

WESTERN COAL MEASURES AND INDIANA COAL.*

The study which I have given to the geology of the West, has led me to conclude that the carboniferous rocks embracing the coal beds, both of the Appalachian and Western coal fields, were formed in two great depressions that gave rise to large inland seas. These seas communicated with the ocean, on the south and west, which then extended far up the Mississippi valley, and covered most of the Southern States, as far north as the 35th parallel.

A high ridge, or plateau of Silurian rocks, capped in places with the Devonian, and lying in a northeasterly direction across the States of Tennessee and Kentucky, and along the western border of Ohio, and the eastern border of Indiana, separated these two seas from each other, and spreading out over the northern portion of the two latter States, extended into Pennsylvania, on the east, and Illinois and Iowa, on the west, formed an almost unbroken chain along their northern shores.

In these seas were formed the sub-carboniferous rocks, and, as the water became shallow from the accumulated sedimentary material that went to build them up, a barrier was formed, which shut out the ocean and cut off the source of salt water supply. Facilitated, also, by the drainage from a large surface area, the water of these seas became less and less brackish, and the conditions necessary for the accumulation of the coal vegetation, were, in this way, brought about so gradually, that many marine forms of life continued to exist, and, by degrees, accommodate themselves to the new condition of things.

That marine forms of life are brought to adapt them-

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selves to fresh water habitudes, under favorable conditions, has been shown by Dr. William Stimpson, who found, by deep dredging in Lake Michigan, a species of marine crustacea, in great abundance, and similar discoveries had previously been made of marine forms of life, by dredging in the large fresh water lakes of Europe.

From this, we may readily infer that the North American lakes communicated, at one time, with the ocean, and that their fauna and flora, were, to a certain extent, brought to accommodate themselves to the gradual change from salt to fresh water.

The position of the ocean relative to the land, and the great preponderance of water on the American continent during the carboniferous epoch, must have had a decided influence in modifying the temperature, and increasing the humidity of the atmosphere, thereby rendering it in every way adapted to the luxuriant growth of the tropical plants, which furnished the carbon so providentially stored away in the fossil fuel; for we find that many of these coal-producing plants, whose dwarfed prototypes are now confined to the tropics, flourished then, as far north as the arctic zone.

There could have been no necessity for any increase of carbonic acid, or other material change, as many have supposed, in the composition of the atmosphere, beyond a slight increase in its humidity, and the probability is that, none existed.

The two great coal fields being separated from each other from the very beginning, as I have endeavored to show, by a barrier of rocks, which show no evidence of any subsequent submergence, and which long antedate the carboniferous era, renders it difficult to comprehend how an equivalency in the coal beds of the Appalachian field can be found in those of the West, as many of our eminent geologists have maintained.

It is true, that the fluctuations in level, which serve to build up the various strata, may have been, and in all probability were, synchronous over the two basins, but the special requirements for the production of coal beds could

hardly have proved uniform over districts so widely separated.

Though once a firm believer in the equivalency of coal seams throughout the western coal measures, I have seen much, of late, to shake my faith in the possibility of determining an entire agreement in the coal beds, even in the limited area of the coal field in Indiana.

From a marked irregularity in the thickness of the carboniferous beds over a great extent of territory, we have good reason to believe that these inland seas, like all other great bodies of water, were of unequal depth, and, consequently, did not present, at all times, over their entire area, the conditions alike favorable for the formation of coal, and that, while the ocean was excluded from the Appalachian sea, where the material for coal beds was forming, the sea on the Western side was still filled with salt water, in which was accumulating the sediment that was subsequently changed to rock, and the conditions favorable to the production of coal, had not yet been reached.

Such a state of things will serve to account for the great discrepancy in the aggregate thickness of the strata in the two coal fields. The Appalachian being estimated at 2,500 or 3,000 feet, whereas in the Western coal field, the greatest depth will hardly exceed 1,000 feet, and in Indiana, not more than 700 feet, if so much, though we include in the latter estimate every stratum, from the Archimedes limestone upward.

From observations made in the western coal fields, during the past three years, over portions of southern Illinois, western Kentucky and Indiana, so many errors have been found in the sections of the coal strata given in the Third Kentucky Report, and which were pretty generally copied by other geologists, in more recent reports, that I have found it necessary to make an entirely new classification of the coals in the west. In speaking of the errors in Dr. D. D. Owen's section of the western coals, I do not want to be understood as referring to the errors of the sections published in his First and Second Reports on the Geology of

Kentucky, as some have supposed from reading the remarks on this subject made in my First Report on the Geology of Indiana, 1869, but to the subsequent general section to be found at page 18-24 in the Third Volume Kentucky Report, published in 1857, in which some of the most glaring errors of the previously published sections are omitted.

The Kentucky column was the first effort at a general classification of the western coals, and considering the difficulties encountered in accurately accomplishing so gigantic an undertaking at a time when a large portion of the country surveyed was almost in the condition of a wilderness and devoid of practical developments from mining operations, it is not at all strange that errors should be found by those who subsequently review the grounds, assisted in their researches by a knowledge of the labors of former explorers, and the still greater advantage derived from more recent developments. Hence, no undue merit is claimed for having been enabled to make more accurate observations than those able geologists who have gone before me, and with a due conviction that there are many facts yet to learn from the study of the measures before a correct general section of the western coal beds can be given, together with their equivalency over the field to which they belong, I have, in presenting a column of the Indiana coals, at this time, omitted the use of numbers and adopted, provisionally, letters in their place, while gaps are left in the order of succession to be filled by undiscovered seams of coal, or verified by future research.

The following diagram represents three columns of coal arranged on a common horizon for the purpose of comparison. No. 1, is copied from "A Geological Reconnaissance of Indiana, by Prof. Richard Owen, 1859-60," and represents the order of the coals in Indiana according to Prof. Leo. Lesquereux, with the exception of some unimportant changes in the lower portion, this column is the exact counterpart, as claimed by its author, of the Kentucky column above referred to. No. 2, presents a column of the Kentucky coals as corrected by myself, and No. 3 a corrected column of the Indiana coals:

The column No. 3, is established upon the best evidence now before me, and though in some of its parts there may prove to be errors, still, as a guide in conducting researches for coal beds, it is confidently believed that it presents the best solution of the Indiana coal strata yet given to the public, and that in the main, it will be sustained by future investigations. In prosecuting the survey of Indiana my assistants are requested not to force local sections to agree with this column, but, rather give the order of the strata just as they are found and leave equivalencies, unless clearly proved, to a final summing up of all the evidence collected.

In the connected section of the western coal beds, given at page 18-24, Third Volume Kentucky Reports, the measurers are divided into upper and lower coal measures, and this arrangement, with some local modifications, has, until recently, been generally adopted by geologists.

Now, so far as my observations go, either in Kentucky, Illinois or Indiana, I can find neither lithological nor palæontological evidence which can be relied upon for cutting up the western coal measures into separate epochs. The Anvil Rock sandstone, which was brought into requisition for this purpose, can hardly be depended upon as a horizon, beyond the small district in which it was first discovered, and the equivalency of the Mahoning sandstone of the Pennsylvania geologists, as designated by Owen and Lesquereux, has also proved totally unreliable as a basis for division, even though it should be found necessary to establish one. In the Third Volume Kentucky Report and in the Report of a Geological Reconnaissance of Indiana, 1859, the latter stone is at one place referred to the horizon of the Anvil Rock sandstone, and at another locality to that of the millstone grit. Indeed, so unfortunate has been the effort to transplant the Mahoning sandstone of Pennsylvania into our western coal measures, that I can recall no prominent locality where it is not distinctly referable to one or the other of the above sandstones. For the equivalency of sandstones in the western coal field I have as yet been unable to find any lithological or palæon-

CONNECTED SECTION OF COAL MEASURES IN
INDIANA, BY PROF. E. T. COX.

Ft.	In.		
45			
4	6		Coal N.
31	3		Coal M.
	6		
41			Coal L.
8			
40			Coal X.
4			
40			Coal K.
5			
17	7		Coal J.
2			
16			
4	4		Coal I. Main Block.
13			
1	6		Coal H.
17			
4			Coal G. 2d Block.
23	6		
4			Coal F. 3d Block.
265	3		"MILLSTONE GRIT."
2			Coal B.
20			
3			Coal A.
47			
			Shales and thin Coal.
659	5	TOTAL.	

GENERAL SECTION OF COAL MEASURES IN
SOUTHERN ILLINOIS AND WESTERN KEN-
TUCKY, BY PROF. E. T. COX.

Ft.	In.		
118			"ANVIL ROCK."
3			Shale and thin Coal.
36	8		
2			Coal No. 8.
46			
5			Coal No. 7.
41			
2	6		Coal No. 6.
65			
5			Coal No. 5.
86			
2	6		Coal No. 4.
90			
3			Coal No. 3.
24			
4			Coal No. 2.
140	6		
1	8		Coal No. 1.
130			
3			"MILLSTONE GRIT."
65			Thin Coal.
8			
165			Coal.
1036	9	TOTAL.	

CONNECTED SECTION OF COAL MEASURES IN
INDIANA, BY PROF. LEO LESQUEREUX.

Ft.	In.		
50			
	8		Coal No. 1B.
58			"CARTHAGE LIMESTONE."
2	8		Coal No. 17.
35	8		
	8		Coal No. 16.
82	9		
2	6		Coal No. 15.
115	4		
1			Coal No. 14.
78	6		
	4		Coal No. 13.
100	2		
	3		"ANVIL ROCK."
20	9		Coal No. 12.
5			Coal No. 11.
45	10		
3			Coal No. 10.
67			
5			Coal No. 9.
49			
2	6		Coal No. 8.
43			
2			Coal No. 7.
84			
3			Coal No. 6.
65			
4			Coal No. 5.
119			
4			"MAHONING."
34			Coal No. 4.
4			Coal No. 3.
103			
3			Coal No. 2.
62			
4			Coal No. 1C.
53			
5			Coal No. 1B.
32			Coal No. 1A.
2			
60			"MILLSTONE GRIT."
3			Subconglomerate Coal.
1415	7	TOTAL.	Archimedes Limestone.

tological evidence which can be relied upon as a guide to identity.

In the Indiana Report, by Prof. Richard Owen, published in 1859-60, Prof. Lesquereux refers, from palæontological evidence, the sandstone above the "Knob" coal in Spencer county, to the Mahoning sandstone, and appears undecided whether the position of the "Martha Washington" sandstone, which forms the bluff at Rockport and presents a vertical face of thirty to fifty feet on the side fronting the river, should be referred to the Mahoning or the sandstone above coal No. 2, of his general section given at page 299-305, (column No. 1, of diagram.) At these localities, from my own examinations, I found the Rockport sandstone to be the millstone grit, and the "Knob" coal to be coal L of my general section of the coals in Clay county, (column No. 3, of diagram.) Consequently, the sandstone which overlies it in the hill, if referred at all to an equivalency in the Kentucky section, will be, at least, about the place of the Anvil Rock sandstone.

At Washington, in Daviess county, Prof. Lesquereux found a paucity of palæontological evidence, nevertheless, it was believed to be sufficient to warrant him in referring the main coal of that place to No. 1, B, of his section. In his account of the measures in Daviess county, no mention is made of the heavy bed of sandstone two miles northeast of Washington, which is overlaid by the "Washington" coal, which he refers to No. 1, B, this sandstone is quite a marked feature in the geology of this part of Daviess county and is underlaid by two workable beds of coal—the upper three feet thick and the lower three to six feet thick, the space between the two varying from twenty to forty feet. The lower coal has usually a limestone over it and being the second coal, in the descending order, below the "Washington" coal, is represented as K on my section.

A coal fourteen miles north of Washington, overlaid by limestone, is, from its position, referred by him to coal No. 1, C. I suppose the coal in the bed of the river below Edwardsport, in Knox county, is the seam here referred to,

if so, it is the second seam below the "Washington" coal. Now, the "Washington" coal is at least as high up in the measures as coal L of my section. The first coal below it in Daviess county was not recognized in Clay county, and at the time of making my section it was thought that no coal would be found intervening between L and K, consequently I am now compelled to make an interpolation of a letter and designate this coal, provisionally, as X; the coal with the limestone above it as K and the five foot coal bed near the top of the hill at Edwardsport, which is the equivalent of the "Washington" coal, as L. Passing on northward into Clay county, coal I, of my section, refers to No. 1 A, and K to No. 1 C, of Prof. Lesquereux's section.

Now, it is clearly demonstrated in this county that there are two workable block-coal beds in a space of fifty to sixty feet below the seam reported by Prof. Lesquereux as No. 1 A, or the lowest workable seam.

At Garlick & Collins' mine, on Otter Creek, in Clay county, coal K is seen on the side of the hill in the road cut. Coal I is worked by a drift, and coal G is worked by a shaft sunk at the foot of the hill on the bank of the creek. Both coals I and G, are here loaded into the cars from the same coal tip.

In my First Report, 1869, I pointed out the existence of a second workable seam of block coal below the seam then generally worked. Its position in the column was determined from imperfect outcrops, and, for a time, an error was committed in confounding it with a still lower seam, F.

Previous to my survey of Clay county no geologist or other person who had examined the ground, ever dreamt of finding another workable bed of coal below what was called the Brazil seam (I.) They universally believed that the strata at Brazil indicated the latter seam to be the lowest workable coal in the coal measures proper, and, consequently, that no lower seam of any economical value could be found below it. Since the publication of my First Report, the second seam has been reached by shafts and worked at a

number of localities in the county, and the existence of the third seam is fully proved by bores.

At Highland, two miles west of Brazil, coal L, of my column, is the principal seam worked, and, probably, the only seam in the basin, at that locality, which is of suitable thickness to be mined with profit. Notwithstanding the high position which it undoubtedly occupies in the measures, we find that it is referred by Prof. Lesquereux to No. 4 of his column. The same seam at Williams' is referred to No. 3, and the sandstone which is seen above the coal at Highland, he refers, without doubt, to the Mahoning sandstone. In fact, the misplacing of coal seams, and the confounding of sandstones at all levels with the Mahoning sandstone of Pennsylvania and the Anvil Rock sandstone of Kentucky, I might continue to trace throughout the entire coal field of Kentucky, Indiana and Illinois.

In the Kentucky Reports and the Report of a Geological Reconnaissance of Indiana, made in 1859, as well as in the reports of other geologists who have written on the Western coal measures, the distinguished authors have satisfied themselves that the Western coal beds and sandstones are synchronous with the Appalachian strata, and that the Mahoning sandstone, which is there a conspicuous horizon, must, as a matter of necessity, have a similar place in the Western field, and to divide the coal measures here, as there, into upper and lower measures, and that the coal beds should conform thereto.

Having pointed out a few of the errors committed in the stratigraphy of the Indiana coals, at localities where their position can be proved beyond a doubt, I will now proceed to show some of the errors that exist in the Kentucky column, from observations made at the same localities that furnished the data upon which it was constructed, and which column served as a basis for the arrangement of the coal beds and sandstones of all other districts in the West.

The column of the coal measures of Kentucky given at pages 18-24, Third Volume Geology of Kentucky, presents

us with 1350 feet of strata above the Millstone Grit, or Caseyville conglomerate.

From the sandstone under coal No. 18, down to the Anvil Rock sandstone, there is a repetition of the strata, including the latter rock, probably as far down as No. 7. This part of the column was constructed from bores that started on the Carthage limestone, which, in Union county, Ky., is, I now believe, the equivalent of the limestone over coal No. 11. Though the details of strata passed through in these bores can hardly be relied upon, and in no two instances do they fully agree as to the character of the rocks, still the place of the coals, and, probably, their full thickness, is given with considerable accuracy, as the parties who made the bores were in search of that mineral. Therefore, in the arrangement of this part of the column, it was erroneously assumed that the bottom of the lowest bore in Union county, starting from the horizon of the Carthage limestone, stopped just before reaching coal No. 11. From No. 17 down to No. 13, by reference to column No. 3 of the diagram, you will observe the close agreement in the spaces between the coals above and those below No. 11. In the former they are 35, 102, 115 and 77 feet, respectively, while in the latter they are 46, 67, 86 and 127 feet—the aggregate distance from No. 17 to No. 13 being 329 feet, and from No. 11 to No. 6, 326 feet. In giving the space from No. 8 to No. 6 I have omitted No. 7, which, at best, is but a streak of coal, and has no existence in Union county where the principal data for the section was obtained. We are thus carried down to about the place of the little coal at Mulford's, now Shotwell's mines, or No. 6 of the Kentucky column, and from No. 5, passing down, there is but one thin coal seam in the space intervening between it and Bell's coal or No. 1, B.

The Curlew sandstone, that is referred to a horizon just below the Mahoning sandstone of Pennsylvania, is the equivalent of the Anvil Rock sandstone; No. 4 coal is No. 11; and No. 3 is the equivalent of No. 1 B, or Bell's coal, which lies just above the Millstone Grit, or Caseyville conglomerate. In Union county, Ky., there is a thin coal in the conglom-

erate below Bell's coal, but there appears to be no workable seam.

The total thickness of the strata in the Kentucky column, exclusive of the Millstone Grit, is 1350 feet; now, strip it of the above errors of repeated strata, and we have, as the depth of the carboniferous rocks in Union county, Ky., only 612 feet, including the Millstone Grit.

The above errors are, in a great measure, to be attributed to too great a reliance on palæontological evidence and to an apparent desire to make the measures conform to the Pennsylvania sections of the Appalachian coal field. Though there are some striking analogies, so far as relates to the character and peculiar arrangement of their accompanying rocks, which were first pointed out by myself in a lecture on the Western coals in 1857, between the Pittsburg seam of Pennsylvania and the mammoth seam of the Western measures, (No. 11 of Owen, and which may prove to be K of my column,) yet, from the undoubted disconnection of the two fields while the coals were being formed, it is difficult to conceive how any reliable equivalency can be established.

More especially are we led to doubt the equivalency if we take into account the great preponderance of coal measure strata in the Pennsylvania district, which goes to show that, the conditions necessary for the production of coal, extended over a much greater period of time in the Appalachian than in the western field.

Though I have assumed that the greatest depth of coal strata in the western measures will not exceed 1,000 feet, in Indiana it will not be found greater than 650 feet, including the millstone grit. In a few localities in this State there are, one or more, very thin seams of coal below the Archimedes limestone, but no coal of any economical value has yet been found lower than the base of the Millstone Grit.

There are, in Indiana, two well defined zones of coal, the eastern and the western zone, and though an equivalency, in some of the seams, is clearly traced from one to the other, yet the quality of the coal is quite distinct in each. The eastern zone extends from the Ohio river, in Perry county,

on the south, to Warren county on the north, being about 150 miles in length with an average width of three miles.

The outline of the eastern boundary has a northwesterly and southeasterly trend, but is very irregular and marked by numerous tongue shaped projections which have been, here and there, cut across by denuding forces, leaving patches or outliers of carboniferous rocks, with their seams of coal resting on the subcarboniferous limestone far beyond the true boundary of the coal measures.

The area of the eastern zone is about 450 square miles or 288,000 acres, and the included coals belong to the bituminous variety characterized as *non-caking* or *free-burning*. The *cherry-coal* or *soft-coal* of England is a non-caking coal, but the non-caking coals of Indiana differ somewhat in physical structure from the English coal and a similar class of coals found in the Mahoning valley, Ohio, and the Shenango valley, Pennsylvania, the two latter being the only other localities in the United States where non-caking coal is found in any quantity. The Indiana coal from this zone has received the local name of BLOCK-COAL, a name given to it by the miners on account of the facility with which it can be mined in blocks as large as it is possible to handle. The beds are crossed, nearly at right angles, by joint seams that greatly facilitates the operation of mining which is usually carried on without resort to blasting. Blocks are taken out smooth the full depth of the seam and leave a zigzag notched outline, on the face of the mine, resembling a Virginia worm fence.

Block coal has a laminated structure and is composed of alternate thin layers of vitreous dull black coal and fibrous mineral charcoal. In the direction of the bedding lines, it splits readily into thin sheets like a slate but breaks with difficulty in the opposite direction. When struck with a hammer it emits a sound like that given by wood. Chemically it does not appear to differ from the caking coals, but in burning behaves quite differently. Unlike the latter it does not swell, shoot out jets of gas nor form a cake by running together, neither does it leave an ash mixed with

clinkers, but retains its shape like hickory wood, until entirely consumed to a small quantity of white ash which contains no trace of clinker. I have not yet had time to make an ultimate analysis of the block coal, but I believe that when so examined its superior heating properties, which have been determined in practice, by actual work done, though mainly due to its physical structure, will be found in part owing to its containing less oxygen and relatively more hydrogen than is commonly found in bituminous coals. The block coal in the great majority of the mines that have been opened, is remarkably free from sulphur and phosphorus.

A specimen taken from Garlick & Collins' new shaft, coal G of my section, of Clay county, and which has a specific gravity of 1.232, gave in 100 parts: Water 2.10, gas 37.35, fixed carbon 57.95, ash, white, 2.60, and contained sulphur 0.07, phosphorus 0.22.

At the White River Valley Rolling Mills, in this city, I was informed by the Superintendent, Mr. Sims, an experienced iron master from Pittsburg, Pennsylvania, that it not only required a less quantity of block coal, than of any of the coals in use around Pittsburgh, to make a ton of wrought iron, but that, they were likewise enabled to bring off the heats in a much shorter space of time, and the resulting iron is of a superior quality. Three important advantages that can not be overlooked by iron masters. And it must be conceded that the good behaviour of a coal in the puddling furnace is one of the very best tests, of purity and effective heating properties, to which it can be subjected, for here its good qualities are brought into requisition and the bad ones are soon made manifest in the poor quality of the iron produced.

Though the blast furnaces of Clay county can not be looked upon as filling all the requisites of an iron furnace best adapted to the use of block coal, still they are enabled to make a ton of No. 1, foundry iron that will in quality compare favorably with charcoal iron, by the use of less than two tons of coal. And I feel fully satisfied that by

materially increasing the width of these furnaces across the boshes and raising the temperature of the blast to 1200°-1500° F., that the make will be greatly increased and the consumption of coal very much reduced. By increasing the cubic contents of the furnaces and raising the temperature of the blast, they have been enabled, in the Cleveland district, England, to lessen the quantity of coke fully one fifth, per ton of iron made.

In the block coal zone, of the Indiana coal fields, there are as many as eight seams of non-caking coal, four of which are of good workable thickness over a portion of the field: these are I, G, F, and A, which together have a maximum thickness of fifteen feet, and by including the other four seams we have six feet more, making a total of twenty-one feet of block coal. If we take one half of this as a moderate average over the 288,000 acres, comprised within the eastern zone, it will give us 5,269,017,600 tons of coal, adapted to the smelting of iron, which will produce, at the rate of two dollars and twenty-five cents per ton, the average price of this coal at Brazil, the sum of 11,855,-289,600 dollars.

Ample allowance is here made for loss of coal incurred in mining, and the estimated value is believed to be within bounds. The superior excellence of the block coal for smelting and working iron and steel, in all the varied departments of their manufacture has been fully established by practical tests. Pig iron made with this coal is, in every respect, equal to charcoal iron made from the same ores. It is a soft gray iron of a highly crystalline structure, contains a large per centage of combined carbon, with but a mere trace of sulphur and phosphorus—properties which render it admirably adapted to the manufacture of Bessemer steel. For steam and household purposes, it likewise has an unrivaled reputation. It burns under boilers with a full and uniform flame that spreads evenly over the exposed surface, thus securing a more uniform expansion of the boiler plates and greater freedom from leaks that are so common when caking coals are used. No clinkers are formed and,

owing to its freedom from sulphur, it has but little detrimental effect upon the boilers, grates or fire boxes.

I am informed by the owner, Mr. Stunkard, that a boiler in a saw mill at Brazil, under which block coal is burnt, has been in use for sixteen years without requiring any repairs, and is now in good condition.

Mr. Charles R. Peddle, late General Superintendent of the St. Louis, Vandalia, Terre Haute and Indianapolis Railroad, informed me, by letter, that their company has been using the block coal from Clay county for the past two years, on locomotives, with excellent results. He says, "the coal is free burning, does not cake in the fire box, makes no clinkers, burns completely to ash, and requires very little more attention in firing than wood. Its freedom from sulphur renders it comparatively harmless to the iron of the furnace and flues, and the only difference between it and wood is that the heat is concentrated upon the lower sheets of the fire box, instead of being more generally diffused as in wood, and greater care must be taken in keeping the legs of the fire boxes clear of scale and mud. We are running our western division of passenger engines from Terre Haute to St. Louis, 165 miles, with one tender of coal, averaging three tons (of 2,000 lbs. each) per trip."

"On the eastern division (Terre Haute to Indianapolis) it is used on freight engines only, and the average number of miles run to one ton of coal, in the year 1870, was $26\frac{2}{3}$, and the cost per one hundred miles was nine dollars and a half, which includes cost of hauling and cost of wood for kindling fires. This statement, of course, does not show as favorable results as would be obtained if the coal was used on both passenger and freight engines, as the latter requires as much as fifty per cent. more fuel, per mile run, than the former."

This coal has recently been introduced on many other roads, on all of which it has given perfect satisfaction.

The block coal does not require as much draft as caking coal, consequently, an engine may be run with it that is constructed for burning wood. But to obtain the best results on engines designed for burning block coal, they

should be so constructed as to secure the proper draft, as all in excess of this will cause a waste of fuel. This rule holds good, also, with regard to burning the block coal in grates or heating stoves: *i. e.*, the draft should not be as strong as is required for burning the caking coals. Block coal burns in grates with a bright, cheerful blaze like hickory wood, making a very hot fire, and for comfort and economy, when properly burnt, surpasses any other bituminous coal with which I am acquainted.

It is used at the Indianapolis Glass Works, and Mr. Fought, one of the Company, informed me that the glass pots, which cost from \$100, to \$125, each, and last from six to eight weeks, when fired with Pittsburg coal, will last, at least, two weeks longer when block coal is used.

The western zone of coals in Indiana, comprises, by far, the greatest area of measures, being somewhat over 6,000 square miles, and contains three or more very thick beds of coal, besides a number that are too thin for working. Its eastern boundary, which is formed by the zone of block coal, is irregular in outline, and with my present knowledge of the geology of the country, it can not be well defined. It is evident, however, that the block coal beds, as we go west, are changed in character, and pass into caking coal. The lower members thin out and are no longer of workable thickness, even before reaching the Wabash river. Of this we have abundant proof by the three deep bores made at Terre Haute.

These bores commence about forty feet above low water of the Wabash river, and after passing a few feet of alluvium deposit were in strata of gravel, sand and hard pan, peculiar to the drift epoch, for a depth of about 150 feet, and though they penetrated the Silurian rocks, the records show that but five seams were passed, only the top one being of workable thickness, while the lowest is but 293½ feet below the surface.

Two and a-half miles east of Terre Haute, coal N, which is worked by a shaft at Seelyville, crops out, thus indicating a rise of the strata to the west, and as a still further means of accounting for the absence of the upper part of the coal

measures in the bores, it is possible that the great bed of drift which is found on the east bank of the river at Terre Haute, filled up a ravine, or valley, from which some of the upper coal beds were removed by abrading forces.

On the west bank of the Wabash river, coal L is mined in a number of places, from shafts thirty to fifty feet deep.

From the foregoing data, therefore, I am enabled to correct the error into which I fell, in my First Report, 1869, of making the top coal in the Terre Haute bore, coal L, and now place it, at least, as low down as coal I.

Though, from the records that were kept of these bores, it is difficult to point out the base of the coal measures, or that of the Millstone Grit, with accuracy; it is, nevertheless, my opinion, that the latter epoch commenced at about the depth of 500 feet.

This thinning out of the coal seams as we go west, toward the center of the basin, is a remarkable feature first pointed out by myself in 1867. A few miles west of the Indiana line, in Clark county, Illinois, bores have been made, in searching for petroleum, to the depth of 800 feet, without passing a single workable seam of coal, and the two or three thin seams reported in some of these bores are in the upper part of the measures.

Judged by the dip of the coal, on both sides of the river, the Wabash runs on a slight anticlinal axis, and I believe this to be the case from Attica, in Fountain county, to its mouth, in Posey county, and that along its course it cuts through the same strata of rocks from the bluff at Merom to its confluence with the Ohio river.

Near the eastern boundary of the zone of caking coals in Indiana, we find coals K and L, and sometimes N, of good workable thickness, averaging from four to eight feet, and, at one locality in Pike county, there is a bed not yet studied, but thought to be coal K, that attains to the thickness of ten feet, or more. Taken altogether, the maximum thickness of these beds may be estimated at twenty feet, and will yield an average, over the greater part of the district, of ten feet of coal. At some localities, the caking coal is of

inferior quality, and largely contaminated with pyrites, which is so generally disseminated through the seam that it is impracticable, in mining, to separate it from the coal. In many of the counties, however, within this zone, the caking coals will compare very favorably with the caking coals of the Pittsburg district.

Coal K, at Washington, in Daviess county, is a bright, rich looking coal, quite free from sulphur; is extensively mined; and meets with a ready market at St. Louis, and all the towns along the Ohio and Mississippi Railroad. I am informed that this coal is used by the gas companies at St. Louis and Vincennes, and, that both as to yield and illuminating quality of the gas produced, it holds an average rank with the gas coals that have been tried at these places.

The specific gravity of this coal is 1.294, a cubic foot weighs 80.87 lbs., by analysis it yields, fixed carbon, 60.00, ash, 4.50, volatile matter, 35.50. The coke is bright, porous, and slightly laminated.

The per centage of coke in the caking coals of Indiana, ranges from 52.00 to 64.50, and the ash from 0.50 to 7.00 per cent.

In Perry, Spencer, Warrick, Vaudenburg, Gibson, Pike, Daviess, Sullivan, Greene, Clay, Vigo, Parke, Vermillion, and Fountain counties, there are seams of rich looking and pure caking coal, which have, for the most part, been but recently developed by the survey, and I feel assured in saying, that they will prove to be good gas coals when subjected to a practical test on a large scale.

The chemical analysis of a coal is not always a safe guide for determining its value for gas purposes.

From her geographical position, and more especially on account of the extent and value of her coal beds, and the peculiar adaptation of this coal to the metallurgy of iron and steel, which now forms one of the leading industries of the world, we can safely predict for Indiana a bright future as a manufacturing State. The commerce of the new far-west, which is increasing with a rapidity unprecedented in the growth of empires, will just as naturally look to Indiana

for its supply of iron and steel, with which to keep up the system of railroads traversing the great plains to the Pacific ocean, as the old west formerly looked to Pennsylvania. In Indiana, we find the last great belt of timber suited for manufacturing purposes, and, after crossing her borders, from thence to the Pacific ocean, no coal has yet been found that can successfully be used in the manufacture of iron.

ANALYSES OF COALS—DAVISS COUNTY.

COUNTY.	NAME OF MINE OR OWNER.	Specific Gravity.	Weight of one cubic foot.	Fixed Carbon.	Ashes.	Coke.	Gas.	Water.	Total Volatile Matter.	Color of Ash.
Davies	Allen, Josephcoal K	1.293	80.81	56.00	6.50	62.50	30.50	7.00	37.50	Brown.
Davies	Alkman's coalL	1.270	79.37	56.50	3.00	59.50	35.50	5.00	40.50	Nearly white
Davies	Berry's, Walter, coal.....	1.288	80.50	59.00	5.50	64.50	28.50	7.00	35.50	Red brown.
Davies	Cox's coalL	1.259	78.68	57.50	3.50	61.00	35.00	4.00	39.00	White.
Davies	Clark's coall	1.277	79.81	57.30	3.50	60.80	34.70	4.50	39.20	White.
Davies	Dutch BankL	1.264	79.00	61.50	2.00	63.50	34.50	2.00	36.50	White.
Davies	Gregory's coal.....K ?	1.276	79.75	60.50	2.00	62.50	30.50	7.00	37.50	Drab.
Davies	Gregory's, John, coalK ?	1.275	79.68	49.50	2.00	51.50	42.00	6.50	48.50	Lilac.
Davies	McCord's coalK	1.245	77.81	54.00	2.00	56.00	40.00	4.00	44.00	Flesh.
Davies	O'Brian's, Cornelius.....K	1.270	79.37	56.50	1.50	58.00	35.50	6.50	42.00	Salmon.
Davies	Odell's coalA	1.262	78.87	53.00	2.00	55.00	36.50	8.50	46.00	White.
Davies	Raymond's coalX	1.200	75.00	50.75	1.75	52.50	46.50	1.00	47.50	Cream.
Davies	Spink, Cable & Co.'s main shaft L.	1.294	80.87	60.00	4.50	64.50	30.00	5.50	35.50	Fawn.
Davies	Sulphur Spring bank,L	1.280	80.00	58.30	6.00	64.30	31.20	4.50	35.70	Brown.
Davies	Spicer's MillL	1.268	79.25	48.50	1.00	49.50	44.00	6.50	50.50	Blue.
Davies	Stone's coal.....	1.264	79.00	54.30	2.00	56.30	35.20	8.50	43.70	Red brown.
Davies	Shaffer's, John, coalA	1.308	81.75	58.00	3.50	61.50	30.50	8.00	38.50	Brown.
Davies	Turner's coalA	1.278	79.75	55.50	1.50	57.00	35.50	7.50	43.00	White.
Davies	Ward's coalA	1.261	78.81	55.00	2.50	57.50	36.00	6.50	42.50	White.
Davies	Wilson's, Thomas, coalL	1.268	79.25	59.20	2.50	61.70	34.90	3.40	38.30	White.

ANALYSES OF COALS—MARTIN, VIGO, AND FOUNTAIN COUNTIES.

COUNTY.	NAME OF MINE, OR OWNER.	Specific Gravity.	Weight of one cubic foot.	Fixed Carbon.	Ashes.	Coke.	Gas.	Water.	Total Volatile Matter.	Color of Ash.
Martin.....	Baker's coal, (upper part).A	1.238	77.37	51.25	1.50	52.75	44.75	2.50	47.25	White.
Martin.....	Baker's coal, (lower part)A	1.239	77.43	48.75	0.75	49.50	47.50	3.00	50.50	White.
Martin.....	Horn & Co.....A	1.246	77.87	42.50	2.50	45.00	52.00	3.00	55.00	Light brown.
Martin.....	Hutz, PhilipA	1.262	78.87	47.50	2.50	50.00	46.50	3.50	50.00	White.
Martin.....	Munson's Ridge, (upper part).....A	1.270	79.37	50.00	1.50	51.50	45.50	3.00	48.50	Brown.
Martin.....	Sampson's Hill, (upper part)I	1.588	99.25	28.50	41.00	69.50	25.00	5.50	30.50	Gray.
Martin.....	Sampson's Hill, (middle).....I	1.232	77.00	53.00	1.00	54.00	44.00	2.00	46.00	White.
Martin.....	Sampson's Hill, (bottom).....I	1.252	78.12	47.00	1.50	48.50	48.50	3.00	51.50	Red.
Martin.....	Sampson's Hill, (carbon. markings).....			83.40	6.80	84.20	13.30	2.50	15.80	
Martin.....	Turner's Bank, (Sampson's Hill) A	1.359	84.31	45.50	9.00	54.50	41.50	4.00	45.50	Red.
Martin.....	Willow Valley.....A	1.286	80.37	48.00	2.50	50.50	46.75	2.75	49.50	Lead color.
Vigo.....	Foot's coal, (Honey creek).....	1.217	76.06	50.10	1.80	51.90	44.40	3.70	48.10	Light brown.
Vigo.....	Titcomb's coal, (Grant).....L?	1.257	78.56	46.50	2.50	49.00	48.00	3.00	51.00	White.
Vigo.....	Titcomb's coal, roof of.....	1.496	93.50	39.00	32.00	71.00	25.00	4.00	29.00	Fawn color.
Fountain.....	W. B. Coats, coal N, (top).....	1.249	78.06	51.80	2.60	54.40	42.60	2.00	45.60	Dark brown.
Fountain.....	W. B. Coats, coal N, (bottom).....	1.301	81.31	49.00	7.20	56.20	40.20	3.60	43.80	Blue gray.
Fountain.....	Hatfield's Mill, (Cannel coal).....	1.195	74.68	47.50	1.00	48.50	47.00	4.50	51.50	Red.
Brookfield, Ohio..	Mahoning Valley.....	1.270	79.37	53.70	2.50	56.20	39.80	4.00	43.80	White.
Spencer Co., Ind.	Priest Coal.....	1.282	80.12	51.90	1.50	58.40	43.10	3.50	46.60	Cream.
Lake Co.....	Peat from Crown Point.....			21.50	23.00	42.50	51.25	6.25	57.50	Buff.

ANALYSES OF COALS IN SULLIVAN AND CLAY COUNTIES.

COUNTY.	NAME OF MINE OR OWNER.	Specific Gravity.	Weight of one cubic Foot.	Fixed Carbon.	Ashes.	Coke.	Gas.	Water.	Total Volatile Matter.	Color of Ash.
Sullivan.....	Chamber's coal	N 1.206	75.37	48.50	2.00	50.50	45.00	4.50	49.50	Light brown.
Sullivan.....	Burke, B. & L.,	M 1.210	75.62	51.00	1.50	52.50	44.00	3.50	47.50	White.
Sullivan.....	Dick's coal (upper part)	M 1.258	78.62	50.50	1.50	52.00	43.50	4.50	48.00	White.
Sullivan.....	Dick's coal (middle part)	M 1.252	78.25	55.80	0.50	55.30	39.20	4.50	44.70	White.
Sullivan.....	Dick's coal (lower part)	M 1.278	79.05	52.00	2.50	54.50	42.00	3.50	45.50	Red brown.
Sullivan.....	Hanna, J. M., (Standard Shaft,) ..	M 1.281	80.06	54.00	2.50	56.50	40.50	3.00	43.50	Gray.
Sullivan.....	Pigg's coal	M 1.271	79.43	49.00	2.50	51.50	42.50	6.00	48.50	Red brown.
Sullivan.....	St. John's coal	M 1.287	80.43	49.00	2.50	51.50	45.00	3.50	48.50	White.
Sullivan.....	Wilson, Henry K.,	M 1.228	76.75	51.60	0.80	52.40	45.25	2.35	47.60	White.
Sullivan.....	Wilson, H., (Cass Tp.)	M 1.249	78.06	52.00	2.00	54.00	43.00	3.00	46.00	Blue white.
Sullivan.....	Curryville Shaft, (upper part,) ..	L 1.282	80.12	51.50	1.00	52.50	43.50	4.00	47.50	Rust color.
Sullivan.....	Shelburn, Richards & Buckley, top	L 1.278	79.05	51.50	2.50	54.00	43.00	3.00	46.00	Light red.
Sullivan.....	" " " mid. L	L 1.284	80.25	50.25	2.00	52.25	44.75	3.00	47.75	Cream.
Sullivan.....	" " " bot. L	L 1.296	81.00	53.75	2.75	56.50	39.75	3.75	43.50	Light red.
Sullivan.....	Standard Coal Co.,	L 1.333	83.31	55.20	2.90	58.10	40.10	1.80	41.90	White.
Clay.....	Carbon Block Coal Co.....	G 1.296	81.00	55.25	1.50	56.75	39.85	3.40	43.25	White.
Clay.....	Garlick & Collins (Otter Cr. Shaft) G	L 1.244	77.75	57.90	3.50	61.40	35.85	2.75	38.60	White.
Clay.....	Garlick & Collins (lower seam)	G 1.232	77.80	57.95	2.60	60.55	37.35	2.10	39.45	White.
Clay.....	Niblock, Zimmerman & Co.....	I 1.231	76.93	55.63	0.75	56.38	40.82	3.00	43.62	White.
Clay.....	Morris Coal Co., Brazil	I 1.244	77.75	52.00	1.00	53.00	43.50	3.50	47.00	White.

ANALYSES OF COALS.—SPENCER, WARRICK AND PARKE COUNTIES.

COUNTY.	NAME OF MINE OR OWNER.	Specific Gravity.	Weight of one cubic foot.	Fixed Carbon.	Ashes.	Coke.	Gas.	Water.	Total Volatile Matter.	Color of Ash.
Spencer.....	Barker's, W. L., Mine.....I	1.317	82.31	43.50	6.50	50.00	47.50	2.50	50.00	Brown.
Spencer.....	Brashear & Howard.....I	1.281	80.06	52.50	1.00	53.50	43.00	3.50	46.50	White.
Spencer.....	Barr & Bro. (upper part).....L	1.274	79.62	46.00	2.50	48.50	48.00	3.50	51.50	Brown.
Spencer.....	Barr & Bro. (middle part).....L	1.282	80.12	48.50	2.50	51.00	45.00	4.00	49.00	Brown.
Spencer.....	Barr & Bro. (bottom part).....L	1.278	79.87	48.50	3.00	48.50	47.00	4.50	51.50	Light red.
Spencer.....	Crosley, B. L.....L	1.267	79.17	47.50	4.00	51.50	45.00	3.50	48.50	Red.
Spencer.....	Lewisport Vein.....I	1.294	78.06	47.50	1.00	48.50	47.50	4.00	51.50	White.
Spencer.....	Rockport Vein.....I	1.275	79.68	49.50	4.00	53.50	40.00	6.50	46.50	White.
Spencer.....	Smith, L. G.....I	1.232	77.00	45.50	1.50	47.00	47.00	6.00	53.00	White.
Spencer.....	Staab's Coal.....I	1.237	77.31	47.20	3.50	50.70	44.30	5.00	49.30	Gray.
Spencer.....	Staab's Coal*.....I	1.243	77.68	54.00	1.60	55.60	42.60	1.80	44.40	White.
Spencer.....	Stocking's Coal.....I	1.267	79.18	46.60	3.00	49.60	47.90	2.50	50.40	Brown.
Spencer.....	Wood's Coal.....I	1.289	80.56	48.00	3.50	51.50	45.50	3.00	48.50	Brown.
Warrick.....	Locust Grove, No. 1.....I	1.300	81.25	47.50	14.00	61.50	34.50	4.00	38.50	Dark brown.
Warrick.....	Locust Grove, No. 2.....I	1.279	79.93	50.50	2.00	52.50	44.50	3.00	47.50	White.
Warrick.....	Locust Grove, No. 3.....I	1.313	82.03	46.00	7.00	53.00	45.00	2.00	47.00	Brown.
Warrick.....	Locust Grove, No. 4.....I	1.282	80.31	50.50	2.50	53.00	44.50	2.50	47.00	White.
Parke.....	Judge Maxwell, near Rockville.....			48.75	2.50	51.25	45.50	3.25	48.70	White.
Parke.....	Cannel ? Coal, near Rockville.....			34.50	26.00	60.50	32.00	7.50	39.50	Dark brown.

*Specimen sent by Col. J. W. Foster.

ANALYSES OF COALS—ILLINOIS, WEST VIRGINIA, COLORADO TERRITORY.

LOCALITY.	NAME OF MINE OR OWNER.	Specific Gravity	Weight of one cubic foot.	Fixed Carbon.	Ashes.	Coke.	Gas.	Water.	Total Volatile Matter.	Color of Ash.
Danville, Illinois.....	Moss Bank, specimen No. 1*.....	1.357	84.81	46.78	8.64	55.42	40.58	4.00	44.58	Brown.
Danville, Illinois.....	Moss Bank, specimen No. 2*.....	1.298	81.12	45.93	5.73	51.66	44.94	3.40	48.34	Light red.
Kanawha County, West Virginia...	Kanawha Coal Co., Coalburg.....	1.257	78.56	56.00	1.50	57.50	40.50	2.00	42.50	White.
Kanawha County, West Virginia...	Campbell Creek Coal.....	1.290	80.02	57.00	2.50	59.50	38.00	2.50	40.50	Dark red.
Boone County, West Virginia.....	Peytona (cannel coal).....	1.322	82.62	59.50	3.50	63.00	34.50	2.50	37.00	White.
Colorado Territory.....	Carbon City†.....	1.291	80.68	41.26	9.25	50.50	46.00	3.50	49.50	Lead color.
Colorado Territory.....	Canon City†.....	1.279	79.23	56.80	4.50	61.30	34.20	4.50	38.70	Ochre yellow.
Colorado Territory.....	Fair Play*.....	1.254	78.37	55.58	2.00	57.58	37.92	4.50	42.42	Fawn.
Colorado Territory.....	Godfrey's, 75 miles east of Denver†..	1.383	86.43	48.95	6.40	55.35	42.40	2.25	44.65	Sap green.
Colorado Territory.....	Hodgson's, 33 m's north of Denver†..	1.269	79.31	53.95	3.80	57.75	33.85	8.40	42.25	Dirty yellow.
Colorado Territory.....	Murphy's, 15 miles west of Denver†..	1.332	83.25	52.55	1.25	53.80	39.45	6.75	46.20	Sap green.
Colorado Territory.....	Rock Spr'g, 312 m's w. of Cheyenne*	1.254	78.37	53.90	0.50	54.40	38.10	7.50	45.60	White.
Colorado Territory.....	Van Dyke's, Hulleville*.....	1.257	78.56	50.50	1.75	52.25	40.95	6.80	47.75	Cream.
Colorado Territory.....	Briggs Coal, 32 m's n.w. of Denver†..	1.252	78.25	53.80	1.00	54.80	35.65	9.55	45.20	Pale yellow.
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*Caking coal.

† Brown coal.

ANALYSES OF IRON ORES.

COUNTY.	OWNER AND NUMBER OF SPECIMEN.	Moisture dried at 212° F.	Loss from Ignition.	Silica.	Ferric Oxide.	Metallic Iron.	Alumina.	Lime.	Magnesia.	Sulphur.	Phosphorus.
Martin.....	B. F. Devol, No. 1			27.00	66.40	44.48	1.10	trace.		trace.	trace.
Martin.....	do No. 2	1.24	6.56	28.60	54.45	38.10	7.20	1.95		trace.	trace.
Martin.....	do No. 3	1.00	8.00	36.80	49.95	34.96	2.12				
Martin.....	do No. 5	4.00	9.11	32.35	53.00	37.10		1.54			
Martin.....	do No. 6	1.00	28.00	7.00	60.50	42.35				trace.	trace.
Martin.....	do No. 7	1.15	24.05	8.00	60.00	42.00		6.80			
Martin.....	do No. 8	1.40	22.80	13.00	55.60	38.92		5.60		.90	
Martin	do No. 9	3.00	10.50	23.00	59.65	41.75	2.70	1.15			trace.
Martin.....	do No. 10	3.00	8.00	37.75	48.05	33.63	1.15	2.05			trace.
Martin.....	do No. 1130	28.50	8.50	53.60	37.52		9.10		trace.	trace.