GEOLOGICAL SURVEY OF KENTUCKY.

N. S. SHALER, DIRECTOR.

REPORT

UPON THE

AIRDRIE FURNACE AND PROPERTY,

MUHLENBURG COUNTY, KENTUCKY,

BY P. N. MOORE.

PART IV. VOL. II. SECOND SERIES.

This page in the original text is blank.

INTRODUCTORY LETTER.

Professor N. S. SHALER, *Director Kentucky Geological Survey:*

SIR: In accordance with your instructions, I made, during the past summer, an examination of the Airdrie Furnace and property, with a view to ascertain something of the resources of the estate, the causes of the former non-success of the furnace, and to suggest, if possible, the means whereby it can be brought into successful operation. The time at my command did not suffice for a careful geological examination of the whole property, and my attention was therefore given only to that portion in the immediate neighborhood of the furnace. It is to this that the furnace must look for its supply of fuel for a long time to come, and, as on examination it proved sufficiently rich in coal to place the matter of a sufficient supply beyond reasonable doubt, little attention was given to any other part of the property.

P. N. MOORE, *Assistant.*

LEXINGTON, KY., December, 1874.

REPORT UPON THE AIRDRIE FURNACE AND PROPERTY, MUHLENBURG COUNTY, KY.

SITUATION.

Airdrie Furnace is situated near the village of Paradise, Muhlenburg county, Kentucky, on the bank of Green river, one hundred and thirty miles above its mouth, eighty-five miles below the head of slack-water navigation at Bowling Green. It is also four miles above Rockport, where the Louisville, Paducah and Southwestern Railroad crosses Green river, a stream which furnishes slack-water navigation for two hundred and fifteen miles, at nearly all times of the year, to boats drawing four feet of water; and during the greater portion of the time is navigable for boats drawing six feet.

There are but two locks between Airdrie Furnace and the Ohio river, and these are of a size uniform on Green river—one hundred and forty-five feet long by thirty-six feet wide.

THE FURNACE.

The furnace was built in 1855–'56. It has an iron shell stack, resting upon a masonry base, twenty-six and a half feet square by twenty-one feet high. The outside diameter of the shell is twenty-three feet.

The internal dimensions of the furnace are as follows: height fifty feet, diameter of bosh seventeen feet, height to bosh twenty-four feet (bosh cylindrical for six feet), diameter of throat eleven feet. The hearth is four feet high (elliptical in shape), seven feet four inches by (about) five feet.

The furnace is entirely open-topped, having no facilities for saving the gases, and requiring separate firing for both boilers and hot-blast.

There are two hot-blast ovens of the old-fashioned pistol-pipe pattern, with thirty-four pipes in each oven, ten curved pipes on each side, with seven straight at each end. The pipes are eight feet long, elliptical in cross section, nine by eighteen inches, with diaphragm through the center of each.

There are four boilers, each forty inches in diameter by twenty-eight feet in length, each boiler having two flues. The engine is vertical, with direct connection between the steam and blast cylinders, and also connected with a heavy walking beam and fly-wheel, the walking beam working with a counterpoise at one end.

The steam cylinder is twenty inches in diameter, and nine feet stroke; the blast cylinder six feet ten inches in diameter, stroke same as steam cylinder.

The engine-house is a splendid stone structure, built of a fine free stone, which occurs at the furnace. Everything about the furnace is constructed in the most thorough and durable manner.

The top of the furnace is about the level of the No. 11 Coal, to be hereafter described, and the ore and coal from the No. 12 seam were brought to the furnace mouth through a tunnel cut in the No. 11 Coal.

The engine is in good order and well preserved.

The furnace proper stands perfectly sound, and could, in a very brief time, be put in condition to go into blast; but among the buildings attached thereto the lapse of the many years since they were in use has not been without its effect, so that repairs to both buildings and hot-blast apparatus will need to be made before they can be used again.

THE PROPERTY.

The Airdrie Furnace property consists of about 17,000 acres of land in Muhlenburg county, Kentucky. This land is not all in one body, but lies in various sized lots, ranging from 500 to

5,000 acres. The greater portion of the estate lies within a short distance of the furnace; but one tract of about 5,000 acres—the old Buckner Furnace property—is about five miles from Greenville, the county seat of Muhlenburg county, and fifteen miles from Airdrie. Upon this tract, if all reports be true, there are extensive beds of iron ore, as well as some of the lower coals, one of which, said to be four feet thick, was mined and coked for use at the old Buckner Furnace. The situation is such, however, being five miles from the railroad at Greenville, that for the present, at least, the minerals of this tract cannot be rendered available.

We come then to the examination of the property adjacent to the furnace. A geological section showing the number and position of the coals here is given in the third volume of the Kentucky Geological Reports, first series, page 24. This section was obtained in sinking a shaft at the furnace, and the measurements are therefore probably much more accurate than those usually obtained by boring. In reproducing the essential parts of the section, and describing the coals, the numbers assigned to them in the first series Geological Survey Reports will be used provisionally, for the reason that they are best known by these numbers, and that, although they have been discarded by the present Survey, the final nomenclature has not yet been decided upon.

We have, then, at this place the following coals:

I. Coal No. 12, two feet thickness of clear coal, then two feet of brashy coal. Resting upon this is a bed of slaty carbonate of iron, which sometimes contains a small amount of carbonaceous matter, and is called a Black-band iron ore. This ore ranges from four to fourteen inches in thickness, with an average of perhaps five or six. Its chemical constitution will be referred to hereafter.

II. Twenty-one feet below Coal No. 12, resting immediately under a hard, blue limestone, is Coal No. 11, six feet thick, in three members, each about two feet in thickness, with a parting of one to two inches of pyritiferous shale between each member. This coal is about sixty-five feet above Green river.

III. Below the level of Green river, and eighty-four feet under Coal No. 11, is Coal No. 9, five feet thick. This is the same coal as that mined so extensively for the Louisville market along the line of the Louisville, Paducah and South-western Railroad. Little is known of its quality here, but it is safe to suppose that it does not vary greatly from that along the railroad.

IV. There are one or two thin coals below this, but it is not until a depth of three hundred and forty-one feet below No. 9 is reached that another coal of workable thickness occurs. This is called No. 5 by Dr. Owen, and is three feet six inches thick. If the report of the miners who sunk the shaft, and of others who were employed at the furnace, is to be believed, this coal is of most excellent quality. A drift was run, and considerable coal taken out and used under the boilers with great success.

We see, therefore, that there are here, including the No. 12 Coal, which can be profitably worked with the overlying iron ore, no less than four coals of workable thickness.

QUALITY OF THE COAL.

Of the quality of No. 5 and No. 9 Coal at this place, we of course know nothing, for it was impossible to obtain samples for analysis. Samples of the No. 11 coal were obtained from the mine at Paradise, adjoining the Airdrie property. They were taken with great care from a number of rooms in the mine, in order to obtain as nearly an average as possible, representing the coal as actually mined and shipped. It is a brilliant black, firm coal, with comparatively little fibrous coal or mineral charcoal. It cleaves readily into large rectangular blocks in mining. There is considerable pyrites mingled with it in an increasing ratio from the top to the bottom, the upper member carrying the least. A sample was taken from each member. The following analyses are by Dr. Peter and Mr. Talbutt, chemists of the Survey:

ANALYSES OF NUMBER ELEVEN COAL, PARADISE MINE.

	Upper.	Middle.	Bottom.
Specific gravity	1.274	1.326	1.331
Moisture	3.60	4.10	4.20
Volatile combustible matter.	38.70	35.90	36.10
Fixed carbon	53.70 } coke 57.70	53.60 } coke 60.00	50.50 } coke 59.70
Ash	4.00 }	6.40 }	9.20 }
Total	100.00	100.00	100.00
Sulphur	3.158	4.394	4.573

It will be seen from the above that while an extremely good coal in the matter of freedom from water and ash, yet there is a very considerable per centage of sulphur present. It is, however, an excellent household and steam coal, and is held in high repute wherever it has been tried. Large quantities are sent from the Paradise mines to Bowling Green, where it is used for domestic purposes and by the railroad, and it is there rated higher than any other coal from Green river.

The No. 12 Coal.—As it was in the expectation of using this coal raw for fuel that the furnace was built, and as it was actually so used during the short campaigns of the furnace, it became a matter of considerable importance to obtain a perfectly average representative sample for analysis.

The attempt to obtain such a sample was only partially successful. The old entries by which the coal was worked have fallen in, so that it was impossible to get at the face of the coal where a sample from a number of places could be taken.

A shaft was, therefore, sunk through the coal near one of the entries, and an average sample taken. Another was taken from a pile of several thousand bushels which lies at the mouth of one of the old drifts, where it has been exposed to the weather for seventeen years. Although these must both represent the coal with a certain degree of accuracy, yet at both places it had been to a certain extent exposed to the weather, and may have absorbed water and parted with some sulphur.

The fact that the coal is quite "fat," however, containing much bituminous matter, tended to preserve it from the action of the weather. In the interior of the pile of coal at the entry many pieces were found only very slightly affected by its protracted exposure.

It is a deep black coal, showing little pyrites, and quite bituminous, too much so apparently to be successfully used alone raw in the blast furnace. Of the following three analyses the first was made by Dr. Peter, and published in the fourth volume of Kentucky Geological Reports, first series, page 230. Of the character of the sample and by whom taken I am ignorant. The second and third are by Dr. Peter and Mr. Talbutt, from average samples taken by myself. The second is the weathered coal from the stock-pile; the third from bottom of shaft near entry No. 4.

ANALYSES OF NUMBER TWELVE COAL, AIRDRIE FURNACE.

	I.	II.	III.
Specific gravity	1.593	1.332	1.278
Moisture	7.06	4.70	3.60
Volatile combustible matter.	30.84	30.60	31.40
Fixed carbon	58.70 } coke 62.10	58.80 } coke 64.70	58.50 } coke 65.00
Ash	3.40 }	5.90 }	6.50 }
Total	100.00	100.00	100.00
Sulphur	0.789	1.455	1.438

A remarkable resemblance will be noticed between analyses two and three, showing that they have weathered very similarly; but the coal of No. 2 has absorbed more water and lost some of its volatile combustible matter. They show this to be a coal of very good quality, with neither sulphur nor ash sufficient to seriously injure it. It is so bituminous that it did not work well raw in the furnace, and after three unsuccessful trials it was decided to use it coked. A large amount of coke, several thousand bushels, was made; but the furnace was never started again, and it now lies on the stock bank, some

of it good looking coke yet, after the rain and snows of seventeen years have fallen upon it. It is difficult to tell what the quality of it was when first made, and a sample taken from this pile does not fairly represent the coke that can be made from the coal; but it was regarded as matter of sufficient interest to be worth an analysis. I accordingly selected from the least weathered of the coke a sample for analysis, which is here given. The coke was made in open heaps, and therefore is not as firm and dense as it would be if coked in close ovens:

Moisture expelled at 212°	7.50
Moisture expelled at red heat	4.20
Fixed carbon	82.90
Ash	5.40
Total	100.00
Sulphur	0.642

The composition of the ash is as follows:

Silica and silicates	4.32
Alumina, oxide of iron, and manganese	.48
Lime	.33
Magnesia	.18
Phosphoric acid	.08
Total	5.39

As was to be expected, the coke has absorbed a very considerable per centage of water; but the amounts of both sulphur and ash are small.

THE IRON ORE.

Above the No. 12 Coal, already referred to, is a hard, dense, slaty carbonate, often containing fern leaf impressions between its cleavage planes. The amount of bituminous matter shown by analysis is small, and probably adheres to it from the associate shale and coal. It contains occasional specks of pyrites large enough to be easily seen by the unassisted eye. Its appearance is decidedly against it, and it seems to be much leaner than it really is.

The same difficulty was experienced in obtaining a fair average sample of the ore as with the No. 12 Coal. A sample was obtained from the same shaft, sunk to reach the coal near the old No. 4 entry, but it was so near the surface that the ore had been altered to a limonite. At this place, too, it seemed to be less silicious than usual, and the average, of course, was taken from only a limited amount of ore. Another sample was taken from a pile of unroasted ore lying near the mouth of the entry, where it has been exposed to the weather for seventeen years.

Still another sample was taken from a large pile of roasted ore, which had undergone a like period of exposure since roasting. In all of these there is a possibility that the ore is a little richer in iron and more free from sulphur than will be found to be the case when it is reached at a place where it is wholly unaltered; for the exposure to the air has a most beneficial effect in peroxidizing the iron and removing the sulphur.

The analyses by Dr. Peter and Mr. Talbutt are as follows:

	1.	2.
Peroxide of iron	63.048	59.810
Alumina	5.290	2.972
Brown oxide of manganese	.090	.720
Carbonate of lime	.680	. . . . .
Lime	. . . . .	2.263
Magnesia	.930	4.270
Phosphoric acid	.147	.223
Sulphur	.044	.065
Combined water	12.430	.206
Silica and insoluble silicates	17.250	29.880
Total	99.909	100.409
Specific gravity	3.246	3.652
Metallic iron	44.133	41.867
Phosphorus	.064	.097

No. 1. Ore from bottom of shaft near No. 4 entry.

No. 2. Roasted ore from the stock-pile, weathered seventeen years since roasting.

The above ores are both altered from the carbonate; one by the slow natural process of oxidation, the other by the process of roasting.

The analyses of the carbonate ores:

	1.	2.
Carbonate of iron	47.810	59.344
Peroxide of iron	9.054	4.180
Alumina	5.205	2.290
Carbonate of manganese	.797	2.017
Carbonate of lime	3.740	3.390
Magnesia	7.180	7.149
Phosphoric acid	.179	.428
Sulphur	.094	.246
Carbonaceous matter and water	8.788	4.071
Silica and insoluble silicates	17.010	16.280
Total	100.099	100.609
Potash	. . . . .	.286
Soda	. . . . .	.322
Specific gravity	3.376	2.959
Metallic iron	29.418	31.598
Phosphorus	.078	.186

No. 1. Average sample from the stock pile, where the ore had weathered seventeen years.

No. 2. Analysis by Dr. Peter, published in volume three, page 337, of the first series Kentucky Geological Reports, of "Black-band ore, roof of upper coal, Airdrie Furnace."

From the foregoing analyses the following conclusions are drawn:

First. The No. 11 Coal, while a fine domestic and steam-producing fuel, contains too much sulphur to be used in the manufacture of iron, without a previous preparation by washing and coking.

That this could be successfully done there is little doubt. The strength and density of the coke might not be equal to the best, but it would be a fuel of fair quality; such as could, it is believed, be used successfully in the manufacture of iron.

Second. The No. 12 Coal is an excellent fuel, on account of its small per centages of sulphur and ash; but the former experience of the furnace seems to prove conclusively what

the appearance of the coal indicates, that it is too fat to use raw in the furnace, and should be coked. The amount of sulphur is so small that the coal can be coked without previous preparation, to free it from sulphur, and it will probably produce a superior coke; this, however, can only be demonstrated by actual trial on a large scale.

Third. The ore contains enough iron and is sufficiently free from injurious mixture to be safely used to a certain extent; but it will probably prove necessary to use other ores with it.

It is not unlikely, as already stated, that the analyses represent the ore as somewhat better than it really is, and that it will be found on trial, when used alone, to make a low grade of iron. There is, furthermore, the fact that, while both the coal and ore have to be mined together in order to be cheaply obtained, the output of coal for a given area will be more than twice as much as is required for the reduction of the ore from the same area, assuming from the general testimony that the coal will average two feet in thickness and the ore six inches. Of the coal, with a specific gravity of 1.33 and a thickness of two feet, each acre of land will contain 3,300 tons of 2,240 pounds each.

Of the ore, with a specific gravity of 3.25, and six inches thick, each acre will contain 2,015 tons. The ore will probably not yield in the furnace more than an average of twenty-eight or twenty-nine per cent., thus requiring for the production of one ton of iron three and a half tons of the raw ore. For the reduction of this amount of ore only from two to three gross tons of coal will be required, probably not exceeding an average of two and a half tons.

The coal from one acre of land will, therefore, be sufficient for the reduction of more than two and a fifth times as much ore as is produced from the same area. The necessity, then, of looking elsewhere for a partial ore supply is evident.

The situation of Airdrie Furnace is one remarkably favorable for the facilities with which ores from a number of regions can be cheaply laid down at the furnace. It can command, at very reasonable rates for freight, the following ores:

(*a*) Coal measure ores from Green river valley.
(*b*) Limonites from the Cumberland river region.
(*c*) Specular ores from Missouri.

(*a*) Coal measure ores from the Green river valley. There are, in a large number of places in the valley of Green river, ores of workable thickness and apparently considerable area; but they are as yet generally undeveloped, and frequently so far from the river or other means of transportation that they cannot be rendered available without the expenditure of considerable sums to provide such means of transportation. To this class belong the ores of the Buckner Furnace tract, already referred to. These must some day be developed and used at the furnace; but for the present they are inaccessible. They comprise both slaty carbonates or Black-band, and fossiliferous ores.

One locality was visited where is an exposure of eight or ten inches of the Black-band ore, and a sample for analysis selected. The ore from which it was taken had been exposed to the weather for thirty years or more.

The following is the analysis by Dr. Peter and Mr. Talbutt:

Carbonate of iron	42.950
Peroxide of iron	29.618
Alumina	2.454
Carbonate of manganese	1.083
Carbonate of lime	2.490
Carbonate of magnesia	4.828
Phosphoric acid	.083
Sulphuric acid	1.596
Carbonaceous matter and loss	5.868
Silica and insoluble silicates	9.030
Total	100.000
Metallic iron	36.916
Phosphorus	.036
Sulphur	.638

In Edmonson county, on the north side of Green river, between Bear Creek and Nolin river, is an extensive and valuable deposit of oölitic ore; but it is, where best developed, some six miles from Green river, and it cannot be hauled to the river cheaply enough to compete with ores from other

places lower down. It is of excellent quality, and can be mined quite cheaply, and, if accessible, would be one of the most available ores. I append analysis, by Dr. Peter and Mr. Talbutt, of ore from a bank at the head of Beaver Dam Branch of Bear Creek. Average sample by Prof. N. S. Shaler:

Peroxide of iron	52.926
Alumina	4.792
Brown oxide of manganese	.210
Carbonate of lime	.180
Magnesia	.425
Phosphoric acid	.355
Sulphur	.057
Combined water	10.400
Silica and insoluble silicates	30.589
Total	99.934
Metallic iron	37.048
Phosphorus	.155

In Butler county, near the mouth of Little Reedy Creek, from one and a half to two miles distant from Green river, on the James E. Taylor farm, is a deposit of ore which shows at the outcrop three feet thick. It was only seen at one place, and little or nothing is known of its horizontal range. It has never been worked. An average sample was taken by Mr. J. R. Proctor, who first discovered it, and analyzed by Dr. Peter and Mr. Talbutt, with the following result:

Peroxide of iron	48.049
Alumina	8.171
Brown oxide of manganese	.140
Carbonate of lime	.540
Magnesia	.195
Phosphoric acid	.345
Sulphuric acid	.473
Combined water	9.750
Silica and insoluble silicates	31.900
Total	99.563
Metallic iron	33.634
Phosphorus	.150
Sulphur	.189

It is a silicious, somewhat oölitic limonite, altered from the carbonate; and as it occurs in shales, with a high hill above it, it will probably be soon found as the blue carbonate.

Its situation is such that it can be very cheaply placed in boats, on the slack-water of Green river, about seven miles above the lock at Woodbury. Should it be found, on closer examination, to retain its thickness, and extend over a considerable area, it can be mined very cheaply.

A reasonable estimate of its cost at the furnace, provided the above conditions hold, would be:

	Per ton.
Mining and royalty	$1 75
Hauling to river and loading on barges	75
Freight on Green river	1 25
Unloading at furnace	25
Making the total cost	$4 00

Two of these items, the freight on Green river and the hauling to the river, might be considerably reduced. It is probable that three dollars or three dollars and fifty cents would be a minimum cost at the furnace.

In Muhlenburg county, on Mud river, on land belonging to Jeremiah M. Hope, is a deposit of ore which, over a limited area, shows the unusual thickness of twelve to fifteen feet. The ore is exceedingly fossiliferous, partly a limonite and partly an unaltered carbonate. The upper portion of the ore is somewhat lean and silicious; the middle and lower portions of the bed are of fine quality.

The following analyses by Dr. Peter and Mr. Talbutt show the character of the ore:

	1.	2.	3.
Peroxide of iron	46.866	60.492	18.374
Carbonate of iron	.....	.....	26.643
Alumina	5.930	7.075	6.548
Brown oxide of manganese	.103	.360	a trace.
Carbonate of lime	2.535	1.980	13.430
Magnesia	1.073	1.550	5.698
Phosphoric acid	.179	.083	.211
Sulphur	.059	.074	.074
Combined water	9.550	12.530	6.792
Silica and insoluble silicates	33.530	15.560	22.230
Total	99.825	99.674	.....
Metallic iron	32.806	42.344	27.136
Phosphorus	.077	.032	.092

1. Sample, not carefully averaged, of limonite from the upper portion of the deposit.

2. Average sample of the limonite of the lower and middle portions of the deposit.

3. Average sample of the blue carbonate ore of the lower part of the deposit.

This ore seems to be in a regularly stratified deposit, but it only retains its unusual thickness over an area of perhaps 1,200 square yards. It is found at another locality, one third of a mile distant, on the opposite side of the ridge, two and a half feet thick.

The distance of the principal deposit from the head of slack-water, on Mud river, is four miles. Over this distance the ore would have to be wagoned, at a probable cost of one dollar and fifty cents per ton. The distance from the head of navigation, on Mud river, to Airdrie, by water, is about twenty miles, and in that twenty miles one lock to be passed. The cost of freight would be about seventy-five cents per ton. The ore can be mined quite cheaply, as very little stripping will be required for some time. One dollar and twenty-five cents will probably be sufficient to cover the cost of mining and royalty. The cost of this ore would therefore be:

	Per ton.
Mining and royalty	$1 25
Hauling to river	1 50
Freight to Airdrie	75
Unloading at furnace	25
Total	$3 75

By the purchase of the deposit and the use of their own barges by the owners of the furnace, this cost might be reduced to three dollars, or even less.

In Muhlenburg county, near Greenville, on the farm of Mr. Dabney Martin, some three miles from the Louisville, Paducah and Southwestern Railroad, is a bed of quite pure limonite ore. It is only eight inches thick, but is so situated that it could be mined over a large area, as the stripping above it would not be deep. It is of excellent quality. The analysis is as follows:

Peroxide of iron	69.546
Alumina	3.914
Brown oxide of manganese	.230
Carbonate of lime	.480
Magnesia	.921
Phosphoric acid	.115
Sulphur	.086
Combined water	11.250
Silica and silicates	12.730
Total	99.272
Metallic iron	48.882
Phosphorus	.050

This ore would cost, delivered on the cars at Greenville, three dollars per ton; freight from Greenville to Rockport, one dollar and fifty cents; hauling and freight from Rockport to Airdrie, fifty cents—making the cost of the ore at the furnace five dollars per ton, a price which renders its use at present out of the question.

(*b*) Limonites of the Cumberland river region. The ores of this region are too well known to need especial description. They are cherty limonites found in the clays on the

sub-carboniferous limestone, in unstratified and irregular but extensive deposits. They vary greatly in quality at every deposit, and great care is required in mining to prevent the cherty ore from becoming mixed with the better quality. They yield from thirty-five to fifty per cent. of the iron, and even higher when free from chert. There are numbers of these deposits in Lyon county, close to the line of the Louisville, Paducah and Southwestern Railroad. I visited some of these and obtained samples for analysis:

	1.	2.	3.	4.
Peroxide of iron	59.370	70.518	66.117	69.412
Alumina	1.622	.045	1.064	not est.
Brown oxide of manganese	.090	.190	.170	.170
Carbonate of lime	.170	.090	.090	.140
Magnesia	.100	a trace.	a trace.	a trace.
Phosphoric acid	.179	.275	.434	.313
Sulphur	.212	.045	not est.	a trace.
Combined water	8.400	9.850	9.800	9.550
Silica and insoluble silicates	30.000	18.910	22.330	20.500
Total	100.053	99.923	100.005	100.085
Metallic iron	41.559	49.363	46.282	48.588
Phosphorus	.077	.120	.189	.144

These ores are all from the old Suwanee Furnace lands, in Lyon county, and the samples were taken to represent, as nearly as possible, the average character of the ore of each deposit, chert and all. All of the ore could be picked so as to give a much better average, and it would be necessary to do so in shipping.

No. 1. Ore from "Big Showing" bank, Suwanee Furnace property, Lyon county.

No. 2. Ore from bank close to the furnace, Suwanee Furnace property, Lyon county.

No. 3. Ore from bank at railroad cut, Suwanee Furnace property, Lyon county.

No. 4. Ore from Iron Mountain bank, Suwanee Furnace property, Lyon county.

It would be safe to estimate that these ores can be relied on to yield forty-five per cent. of iron, where properly sorted before shipment.

These deposits are situated about eighty miles from the crossing of Green river at Rockport.

Parties stand willing to-day to deliver these ores on the cars at two dollars and fifty cents per ton. The Louisville, Paducah and Southwestern Railroad will transport, in small quantities, from Lyon county to Rockport for one dollar and fifty cents per ton, and will take large quantities at much less rates. It is probable that on a regular contract the rates would not exceed one dollar or one dollar and twenty-five cents per ton. The expense of loading into barges at Rockport, towing to Airdrie (four miles) and unloading, should not exceed fifty cents per ton. By the erection of a proper chute or tip at Rockport this could be reduced nearly one half.

Assuming the maximum rates for freight, the cost of Lyon county ore at Airdrie would be:

	Per ton.
Ore delivered on cars	$2 50
Freight to Rockport	1 25
Handling and towage to furnace	50
Total	$4 25

This could be reduced by making large contracts and some expenditure for a dock at Rockport; but this estimate, like all the others, is made on a basis of the purchase of the ore without the investment of any capital. With such investment, four dollars per ton would safely cover the cost of a ton of ore at the furnace.

(*c*) The specular ores of Missouri. These well-known ores are known under two classes, the Iron Mountain ore and the Central Missouri ores. There is not a great deal of difference in their quality. They are all rich, yielding from sixty to sixty-seven per cent. of iron. The Iron Mountain ore has a little the largest per centage of iron, and is of the most

uniform quality. It averages sixty-five to sixty-seven per cent. of iron; the Central Missouri ores from sixty to sixty-five. Iron Mountain ore is now worth in St. Louis seven dollars per ton; Central Missouri ores, six dollars. These ores can be brought in barges directly from St. Louis to the furnace, or they can be shipped to Evansville by rail, and from there to the furnace in barges. In either case, the cost for transportation from St. Louis should not exceed two dollars and fifty cents to three dollars per ton; thus making the cost of the Missouri ores nine dollars and fifty cents to ten dollars per ton at the furnace for Iron Mountain ore, and eight dollars and fifty cents to nine dollars for Central Missouri.

THE AVERAGE COST PER TON OF IRON

for each of the two classes of ore available to Airdrie Furnace, based on the foregoing estimates, which are certainly large enough in each case to be almost called maximum estimates, would be:

3 tons Green river ore, at	$3 75	per ton	$11 25
2¼ tons Cumberland river ore, at	4 25	"	9 56
1½ tons Iron Mountain, at	10 00	"	15 00
1⅔ tons Central Missouri, at	9 00	"	15 00

The Cumberland river ores, therefore, are considerably the cheapest that can be obtained at present without the outlay of considerable additional capital.

Their richness is such as to add another considerable advantage to them over ores with a less per centage of iron, for they are proportionately more economical to use in the furnace, as they require less fuel for their reduction.

In a time of ordinary prosperity of the iron market, any of the other ores can be profitably and successfully used.

Limestone for use as flux will have to be brought from upper Green or Barren river. It occurs at many places there in heavy deposits immediately on the bank of the stream, and can be quarried and placed in barges very cheaply. It is probable that seventy-five cents per ton will cover the cost of the limestone at the furnace.

The limestone required will not exceed twenty-five per cent. of the ore used, and may be less, as the Black-band ore, although lean, contains a considerable proportion of lime and other bases and will partly flux itself. There is a limestone four to five feet thick forming the roof of the No. 11 coal; but it is somewhat earthy, and at places quite sulphurous. It was tried during the former campaign of the furnace, but soon abandoned, and its place supplied with limestone from the mouth of Gasper Creek, on Barren river. This, as will be seen by the following analysis, is a nearly pure limestone of excellent quality:

Alumina and oxide of iron	0.917
Carbonate of lime	93.020
Carbonate of magnesia	2.088
Phosphoric acid	.243
Sulphuric acid	.604
Silica and insoluble silicates	2.760
Water and loss	.368

We have shown the number of alternatives possible to the furnace in the matter of an iron ore supply: let us look for a moment at the corresponding advantages for fuel.

Suppose No. 12 Coal should prove too thin to work, and the No. 11 not of as good quality as needed. The great shaft stands open, the boiler, winding drum, and engine for operating it are ready to be put in operation, in a short time, to give access to the two coals below the drainage. Suppose on trial neither of these proves a suitable fuel for iron making: Airdrie Furnace is only twenty miles by water from the well-known Mud River mines, the coal from which is among the best (if not the best) in the Green River country. That this will make iron raw, there is little doubt. A barge load of it was taken to St. Louis a few years since and tried very successfully in one of the Kingsland (now Vulcan) Company's furnaces. These mines are on slack-water, and can be reached from Airdrie at all times of the year.

The excellent quality of coal can be seen from the following analysis by Dr. Peter and Mr. Talbutt. The sample was a carefully taken average from all parts of the seam by myself:

MUD RIVER COAL.

Moisture	3.80	
Volatile combustible matter	32.70	
Fixed carbon	58.00	Coke 83.50.
Ash	4.90	
Sulphur	1.929	
Specific gravity	1.221	

Yet another alternative remains to Airdrie Furnace. Its situation on the bank of Green river is such that it can be cheaply and easily supplied with charcoal in case the manufacture of charcoal iron should be desirable.

Large portions of the valley of Green river are an almost unbroken forest, both above and below the furnace. Timber for the manufacture of charcoal can be purchased along the river at very small prices, and sometimes can be had for the clearing. This can either be rafted to the furnace, and there made into charcoal in ovens, or it can be charred on the ground and carried to the furnace in barges. In either case it can be furnished there cheaply enough for the manufacture of charcoal iron at a profit in the ordinary stage of the market.

We see, therefore, that Airdrie furnace is so fortunately situated as to be able to command, at reasonable prices, at any of which, in the ordinarily prosperous condition of the iron market, iron can be made at a profit:

Ore from four different regions.

Coal from four different beds at the furnace.

The Mud River coal.

Charcoal.

Such advantages as these, it can be truly said, are unsurpassed, and they render it certain, beyond reasonable doubt, that, with proper management, Airdrie Furnace can be made one of the most successful in the country.

Having thus considered in detail the resources of this property, and seen the remarkable advantages it possesses for obtaining fuel and cheap and varied supplies of ores, the

question naturally presents itself: why, then, with all these advantages, was the furnace no more successful on its former trial? This is a serious and important question, for the reproach of failure laid against an enterprise of this kind outweighs many advantages.

Into the answer a number of reasons enter, and to render them properly understood it will be necessary to go into the history of the former campaign of the furnace in some detail, and to refer to the management of the enterprise in language which is unmistakable, although it may seriously reflect upon the business sagacity of some persons once connected with it who are no longer living. It should be premised that the information upon which the following account is based was obtained partly from the books of the furnace and partly from men who were on the ground, connected with the furnace in various capacities.

The enterprise seems to have been conceived by its proprietor in a spirit in which benevolence, national pride, and the desire for a profitable investment, were strangely mingled. Being a Scotchman, and having some knowledge of iron manufacture as practiced in Scotland, he not unnaturally believed men of that nationality to be the most competent and desirable persons to conduct establishments for iron making.

He therefore committed from the beginning the serious mistake of employing almost exclusively newly-arrived foreigners, men who, however competent at home, were without any knowledge of American prices and metallurgical practice, or experience with American ores and fuel.

Having found what was firmly believed to be the equivalent of the celebrated Scotch Black-band iron ore, and an associate coal which it was thought could be used raw in the furnace, he proceeded to erect a furnace modeled after the Scotch pattern. He brought over large numbers of Scotch miners and furnace men, and employed them almost exclusively; giving them to understand, it is reported, that it was to improve their condition, rather than in hopes of great returns, that he had made the investment. He employed as superintendent and

manager an uneducated, dissipated Scotchman, a man wholly unfit to fill so important and responsible a position, and to him he gave almost entire charge of the whole enterprise, often not visiting the property for months at a time.

Under such conditions, it is no wonder that there was mismanagement, and that ill-advised expenditures were made.

For three years, while the slow process of development was going on, the furnace and machinery erected, entries driven, and the great shaft, five and a half by eighteen feet, sunk to a depth of four hundred and thirty feet in search of a mythical ore (known to exist fifteen miles distant and nowhere between), the proprietor continued uncomplainingly to increase his investment.

At last the furnace was started. It ran a few days very unsuccessfully, producing iron of a poor quality and in small amount, when an accident to the boiler compelled it to be blown out.

Repairs were made in due time and the furnace again started. The working was no better than before, and the iron not improved in quality or quantity. In twenty-two days from the time of starting the saddle-plate of the walking-beam broke, disabling the engine and compelling the furnace to be shoveled out. Again it started, and again, after a short run, no more successful than the last, an accident happened to the engine, the cast-iron shaft of the fly-wheel broke, and once more the furnace was shoveled out.

In all three of these unfortunate campaigns the furnace was not in blast altogether more than six weeks or two months.

After the last blast the manager concluded that the coal did not work well raw, and so made a large amount of coke from it to be tried at the next blast, but the next blast never came; the proprietor's patience was exhausted; he stopped operations entirely, discharged his men, and shut up the mines and furnace.

Since that time (November, 1857) the furnace has never been in operation. The No. 11 Coal has been worked largely

for shipment to the Southern market, but beyond that the property has been lying idle and unproductive.

The closing of the furnace at that time was a mistake no less serious than some committed in starting it. The manager was beginning to learn, by the only method by which a so-called practical, uneducated man can learn—his own dear-bought experience—that American ores and fuel are not exactly like the Scotch, and that different practice is required for their treatment. Had he been allowed to go on, using coke for fuel, it is not unlikely that his next campaign would have proved much more successful.

It can be truly said that the furnace has never been subjected to a fair trial. A total campaign of six weeks or two months, divided into three short blasts, affords no fair basis for judgment as to the merits of furnace, fuel, or ore.

The iron made at the furnace was of notoriously poor quality. In order to ascertain to what cause this was due, three samples were procured from the iron remaining at the furnace, the analysis of which, by Dr. Peter and Mr. Talbutt, are herewith appended. The samples are all from a grade of iron variously known as silver gray, burnt iron, or glazed pig. It was impossible to procure samples of any other grade of iron. It is a fine-grained, light-colored iron, extremely weak and brittle.

The analyses are as follows:

	I.	II.	III.
Iron	86.645	85.863	86.842
Graphitic carbon	.900	.400	.780
Combined carbon	2.080	2.570	2.070
Silicon	7.704	7.747	8.614
Manganese	.571	.696	.355
Aluminum	.202	.274	.136
Calcium	.072	.112	.112
Magnesium	.035	.017	.056
Sulphur	.127	.227	.173
Phosphorus	.253	.509	.122
Total	98.589	98.415	99.260

Slag undetermined.

It will be seen that the proportion of sulphur and phosphorus is quite high in No. II, but it is probable that the poor quality of the iron is due more to the excessive amount of silicon than to any other cause.

The attempt was made to produce a No. 1 foundry iron by working the furnace hot, and the result was, that with a hot working of the furnace much silicon was reduced with the iron, and rendered it very brittle or "cold-short." Had the manager been content to burden his furnace for a "mill iron," working colder, it is probable the product would have been of much greater strength, although, as already stated, it is not unlikely that the Airdrie ore worked alone will always have a tendency to produce a low grade of iron. Hence, the necessity for some supply of ore from other sources.

That Airdrie Furnace, with some alterations and proper management, can be made to produce iron of good quality, and at a very low price, there is little doubt. In order to this, however, it will be advisable to considerably alter and modernize the furnace. It should be raised ten to fifteen feet in height, in order to give it dimensions better adapted to economical working, and a closed top and down-takes to carry the waste gases to boilers and hot blast added. The position of the boilers will have to be altered, the smoke-stack raised, new hot-blast ovens erected, or the present ones changed, and a new casting-house built. It will be also advisable to erect coking-ovens; and, in case the No. 11 Coal is used, washing machinery will be required in addition.

The total amount required to make all the needed changes, open the mines, and put the furnace in operation, will not exceed $60,000.

These changes made, Airdrie Furnace can produce iron, considering its nearness and cheapness of transportation to market, for a less price per ton than any other furnace in Kentucky.

We have already shown the cost at which ore and limestone can be supplied at the furnace. We have now to consider the

cost of fuel, when we will have the material in hand to prove the above statement.

Mining the coal and the ore together, the No. 12 Coal can be mined for one dollar per ton, the ore for one dollar and seventy-five cents.

Allowing fifty cents per ton as the cost for handling and mine expenses, &c., we have the cost of the coal one dollar and a half per ton. Three tons of coal will make two tons of coke, at a cost for coking of fifty cents per ton. Allowing the large consumption of two tons of coke to the ton of iron, and using one and one eighth tons of Cumberland river ore to one and three fourths tons Airdie ore, the cost per ton of pig iron at the furnace would be:

Two tons of coke, at $2 75 per ton	$5 50
One and three fourths tons of Black-band ore, at $1 75 per ton	3 06
One and one eighth tons Cumberland river ore	4 78
Roasting two and three fourths tons of ore, at twenty cents per ton	55
Two thirds of a ton of limestone	50
Labor and superintendence	3 50
Sundries	1 00
Total estimated cost per ton	$18 89

The iron can be put in market for from two dollars to three dollars per ton additional. Even supposing all the odds against the furnace, and that the iron produced is of a low grade, yet there would be a profit in it, even in the present fearfully depressed condition of the iron trade.

The demand of the future is for cheap iron. The days of high-priced iron have gone, not to return for months to come, if ever; and, in the struggle for existence, only those furnaces which are favorably located and carefully managed can survive. For such as can produce iron economically and cheaply, there will always be a profitable market, and only for those.

To this class Airdrie Furnace certainly belongs.