edgar Thomson Furnaces, for example, could produce 325 tons per day compared to Eureka's 125. The largest output possible in the Birmingham Industrial District at the time was not much more than 150 tons per day.[231]

Over the next four decades ironmakers of the two Districts would continue to increase the capacity of their respective furnaces, but the rate of increase was always in favor of Pittsburgh. Birmingham's largest recorded daily tonnage in the 1890s was 265 tons. By contrast, Pittsburgh furnaces using Connellsville coke were beginning to reach the 500-ton plateau. The largest tonnages produced in the Birmingham Industrial District in the early 1930s had risen to slightly more than 600, but by this time, the output of the northern steel mill furnaces had risen to 1,000

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[229] Fuller, "History of TCI," 236; Testimony of T.T. Hillman, Labor and Capital, 4: 406; "New Southern Furnace," Iron Age 32 (February 26, 1883): 25; "Lucy Furnace, Pittsburgh," 1; "Large Orders of Allis-Chalmers Engines," 1332.
[230] J.H Woodward to MacKintosh Hemphill Co., Pittsburgh, February 10, 1889, Woodward Papers, W.S. Hoole Special Collections, University of Alabama; "World's Records in Building Large Engines," 204-207; "Woodward Plant Improvements," 905-910.
[231] DAISI, 1890, 43; Woodward Iron Company, Alabama Blast Furnaces, 110; The Modern Blast Furnace and Auxiliaries (Chicago: Blast Furnace and Coke Association, 1930), 2-10; Mussey, "Blast Furnace Practice in Alabama," 441; Pennsylvania Historical Review- Cities of Pittsburgh and Allegheny, 94.

tons per day.[232]

The disparity between Birmingham's foundry iron furnaces and northern furnaces was even greater than these figures reveal. The largest producers in the District were the blast furnaces at the steel mills at Ensley and Fairfield, which continued to push for ever greater capacities. The foundry iron furnaces had begun to focus on the consistent production of high grade foundry iron at the expense of greatly increased capacity. While the Fairfield Furnaces could produce an average of 611 tons per day in 1931, the maximum output of the new Sloss City Furnace Number Two, built in 1927, was about 475 tons although its average sustainable output of high-quality iron was much less. This was a tremendous increase over the 87 ¾ tons produced in the original Number Two City Furnaces in 1887, but a still far smaller amount than a large steel mill furnace could produce. By the mid-1930s, makers of foundry iron in the Birmingham Industrial District seem to have tacitly acknowledged that somewhere between 425 and 475 tons per day was an optimal output.[233]

Local ironmakers discovered that the Birmingham Industrial District would have to make do with smaller furnaces the hard way, by costly trial and error. When, for example, Alice Number Two was put in blast in 1882, it had to be quickly shut down and its interior lining of fire brick replaced because the attempt to increase its capacity had caused significant damage. By 1885, spokesmen for the District acknowledged in trade journals that it was not possible to achieve good results in furnaces averaging only 100 tons daily. When local ironmakers dropped production down to seventy or eighty tons most problems disappeared, and an acceptable grade of pig iron could be made. The same findings were confirmed by E.C. Potter in 1887 when he stated in an article in Iron Age that fast driving on lean ore and substandard coke produced bad iron and wore out furnace linings.[234]

Fortunately, it was possible to produce pig iron profitably in Birmingham's smaller furnaces. Local ironmakers had begun to achieve excellent production records by the mid-1880s, so long as they did not attempt to push their furnaces too hard. The Woodward Iron Company's previously-mentioned "conspicuously good run," for example, was so profitable that the company was able to pay off the construction cost of its first furnace in less than three years of

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[232] William B. Phillips, Ironmaking in Alabama, Geological Survey of Alabama, Monograph No. 3 (Montgomery, Al.: Jas. P. Armstrong, 1896), 2nd ed., 139; "By Product Coke Pittsburgh Coal and Natural Gas," Coal and Coke Operator 15 (August 1, 1912): 68; Ralph H. Sweetzer, "Blast Furnace Progress in 1930," Blast Furnace and Steel Plant 19 (January 1931): 104; "A By-Product Coke Plant for a 1000-Ton Blast Furnace," Blast Furnace and Steel Furnace (October 1931): 1357.

[233] F.G. Cutler, "Fairfield Blast Furnace Power Plant," Blast Furnace and Steel Plant 17 (June 1931): 850; H.R. Stuyvesant, "Alabama Furnace Breaks Output Record," Iron Age 109 (May 25, 1922: 1443; "Birmingham's Most Modern Iron Maker," Pig Iron Rough Notes (August-September 1937): 2; James P. Dovel, "Dovel Type Blast Furnace Put on Test," Blast Furnace and Steel Plant 16 (December 1928), 1556; For an account of the construction of the New City Furnaces, see chap. 14 of W. David Lewis, Sloss Furnaces and the Rise of the Birmingham District. There is little documentation to confirm what may have been considered optimal daily output, but an unpublished report written by an engineer for the Republic Steel Corporation about 1937 lists the daily tonnage on most of the foundry iron furnaces in the District at between 425 to 475 tons. F.H. Janecek, "Blast Furnace Lines," unpublished report in the Thomas Collection, Wade Sand and Gravel, Co., Inc., Birmingham, Alabama.

[234] Du Bose, The Mineral Wealth of Alabama, 589; "Southern Coke in the Furnace," Iron Age 36 (November 5, 1885): 21; "Iron Making in the Birmingham District," Iron Age 40 (December 8, 1887): 14; E.C. Potter, "Fast Driving in Blast Furnace Practice," Iron Age 39 (June 16, 1887): 16.

operation.[235]

Fifty years later, the concept of small, slow-driven foundry iron furnaces had become so institutionalized in the Birmingham Industrial District that one nationally-prominent expert on blast furnace practice went to great lengths to defend their method of operation:

> Excessive driving or blowing of a furnace has its bad effect on the grade of metal by creating the tendency to "drive the life" out of it… The slow-driven blast furnace—small or medium in size… produced the most desirable grades of foundry pig irons.[236]

At about the same time that Birmingham ironmakers began to master the subtleties of producing consistently high grades of pig iron over the duration of an extended furnace campaign, they also began to recognize the particular suitability of their raw materials for making foundry iron.[237] In a series of reminiscences about the development of the southern iron and steel industry that he published in 1917 in Iron Age, a prominent local executive, James Bowron, stated that this recognition began to occur about 1889:

> The writer has seen what the English call 'glazed' pig iron put back into the furnace to be remelted, as unmerchantable, but it was not very long before the Southern high silicon or 'bright' iron, as we called it, worked its way into favor as a softener and scrap carrier, and the virtue of pig iron, high alike in phosphorous and silicon, gave it preference for the production of stoves, radiators and architectural castings.[238]

Mechanical Thresholds

Although their progress was slower than that of their counterparts in the Pittsburgh District, Birmingham's foundry ironmakers gradually increased the output of their furnaces. They began to reach one mechanical threshold after 1900, when some local blast furnaces had become so large that the hand-loading of raw materials into the furnace top could no longer be achieved economically and efficiently. It therefore became necessary to adopt mechanical alternatives to insure continued efficiency. Once again, Birmingham ironmakers displayed their characteristic ability to draw upon the latest ideas emanating from the country's other ironmaking centers and adapt them to the special needs of their relatively small furnaces.[239]

One of the most notable cases of such adaptation was the single-skip, Crockard furnace top installed at the Number Two Woodward Furnace in 1921. The Crockard stock distributor was named after its inventor, Frank H. Crockard, who became vice president and general manager of TCI and district manager of the Republic Iron and Steel Company in 1906. Crockard had originally designed his own version of a Brown stock distributor to serve TCI's Ensley Furnace

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[235] "Birmingham," 31; "Good Furnace Work in the South," 25.
[236] Y.A. Dyer, "Some Defects in Foundry Pig Irons," Iron Age 107 (April 1921): 1093-1094.
[237] For a brief discussion of the complex ways that the constituent elements contained in the District's red and brown ores could be manipulated in the blast furnace to make excellent iron, see Y.A. Dyer, "Why Alabama Irons Are Valuable," Iron Trade Review 59 (October 19, 1916): 785-786.
[238] Bowron, "Southern Iron and Steel Industry," 1184.
[239] R.H. Ledbetter, "Blast Furnace Practice in the Birmingham District," Iron Age 114 (October 1924): 1129. Y.A. Dyer, "Foundry Pig Iron in the Birmingham District," Iron Age (April 7, 1921): 907.

to produce 1.4 million tons of pig iron before relining was required. The original Crockard top employed two skip cars to convey raw material to the top of the furnace but the capacity of the Woodward Furnace was sufficiently modest that only one skip car was required. The single-skip version was ideally suited to Woodward's needs, enabling the company to load its smaller furnace efficiently without having to spend the extra money that would have been required to install a second skip.[240]

Such specialized adaptations of standardized equipment allowed foundry iron furnace operators in the Birmingham Industrial District to achieve optimum levels of mechanization on a more diminutive scale that was more in line with the amortization rates of their plants. Local ironmakers showed an ability to make these incremental improvements whenever they reached production thresholds requiring increased mechanization.

This was true with the sand casting process, which, as preciously noted, was a standard feature of Birmingham's foundry iron furnaces until the early 1930s. Foundry ironmakers faced problems different from those of steel mill blast furnaces in handling molten pig iron as it was tapped from the furnace. Led as usual by manufacturers in the Pittsburgh District, the steel industry had developed techniques for transporting molten iron directly form blast furnaces to Bessemer converters or open hearth furnaces, where it was converted into steel. On Sundays or at other times when it was not possible to take the molten pig iron directly to the steel furnaces, mechanical pig-casting machines, such as the one invented by Edward A. Uehling, were used. Casting cars also allowed greater integration of individual mills, as iron production at Dusquesne was often transported to Homestead or Edgar Thomson Furnaces for conversion. For two principal reasons, pig casting machines were absolutely essential in such instances. On one hand, the furnaces involved were too large for hand casting, producing 500 tons per day by 1900. That much pig iron would have swamped a sand casting shed. On the other hand, pig iron cast in sand was unacceptable for steelmaking, because the sand that adhered to it produced detrimental results in a steel furnace.[241]

The foundrymen who brought pig iron from Birmingham's merchant blast furnaces, however, actually preferred sand-cast pig. The MacKintosh-Hemphill Company of Pittsburgh, for example, was still using sand-cast pig to make rolls for steel mills in the 1930s. Whether because of prejudice in favor of the obsolescent sand-cast pig, or due to verifiable limitations in scientific testing techniques, a strong demand for sand-cast foundry pig iron continued into the third decade of the twentieth century.[242]

For many years, sand-casting harmonized will with the scale of blast furnace operations in the Birmingham Industrial District. A typical foundry iron furnace in Birmingham in 1900, which

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[240] For a comprehensive but brief discussion of developments in the machinery used to distribute raw materials in blast furnaces during this period, see George W. Vreeland, "The Distribution of Raw Materials in the Blast Furnace," Yearbook of the American Iron and Steel Institute, 1916 (New York: American Iron and Steel Institute, 1917): 106-134; Bowron, Southern Iron and Steel Industry, 1228; Crolius, "Straight Line Production," 265; Mussey, "Blast Furnace Practice," 442; M.P. Gentry Hillman, "Birmingham Furnace Practice Development," Iron Age 94 (October 29, 1914): 995.

[241] James P. Dovel, "Reasons Why Foundry Iron Should be Hand Cast," Iron Age 107 (April 21, 1921): 1035. Uehling, "Pig Casting and Conveying Machinery," 115.

[242] Pat Dwyer, "MacKintosh-Hemphill Melts Iron in Air Furnaces," Foundry 63 (July 19, 1935): 18. For two opposing views of the merits of sand-cast versus machine-cast pig iron, see Y.A. Dyer, "Foundry Pig Iron in the Birmingham District," 907-909 and Dovel, "Reasons Why Foundry Iron Should be Sand Cast," 1035.

produced well under 300 tons daily, did not require mechanical pig casting machines. Even after output exceeded this level, the tasks of molding the sand in a casting shed and removing and breaking the chilled pig iron could be achieved by selective mechanization that was not as costly as the ladle car-and-conveyor system utilized by Uehling and Heyl-Patterson mechanical pig-casting machines. The foundry iron producers of the Birmingham Industrial District developed techniques that reduced the amount of manual labor required, but still retained the sand-casting feature desired by their customers. Their efforts in this particular area of furnace practice were already being manifested as early as 1894, when Pennsylvania inventor John S. Kennedy traveled to the District, observed the local blast furnace cast sheds, and stated that "the possibility of handling an entire cast cold was impressed upon me in Alabama where it is general practice," Kennedy went on the describe a pig-breaking machine, based upon models he had seen in Birmingham, that he had recently patented and was attempting to sell to northern foundry-iron producers.[243]

Sloss and Woodward continued to improve their methods of handling sand-cast pig iron as the years passed. They frequently borrowed pre-existing technology, such as the Ladd and Backer pig breaker, but also devised equipment for use in individual cast houses. Woodward for instance, developed a long, square-shaped harrow that could be dragged across a sand bed to create identical, exactly spaced imprints of pig beds. After the molten pig iron had been run into the big beds and allowed to cool, the entire pig beds were removed as separate units and carried by a crane to automatic pig breakers. At that point the pigs were broken and allowed to fall into railroad cars for immediate shipment. James P. Dovel also devised a mechanical pig breaker that was originally installed at Sloss's North Birmingham plant. Such a device was capable of handling an entire cast of pig iron with little more human effort than was employed by pig-casting machines. Dovel's technique was finally abandoned not so much because it was less efficient than automatic pig-casting but because demand for sand-cast iron had dropped significantly and the last objection to mechanically cast iron, imbedded kish, had been overcome with new skimming methods.[244]

THE MODEL FOUNDRY IRON FURNACE

By the late 1920s and early 1930s, ironmakers had learned so well the nature of the Birmingham Industrial District's raw materials and developed various ways of overcoming their limitations that they were ready to build a new generation of foundry iron furnaces that could regularly produce between 425 and 475 tons of iron daily. Coal washing had been greatly improved by the installation of the third generation of coal washing plants in the District. By-product coking practice had been refined to a point at which plant operators could produce coke that was stronger, with better porosity and lower ash content than ever before. Local furnacemen had so enhanced their ability to control the metallurgical qualities of their coke that they began to consider the preparation of Red Mountain ore and the subtle techniques of properly loading it into the furnace to be their greatest raw material challenge. They had recently learned to crush Red Mountain into various sizes to be fed into the furnace separately. It remained only to enlarge

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[243] John S. Kennedy, "Apparatus for Breaking Pig Iron," Iron Age 54 (August 2, 1894): 184-185.
[244] Young, "Iron Mining in the Birmingham District," 254; "Little Pigs-Little Pigs," Pig Iron Rough Notes (Winter-Spring, 1939): 3-4; Crolius, "Straight Line Production," 266-267, 305; Mussey, "Blast Furnace Practice in Alabama," 448-450; Crockard, "Southern Blast Furnace Practice,: 51-54.

existing furnaces or build new ones that could better accommodate these advances in raw materials preparation.

This period of blast furnace remodeling and construction is a study in the microcosm of the dynamics that had guided the development of the Birmingham Industrial District since the Eureka experiments had taken place a half-century earlier. It featured not only the input of outside technical experts, and ample borrowing of ideas and designs, but also what had always been the most persistent characteristic of the District from its start: the skill shown by local ironmakers in accommodating themselves to the idiosyncrasies of local raw materials. It was this skill, anchored by this time in nearly a half-century of experience, which resulted in foundry iron furnaces that were custom designed to smelt Red Mountain ore. Two installations in particular, the new Sloss City Furnaces, built between 1927 and 1929, and Republic's Thomas Furnaces, modified several times between 1929 and 1935, are indicative of these dynamics at play.

The design that James Pickering Dovel developed for Sloss-Sheffield reflected the best understanding of the way in which Red Mountain ore and Warrior coke worked together in a furnace. The interiors of the new City Furnaces were proportioned to insure that the correct physical and chemical interactions occurred at the right points in the slow, downward movement of raw materials so that sufficient coke and properly-reduced ore reached the zone of fusion in the hearth. The new design for the first time brought together many ideas that Dovel had been able to implement only on a piecemeal basis in modifying Sloss-Sheffield's earlier stacks.[245] Of particular importance was the diameter of the stock line, located directly below the bell-shaped closing device that distributed raw material into the furnace.[246]

Dovel's emphasis on the stock line is indicative of a divergence from northern practice taken by the Birmingham Industrial District to accommodate its unique raw materials. The designers of northern steel furnaces, by contrast, placed greater emphasis on improving the proportions of the hearth and bosh sections.[247] Dovel chose to leave the interior dimensions the hearth and bosh essentially unchanged while greatly increasing the diameter of the stock line because lean Red Mountain ore and the large volume of slag that it produced required blast volumes that were 20 to 40 percent higher than northern practice. If the stock line was too narrow, this higher blast volume, known as wind rate, increased the velocity of gases moving at high velocity through a constrained opening blew excessive particles of coke and ore back out the top of the furnace. Dovel's wide stock line reduced the gas velocity and hence reduced the loss of this particulate, known as flue dust, to unprecedentedly low levels. His achievement so impressed his peers that it was cited in journals articles and in Ralph Sweetzer's important book on blast furnace practice.[248]

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[245] For an incisive summary of Dovel's innovations, see chap. 14 of W. Davis Lewis, Sloss Furnaces and the Rise of the Birmingham District.

[246] James P. Dovel, "Furnace Operations in the South," Blast Furnace and Steel Plant 18 (January 1930): 113; Dovel, "Improved Furnaces on Southern Ore," Iron Age 113 (September 22, 1927), 22; William A. Haven, unpublished report to Republic Steel Corporation, ca. February, 1934, Thomas Works Collection, Wade Sand and Gravel Company, Inc., Birmingham, Alabama.

[247] Ralph H. Sweetzer, "Blast Furnace Theory and Practice," Blast Furnace and Steel Plant 18 (December 1930), 1825.

[248] Haven, unpublished report to Republic Steel Corporations; Crockard, "Five Years of Progress in Southern Blast-furnace Practice," 46; James P. Dovel, "Improvement of Existing Blast Furnaces," Blast Furnace and Steel Plant 18

While his stock line dimensions were a masterstroke, the 7'-9" diameter of Dovel's large charging bell proved to be too small. It was replaced after 1930 by a bell that was 11'-9" in diameter. While it is difficult to document the reasons that made a large-diameter charging bell as essential as a wide stock line, it is clear from Republic's subsequent experience with its rebuilt furnaces that such is the case.[249]

In 1929, Republic had enlarged the stock lines of its Thomas Furnaces to 16'-6" and installed a charging bell that was ten feet wide. This new design did not work well, causing an excessive loss of flue dust. The company therefore, replaced its old Brown stock distributor with a McKee top, which had proved very effective at the new Sloss City Furnaces. In addition, Republic went counter to the prevailing trend in the District by reducing the stock line to fourteen feet in an effort to create "the northern orthodox relationship between bell and stock line diameter." This imposition of conventional northern proportions further increased flue dust loss and caused scaffolds to form in the top of the furnace.[250]

The results of this design flaw became so serious that Republic sent its blast furnace committee to observe all of the operating furnaces in the District and make recommendations for overcoming the problems that had developed at Thomas. Among the members of the committee were its chairman, J.H. Slater, and William A. Haven of Arthur G. McKee and Company, developers of the McKee top. The committee's visit to the Sloss City Furnaces on January 22, 1934 proved to be the most educational stop on the tour.

The success that Sloss-Sheffield had enjoyed in operating its newly-built stacks prompted the visiting committee to recommend that Republic virtually copy the City Furnace design. Because Republic had already installed a McKee top like the ones that had proved so effective at Sloss, the elements to be mimicked included the ratio of stock line to charging bell that was employed in the City Furnaces and the hanging iron skirts that had replaced Dovel's patented iron top. The proportions between the stock line and charging bell constituted a strictly local innovation, while the hanging iron skirt was borrowed from northern practice. Republic subsequently adopted the same devices at its Canton and Massillon Furnaces in Ohio because this blend of local and borrowed ideas had been so profitable to Sloss. On his return to Ohio, Slater reported to R.J. Ryson, Republic's vice president in charge of operations:

> I feel that these improvements should be started as soon as possible because any expenditures, within reason, which will result in a furnace practice comparable with that of Sloss would justify itself in very short time.[251]

While Republic benefitted greatly from the ideas that it borrowed from Sloss-Sheffield, its officials were convinced that they could draw upon their own experience to improve upon the City Furnace model. The visiting committee had observed that flue dust loss at Sloss during

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(August, 1920), 1296; Ralph H. Sweetzer, Blast Furnace Practice (New York: McGraw-Hill Company, Inc., 1938), 214.

[249] J.H. Slater, Chairman, Blast Furnace Committee, Republic Steel Corp., to R.J. Wysor, Cleveland, Ohio, February 2, 1934, material in Thomas Works Collection, Wade Sand and Gravel Co., Inc., Birmingham, Alabama. F.H. Janecek, "Blast Furnace Lines," unpublished inter-office report; C.L. Bransford, Assistant District Manager, Thomas Works to J.H. Slater, Warren Ohio, July 27, 1935, material in Thomas Works Collection, Wade Sand and Gravel Co., Inc., Birmingham, Alabama.

[250] Haven, unpublished report to Republic Steel Corporation.

[251] Slater to R.J. Wysor, Cleveland, Ohio, February 2, 1934.

normal operation was less than fifty pounds per ton of pig iron produced. When problems occurred, however, the furnace's single, horizontal gas off take could draw as much as 500 pounds of flue dust per ton of iron for four or five days at a time. To remedy this problem, Republic installed four forty-five degree off takes equipped with baffled risers like those used at most steel mill blast furnaces.[252]

Despite such improvements, Republic could not duplicate the results that Sloss and Woodward had achieved. This was because Republic's furnaces made both basic and foundry iron. Design compromises that were made in order to produce two kinds of iron in the same furnace resulted in reduced efficiency. Although Republic's officials frequently contributed articles to professional journals touting the innovations that their firm had introduced in the Birmingham Industrial District, including flue dust sintering and iron skimming devices for pig-casting machines, they could not overcome the advantages that Sloss and Woodward had gained by devoting their undivided attention to foundry iron production. By the end of the 1930s, Republic withdrew from full competition with the latter two companies, directing most of its energies toward supplying basic iron to its steel mill at Gadsden.[253]

By devising ironmaking operations that recognized and accommodated the idiosyncrasies of their local raw materials and by concentrating their full attention on producing the one product to which these raw materials were best suited, Sloss and Woodward had created models that were difficult to emulate. Even the best efforts of Republic's top experts, bringing to bear the tremendous resources of their large corporation, could not overcome the advantages that two smaller companies had gained by focusing their attention for nearly fifty years on the subtleties of making foundry iron. The lessons that Sloss and Woodward had learned from this single-minded devotion insured that they would continue to dominate their small niche in the American iron and steel industry for nearly another half-century, until foundry iron itself became virtually obsolete.

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[252] Ibid

[253] Articles published by Republic officials during the period include: Hassler. "Offsetting Increased Labor Cost," 47-72; Curran, "Trend of the Southern Pig-iron Business," 37-43; and Crockard, "Five Years of Progress in Southern Blast-furnace Practice," 37-56, and M.F. Morgan, "Sintering Plant Improves Blast Furnace Practice," Steel 100 (February 8, 1937): 60-61. See also Woodward Iron Company, Alabama Blast Furnaces, 144.

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