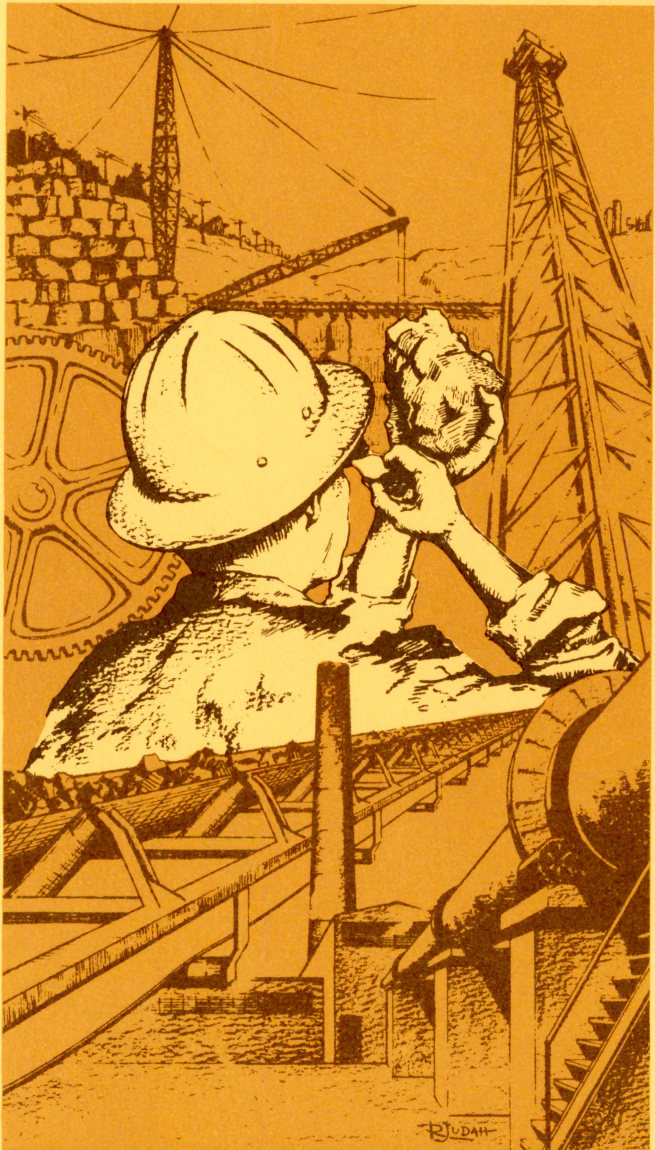


Native Indiana Iron Ores and 19th Century Ironworks

BULLETIN 42-E



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DEPARTMENT OF NATURAL RESOURCES
GEOLOGICAL SURVEY

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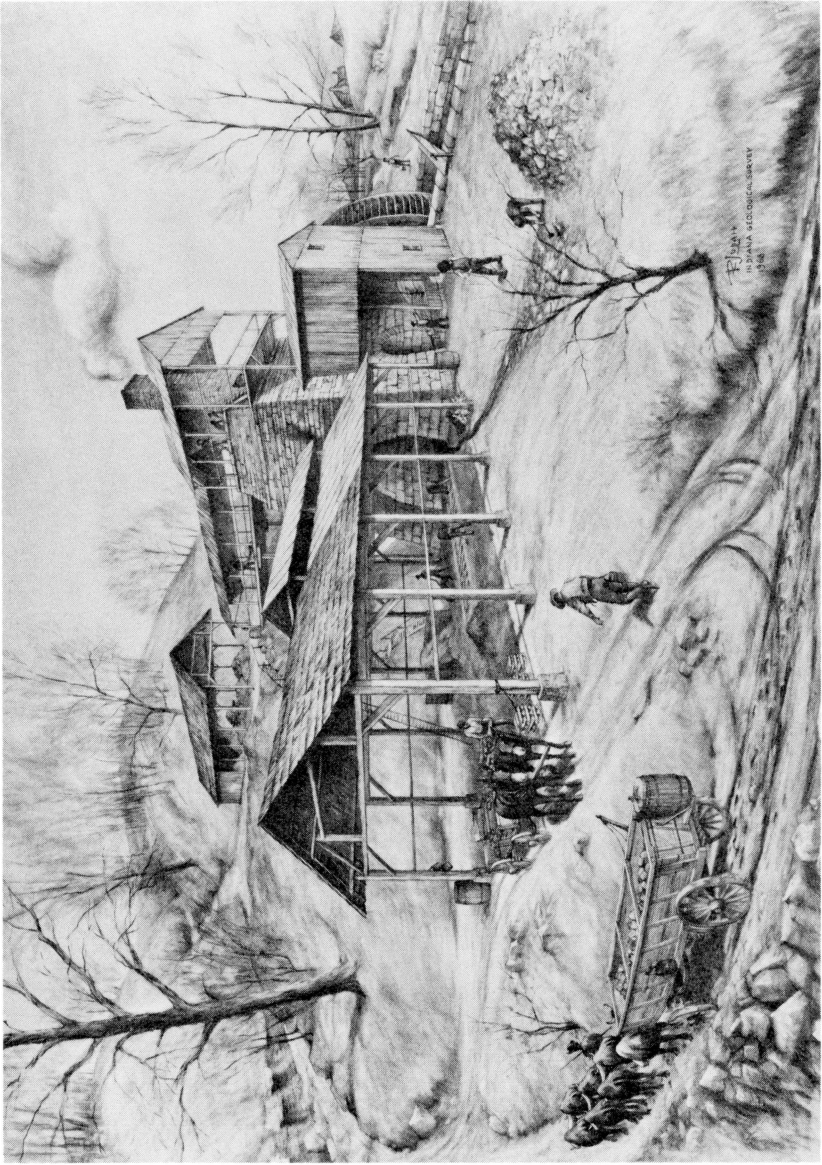
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FRONTISPIECE

Artist Robert E. Judah's concept of the first blast furnace in southern Indiana. A stone blast furnace similar to the frontispiece illustration was built on Indian Creek in southwestern Monroe County in 1839. Called the Randolph Ross & Sons Virginia Iron Works, the furnace successfully produced iron for local use and export to New Albany for about 5 years.



Native Indiana Iron Ores and 19th Century Ironworks

By WILLIAM J. WAYNE

DEPARTMENT OF NATURAL RESOURCES
GEOLOGICAL SURVEY BULLETIN 42-E



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Native Indiana Iron Ores and 19th Century Ironworks

By WILLIAM J. WAYNE

Introduction

“The coming of iron manufacturers into the Indiana field should be encouraged. The reopening of ore deposits, the development of the coal fields, the building of furnaces within the state to smelt northern ores, the building of new railroads, and the extension of others, and the aggressive policy of existing roads to encourage industries along their lines, will undoubtedly make Indiana a great producer of iron and other products of commerce that will later be developed.” So wrote C. W. Shannon in 1907, when Indiana was entering its third phase in the reduction of iron ore and in the manufacture of iron and steel. The U.S. Steel Corp. had recently purchased land at Indiana Harbor on Lake Michigan, and the new city of Gary was being laid out. Indiana was destined to become an iron- and steel-producing state again, and on a scale unheard of when the industry had its first start in the state.

In the early part of the 19th century, farm implements and heavier household articles, such as kettles and stoves, were carried into the newly settled parts of Indiana by flatboat as far as the streams were navigable and then by wagon over trails that were difficult to travel even in good weather; therefore replacements for broken tools and utensils cost dearly. Early prospectors brought back to the East reports of abundant supplies of iron ore and plenty of timber to make charcoal. With these reports as a basis, several enterprising ironworkers set out for Indiana. Between 1835 and 1850 they built four blast furnaces and at least five Catalan forges (hearths for direct reduction of ore) to produce iron from the Indiana ores (fig. 1). After the Civil War several blast furnaces were designed to use Indiana

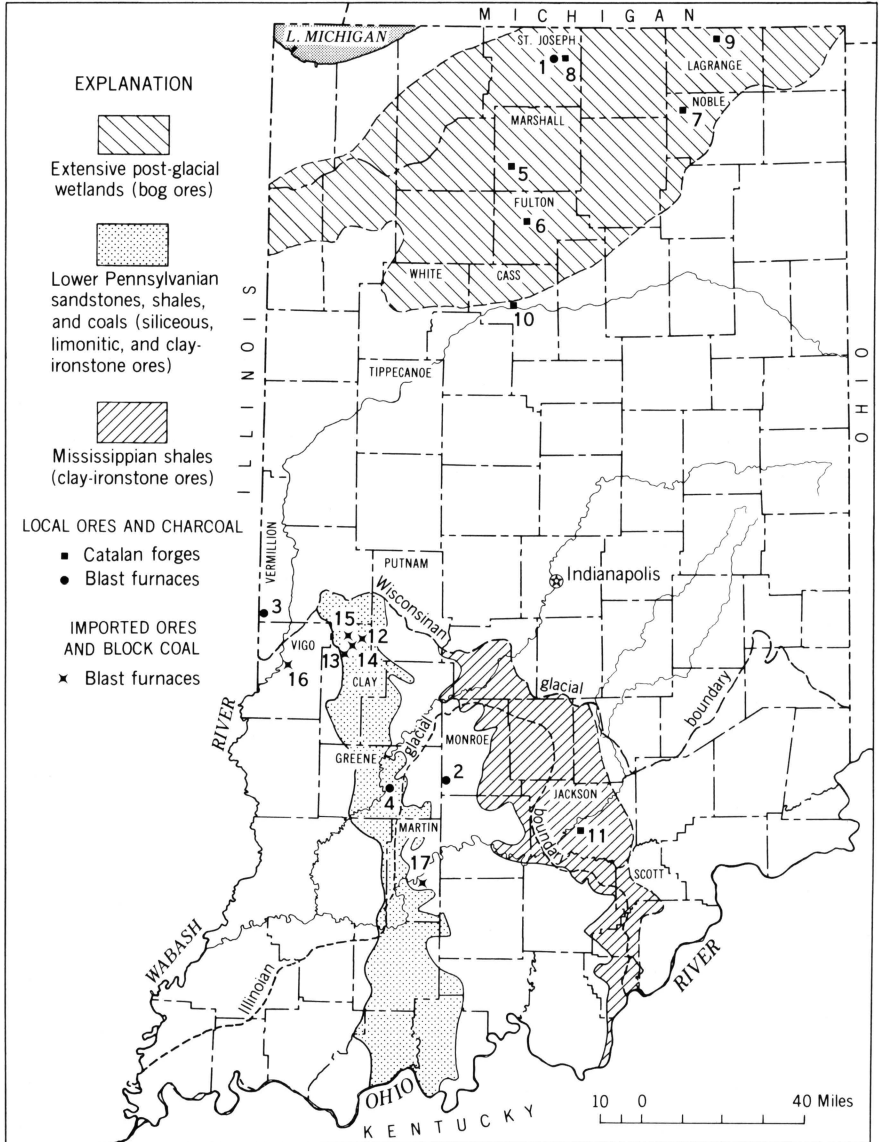


Figure 1. Map of Indiana showing locations and types of ironworks and distribution of ore-bearing rocks. Furnaces and forges are numbered in order of the dates they went into production.

Block coals. They reduced some local ore, but most of their ore was imported from Missouri.

Indiana Ironworks Before 1900

[Locations shown in figure 1]

1. Blast furnace of St. Joseph Iron Co. at Mishawaka, St. Joseph County, 1837-56; used bog ore, marl, and charcoal. (NE $\frac{1}{4}$ sec. 16, T. 37 N., R. 2 E.)
2. Blast furnace of Randolph Ross & Sons Virginia Iron Works in southwestern Monroe County, 1839-44; used Pennsylvanian siliceous and carbonate ores, Mississippian limestones, and charcoal. (SE cor. NW $\frac{1}{4}$ sec. 7, T. 7 N., R. 2 W.)
3. Indiana Blast Furnace west of Clinton, Vermillion County, 1840-61; used Pennsylvanian carbonate rocks and siliceous ores and charcoal. (NW $\frac{1}{4}$ SW $\frac{1}{4}$ SW $\frac{1}{4}$ sec. 23, T. 14 N., R. 10 W.)
4. Richland Furnace east of Bloomfield, Greene County, 1841-58; used Pennsylvanian carbonate and siliceous ores and charcoal. (SW $\frac{1}{4}$ SE $\frac{1}{4}$ NW $\frac{1}{4}$ sec. 25, T. 7 N., R. 5 W.)
5. Catalan forge of Plymouth Iron Works in Marshall County, 1840?-50; used bog ore and charcoal. (NW cor. sec. 22, T. 33 N., R. 1 E.)
6. Rochester forge, Catalan forge at north edge of Rochester, Fulton County, 1840-50; used bog ore and charcoal. (Exact location uncertain, but probably on Mill Creek.)
7. Rochester forge, Catalan forge along Elkhart River east of Ligonier, Noble County, 1845-55?; used bog ore and charcoal. (Near center S $\frac{1}{2}$ sec. 26, T. 35 N., R. 8 E.)
8. Mishawaka forge, Catalan forge at Mishawaka, St. Joseph County, 1847-50?; used bog ore and charcoal. (Exact location uncertain.)
9. Lima forge, Catalan forge at Howe (Lima), Lagrange County, 1850-55?; used bog ore and charcoal. (Probably in sec. 30, T. 38 N., R. 10 E.)
10. Logansport forge, Catalan forge along a lock of the Wabash and Erie Canal 4 miles from Logansport, Cass County, 1856-58; used bog ore from White County and charcoal. (Exact location uncertain.)
11. Brownstown forge, Catalan forge started but never completed south of Brownstown, Jackson County, about 1850; Mississippian (carbonate) kidney ore and charcoal. (Probably in S $\frac{1}{2}$ sec. 13, T. 5 N., R. 4 E.)
12. Planet Furnace, blast furnace of Indianapolis Rolling Mill Co. northeast of Harmony, Clay County, 1867-90?; used hematite ore from Missouri, uncoked Block coal, and limestone from Putnam County. (Probably in SE $\frac{1}{4}$ SE $\frac{1}{4}$ sec. 22, T. 13 N., R. 6 W.)
13. Brazil Furnace, blast furnace of Central Iron & Steel Co. in Brazil south of Pinckney and west of Meridian Street, Clay County, 1867-90?; used hematite ores from Missouri and Lake Superior, uncoked Block coal, and limestone from Putnam County. (NE $\frac{1}{4}$ NW $\frac{1}{4}$ NE $\frac{1}{4}$ sec. 1, T. 12 N., R. 7 W.)
14. Two blast furnaces of the Western Iron Co. at Knightsville, Clay County, 1867-90?; used hematite ores from Missouri and Lake Superior, uncoked Block coal, and limestone from Putnam County. (Probably in SE $\frac{1}{4}$ sec. 29, T. 13 N., R. 6 W.)

15. Lafayette Blast Furnace north of Brazil, Clay County, 1869-90?; used hematite ores from Missouri and Lake Superior, uncoked Block coal, and limestone from Putnam County. (SW¼ sec. 19, T. 13 N., R. 6 W.)
16. Vigo Blast Furnace in Terre Haute on Wabash and Erie Canal south of Washington Street, Vigo County, 1870-95; used hematite ores from Missouri, uncoked Block coal from Clay County, and limestone from Putnam County. (Near center SE¼ sec. 27, T. 12 N., R. 9 W.)
17. Blast furnace of Nelson Furnace Co. near Shoals, Martin County, 1871-80?; used hematite ore from Missouri and some local Pennsylvanian limonite and siderite ores, local coal, and limestone. (SW¼ sec. 29, T. 3 N., R. 3 W.)

Although Indiana iron ores have not been dug commercially for three-quarters of a century, they were a most important mineral resource during the pioneer period and remained significant in the economy of the state until late in the 19th century. In this review I have tried to summarize the major aspects in those first two phases of the iron and steel industry in Indiana, when local ores and fuels provided the raw material for the tools, utensils, and weapons essential to our forebears. Published descriptions of most of the early furnaces and forges of Indiana are something less than adequate, so much of that offered here is based on the excellent description of the Maramec Iron Works provided by Norris (1964), but adapted to Indiana conditions and materials.

Phase One: Charcoal and Native Ores

NORTHERN INDIANA IRONWORKS AND THE POSTGLACIAL BOG ORES

St. Joseph County had been organized only 3 years when, in 1833, Alanson M. Hurd arrived from Detroit to build an ironworks. He first laid out the central part of a town, and in 1835 he incorporated it as St. Joseph Iron Works. It became a part of Mishawaka in 1839. Hurd's company built a low dam across the St. Joseph River and diverted water along the south side to a race that was to power the bellows and other machinery for the ironworks. When his blast furnace was completed in 1834, the first period of the iron industry in Indiana, using local ores and charcoal for fuel, was underway. Little mention is made of the use of flux, although Richard Owen, in 1862, stated that the blast furnace at Mishawaka had used marl rather than limestone. The furnace remained in blast and produced as much as 800 tons of iron a year until 1856.

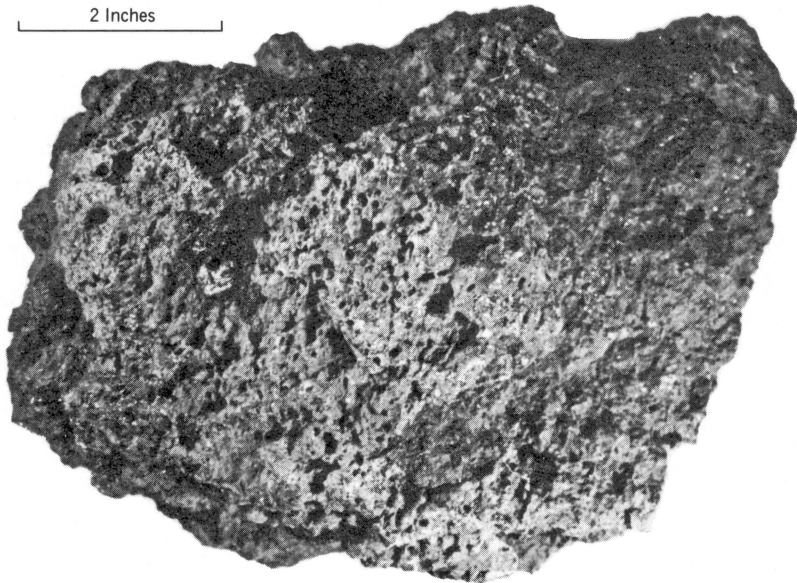


Figure 2. Mass of bog ore from small bog near Lafayette, Tippecanoe County.

The St. Joseph Iron Works worked bog ore dug from the swampy land along the St. Joseph River valley south of the town. Bog ore, as this kind of deposit is called, is a mixture of hydroxides, carbonates, silicates, and sulfides of iron. Common impurities are clay, sand, iron phosphate, manganese oxides, and organic material (Twenhofel, 1932, p. 433-442; Tyler, 1950, p. 517). Deposits of bog iron ore accumulate in shallow water that is rich in vegetation and has a high iron content. They form in water as much as about 2 feet deep as yellowish-brown to dark-brown irregular to lens-shaped masses or concretions about a foot thick (fig. 2).

Groundwater in glacial gravels ordinarily carries a large amount of iron in solution, but where the water emerges at the surface and its carbon dioxide content escapes, its ability to hold the iron in solution goes down, and some of the iron is precipitated as ferric hydroxide. Certain bacteria require iron salts in their life processes and also cause ferric hydroxide to be precipitated. Where decaying organic material is abundant, the iron deposits may contain large amounts of siderite, the iron carbonate, as well as goethite, probably the most common of the hydrous iron oxides.



Figure 3. Bog ore digging. Sketch by Robert E. Judah.

In northern Indiana many of the broad, flat sluiceways carried meltwater and outwash from the glaciers during the waning phases of the Wisconsin glacialiation but became flat swampy prairies after the ice had melted. Early settlers found abundant bog ore in the undrained swamps. Bog ore deposits were located by probing the shallow marshy ground with a pole or iron rod, and then the masses of ore were grubbed out and carted to the furnaces and forges (fig. 3). Bog ores have been mined at many places in the world, but the deposits are small and no longer of economic importance except in a few primitive cultures not yet disturbed by 20th century technology.

The pioneer furnaces and forges used charcoal for fuel. Virgin forests near the ironworks provided the wood needed for a couple of decades of operation. Some of the companies employed a hundred men or more, most of whom were engaged in making charcoal, and local farmers welcomed the opportunity to pick up some extra cash in the winter by cutting and hauling wood for charcoal. To produce a ton of pig iron in blast furnaces like the one

at Mishawaka required about 3 tons of ore and 400 bushels of charcoal. Each cord of wood yielded about 25 bushels of charcoal. The amount of charcoal consumed depended on the rate of production at each furnace, but a year's supply required from 100 acres to as much as a square mile of timber (Rowe, 1938, p. 11; Norris, 1964, p. 44). The woodchopping crews of the early furnace companies cleared many acres of forest for farming. Generally the charcoal-making season lasted from March to December, when the pungent smoke from the charring wood must have permeated the air near the furnaces constantly.

Indiana's first blast furnaces operated on the same principles as do the ones today, but they were vastly different in appearance (fig. 4). The stack was 25 to 45 feet high, and the exterior was generally unmortared masonry. That of the Mishawaka furnace probably was squared blocks of granite and other glacial erratic boulders; the three furnaces in southern Indiana were built of sandstone. Where possible, the stack was built beside a hill to make it easier to charge with wheelbarrow loads of ore, flux, and charcoal. The furnace lining was squared bricklike blocks of fine-grained sandstone, and the crucible, from which the molten slag and iron were tapped, was made of carefully fitted blocks of the same kind of rock. The space between the outer wall and the lining was filled with loose stone chips. Most of the early stone furnaces were square in plan and had two tuyere arches (blast openings) and a casting arch (Norris, 1964). At least three of the stone blast furnaces built in Indiana probably were equipped to use heated waste gases as part of the blast. The cost of erecting such a furnace was \$1,500 to \$2,000.

The bog ores of northern Indiana were reduced at five other places (fig. 1) in bloomery furnaces called Catalan forges. The Catalan forge utilized a direct reduction technique of smelting iron ore that had been developed in Corsica and Catalonia in the 15th century. It required much less capital outlay to build and fewer men to operate than did a blast furnace, although it used more fuel for each ton of iron produced. Catalan forges operated where the market was limited and the construction and operation of a small blast furnace probably would not have been a profitable investment.

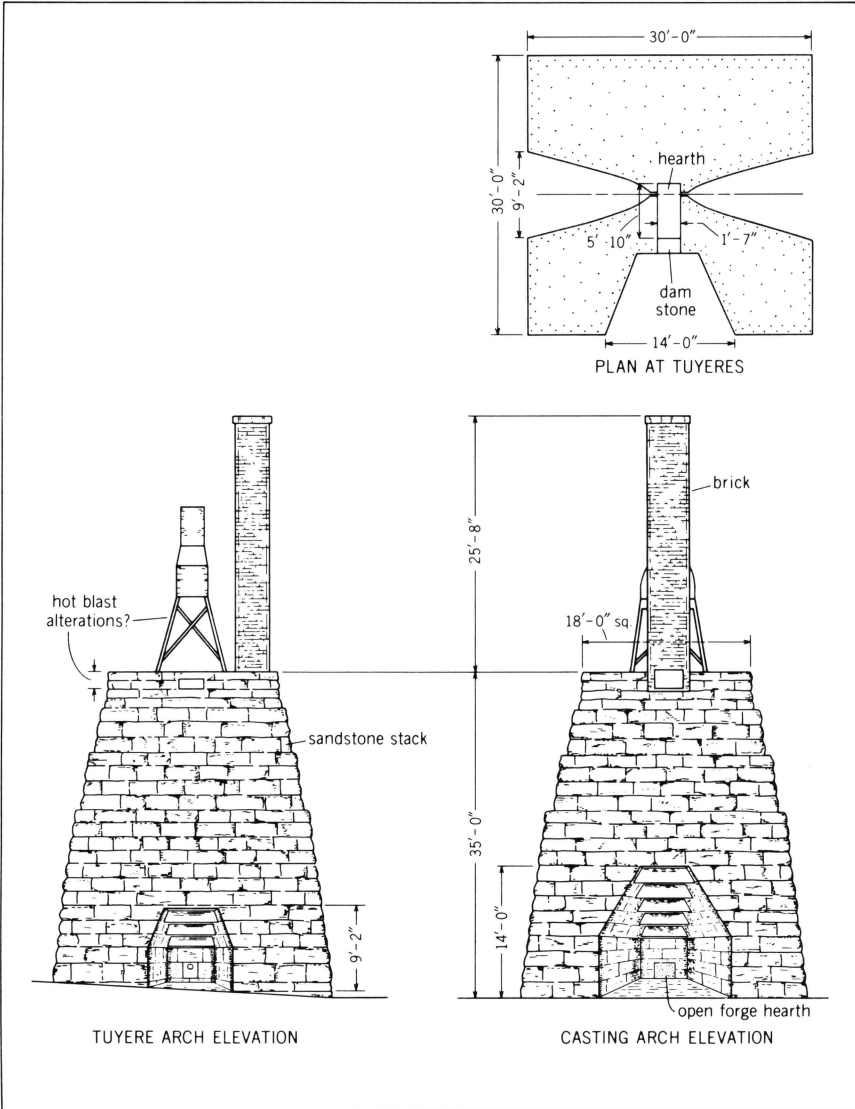


Figure 4. Reconstructed 1840 or 1850 blast furnace. From James D. Norris, 1964, "Frontier Iron: The Maramec Iron Works, 1826-1876," p. 27. Reproduced by permission of the State Historical Society of Wisconsin.

The Catalan forge was basically a raised hearth with a shallow pit or crucible, into which charcoal was placed, and through which a draft of air was blown through tuyeres in the sides of the forge. Water powered the bellows or pistons to produce the draft for both the Catalan forges and the early blast furnaces; therefore they were located along streams. Charcoal evidently served as both a fuel and a flux in most of the forges; the potash in the wood ash combined with impurities in the ore to make a slag. The ore was first roasted around the burning charcoal and then pushed into the fuel to be reduced. After several hours, it became a pasty white-hot mass, or bloom, which was taken off the hearth and beaten with a heavy water-powered trip hammer to squeeze out the slag and to consolidate the iron. Repeated heating and hammering produced a mass of wrought iron. Each charge yielded as much as 200 to 300 pounds of iron, in contrast to 3 tons or more per day reported for blast furnaces of the same period. (See Agricola, 1556, p. 420-426.)

Even though Catalan forges made much smaller quantities of iron than did furnaces, and they consumed more fuel, they had a place in the pioneer iron industry of the state. They existed partly because they required less capital outlay to build and because it was possible to make a better quality iron from the ores available in northern Indiana. Bog ores tend to be high in phosphorus, which makes iron brittle. Because the direct reduction process was used in a Catalan forge, the iron never became molten, and such impurities as sulfur and phosphorus did not get into it (Schubert, 1957, p. 152).

One of Indiana's earliest Catalan forges was built about 1840 at the lower end of Twin Lakes southwest of Plymouth by Charles Crocker and French Fisher, who had moved there from Mishawaka. Known as the Plymouth Iron Works, the forge produced a good grade of wrought iron from the local bog ores. It operated until 1849, when the structures around it burned. Crocker rebuilt it, but a few months later sold his interest and moved west. Ore was becoming less abundant, and the forge shut down not long after Crocker left.

In addition to the Plymouth Iron Works, Catalan forges in Indiana that used local bog ore were built and operated along Mill Creek at

the north edge of Rochester in Fulton County; along Pigeon River at Lima, now Howe, in Lagrange County (near the west end of the Pigeon River State Fish and Game Area); on the Elkhart River at Rochester, a now-vanished community just east of Ligonier in Noble County; and on the Wabash and Erie Canal 4 miles above Logansport in Cass County (fig. 1). A forge also is reported to have been built and operated for a short time in Mishawaka during the same period, 1845 to 1855.

Not all iron was reduced in the furnaces and forges; some blacksmiths occasionally used local ores to make small amounts of wrought iron when pig or bar iron was in short supply. The coming of the railroads across northern Indiana meant that bar and pig iron for blacksmiths and founders could be brought in more cheaply than it could be produced in the Catalan forges. None of them survived the competition.

SOUTHERN INDIANA IRONWORKS, PENNSYLVANIAN AND MISSISSIPPIAN ORES

Except for a single forge started at Brownstown and never completed, all the ironworks in southern Indiana were blast furnaces. Three of them, all built about 1840, used native ores and charcoal; the seven post-Civil War furnaces relied primarily on imported ores but used Block coal from Indiana for fuel (fig. 1).

The iron deposits used in early furnaces in southern Indiana were mined from shales and sandstones of Pennsylvanian age. Most of these deposits were one of three types: siliceous ores, carbonate ores, and limonite ores. The siliceous ores used were sandstone in which hydrous iron oxides, mostly the mineral goethite, had filled the spaces between the sand grains, cementing them firmly. Such ores seem to be limited to locations near the tops of hills and do not extend back very far into the sandstone. They probably formed as a part of the process of weathering. Some of the siliceous ores were reported to contain as much as 40 percent metallic iron, but most probably were not that rich.

Smooth nodular masses of iron-rich materials found in shales are known as "kidney ore," because their shape bears some resemblance to that of a kidney. Kidney ores may be the iron carbonate, siderite, the hydrous iron oxide, limonite, or both, generally mixed with varying amounts of clay, calcite, and pyrite. The iron ores that were to have been exploited for the forge near Brownstown were found as clay-rich iron carbonate ("clay ironstone") concretions in Mississippian shales of the region. Clay ironstone nodules are more resistant to weathering and erosion than the enclosing shales, and so concentrates of the concretions can be found in many creek beds near Brownstown (fig. 5), and the nodule layers stand out in shale outcrops. Similar sideritic kidney ore from Pennsylvanian rocks was used in the furnaces in Greene and Vermillion Counties, where it was picked from streambed concentrates as well as mined from the outcrops (fig. 6). Kidney ores that contain only iron oxides and clay may represent sideritic concretions from which the carbonate has been leached by groundwater.

Some of the iron carbonate used in the southern Indiana furnaces was black-band ore, so called because it was found as black layers interbedded with shale. The dark color was caused by carbonaceous matter in the siderite. Black-band ores were reported in the ore beds in Martin and Greene Counties (Shannon, 1907).

Limonite ore masses, mostly irregularly shaped but as much as 4 feet thick, are in the lower part of a clay layer that lies sandwiched between the base of Pennsylvanian rocks and the underlying Mississippian rocks in a few places in Indiana. The clay is thought to be part of an old soil that developed when these rocks were above sea level during late Mississippian time. It was buried when Pennsylvanian sediments were deposited on the eroded surface. The richest Martin County ore is of this kind, and perhaps similar ore may have been used in other furnaces. The ore is mostly the mineral goethite with some clay and has given yields as high as 60 percent iron (Shannon, 1907, p. 394-397), although most of the yields were considerably lower. It formed either as a secondary deposit in the old soil or as a



Figure 5. Siderite concretionary ore from Pigeon Creek bed 3 miles west of Underwood, Scott County (NW $\frac{1}{4}$ SW $\frac{1}{4}$ sec. 23, T. 2 N., R. 6 E.).



Figure 6. Old iron pit along Ore Branch, Greene County (NE $\frac{1}{4}$ SE $\frac{1}{4}$ sec. 21, T. 7 N., R. 4 W.).

bog deposit on the old weathered and eroded surface before the first Pennsylvanian sandstones were deposited over it (Bundy, 1956).

The earliest furnace of southern Indiana and the second furnace in the state went into blast in 1839 on Indian Creek about 10 miles southwest of Bloomington. Called the Randolph Ross & Sons Virginia Iron Works, it was operated, apparently successfully, for about 5 years. Although it had been abandoned for 25 years, it was still standing when visited by State Geologist E. T. Cox in 1869. He described it as not “more than five or six feet across the boshes,¹ and twenty to twenty-five feet high.” He said that it “was poorly constructed, and the only wonder was that it made any iron at all” (Cox, 1869, p. 90).

Raw material for the Virginia furnace came from siliceous ores of Pennsylvanian age about a half a mile northeast of the furnace, but some of the ore also came from Greene County. Limestone for flux was readily available at the furnace site.

The Virginia furnace produced kettles and other cast and wrought iron household goods for local use and pig iron for shipment to New Albany. At least three reasons have been offered for abandonment of the operation: The company was bankrupt from poor investments elsewhere; the cost of shipping the iron to New Albany was too great; and the men damaged the furnace by allowing it to cool while Mr. Ross was away on a business trip. Ruins of the base of the furnace still stand as a low mound on the edge of the floodplain along a small tributary of Indian Creek in southwestern Monroe County (fig. 7). The remains of the furnace suggest that it may have been circular in plan, as was “Soapfat” furnace in Blair County, Pa. (Sharp and Thomas, 1966, p. 23, pl. 2), rather than square as were most of the stone furnaces built in the early 1800’s. Fragments of a greenish-blue slag can be found in the bed of the creek below the furnace.

¹Boshes are the sloping sides inside the lower part of a blast furnace and above the hearth.



Figure 7. Ruins of Virginia furnace in southwestern Monroe County (SE¼NW¼ sec. 7, T. 7 N., R. 2 W.).

At almost the same time (1840), the Indiana Blast Furnace began producing iron on Brouilletts Creek near Clinton in Vermillion County. Larger than the Virginia furnace in Monroe County, it had a sandstone stack about 40 feet high, and the furnace was 9 feet across the boshes. It was designed to use the hot waste gases to preheat the blast. The ore used was mostly local sideritic kidney ore that came from along Brouilletts Creek near the state line (Bradley, 1869, p. 167). Daily production was estimated at 9 or 10 tons. It continued to produce iron until the beginning of the Civil War. In 1869, Cox indicated that it looked as if it were still in operating condition, but little remains of the old furnace now.

Richland Furnace, just east of Bloomfield, used sideritic kidney

ore and siliceous ores from the Pennsylvanian shales and sandstones along Ore Creek when it went into blast about 1841. Fluxstone was hauled from quarries in Monroe County near the old Virginia furnace. It was 45 feet high, slightly larger than the furnace near Clinton, and was worked with a heated blast (Cox, 1869, p. 93). It produced iron until about 1858. By 1869, the stack had been torn down in order to reuse the squared sandstone blocks for a bridge over Richland Creek. Dark-green slag exposed in a barnyard along the banks of a small creek is all that remains now to show the location of the old furnace. Nature has healed the scars, but at least four old mines along Ore Creek that supplied the Richland Furnace still can be recognized by their manmade topography (fig. 6).

Phase Two: Block Coals and Missouri Ores

All forges and furnaces in Indiana that used native ores and charcoal had ceased operation before the end of the Civil War. Discovery that uncoked Block coal would make a serviceable blast furnace fuel started a second phase of ironworks in Indiana at Brazil and at Terre Haute that lasted from the late 1860's almost to the 20th century.

After coal and coke began to replace charcoal as the fuel used in blast furnaces, the sites for new furnaces were selected as near as possible to the source of the fuel. If satisfactory ore was not available locally, high-grade iron ore from Missouri and the newly discovered Lake Superior orefields could be shipped in by rail.

Block coal is a name used by miners to refer to a particular kind of bituminous coal that could be worked from the bed in large, nearly cubical blocks. The Block coals are broken nearly at right angles by joints, and the coal has a structure that causes it to split readily along the horizontal plane parallel to the bedding and to break across the grain into cubical smaller chunks. The chunks of Block coal had sufficient strength to support the iron and flux in a blast furnace charge, and they did not break down or swell unduly during coking and burning in the stack, as do many of the other bituminous coals; thus raw Block coal could be used directly in a blast furnace charge (Cox, 1869, p. 36-47).

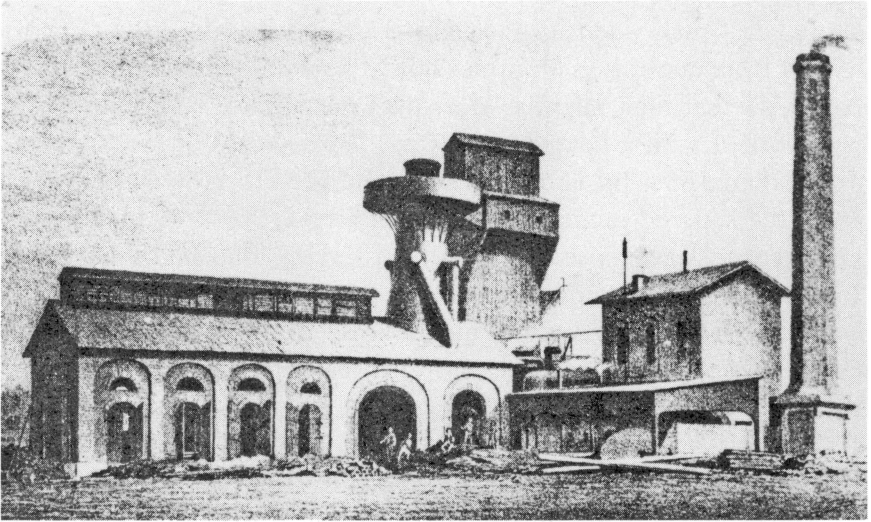


Figure 8. Brazil Furnace, Clay County. From Cox, 1869, frontispiece.

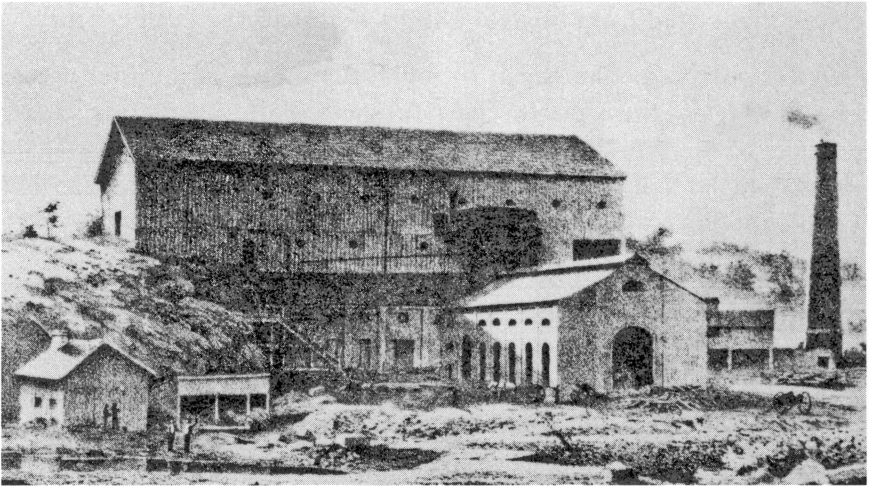


Figure 9. Lafayette Blast Furnace, Clay County. From Cox, 1871a, facing p. 163.

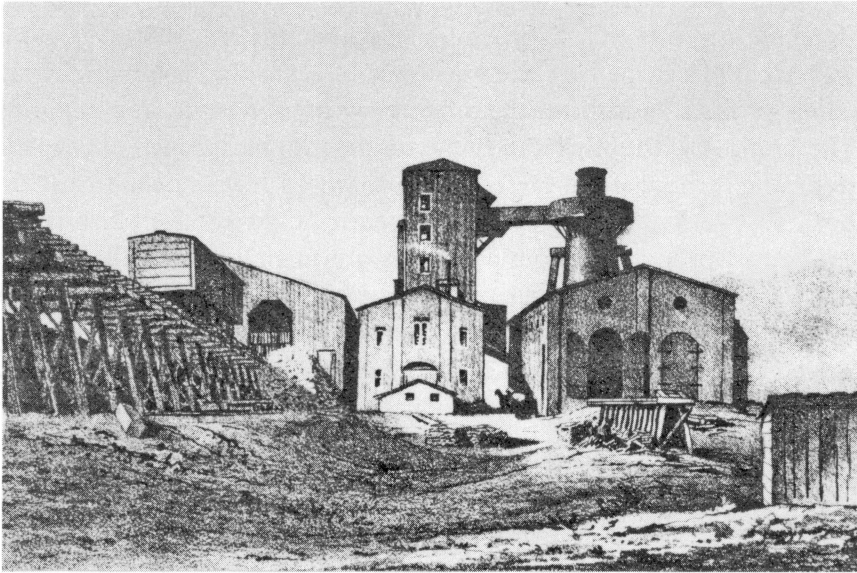


Figure 10. Vigo Blast Furnace, Terre Haute, Vigo County. From Cox, 1871c, facing p. 124.

The year 1867 saw the blowing in of three furnaces: one at Brazil (fig. 8); the first of two furnaces at Knightsville, 2 miles east of Brazil; and the Planet Furnace, a mile northeast of Harmony and 4 miles east of Brazil. All three furnaces used local ores to some extent, but they depended on high-grade magnetite and hematite ores from the Lake Superior iron region and from Iron Mountain, Mo. Uncoked Block coal mined near Brazil was used for fuel, and most of the coal used in these furnaces came from captive mines near the furnace. Limestone for flux came from quarries near Greencastle. The Western Iron Co. added a second furnace at Knightsville in 1868, and the Lafayette Blast Furnace (fig. 9) on Otter Creek north of Brazil was “blowed in” in May 1869. A fairly complete description of each of the Clay County furnaces was given by Cox (1869, p. 72-80).

The last furnace built in Indiana to use Block coal from mines at Brazil, the Vigo Blast Furnace (fig. 10), went into blast in the fall of 1870. It was in Terre Haute on the east side of the Wabash and Erie Canal, a few hundred feet south of the intersection of Washington and 16th Streets.

These blast furnaces were much larger than the early ones. The Brazil Furnace (fig. 8), for example, which cost \$150,000 to build, was a cupola shaped by joining a pair of truncated solid brickwork cones at their bases, with the upper cone supported on iron columns. The lining was firebrick and the exterior was quarter-inch boilerplate iron. The furnace stood 60 feet high; it was 14 feet in diameter at the boshes and 5 feet in diameter at the hearth (Cox, 1869, p. 73). It was capable of producing about a ton of pig iron an hour. All furnaces of the Block coal period used waste gas from the stack to preheat the blast to 700°-900° F. Combined, the five furnaces near Brazil consumed each day 300 tons of Block coal, 150 tons of ore, and 50 tons of limestone. The total daily production of iron from these furnaces was about 110 tons, worth about \$40 per ton for all grades averaged. Not including the miners who worked the captive coal mines, these furnaces employed about 200 men (Cox, 1869, p. 72).

Most of the iron produced near Brazil and at Terre Haute was used in Indiana markets. Some went to Indianapolis and Terre Haute rolling mills which produced rails, and part of the iron was made into wrought iron and cast iron products for local use.

Even though most of the ore used in the Brazil and Terre Haute furnaces was shipped from Missouri and Lake Superior, some limonite ore mined from the base of the Mansfield Formation along the west edge of Putnam County was carted to the Planet Furnace. The ore bed was no more than 6 inches thick, though, and back into the hill from the outcrop the overburden became too great to handle (Cox, 1869, p. 27). The local mines were soon abandoned because production costs were so great that ores from these mines were unable to compete with the Missouri ores, which were reported to yield about 68 percent iron (Cox, 1869, p. 75).

The last furnace to be built in southern Indiana was the ill-fated one in Martin County. Local investors employed Richard Owen to prepare a geologic report on iron ores in Martin County. By November 1872 the Southern Indiana Coal and Iron Manufacturing Co. had built a new blast furnace at Ironton, half a mile east of Shoals (Cox,

1872, p. 10-11). The furnace was 50 feet high and 13 feet across the boshes. Waste gases heated the boilers and hot blast. The steam engine that operated the blowing cylinder was imported; it had been taken from a captured blockade runner during the Civil War. Missouri ores were mixed with the somewhat clayey and siliceous sideritic kidney ores and limonitic ores from several mines near the furnace (Cox, 1872, p. 10-11). The fuel was from Sampson Hill in Martin County. Limestone for flux was available nearby.

The furnace was capable of producing 20 to 25 tons of pig iron daily, but it operated for only a few years. Reports indicate that it failed to continue at a profit because of high freight rates. The superintendent was replaced with a less experienced man in order to reduce costs, but this personnel change proved to be an expensive one, for the new superintendent allowed the furnace to cool and it exploded. The operation was discontinued at that time.

After the close of the early period of iron and steel manufacture in Indiana, when the use of local iron ores had virtually ceased and the blast furnaces in the state relied heavily on ores imported from Missouri, several attempts were made to develop the Indiana iron deposits again. The later proposals were based on the use of Indiana coals for fuel and a mixture of imported and Indiana ores to manufacture ferroalloys that were needed in the making of steel, in contrast to the pre-Civil War use as the ore available for wrought and cast iron manufacture primarily to serve a local area.

The Bessemer converter, in which impurities in the iron are oxidized by a hot blast, was patented in 1855, but during the early years of its use when the metallurgy of steel was as much an art as a technology, many problems plagued those who used it. Addition of spiegeleisen, a coarsely crystalline gray pig iron that contained a large percentage of manganese, had been found to help greatly in the production of steel in the Bessemer process. For a time the demand for spiegeleisen outstripped production of the alloy. In the early post-Civil War days, evidently spiegeleisen was imported from Germany and England to mix with the pig iron charge for Bessemer

converters in the United States. In the early 1870's production of spiegeleisen in the Brazil area, using the Block coals for fuel and both Indiana and Missouri ores for iron, was proposed (Hartmann, 1872; 1874b). More recent analyses of the Indiana ores (Shannon, 1907; Bundy, 1956) indicate, however, that their manganese content was variable (a trace to 2.0 percent) and that they probably contained too much phosphorus (0.1 to 0.5 percent) to have served well for this purpose in the acid refractory furnaces of the early 1870's. The development of basic refractories that permitted use of phosphatic ore took place in 1875. With the development of good metallurgical coke, the Block coals fell into disuse as a smelting fuel and were not used after the Vigo furnace went out of blast in 1895.

About the end of the 19th century and during the first few years of the 20th, some of the siliceous ores from Martin County, Ind., were being shipped 300 miles to furnaces at Jackson, Ohio, where they were used in manufacturing ferrosilicon, another ferroalloy used to adjust composition in manufacturing steel. Extensive exploration took place in Martin County as a result of this interest, and Shannon (1907, p. 427) suggested that the construction of a furnace near Shoals or Bloomfield using Indiana coals and iron ore from Martin County or Greene County to manufacture ferrosilicon could be a profitable venture. But no large-scale use of Indiana ores for ferrosilicon manufacture ever developed.

Not long after the publication of Shannon's (1907) report on the iron deposits of Indiana, the state entered its third phase of the heavy industry, in which ores from the Lake Superior fields and coke from Pennsylvania were brought together by ship to Gary and East Chicago at the head of Lake Michigan. Although some fluxstone is brought in by rail from quarries in Indiana, most of it arrives by lake freighter. The steel industry complex along the Lake Michigan shoreline has made Indiana one of the leading states in the production of iron and steel in this century.

Indiana iron deposits were examined again in the early 1950's, but not with the view of reduction to pig iron. A cement company that

used small amounts of iron in manufacturing cement explored the possibility of a nearby source, and the Indiana ores, though inadequate to consider as potential reserves for blast furnace use, were looked upon for a short time as a possible source for the quantities needed by the cement plant.

It is indeed unlikely that the small deposits of iron ore in Indiana will ever be used again in manufacturing industrial pig iron. This home-based industry is and will remain one of the romantic aspects of Indiana history. As a tourist attraction, however, a working reconstruction of a small 1840 blast furnace or a Catalan forge, using charcoal or Block coal and one of the Indiana ores, might be as profitable a venture as is the grist mill at Spring Mill State Park. Perhaps cast iron or wrought iron souvenirs of the state and of such a furnace or forge could be produced for sale at a price that would cover the cost of their manufacture. Such a reconstruction, as a central attraction in a state park, would do much to revive interest in the history of mineral resource use in Indiana.

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