GEOLOGICAL SURVEY OF KENTUCKY.

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THE IRON MANUFACTURE

OF THE KENTUCKY DIVISION OF THE

HANGING ROCK IRON REGION,

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SOME NOTES UPON THE IRON MANUFACTURE IN THE KENTUCKY DIVISION OF THE HANGING ROCK IRON DISTRICT.

The Hanging Rock Iron District takes its name from a peculiarly shaped rock exposure upon the Ohio river, near which is now the village of the same name. Some of the early furnaces were located near and had here their landing place. The name Hanging Rock pig iron was applied to the product of these furnaces, and as the number of furnaces increased the name was still retained, until now it is applied to all the iron produced in a number of adjoining counties, in both Ohio and Kentucky. The region now embraces in Ohio the whole or parts of Scioto, Lawrence, Gallia, Jackson, Vinton, and Hocking counties, and in Kentucky, the counties of Greenup, Boyd, and Carter, and it will, without doubt, eventually extend still further to the southward.

In this region the native ores of the coal measures are those in most general use. They are used exclusively by the charcoal, and very largely by the stone-coal, furnaces.

The Hanging Rock iron has an excellent reputation throughout the West. It is used for a variety of purposes; but perhaps more generally for foundry purposes than any other. For general foundry use, combining strength with fluidity and small shrinkage in cooling, it is probably unsurpassed in this country, if anywhere. It can also be used with a considerable proportion of scrap without injury to the resulting castings.

Certain brands of the cold blast charcoal iron have a national reputation for the manufacture of car-wheels, for which purpose they are unsurpassed.

The iron from the stone-coal furnaces of this region is used for both foundry and mill purposes, but most largely in the mills, for conversion into wrought iron. The fuel in use at a majority of the furnaces is charcoal. It was upon charcoal iron that the reputation of this region was established. It was not until within the past ten years that the use of stone-coal for the manufacture of iron was introduced. It has grown rapidly since that time, and is destined to become the prevailing industry; but as yet the charcoal largely outnumber the stone-coal furnaces. There are in this region sixty-one furnaces, either in active operation or in a condition to be put in operation in a short time. Of the whole number, forty-four are charcoal and seventeen stone-coal. Of these, thirteen are situated in Kentucky, of which eleven are charcoal and two stone-coal furnaces.

The following is a list of these furnaces:

CHARCOAL FURNACES.

Name.	When built.	County.	Owners.
Bellefont . .	1826	Boyd . .	Means, Russell & Means.
Boone . . .	1856	Greenup .	Nathaniel Sands & Co.
Buena Vista .	1847	Boyd . .	Means & Co.
Buffalo . . .	1851	Greenup .	Culbertson, Earheart & Co.
Hunnewell .	1845	Greenup .	Eastern Kentucky Railway Company.
Iron Hills . .	1873	Carter . .	Iron Hills Railway, Mining, and Manufacturing Company.
Laurel . . .	1849	Greenup .	Robert Scott & Co.
Kenton . . .	. . . .	Greenup .	Kenton Furnace Railway and Manufacturing Company.
Mt. Savage .	1848	Carter . .	Lexington and Carter County Mining Company.
Pennsylvania.	1845	Greenup .	Eastern Kentucky Railway Company.
Raccoon . .	1833	Greenup .	Raccoon Mining and Manufacturing Company.

STONE-COAL FURNACES.

Ashland. . .	1869	Boyd . .	Lexington and Big Sandy Railroad Company, East'n Div.
Norton . . .	1873	Boyd . .	Norton Iron Works Company.

In addition to these, there were quite a number of furnaces formerly in operation in this region, which have been discontinued from various causes, usually either poor original location, exhaustion of timber supply for charcoal, or unsuccessful management. They were all charcoal furnaces, although one of them, Star Furnace, used stone-coal during the last few years it was in operation.

The following is a list of these:

Name.	When built.	County.	Builders.
Argillite	1822	Greenup	Trimble Brothers & Deering.
Pactolus	1822	Carter	McMurtril & Ward.
Steam	1824	Greenup	Shreve Brothers.
Enterprise	1826	Greenup	Deering, McCoy, Clingman & Co.
Amanda	1829	Greenup	Pogue Brothers, Culvert & McDowell.
Clinton	1830	Boyd	Pogue Brothers.
Globe.	1830	Greenup	Darlington & McGee.
Hopewell	1833	Greenup	Wm. Ward.
Caroline	1833	Greenup	Henry Blake & Co.
Oakland	1834	Boyd	Kouns Brothers.
New Hampshire . . .	1846	Greenup	
Star	1848	Carter	
Sandy	1853	Boyd	

The most of the above given dates and names of builders were kindly furnished the Survey for publication by Col. J. Bell, of Ashland. Mr. J. Russell, of Bellefont Furnace, also furnished information which aided the completion of the list.

From the above list it will be seen that the first furnaces of this region were Argillite and Pactolus, built in 1822. It has been stated by Mr. Andrews, in the Ohio Geological Report for 1870, page 217, that the first furnace in the Hanging Rock region was the Union Furnace, built in 1826, by Sparks, Means & Fair. From the above list it will be seen that three Kentucky furnaces in this region were built before Union Furnace, viz: Argillite, Pactolus, and Steam, while two others, Bellefont and Enterprise, were built the same year. To Kentucky, then, properly belongs the credit of having first started the manufacture of iron in this now important region. Although not relating immediately to this region, the fact is worth stating at this place, that in Kentucky was built the first iron furnace in the West, and one of the earliest in the country. This was called Slate Furnace, and was situated in Bath county, upon Slate Creek, a branch of Licking river. It was built as early as 1791, and went out of blast after about thirty years operation. Of the Hanging Rock furnaces given in the above list, Argillite, Hopewell, Pactolus, Enterprise, and Globe were built adjacent to water-power, which was used for driving the blowing machinery. Argillite, Hopewell, and Pactolus were upon Little Sandy river, Globe and Enterprise upon Tygert Creek. The water-power was not sufficient at all times of the year, and in one case at least a furnace was chilled by the failure of the water requisite to drive her blast engines. The result was that they were all soon abandoned and others erected using steam-power. The first furnaces were of small size compared with those of the present time, and their production was correspondingly small. Steam Furnace, for instance, was first erected twenty-eight feet high by eight and a half feet bosh, and is said to have produced only three tons of iron per day. It is reported that Argillite Furnace was still smaller, being only twenty-five feet high by six feet bosh, and made only two tons per day. The site for this furnace was excavated out of the shale near the end of the dam, and it was so low that in time of floods the water could only be kept from the furnace by means of coffer-dams.

The present charcoal furnaces are much larger, and produce from ten to sixteen and even twenty tons per day. They are nearly all built after the old model, with a massive stone stack in the form of a truncated pyramid. With one exception, Iron Hills Furnace, the model of all the charcoal furnaces, is the same. They are built against a hillside, at the base of which the rock is excavated to give room to place the stack. The ore and charcoal are hauled in wagons to the stock bank at the level of the furnace throat, and thus the necessity for an elevator is obviated. The boilers are placed over the furnace throat, and the hot blast ovens at the end of the boilers, so that the waste gases are utilized effectually. The engine in common use is horizontal, with one steam cylinder working two blast cylinders, which are geared in such a manner that when the piston of one is at its least velocity the other is at its greatest, and thus a comparatively constant pressure of blast is obtained without the use of a reservoir to regulate it. The engines are usually geared to make one stroke of each blast cylinder to two of the steam cylinder, which is equivalent to stroke for stroke, as there are two of the blast cylinders. The furnaces are usually worked with open hearth, and most of them use but one tuyere, entering at the side. The hearths are generally constructed of sandstone, of which there is an abundance of good quality on most of the furnace estates. Formerly the inwall or lining was also generally of sandstone, but of late years the use of fire-brick for that purpose has become more common.

Most of the furnaces are without either pressure gauge or pyrometer, so that the pressure and temperature of the blast are not known with any accuracy, the general rule being to heat the blast as high as possible with the ovens at command, and to keep the pressure as great as the steam will allow, varying it, of course, according to the necessities of the furnace working. It is probable that the general pressure of blast does not vary much from two and a half to three pounds.

The following table gives the principal dimensions and other details of the charcoal furnaces in this portion of Kentucky:

CHARCOAL FURNACES IN THE KENTUCKY DIVISION OF THE HANGING ROCK IRON DISTRICT.

	Bellefont	Boone.	Buena Vista.	Buffalo.	Hunnewell.	Iron Hills.	Kenton.	Laurel.	Mount Savage.	Pennsylvania.	Raccoon.
Height	34′	44′ 7″	40′	36′ 6″	47′	49′	37′	39′	39′	36′	35′
Diameter of bosh	10′ 6″	10′ 6″	10′	10′ 6″	12′	12′ 6″	10′ 6″	10′ 6″	11′	10′ 3″	10′ 6″
Batter or slope of bosh	53°	53°	53°	55°	53°	53°	50°	55°	53°	50°	53°
Diameter of throat	3′ 8″	2′ 4″	3′ 4″	3′	3′ 6″	7′ 6″	2′ 8″	3′	3′	2′ 9″	2′ 10″
Height of hearth	6′	6′	6′	6′	6′	6′ 6″	6′ 2″	6′	6′	6′	6′
Diameter at top	3′ 8″	3′ 8″	3′ 7″	3′ 10″	4′ 1″	4′ 6″	3′ 8″	3′ 9″	3′ 8″	3′ 6″	3′ 4″
Diameter at bottom	2′ 2″	3′ 2″	3′ 1″	3′ 5″	2′ 8″	3′ 6″	3′ 4″	3′	2′ 6″	2′ 7″	2′ 10″
Number of tuyeres	1	1	1	2	1	3	1	1	1	1	1
Diameter of tuyeres	4″	4″	4″	3′ 2″	4¾″	3′ 2″	4″	4″	4″	4″	4″
Height of tuyere above bottom of hearth	2′ 3″	2′ 10″	2′ 8″	2′ 6″	2′ 2″	2′ 9″	2′ 1″	3′	2′ 10″	2′ 8″	2′ 8″
Number of boilers	2	2	2	2	3	3	2	3	3	2	2
Diameter of boilers	2′ 8″	3′	3′	2′ 9″	3′	. . . . .	3′	2′ 9″	. . . .	3′ 4″	. . . .
Length of boilers	46′	48′	52′	32′	50′	. . . . .	48′	37′	38′	50′	. . . .
Number of blast cylinders	2	2	2	2	2	1	2	2	2	2	2
Diameter of blast cylinders	4′	4′	3′ 1″	3′ 4″	4′	5′ 6″	2′ 6″	3′ 3″	3′ 1″	3′ 8″	4′
Stroke of blast cylinders	5′ 6″	6′	5′	6′	5′	4′	5′ 6″	4′	5′	4′ 6″	4′
Diameter of steam cylinder	1′ 6″	1′ 6″	1′ 3″	1′ 3″	1′ 6″	2′	1′ 3″	1′ 3″	1′ 3″	1′ 4″	1′ 3″
Stroke of steam cylinder	5′ 6″	6′ 10″	5′	6′	6′ 6″	4′	5′ 8″	4′	5′	5′ 6″	5′
Kind of hot blast ovens	Davis.	None, cold blast	Davis.	Davis.	Hoop.	Hoop.	Hoop.	Davis.	Davis.	Hoop.	Hoop.
Usual pressure of blast	3 lbs.	. . . .	3½ to 4 lbs	. . . .	3 lbs.	2½ to 3½ lbs.	. . . .	. . . .	. . . .	. . . .	. . . .

It will be seen from the above table that, with the exception of two furnaces, Hunnewell and Iron Hills, there is no very great difference in the size or general details of construction. Hunnewell Furnace is also built on the same model, but is larger than usual.

Iron Hills Furnace is, however, constructed on an altogether different and more modern pattern, and one sufficiently novel for this region to deserve a special description.

The furnace has an iron shell stack resting upon iron pillars, fire-brick hearth and lining or inwall, closed top with bell and hopper charging apparatus, and a gas flue for carrying the waste gases to the boilers, which are situated on a bank about twenty-five feet below the top of the furnace. The boilers are situated upon the same level as the stock bank, and an inclined plane elevator is used to hoist the charges to the furnace throat from this level. The hot blast, which is of the Hoop patent, is situated at the end of the boilers. The furnace was built to run upon the Lambert ore, which has been already described. It started at a very inauspicious time for a new enterprise of the kind, the winter of 1873–'74, and was compelled, through financial troubles, to cease operation in the following spring, after having made only nine hundred and sixty-two tons of iron. Since that time it has been idle, but it is to be hoped that it will not long remain so.

It has been freely charged that the lack of success of the furnace was due to the novelties introduced in its construction: notably the substitution of gas flues for taking the gases down to the boilers instead of placing the boilers over the throat of the furnace, in accordance with the time-honored custom. There is certainly no reason why this plan, which has been successful at other places, and which is being introduced in the latest and most improved charcoal furnaces in other regions, should not be successful here also. If it has not been, it may possibly be due to defective construction, improper size of flues, insufficient draft, or some other similar cause; but there certainly is no reason why the gases from a charcoal furnace cannot be taken down through flues and then consumed in heating boilers and hot blast as well as those from a coke furnace. There is no material difference in the composition of the gases.

In working the furnace it was found that the hot blast apparatus never was heated sufficiently to give a temperature to the blast of more than three hundred degrees to four hundred degrees, and it usually was about two hundred degrees, hardly warm enough to be called hot blast. It is not unlikely that the situation of the hot blast apparatus at the end of the boilers is too far from the place of combustion, which principally takes place where the air is first admitted under the boilers at the end nearest the furnace and farthest from the hot blast stove, so that in reality it receives little more than the waste heat from the boilers, all the combustible portion of the gases being consumed before reaching it. It is probable that if the hot blast apparatus were placed nearer the furnace, with a separate flue to conduct a portion of the gases directly to it, there to be consumed, it would be found as effective as desired, and, with the furnace working properly, there would be abundance of gas for both blast and boilers.

Of the charcoal furnaces in this region, Boone, Buffalo, and Laurel run a large portion of the time, or altogether, with cold blast, for the manufacture of car-wheel pig iron. The remainder use hot blast all the time. The average yield of the ores is generally stated by the furnace managers to be thirty-three and a third per cent. of iron, thus requiring three tons of raw ore for the production of one ton of iron. The figures, however, taken from the stock books at seven furnaces, for periods ranging from one to five years, give an average yield of 31.94 per cent., thus showing that it has been slightly over-estimated.

It will be noticed that the averages for the different furnaces do not vary greatly, three per cent. being about the limit. This shows the general uniformity in quality among the different ores. Those furnaces situated west of Little Sandy, and which use more or less of the lower block ores, show the least average per centage of iron, while those using the limestone and kidney ores show the highest yield. It will also be observed that the average yield shown by the furnaces is a considerably less per centage than indicated in the analyses of the ores which have been given heretofore. This is due to no fault of the analyses; they show accurately the composition of the specimens submitted to the chemist. The discrepancy is due to the following causes: 1st. To the loss of iron, which often attends the working of the furnace, through the combination of iron with the slag. This loss is not constant, but is greater as the furnace is working more irregularly and producing more mill iron. In such case there is usually an appreci able amount of iron in the slag. As the amount of slag is often greater than the iron produced, a very small per centage of iron in the slag involves a considerable loss, and materially reduces the yield of iron. This loss amounts to little or nothing when the furnace is working well and producing a foundry iron; for as the pig iron is not pure iron, but contains from five to eight per cent. of foreign matter, carbon, silicon, phosphorus, &c., the gain by these impurities will more than counterbalance the loss by the iron in the slag. In fact the furnace working should show a gain over the analysis when everything works properly. 2d. To the inaccuracy in selecting samples for analysis. The difficulty of selecting perfectly average samples of ores has been already referred to. The method adopted has been to take a great many small pieces of ore, each broken from a different place in the pile or outcrop to be sampled from, until the whole should amount to four or five pounds. The endeavor has been in every case to obtain as near a representative average sample of the whole as possible; but it is probable that, in the majority of cases, it has been actually taken better than the average. The personal equation in the matter of sampling an ore or coal is of great importance, and it almost invariably works in favor of selecting the best specimens, in spite of the fair intentions of the sampler However careful he may be, he will be apt to think that it is unfair to take a sandy or cherty lump of ore or a piece of pyrites in coal, lest it be more than the general average of the bed. It is a singular feature of human nature, but it exists in every one, whether personally interested in having the ore or coal well represented or not. In addition to this personal bias, it is usually the case that the ore sampled is cleaner and freer from adhering dirt and clay than the average as it is weighed at the furnace scales. This is caused by the sampler usually selecting a clean corner on each lump to chip or break his sample piece from, as he naturally thinks it would misrepresent the ore to take a piece covered with dirt or clay. There is no doubt that the per centage of iron is materially reduced from this cause below what it would yield if the ore could be purchased clean.

Notwithstanding all this, it is believed that the samples of both ores and coals which have been selected for analysis by the different members of the present Survey, approach more nearly to the character of true representative samples than any which have ever before been collected in this State or by the Geological Surveys of many other States. The character of the sample is of as much importance as the accuracy of the analysis, if a true estimate is to be formed of the quality of an ore or coal; and it should be held as requisite for the sampler to be conscientious and unbiased, as for the chemist to be skillful and accurate; and the name of the sampler should be given as well as the chemist. It is because analyses are so often made from small picked specimens representing the very best of the ore or coal, that so many practical men consider an analysis of no value, and charge upon the chemist the fault of misrepresentation which belongs to the sampler. This matter is more important, if possible, in coal than in ore analyses.

The difference which there is between an analysis made from a single lump taken from the center of a bed of coal or from that part of it which is freest from sulphur, and one made from a sample taken by making a number of cuttings through the whole thickness of the bed representing the coal exactly as it occurs, is very great. In the majority of cases heretofore, the former is the kind of sample which has been subjected to analysis.

The average consumption of charcoal per ton of iron in this region ranges from one hundred and forty-five bushels, at some of the best hot blast furnaces, to two hundred and thirty at some of those working cold blast.

The figures from the books at nine furnaces, for periods of time from one to five years, give an average for the whole of one hundred and seventy-nine bushels per ton of pig iron. This requires for its production about four and a half cords of wood, estimating the usual yield at forty bushels of charcoal to the cord of wood. The original forest of this region yields from thirty to fifty cords of wood per acre, with an average of perhaps thirty-five. Each furnace consumes from five thousand to fifteen thousand cords of wood per annum, varying with the length of the blast, thus clearing from one hundred and forty to four hundred and thirty acres of land each year. In 1872, as shown by the tables of production, there were made in this region twenty-four thousand three hundred and twelve tons of charcoal iron, which would require for its production the wood from over three thousand acres of land.

It will thus be seen how rapidly the forests are being destroyed, and how it is that only those charcoal furnaces which are situated on the very largest estates, those of from twelve thousand to fifteen thousand acres and upwards, can be permanent, as they alone afford time for the second growth to attain a size sufficient for charcoal-making before the original forest is exhausted. It is evident, therefore, that in course of time the charcoal iron industry of this region must be supplanted by the manufacture of iron with stone-coal, while the charcoal furnaces will be built further back from the river, where the forests are as yet comparatively unbroken, and from whence the more valuable charcoal iron will bear the higher cost of transportation.

The following table shows the average yield of ore, and the consumption of charcoal, at most of the furnaces of this region. The returns are not as complete as could be desired from all the furnaces, but the number of years from which the averages are made is given in each case, so that the proper weight can be given to the comparative returns by the reader.

In many cases the figures from which this table was constructed were taken directly from the furnace books, which were kindly placed at the disposal of the Survey. The returns of charcoal consumption are not absolutely accurate for comparison, as there is some variation in measurement at the different furnaces. The charcoal receipts are given in loads of two hundred bushels each, but the size of the wagon-beds, which are counted as holding two hundred bushels, varies somewhat at different furnaces. The consumption of charcoal was of course taken at the furnace measurement in each case. It is believed that this error will not amount to more than a few bushels in the general average. The returns of ore are probably accurate.

Furnace.	Number of years.	Ave'ge per centage of iron in the ore.	Number of years.	Average bushels charcoal to ton of iron.
Bellefont	4	32.23	5	185
Buena Vista	2	33.5	5	141
Buffalo	1	30.6	3	*229
Hunnewell	5	32.38	5	161
Kenton	4	32.8	4	197
Laurel	....	....	4	175
Mt. Savage	....	....	3	164
Pennsylvania	5	31.7	5	194
Raccoon	4	30.4	1	163
Average	....	31.94	....	179

* Furnace working cold blast much of the time.

The ores of this region usually contain such a mixture of ingredients that comparatively little lime is required to flux them. This is usually obtained from either the sub-carboniferous or the ferriferous limestones. At Mount Savage Furnace some limestone is used from the fossiliferous beds of the middle coal measures. The amount used varies from two to twenty-two per cent. of the roasted ore charged, as will be seen by the following table showing the ordinary charges, or so-called half charges, in use at the different furnaces. These are given as they were reported, without any guarantee as to the accuracy of the weights or measurements. It is probable that the weight of ore is usually pretty correct. The weight of limestone is, in many cases, estimated; and in the measurement of the charge of charcoal, considerable differences exist among the various furnaces; to reconcile which, in tabulating, no attempt has been made. The following table is, therefore, most valuable as showing the proportion of limestone used at the different furnaces, as the ores vary:

AVERAGE "HALF CHARGES" USED AT THE DIFFERENT CHARCOAL FURNACES.

Name of Furnace.	Roasted ore. Pounds.	Limestone. Pounds.	Charcoal. Bushels.	Average number of half charges in 12 hours.
Bellefont	1000	20	33⅓	......
Buena Vista	1700	20	33⅓	......
Buffalo { C. B.	750	100	30	26
Buffalo { H. B.	950	125	30	28
Hunnewell	1500	60	40	30
Iron Hills	1200	225	33⅓	......
Kenton	1100	240	22	36
Laurel { C. B.	650	100	22	38
Laurel { H. B.	900	60	22	45
Mt. Savage	1050	40	25	30
Pennsylvania	1250	60	35	......
Raccoon	1000	200	28	26

It will be noticed from the above table, that those furnaces situated west of Little Sandy river, working considerable quantities of the silicious lower block ores, use the largest per centage of limestone. Kenton Furnace, which is compelled to use more of these ores than any other, also consumes correspondingly increased amount of lime. Iron Hills Furnace, working the Lambert ore, shows its silicious nature by the amount of lime which it was obliged to use. The furnaces, on the other hand, which work the upper limestone and kidney ores, consume a very small amount of lime, only ranging from two to five per cent. of the amount of roasted ore.

The ore is prepared for the furnace by a preliminary roasting or calcination. This is, as yet, done altogether in open heaps or piles, so-called kilns. The fuel used is charcoal braze, fine charcoal, which is pulverized in the manufacture and handling. The ore is piled in pyramidal heaps upon a framework of logs, in alternate layers of ore and fine charcoal. The pile is then ignited at the bottom, and allowed to burn until the charcoal is all consumed, which usually occupies several weeks, when the ore is screened from the ashes and dust, and charged in the furnace. None of the furnaces as yet have roasting ovens or furnaces. This process, as usually conducted, probably offers more room for improvement than any other feature of the iron metallurgy of this region. It is open to serious objections, not the least of which is, that there is no control over the operation after the fire is once started; the whole success is dependent on the judgment of the man who "sets" the pile; if he properly arranges it and distributes the necessary amount of fuel, the operation will go on successfully; if not, there is no help for it, until the pile is all burned out. It is extremely difficult, if not impossible, to roast all portions of the ore alike. The interior of a heap is apt to become too highly heated, while the exterior may be scarcely warmed. There is great danger also of looping or melting the ore before it is roasted. This is quite a serious injury to the ore, rendering it more difficult to smelt, and materially increasing the liability to loss of iron in the furnace, through its entering into combination with the silicious matter present, forming silicates of iron, which are apt to go into the slag. Looped or melted ore is more difficult to smelt, as it is so dense and compact that it is impermeable to the reducing gases of the furnace.

These features are inherent to the system, and no care can entirely remove them; but the custom of roasting many different kinds of ore together, putting in one pile hard carbonate block ores and shelly limonite kidneys, without regard to the fact that they require very different treatment, as is often done, adds another and probably the strongest objection of all. It is a question whether roasting in open heaps is a method suitable for carbonate ores under the best circumstances; but nothing can be more injudicious than to pile indiscriminately, into one heap, a mixture of carbonate and limonite ores, and then expect to roast them all suitably at one operation. The result is, that if fuel enough be used to properly roast the hard carbonates, the limonites are looped; and if the heat is regulated for the limonites the carbonates will be scarcely affected, and require another treatment. Moreover, the carbonate ores usually contain more sulphur than the limonites, and for this reason they should not be roasted together, as the sulphur escaping from the carbonates is apt to impregnate, more or less, the other ores. This method of roasting is not an effectual one for the removal of sulphur. This can be much more thoroughly accomplished by the use of permanent roasting ovens or furnaces, in which the process can be under complete control, and the heat easily regulated according to the character or requirements of the ore under treatment.

The present inability of the charcoal furnaces to use the hard blue carbonate ores, and continue the regular production of a coarse-grained foundry iron, has been already referred to.

We thus see that by far the greater proportion of all the ore in this region is practically unavailable. If this is ever to be used by the charcoal furnaces, it must be after an improved method of roasting is introduced, by which the sulphur can be effectually removed, and the ore, instead of being looped or melted together, as at present, can be roasted with the admission of air enough to convert it into a porous, easily reducible peroxide.

At present it is regarded as a finality by many furnace managers that the blue ores cannot be worked to produce a hot blast foundry iron, and they are therefore abandoning large quantities of excellent ore of this kind, or else using it in the production of cold blast iron, in which a light color or fine grain is no objection. Where this kind of ore is used and roasted in the ordinary manner, it is sometimes found necessary to roast it two and even three times, before it is all converted into peroxide and ready for the furnace. The bad economy of this operation is readily seen. Any improvement, therefore, which will enable this vast amount of now useless material to be utilized, will add materially to the wealth of this portion of the State.

The introduction of roasting furnaces and an improved and more intelligent conduct of the process, might not, it is true, completely accomplish this result; but it is an experiment which can be easily tried, is not expensive, and if it did not succeed in making the blue ores available, would certainly show an economy and improvement in the process over the old method which would amply compensate for the slight expense.

Roasting in furnaces or ovens consumes less fuel and costs considerably less per ton than the old method, as well as requires less time. In the roasting kilns used in the Cleveland iron region in England, the ore, a hard, impure carbonate, is roasted in about two days, and about one ton of coal slack is used to roast twenty-five or thirty tons of ore. These kilns are shaft furnaces working on a similar plan to the continuously operated lime-kilns.

The quality of the charcoal pig iron of this region has been before alluded to. Its chemical composition is shown by the following table of analyses by Dr. Peter and Mr. Talbutt:

	Bellefont Mill.	Bellefont No. 1 Foundry.	Bellefont Silver Grey.
Iron	92.962	93.208	89.902
Graphitic carbon	2.100	3.350	2.900
Combined carbon	1.310	.220	.070
Manganese	. . . . .	.054	. . . . .
Silicon	2.525	2.389	5.082
Slag	.220	1.160	.280
Aluminum	. . . . .	.193	. . . . .
Calcium	. . . . .	.144	. . . . .
Magnesium	. . . . .	.095	. . . . .
Potassium	. . . . .	.047	. . . . .
Sodium	. . . . .	.032	. . . . .
Phosphorus	.568	.194	.417
Sulphur	.114	.005	.114
Total	99.799	101.091	98.763

	Pennsylvania Mill.	Pennsylvania No. 2 Foundry.	Pennsylvania No. 1 Foundry.	Pennsylvania Silver Grey.
Iron	94.764	92.856	92.060	90.630
Graphitic carbon	2.900	3.230	2.700	2.500
Combined carbon	.780	. . . . .	.630	.830
Silicon	1.193	2.545	3.104	4.969
Slag	.200	.360	.300	. . . . .
Phosphorus	.860	.817	.740	.741
Sulphur	.033	.046	.033	.040
Total	100.730	99.854	99.567	99.710

	Mt. Savage Mill.	Mt. Savage No. 2 Foundry.	Mt. Savage No. 1 Foundry.	Mt. Savage Silver Grey.
Iron	93.268	91.584	91.502	89.687
Graphitic carbon	3.950	2.600	2.670	2.300
Combined carbon	.770	1.070	.030	.500
Manganese	. . . . .	. . . . .	.123	. . . . .
Silicon	1.799	3.058	4.470	5.575
Slag	.160	.620	1.160	.660
Aluminum	. . . . .	. . . . .	.128	. . . . .
Calcium	. . . . .	. . . . .	.144	. . . . .
Magnesium	. . . . .	. . . . .	.112	. . . . .
Potassium	. . . . .	. . . . .	.076	. . . . .
Sodium	. . . . .	. . . . .	.023	. . . . .
Phosphorus	.680	.609	.203	.609
Sulphur	.081	.152	.041	.136
Total	100.708	99.493	100.682	99.467

	Hunnewell No. 2 Foundry.	Hunnewell No. 1 Foundry.	Buena Vista No. 1 Foundry.
Iron	92.368	92.284	93.712
Graphitic carbon	3.690	2.960	2.990
Combined carbon	. . . . .	.690	.210
Manganese	.020	. . . . .	.056
Silicon	2.515	3.011	1.908
Slag	1.130	.880	.600
Aluminum	.582	. . . . .	.644
Calcium	.048	. . . . .	.104
Magnesium	a trace.	. . . . .	.095
Potassium	.056	. . . . .	.063
Sodium	a trace.	. . . . .	.010
Phosphorus	.684	.474	.380
Sulphur	.026	a trace.	.066
Total	101.119	100.299	100.838

The above analyses are all from furnaces east of Little Sandy river, which use the upper limestone and kidney ores almost exclusively. The analyses are all of hot blast iron. The grades of iron are known as Mill, No. 2 Foundry, No. 1 Foundry, and "Silver Grey" or glazed pig. Mill iron is made when the furnace is working "cold." No. 2 Foundry when working between "cold" and "hot," No. 1 Foundry when the furnace is working "hot," and "Silver Grey" when working too hot. No. 1 Foundry is the most valuable, and is the grade which the furnaces endeavor to produce all the time. It is a free flowing, non-shrinking iron, which is used for castings of all kinds. "Silver Grey" or glazed pig is of the least value. It is so brittle that it can be used for no purpose where strength is required.

It will be noticed that there is a regular gradation in the amount of silicon present in the different grades of pig iron, directly proportional to the relative heat required in the furnace to produce them. Mill iron, which is made with the least expenditure of heat, contains least silicon, while "Silver Grey" contains the most. The poor quality of this iron is undoubtedly owing to the excess of silicon, which renders the iron brittle or "cold-short," and unfit for the puddling furnace, as in puddling the silicon oxidizes to silica, and combines with a large proportion of the iron, causing a great waste of iron, and rendering the process slow and difficult.

These irons are all somewhat phosphatic, but not enough to injure them for foundry purposes; on the contrary, it is probable that the free flowing, small shrinking qualities in this iron are largely due to the phosphorus present. Sulphur is low—0.15 per cent. being the highest in any samples analyzed.

The above statements apply equally well to the iron made at the furnaces west of Little Sandy river, which use the block and lower limestone ores exclusively.

	Boone No. 1 F., hot blast.	Boone No. 2 F., hot blast.	Kenton No. 1 F., hot blast.	Raccoon No. 1 F., hot blast.	Iron Hills No. 1 F., hot blast.	Laurel No. 2, cold blast.	Buffalo No. 1 F., hot blast.	Buffalo Silv. Grey, hot blast.	Buffalo No. 1, cold blast.
Iron	93.212	90.558	92.724	91.668	92.387	92.697	91.656	88.106	94.739
Graph. carbon	2.940	2.164	3.320	2.950	3.340	2.100	2.790	1.950	3.620
Comb. carbon.	.060	.116	.660	. . . . .	.760	1.000	. . . . .	.570	.780
Manganese	.083	.115	.612	.332	.056	. . . . .	.084	.014	.056
Silicon	1.634	2.682	2.090	3.817	2.240	1.813	4.106	7.317	.877
Slag	2.460	4.180	.300	1.200	.620	. . . . .	.600	.900	.120
Aluminum	.330	.479	.442	.128	.120	. . . . .	.399	.165	.060
Calcium	. . . . .	. . . . .	.184	.075	.120	. . . . .	.168	.128	.104
Magnesium	. . . . .	. . . . .	.190	.122	.056	. . . . .	.095	.125	.082
Potassium	. . . . .	. . . . .	.104	. . . . .	.080	. . . . .	.086	.048	.048
Sodium	. . . . .	. . . . .	.004	. . . . .	. . . . .	. . . . .	.016	.002	.041
Phosphorus	.486	.304	.622	.334	.836	.454	.695	.768	.609
Sulphur	.079	not det.	.046	.041	.057	.218	.150	.019	.037
Total	101.284	100.998	101.298	100.667	100.672	. . . . .	100.845	100.112	101.773

These irons show a very slight excess in the average amount of phosphorus over those from furnaces east of Little Sandy, but it is small. The superiority of cold blast iron seems, from these analyses, to be due more to its comparative freedom from silicon than any other cause. It is made when the furnace is not working so hot as with hot blast, and those metals, such as silicon, aluminum, &c., which require for their reduction an intense heat, are not reduced to alloy with the iron, but pass into the slag.

THE STONE-COAL IRON MANUFACTURE.

This branch of the iron manufacture, as yet in this region comparatively in its infancy, is destined to become ere long by far the most important industry. The great majority of charcoal furnaces are of necessity, as already shown, short lived through the exhaustion of their timber supply, which happens usually long before the ore supply becomes precarious. The permanent manufacture must then be based upon a supply of fuel which shall be neither precarious nor expensive. Fortunately this portion of Kentucky is richly blessed with an ample supply of a most excellent coal, a coal which the experience of the past six years has proved to stand in the front rank of the iron-making coals of the country. It is a dry-burning non-coking coal, which is used most successfully in a raw state for the manufacture of pig iron. It is known variously as the Coalton or Ashland coal, and is classed as No. 7. Its geological position and equivalency have already been described in

Mr. Crandall's report. It is the Kilgore coal of the old Geological Reports. It is known as the Coalton or Ashland coal, from the fact that it is most extensively mined by the Ashland Coal Company, at Coalton, on the Lexington and Big Sandy Railroad, Eastern Division, about twelve miles back from Ashland, in Boyd county. From the mines of this company the greater portion of this coal for furnace use has been obtained.

In addition, it is mined on the Star Furnace estate, now the property of the Norton Iron Works, of Ashland, and at Willard, Carter county, the present terminus of the Eastern Kentucky Railway, by the Bellefont and Ætna Coal and Iron Company. It is used in this State by the Ashland Furnace, belonging to the Lexington and Big Sandy Railroad, Eastern Division, and by the furnace of the Norton Iron Works Company, both situated in Ashland. It is also used by the Bellefont Furnace, of Ironton, Ohio, and will be used in the large furnaces now being erected by the Ætna Iron Company, near the same place.

As yet the No. 7 is the only coal which has been successfully used as a furnace fuel in this region. An attempt was made several years since to use the No. 3 coal at Hunnewell Furnace, but it was not sufficiently successful to justify a repetition of the trial. A blast of about four months was made, using this coal, but the production did not average over six tons per day, and the iron was of very poor quality, as could have been expected from the character of the coal, which is very sulphurous. It is probable that the working of the furnace when using this coal would have been more successful had the furnace and machinery been adapted to that fuel. They were constructed for charcoal and used for stone-coal without any material alteration. The coal is so sulphurous, however, that it is probable it would always make a poor iron, unless it could be first washed and coked.

The No. 1 coal, which is probably the equivalent of the well-known Jackson coal, of Ohio, which has proved so successful a furnace coal, is found of workable thickness at a number of places in this region, and will probably, on trial, be found to be well adapted to furnace use. It shows, in some places, of very good quality; but it is, unfortunately, somewhat irregular in its thickness. The following are analyses, by Dr. Peter and Mr. Talbutt, of this coal from the Graham bank, near Willard, Carter county:

	I.	II.	III.
Moisture	3.80	3.50	3.60
Volatile combustible matters	34.50	36.30	35.40
Fixed carbon	58.50	57.30	57.60
Ash	3.20	2.90	3.40
Total	100.00	100.00	100.00
Coke	61.70	60.20	61.00
Specific gravity	1.274	1.269	.....
Sulphur	2.164	1.148	1.065
Sampler	P. N. Moore	P. N. Moore	Geo. Gibbs.

No. I is a sample taken from the whole thickness of the coal, including a pyritous band, which can be rejected in mining. Nos. II and III are taken from the whole thickness of the bed, rejecting this band.

From the above analyses it is evident that the coal is of most excellent quality. The ash and sulphur are both low, and the fixed carbon is high. There can be little doubt that it will make an excellent furnace fuel, equal to or superior to any in this region.

The quality of the Coalton or No. 7 coal varies greatly, and it is at some places irregular in its thickness. The difference in quality is due to the greater or less proportion of sulphur present in the coal. This varies greatly in very short distances. The same mine will show coal in different parts of it of greatly different quality. The per centage of ash is quite uniform, as is the general structure of the coal, which retains its dry burning character throughout; but the sulphur is subject to rapid variation. The analyses that have been made by Dr. Peter and Mr. Talbutt, of this coal, usually show more sulphur than the coal was supposed to contain, and more than former analyses had indicated. This is due to the different methods of sampling employed. Heretofore the analyses had been made from single lumps, or from several lumps, which were usually taken by interested parties, and probably represented the coal at its best. This has been too often the plan pursued by members of Geological Surveys in other States, and the result has been to generally represent the coals as better than they actually are. The plan pursued by the members of the present Survey has been to take carefully averaged samples. These were made by cutting a large number of small pieces of coal from the whole thickness of the bed, taking them in regular succession from top to bottom, thus representing the coal exactly as it occurs at the place of sampling. Slate partings, or pyritous bands, large enough to be rejected in mining, were not of course represented in the sample, but otherwise impurities were taken if they occurred at the place of the cutting. Wherever possible the sample was taken from a number of rooms in each mine, or, where the coal was not opened, from as many outcrops as possible. The constant endeavor has been to secure samples representing the coal as it actually occurs in the mine. The personal bias already referred to in the matter of ore sampling, probably does not have as much influence in favor of the coals, when they are sampled in the mine in the way just described, for the reason that the cutting is made right through the coal where it is once started, and in the darkness of the mine it is difficult to see what is the exact quality of each piece taken. In sampling coal from a stock pile it is a different and more difficult matter to select a fair average sample; for the personal bias of the sampler then works in favor of the coal. It requires a strong effort of the will to break off a piece of pyritous coal and drop it into the sample bag when the sampler sees it before him in broad daylight. However conscientious he may be, he will be apt to think that perhaps if he takes that identical fragment of pyritous coal it will be more than the average, and so he will reason in regard to the next piece and the next, until in the end his sample will be much better than the average of the coal.

The following analyses of the No. 7 coal were all made from samples taken in the manner above described. The analyses are by Dr. Peter and Mr. Talbutt. The name of the sample is given with analysis:

	1.	2.	3.	4.	5.	6. Star.
Specific gravity	1.291	1.320	1.336	1.340	1.308	1.377
Water	4.80	5.00	4.06	4.40	3.30	7.70
Volatile combustible matter	34.20	34.50	34.24	31.10	33.30	28.16
Fixed carbon	54.90	55.40	54.70	57.90	57.60	53.04
Ash	6.10	5.10	7.00	6.60	5.80	11.10
Total	100.00	100.00	100.00	100.00	100.00	100.00
Coke	61.00	60.50	61.70	64.50	63.40	64.14
Sulphur	1.312	1.285	1.854	2.095	2.480	1.055
Sampled by	Moore.	Moore.	Moore.	Moore.	Moore.	Crandall.

	7. Star.	8. Star.	9.	10.	11.	12.
Specific gravity	1.290	1.288	1.320	1.340	1.320	1.350
Water	6.40	6.60	6.06	6.40	4.40	3.20
Volatile combustible matter	27.22	34.36	32.94	31.40	38.00	35.06
Fixed carbon	58.88	54.64	54.80	57.66	52.86	54.40
Ash	7.50	4.40	6.20	4.54	9.14	7.34
Total	100.00	100.00	100.00	100.00	100.00	100.00
Coke	66.38	59.04	61.00	62.20	62.00	61.74
Sulphur	.973	.724	1.867	1.670	2.200	2.631
Sampled by	Crandall.	Crandall.	Moore.	Moore.	Moore.	Moore.

No. 1 is an average sample of the coal from the stock-house at Ashland Furnace, taken to represent as nearly as possible the coal as actually used in the furnace.

Numbers 2 to 5, inclusive, are samples, each one taken from several rooms in mine No. 4 of the Ashland Coal Company, above Coalton, in Boyd county.

No. 2 is from several rooms about two hundred and fifty yards from the west end of entry No. 4.

No. 3 from rooms about three hundred yards from east end of entry No. 4.

No. 4 from rooms about eight hundred yards from west end of same entry.

No. 5 from rooms opening into the Dry branch cross-entry.

Nos. 6 to 8 are samples taken from the upper, middle, and lower members of the coal bed at the old Star Furnace mines above the furnace. The samples were taken from the pillars, which had been exposed for some time, and probably contained less sulphur than the freshly broken coal.

No. 6 is the upper, No. 7 the middle, and No. 8 the lower stratum of the coal.

Nos. 9 and 10 are samples from the upper and lower layers of the coal, here consisting of but two members, at an opening on Gum branch of Straight Creek, Mt. Savage Furnace property, Carter county. These samples were selected from coal on the bank, and hence are probably not as accurate averages as those taken in the mines.

No. 11 is a sample from the old Watson drift, on Lost Creek, near Willard, Carter county.

No. 12 is from several rooms in the mine west of Dry Fork, at Willard, Carter county, main entry.

These analyses show the great variation that exists in the amount of sulphur in this coal. In other respects, as will be seen above, the uniformity is remarkable. The per centage of ash is quite uniform. The sample that shows 11.10 per cent. is from the upper member of the coal at Star Furnace, a layer that is not taken down in mining, as it is usually quite sulphurous and slaty.

These analyses were all made from carefully taken samples, and they showed the coal to be more sulphurous than generally supposed, and more than analyses heretofore published had shown. They also indicate a coal poorer than similar coals from other States, judging by the published analyses of them, which, however, had probably been made from picked specimens, or at least there was no description given of the character of the samples from which the analyses were made.

Actual experience with the working of this coal in the furnace, for the past eight years, as will be shown more in detail further on, proves that it is a most excellent iron-making fuel, and that it ranks among the best of the country, although the analyses did not show as well as those of similar coals from other States.

With the view of making a trustworthy comparison with other successful iron-making coals of the country, based upon analyses from samples which were taken in the same way, and were known to be honestly and carefully selected to fairly represent the coal as it actually occurs, not picked to make as good a showing as possible, the Indiana Block, the Big Muddy, Illinois, the Hocking Valley or Nelsonville, and the Jackson, Ohio, coal regions were visited by members of the Survey, and samples selected in the same manner as in all the Kentucky coals.

The following are the analyses by Dr. Peter and Mr. Talbutt:

	1.	2.	3.	4.	5.
Specific gravity	....	1.313	....	1.310	1.310
Water	2.40	2.70	2.68	2.62	3.44
Volatile combustible matter	35.10	36.38	36.32	32.04	31.86
Fixed carbon	55.50	55.64	53.58	58.58	59.54
Ash	9.00	5.28	7.42	6.76	5.16
Total	100.00	100.00	100.00	100.00	100.00
Coke	62.50	60.92	61.00	65.34	64.70
Sulphur	2.373	1.664	1.803	2.472	01.370
Sampled by	Moore.	Moore.	Moore.	Moore.	Moore.

	6.	7.	8.	9.	10.
Specific gravity	1.346	1.303	1.312	1.361	1.322
Water	3.26	3.74	4.40	4.54	3.46
Volatile combustible matter	33.76	36.32	35.08	29.68	36.64
Fixed carbon	54.42	55.74	55.20	57.06	53.80
Ash	8.56	4.20	5.32	8.72	6.10
Total	100.00	100.00	100.00	100.00	100.00
Coke	62.98	59.94	60.52	65.78	59.90
Sulphur	2.247	1.299	1.659	0.758	1.848
Sampled by	Crandall.	Crandall.	Crandall.	Crandall.	Moore.

Nos. 1, 2, and 3 Indiana Block coal, from near Brazil, Indiana. Samples representing the coal from three different mines. Each sample was taken from several rooms in the same mine, so as to represent it as fairly as possible. These mines rank among the best of that region, and coal from all of them has been, or is now, successfully used in the furnace for making iron. The difference between these analyses and those heretofore generally published, strongly points to the probability that they have been made from picked samples.

Nos. 4 and 5 are from two of the best mines in the Big Muddy coal region, near Murphysboro, Illinois. Large quantities of coal from both of these mines have been used in the furnaces at South St. Louis.

Nos. 6, 7, and 8 are samples of the Hocking Valley or Nelsonville coal, from mine near Nelsonville, Ohio. No. 6 from the upper, No. 7 from the middle, and No. 8 from the lower division of the coal.

No. 9 is from the well-known Jackson coal, of Ohio. This analysis compares very favorably with those heretofore published, except that the per centage of ash is much greater.

No. 10 is from the Sheridan mines, Lawrence county, Ohio.

All of the above are excellent fuels, and, with one exception, the Sheridan coal, which has not as yet been tried for iron-making, they rank as the best, or among the best, furnace fuels of the West. The analyses of them heretofore published show much more favorable results; but they have not unlikely been made from picked specimens.

Long trial has proved that these coals work well in the furnace, and that the per centage of sulphur is not sufficient to seriously injure the iron made with them. The conclusion, then, that these analyses point to, is, that a larger proportion of sulphur than heretofore generally supposed, can be present in a coal without destroying its availability for iron-making.

The No. 7 coal, as shown by the analyses already given, compares very favorably with the other iron-making coals, and is superior to most of them. When properly selected for the furnace use, as must be done with all coals, no matter where they are from, it is among the best of the furnace coals in the West.

There is no coal which is of uniform quality throughout its whole range; there is variation in all of them, and the No. 7 coal is no exception. It holds the same general character throughout, but is more or less sulphurous, according to locality.

The first attempt to use this coal for furnace purposes was in 1866, when a considerable quantity of it was sent up the Ohio river to Martinsville, Ohio, and tried in the furnace there. This trial resulted so successfully that in 1867 the Bellefont Furnace was erected at Ironton, Ohio, relying upon this coal for its main supply of fuel, although a considerable proportion of coke is generally used. This was followed, in 1869, by the erection of the Ashland Furnace, at Ashland, and in 1873, by the Norton Iron Works at the same place. These two furnaces are, therefore, as yet, the only ones in this portion of Kentucky which manufacture iron from stone-coal. They are among the most successful and complete furnaces in the West.

The following are the principal dimensions of the two:

	Ashland.	Norton.
Height	60′	67′
Diameter of bosh	15′	18′
Slope of bosh	72°	73°
Diameter of throat	10′	9′
Height of hearth	6′	7′
Diameter of hearth at bottom	6′	6′
Diameter of hearth at top	6′	6′
Number of tuyeres	6	7
Diameter of tuyere	4″	4″
Height of tuyere above hearth	3′ 6″	3′ 4″
Vertical blowing engines	1	2
Diameter of blowing cylinder	7′	7′
Stroke of blowing cylinder	6′	4′ 6″
Diameter of steam cylinder	3′	2′ 8″
Stroke of steam cylinder	6′	4′ 6″
Number of hot blast ovens	5	5
Hot blast ovens—pattern	Player.	Player.
Usual temperature of blast	900°	850° to 1000°
Usual pressure of blast—pounds	8	6 to 7

The Ashland Furnace has an iron-shell stack, resting upon four masonry pillars at the base, between which are the tuyere and casting embrasures. The furnace produces mill iron only. It averages a production of from thirty-seven to forty tons per day. In addition to the native ore, which it receives by the railroad, it uses Iron Mountain ore from Missouri, mill cinder, and sometimes ores from other localities.

For fuel it uses the Coalton (No. 7) coal alone, not consuming a pound of coke after the furnace is filled with that material at starting into blast. This fact is of great interest and inportance, as showing the high rank of the Coalton coal as an iron-making fuel. It is of especial interest for comparison with other dry-burning furnace coals of the West. The far-famed Indiana Block coal has never been successfully worked in the furnace for any length of time without the use of a considerable amount of coke to mix with it, which coke has heretofore been brought all the way from Pittsburg by rail; but lately coking ovens have been erected at some of the furnaces in the Indiana Block coal region, to coke the coal from their own mines.

The Big Muddy coal of Illinois, which is the fuel upon which the iron manufacture of St. Louis is based, and which is an excellent coal, has never been used successfully alone for any length of time. The furnaces of St. Louis have also been compelled to bring coke all the way from Pittsburg to use with the coal.

The Hocking Valley or Nelsonville coal, of Ohio, which is also regarded as an excellent furnace fuel, has not been used alone without some admixture of coke. Only the Briar Hill and the Massillon coal of northern, the Jackson coal of southern Ohio, and the Coalton coal of Kentucky, have been used for any length of time alone, of all the furnace coals of the West.

The Ashland Furnace, in which this coal has proved to be so excellent a fuel, is one of the most successfully managed in the West. On the 20th of June, 1874, it finished a blast of three years and four months duration, during which it made, on a hearth of Mt. Savage fire-brick, forty thousand five hundred and twenty-seven tons of iron; during which time, as already stated, not a pound of coke was consumed after the first filling of the furnace. This is a record such as few furnaces can equal. This furnace stops on Sunday, from twelve to twenty-four hours, so that this production represents a less number of days blowing than the total time of the blast.

The following is the record of this furnace consumption and production for the past five years:

	1870.	1871.	1872.	1873.	1874.
Native ore (roasted) used, tons of 2240 lbs.	6425	7439	8852	10216	6407
Iron Mountain ore " " "	5630	7533	9463	8095	4758
Other ores " " "	4841	41	1077	868	568
Mill cinder " " "	2250	2731	3675	4941	2723
Limestone " " 2268	5990	5184	6820	7655	4800
Coal (tons of 2000 lbs.) used	23466	25166	33923	34499	*19160
Iron made, tons of 2240 lbs.	9316	9509	12105	12741	6710
Tons coal (2000 lbs.) to ton iron, 2240 lbs.	2.51	2.62	2.80	2.70	2.85
Average per centage of iron in the ore mixture	48.6	53.5	52.4	52.8	46.4
Tons of limestone to ton of ore	0.30	0.29	0.29	0.31	0.33

* Including 230 tons coke used in starting the furnace.

There is an error in the amount of coal consumed in 1870. It is probably under-estimated about one fourth ton to the ton of iron made. Leaving the consumption for this year out of consideration, as being uncertain, the table gives us for the four years, from 1871 to 1874, inclusive, an average consumption of 2.74 tons (of 2000 pounds each) to the ton of iron from an ore mixture averaging a little over fifty per cent. This corresponds to about 2.44 tons of coal of 2240 pounds each. This consumption is less than that required for a ton of iron, in the majority of the furnaces of the West using other coals of similar character. At Jackson, Ohio, where, however, the furnaces are mostly of small size, the consumption of coal is stated at one hundred bushels per ton of iron, or between three and four tons. At Massillon, Ohio, where the No. 1 coal is used, the equivalent of the Jackson and Briar Hill coals, nearly four tons of coal are consumed to the ton of iron. In Indiana the consumption of the "Block coal" is about three tons, and the ores used are usually of high grade, from Missouri or Lake Superior. All of these are higher than is desirable, and much more than theoretically required to produce a ton of iron. The volatile matter of the raw coal is considered as having little or no influence in the reduction of the iron, which is effected by the carbonic oxide produced by the combustion of the carbon in the coke, which is therefore the valuable element.

The average per centage of coke in the No. 7 coal, as shown by four analyses from the Ashland Company's mines, is 62.5. The consumption of 2.44 tons of raw coal to the ton of iron is therefore equivalent to 1.52 tons of coke, or about 30 cwt.

When it is remembered that at many of the furnaces of the Cleveland district of England a ton of iron is now made with 18 or 19 cwt. of coke, or less than a ton of coke to the ton of iron, the ores at the same time not yielding more than forty per cent. of iron, the improvement yet to be made in this region will readily be seen.

The average consumption of coal per ton of iron at the Norton Furnace, as will be shown further along, was 2.69 tons of 2000 pounds each, equivalent to 2.4 tons of 2240 pounds. Of this, however, about 8 per cent. was coke used in the early part of the blast. The mixture of ores did not differ greatly from that used at the Ashland Furnace. The consumption of coal is very nearly the same in both furnaces, showing that the quality of the coal is very similar, and that 2.4 to 2.5 gross tons is the amount which as yet the best practice has required in making a ton of iron.

The Norton Iron Works comprise three separate establishments—a blast furnace, a rolling mill, and a nail mill. The works were erected in 1873, but did not go into operation until the spring of 1874. They are among the most extensive and perfect of the kind in the country. The dimensions of the furnace have been already given. It is an iron-shell stack resting upon iron pillars. The hoisting apparatus is an Otis elevator, working in a substantial brick building. Everything about the furnace is constructed in the most thorough and substantial manner. There are five hot blast ovens of the Player pattern, and twelve boilers, each 42″ diameter by 60′

long, which furnish steam for both mills and the furnace. The boilers and hot blast are heated by the waste gases from the furnace. The iron produced at this furnace is mostly mill iron, which is made into nails. There are in the rolling-mill sixteen puddling, and two reheating furnaces. This mill works only for the preparation of plate for the nail machines, of which there are eighty in the nail mill, producing four thousand kegs of nails per week.

For fuel this furnace uses the Coalton (No. 7) coal, from the mines of the company, on the old Star Furnace estate. Some Pittsburg coke was used in starting the furnace into blast, but it was not long continued. The total amount used was not quite 2,000 tons. The No. 7 coal is also used in the rolling-mill, where it proves a very satisfactory fuel in the puddling furnaces. Ore, mostly kidney, is obtained from the Star Furnace lands, and also limestone ore from the old Kentucky Steam and Caroline Furnace estates, which are now owned by the Norton Iron Works Company. In addition to the native ore, a considerable amount of Iron Mountain ore is also used. The following are the statistics of the working of this furnace for 1874. It did not go into operation until the latter part of February, so that these figures represent only about ten months' operations:

Native ore used . tons of 2268 pounds	8592
Iron Mountain ore, " 2240 "	8228
Mill cinder . . . " 2240 "	2417
Limestone . . . . " 2268 "	7810
Coal . . . . . . " 2000 "	26334
Coke . . . . . . " 2000 "	1930
Iron made, tons of 2240 pounds	10502
Per centage of iron in the ore mixture	54.5
Tons coal and coke (2000 pounds) to ton iron (2240 pounds)	2.69
Tons limestone to ton of ore	0.40

As yet only the No. 7 coal, from the mines of the Ashland and Norton Companies, in the valley of Williams' Creek, has been successfully used for iron-making. The coal has a far wider field than this valley, where it has been so extensively mined, and it is certainly highly improbable that it should only be found of quality requisite for smelting purposes in that narrow basin. It is finely developed to the south and southwest, showing at places as full a thickness and apparently as good quality as where first mined. It has been opened at Willard, in Carter county, on the land of the Bellefont and Ætna Company, and the coal unsuccessfully tried in the Bellefont Furnace, at Ironton, Ohio. The opening was made on the west side of Dry Fork, in a spur of the main ridge, where the coal was thin and quite sulphurous; so much so that it showed readily to the eye that it was impure. The analysis shows 2.63 per cent. of sulphur. It is no wonder that the attempt was unsuccessful. There is a large field north and northeast of this, on Lost Creek, Davy Run, Straight Creek, and on the Mt. Savage Furnace property, where the coal is well developed in thickness, and at many places is of very good quality. It is probable, or almost certain, that it will at many places be found of quality suitable for iron-making. It may not be such at every opening or outcrop, as it is not, where most successfully mined; but there is every probability that abundance will be found of the best quality. It should be remembered that not every room nor every entry of the mines on Williams' Creek, where this coal is best developed, furnishes a suitable coal for furnace uses. It has to be selected for that purpose from different parts of the mine, and the locality of the best coal changes frequently.

With careful prospecting and selection, it is certainly probable that furnace coal will be found at many places where the coal is now either unknown or unopened.

There can be little doubt that eventually the immense stores of this excellent fuel, with which this region is so richly endowed, will be made servicable. There is also little doubt that eventually much poorer fuel will be successfully used in the manufacture of iron than is now supposed to be possible, and great quantities of this coal, as well as others which have not as yet been tried, will become sources of wealth.

The tendency of modern improvements in metallurgy is to the invention and introduction of appliances whereby more impure fuels than formerly supposed available can be used in metallurgical operations without detriment to the resulting product. Whether this desirable result will be attained through peculiar construction of furnaces, or by the purification of the coals by some cheap process of washing and coking before they go into the furnace, is impossible to say. It is not unlikely that both methods will be successfully introduced.

The quality of the iron made with the No. 7 coal is shown by the following analyses, by Dr. Peter and Mr. Talbutt:

	No. 1.	No. 2.	No. 3.
Iron	91.420	90.899	89.731
Graphitic carbon	2.460	2.560	1.660
Combined carbon	.240	.160	.799
Manganese	.195	.236	.479
Silicon	3.709	5.121	6.306
Slag	.540	.760	1.120
Calcium	.176	.072	.152
Magnesium	.233	.106	.060
Phosphorus	.385	.394	.461
Sulphur	.082	.045	.015
Total	99.440	100.353	100.768

No. 1 is the No. 1 mill iron, from the Ashland Furnace.

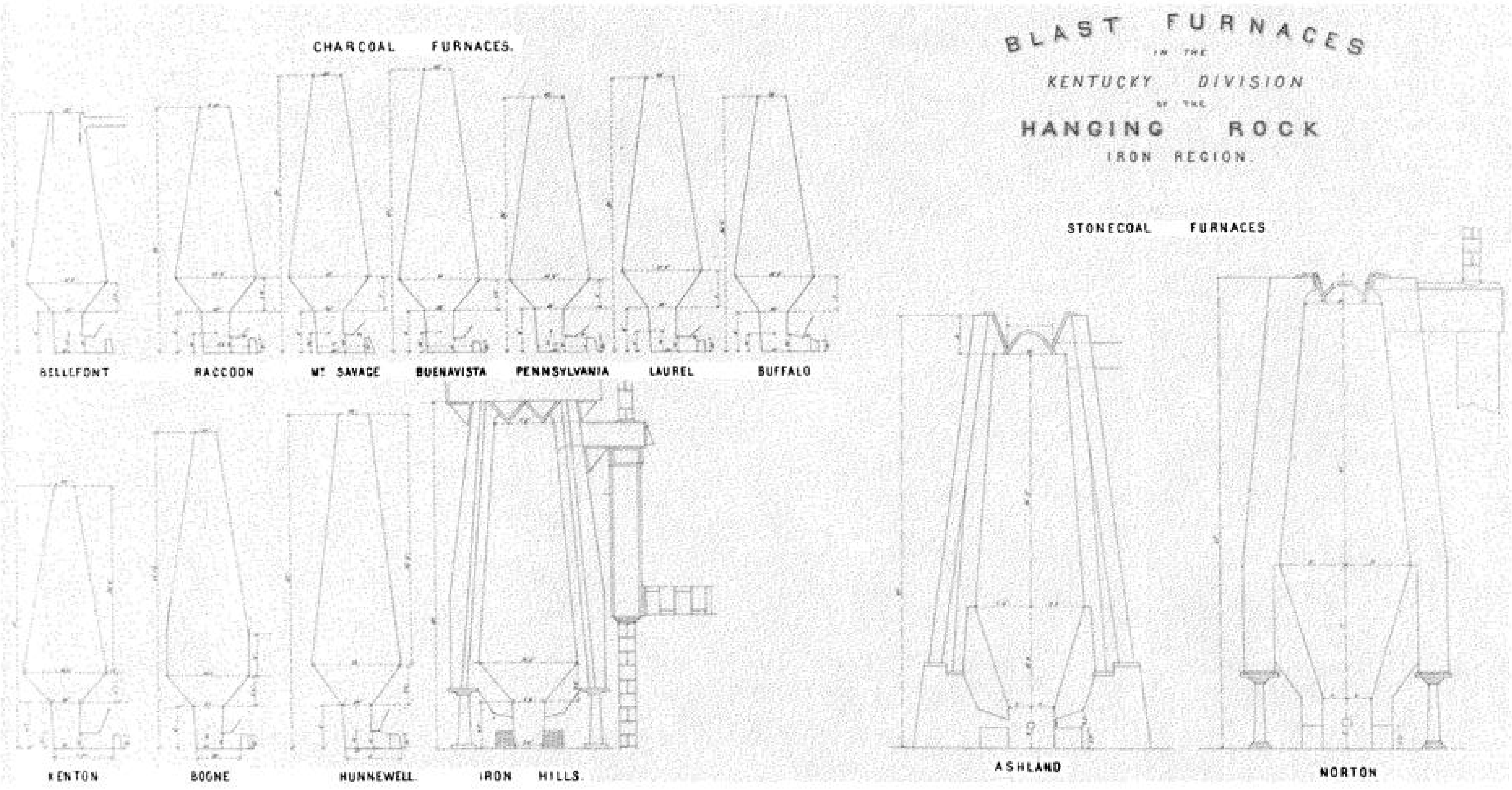
No. 2 is the No. 2 mill iron, from the Ashland Furnace.

No. 3 is a grade of foundry iron, only occasionally made at the same furnace.

All the above were made with the No. 7 coal alone, from a mixture of sixty per cent. native ore, twenty-two per cent. of Iron Mountain ore, eighteen per cent. mill cinder.

STATISTICS OF IRON PRODUCTION.

Below will be found the statistics of the pig iron production of this region for the five years, 1870 to 1874, inclusive. These figures have, in nearly every case, been obtained by a per-


BLAST FURNACES
IN THE
KENTUCKY DIVISION
OF THE
HANGING ROCK
IRON REGION.
CHARCOAL FURNACES.
BELLEFONT
RACCOON
M^T SAVAGE
BUENAVISTA
PENNSYLVANIA
LAUREL
BUFFALO
KENTON
BOONE
HUNNEWELL.
IRON HILLS.
STONECOAL FURNACES
ASHLAND
NORTON

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ional inspection of the furnace books, which have always been kindly placed at our disposal. In a few cases it was impossible to obtain the exact figures, owing to the careless manner in which accounts were kept, or to transfers of furnace property from one owner to another. In these cases the production is given as estimated from the best data that could be had, and the figures are marked with a star (*), showing that they were not as trustworthy as the others. It is believed that this is the most complete, and accurate table of statistics of this region ever published, notwithstanding the few errors which it contains.

TABLE SHOWING THE PRODUCTION OF PIG IRON (GROSS TONS) IN THE KENTUCKY DIVISION OF THE HANGING ROCK IRON REGION, FROM 1870 TO 1874.

CHARCOAL IRON.

Furnace.	1870.	1871.	1872.	1873.	1874.
Bellefont	3217	2790	3304	2850	3600
Boone	*1200	*1400	not in blast.	not in blast.	not in blast.
Buena Vista	3448	2808	3800	3600	4113
Buffalo	1407	1258	2262	1756	*1042
Hannewell	3059	2265	4322	3812	4371
Iron Hills	not in blast.	not in blast.	not in blast.	141	822
Kenton	1250	1334	2865	2300	3525
Laurel	775	1890	1850	1748	1300*
Mt. Savage	not in blast.	2293	2707	3000	2017
Pennsylvania	2110	1592	1847	2213	1751
Raccoon	*750	882	1247	1467	1320
Total charcoal iron	17216	18512	25204	22887	23861

STONE-COAL IRON.

Furnace.	1870.	1871.	1872.	1873.	1874.
Ashland	9316	9509	12150	12741	6710
Norton	not in blast.	not in blast.	not in blast.	not in blast.	10502
Star	1302	1958	1643	959	not in blast.
Total stone-coal	10618	11467	13748	13700	17212
Total pig irons of all kinds	27834	29979	38952	36587	41073

*Not from furnace books. Estimated from the most reliable data at command.