THE CONSTITUTION OF OHIO COALS.

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I wish to present a few practical remarks upon the composition of Ohio coals. I do not attempt anything like a thorough or formal discussion of this important subject. In fact, the time has not yet come, our knowledge is not yet sufficient, for such a decision.

As we all know, there are coals and *coals* in the Ohio scale. The wide range of value in the products of our several seams and fields is recognized in every general market by differences in price, amounting sometimes to 50 per cent. between the lowest and the highest quality. But this popular classification of our coal seams, though based upon facts, is inconsistent and inaccurate, in many of its applications. The good name of some particular mine or field is often made to cover quite inferior quality and the inferior reputation of other fields gives sometimes to the fortunate purchaser, first-class fuel at second-class rates. .

Is there any precise and definite way of determining the relative values of any two coals that we find in market? Can we determine the values of coals as we can of fertilizers, for example?

The two chief means that we possess for answering these questions are *Chemical Analysis* and *Practical Tests*, and it is upon the first that most reliance is placed.

1. In what ways and to what extent, can chemical analysis determine the relative efficiency and value of different coals?

As is now generally recognized by those whose opinions and judgments upon the subject are entitled to consideration, coal is derived from vegetation. It is made up of the various tissues of land-plants, more or less transformed by the process of fossilization. Derived from vegetation, it contains the characteristic elements and products of vegetation. Carbon, hydrogen, oxygen and nitrogen, are the chemical elements that constitute 95 per cent.

or more of the existing vegetable world. These same elements make the substance of all coals. Along with them in the living plant, we find a varying percentage of mineral substances, which we name the ash. When the plant dies, a part of this ash proves soluble and passes readily away in circulating waters, but a part of it cannot be dissolved and therefore shares the fortunes of the de-daying tissues that enclose it. This portion we should expect to find in the coal that represents the remnant that is saved from the vegetable growths of an earlier day—and we *do* find it as the ash. In a few coals the ash is perhaps limited to mineral matters accumulated in such a way; but generally this portion of mineral matter is re-enforced by sand and clay in a fine state of division that were brought in from time to time over the marsh in which the coal seam was formed, by floods or currents of unusual height, and that never composed any part of the vegetable substance.

A small percentage of sulphur, and a still smaller one of phosphorous would also be due in the coal as remnants of its vegetable origin, but all the sulphur of our coals is scarcely to be charged to this source.

A coal seam agrees thus with the vegetation that produced it in being essentially composed of carbon, hydrogen, oxygen and nitrogen and in holding a small percentage of sulphur, iron, phosphorous and ash, derived from the vegetation; but the vegetation fails to explain all of the ash, the iron and the sulphur that the coal contains.

All these facts are chemical facts, and to the chemist we must appeal for exact knowledge in regard to them.

There are two modes in which the chemist answers our questions as to the composition of a coal. He gives us the results of either an *ultimate* or of a *proximate* analysis, or of both. By the former he reduces the compounds, which the coal contains to their simplest forms *i.e.*, to their elements, and gives the amount of each element, as, for example, the Heydenville coal is reported by Wormley to contain of

Carbon	75.00 per cent.
Oxygen	15.96
Hydrogen	5.80
Nitrogen	1.51
Sulphur	.64
Ash	1.09

Or he uses the method of *proximate analysis,* and gives us his results in somewhat different form. The latter method is by far the most commonly used in the analysis of our coals, and is, in fact, the one upon which all the popolar interpretations of the chemical composition of our coals depends. The results of proximate analysis are expressed under the following heads, viz.:

1. Fixed carbon or coke.
2. Volatile combustible matter.
3. Ash.
4. Sulphur, existing chiefly as bi-sulphide of iron or *pyrites.*

In addition there needs to be shown under both systems the amount of *moisture* held by the coal, this making the 5th term of the series given above.

It is obvious that the first two elements, viz., the fixed carbon or coke, and the combustible gases, derived from the burning of the coal, are those on which the value of the coal depends. The ash, the sulphur and the water are all drawbacks. They are of no value in themselves and they reduce the value of the elements with which they are associated. Other things being equal, the less there is of them the better the coal, but the qualification "other things being equal" is an important one. The physical character of the coal is one of these "other things". Firmness and tenacity in a coal will more than compensate in the popular judgment for some inferiority in composition.

The moisture of Ohio coals according to recent determinations ranges from 2 to 9 per cent. A few examples can be found in which it drops below 2 per cent even. The largest per centage is in the excellent coals of Jackson county. The proportion in them seldom falls below 7 per cent. Whoever buys a ton of Jackson coal must pay for at least 150 lbs. of water at the rate of coal.

Few general statements can be made as to ash and sulphur, of our coals. These elements have a wide range. There are coals used with a fair measure of acceptance in the State, in which the sulphur runs from 3 to 7 per cent. In some of our highly valued seams it averages 2 per cent. There is very little Ohio coal in the market in which there is not more than 1 per cent, but occasionally a mine or a portion of a mine will send out some coal of an unusually high character, the sulphur falling as low as $\frac{6}{10}$ per cent.

As to ash, it can be said that very little coal comes to market that does not contain as much as 4 per cent. Our best seams, *in their best condition*, come down to 2 or even to 1½ per cent, but they do not stay long at this low figure. The average ash exceeds 5 per cent. for all our best coals, while 7, 8 and 10 per cent are found in some coals that stand fairly well in their markets.

As to the fixed carbon and volatile matter, it is to be borne in mind that in reporting them something depends on the method by which they have been analyzed. To know what you are to understand by 50 per cent or 60 per cent of fixed carbon, you must know the process by which this element was determined. The older analysis of Ohio coals give the fixed carbon uniformly higher and the volatile matter uniformly lower than more recent analysis. The later methods are undoubtedly the best. Percentages of fixed carbon are frequently quoted as if one analysis was enough to settle the question, but we must know who made it, before we can give it its proper weight, not as questioning chemical competency, but as questioning chemical methods.

But granted that we have undisputed results as to the fixed carbon and volatile matter of two coals, or as to its ultimate composition, can we proceed on this basis to determine the relative efficiency and value of the two coals? Does science furnish us the means of writing out the value of a ton of coal on any settled basis when we know its composition?

It is disappointing to be obliged to answer these questions in the negative, but the present state of our knowledge obliges us to do so. I do not mean to say that we cannot make an approximation, nor do I cast any discredit on chemistry in its application to this province. The trouble is that it has not gone quite far enough, as yet, but it is our only rational guide, and to its progress we must look for the full and final answers that we seek.

The method of calculating the heating power of coal from a knowledge of its composition, as shown by ultimate analysis, seems to me to be discredited, both by theory and practical tests--Gruna 15 per cent.

When the analysis is reported in terms of fixed carbon or coke, and volatile matter, the established interpretations have made the value of the coal depend upon the former element. The fixed carbon gives a good measure of value for some uses, as iron making, it is true, but it has been, and is popularly counted a guide for all other uses, and this application is by no means established. Take a new coal to market, and the intelligent purchaser asks you, for the first question, what its amount of fixed carbon is. A high figure assures him, and a low one gives him an unfavorable view; but it is by no means certain that he is justified in his inference. A coal with a higher amount of volatile matter may do more and better work in some applications than another with higher fixed carbon. But in default of practical tests, we have nothing but the latter to fall back upon.

But the practical question which I specially wish to bring before you is this: Supposing that chemical analysis is able to do for us all that has been claimed for it, how far can we rely on the current analysis of our coals, as practical guides in development and use? In other words, how far do such analysis fairly represent the seams to which they are applied? This question goes to the root of the matter. In my opinion the answer is not altogether assuring. The *sampling* of a coal for analysis is a much more important and difficult task than it has sometimes been counted, if the results of analysis are to prove a trustworthy guide for us. What has the practice hitherto been? To take a small piece of the best block that could be found, and let this represent the mine. But all seams and most mines have layers or beds, or at least pockets, of good coal. The result of such methods of sampling has been to give a monotonous and characterless series of figures. Even under this plan, some differences of composition would appear, but many differences would be masked, or at least would not come to light.

In entering upon the chemical work for volume V., Geology of Ohio, I consulted with Professor Ford, chemist of the survey, with Hon. Andrew Roy, State Inspector of Mines, and with other practical men, as to the best method of sampling coal seams or mines for analysis. The following modes were agreed upon: The seams should be sampled in some good room, by channeling from top to bottom, taking a cubic inch or less from every inch of height, rejecting, of course, the parts refused for the market. These blocks could afterward be reduced, if necessary, in size. When brought to the laboratory, the whole would be reduced in a large mortar to a smaller size, divided and reduced again, until a portion suitable for analysis was found, the sampling being conducted as in the ores of silver, etc.

A second mode was to take small fragments from as many large blocks as possible, from never less than fifty, and often from as many as one hundred. These would be treated in the laboratory as described above. The samples were often selected from the bank cars as they came out, sometimes from the loaded railway cars.

The results of analysis under this mode of sampling have proved very instructive. For the first time, the chemical individuality of our coal seams comes out to view. All of our leading coals have characters of their own as to fixed càrbon, volatile matter, ash, sulphur and moisture. In many cases, the character is so distinct that a coal can be referred to its proper horizon by inspection of the analysis, if the general region from which the coal comes is known.

In particular, chemical analysis seems to clearly distinguish the two great seams of Eastern Ohio that have been confounded under one number, viz: the Middle Kittanning or Tuscarawas Valley No. 6, and the Upper Freeport or Connotton Valley No. 6. For seven counties, the fixed carbon of the lower seam falls below 50 per cent., while the volatile matter in all cases exceeds 40 per cent. There is scarcely an exception to this statement. On the other hand, through the same and adjoining counties, the upper seam in no case falls as low as 50 per cent, while the volatile matter never reaches 40 per cent. The balance has distinguished these two seams, over which so much discussion has been waged, clearly and definitely, as with a chalk on a blackboard.

But what of the older analysis? They were executed at great expense. Abundant chemical knowledge and skill were used in the work. How far can they be made to serve as practical guides in the selection of our coals for particular purposes? I am obliged to acknowledge that they are in very many cases without value, solely because they represent only the better phases of the coal. It is idle to talk of an *average sample* of a coal seam like the great vein of the Hocking Valley, for example. That seam consists of 5 or 6 benches of unequal quality. The bottom coal cannot represent the top coal, nor the top coal, the bottom. In reality they are two distinct seams. An *average sample* must come from one or the other and will misrepresent the one to which it does not belong. In a word, proper samples is as much a necessity in the analysis of coal, as chemical skill, and can no more be dispensed with than the latter. Where it has not been brought into use, the figures derived from chemical analysis have a scientific rather than a practical interest.

The second point, viz., the practical tests of our coals, by use in water works engines, or in locomotives, for example, I cannot dwell upon at this time except to call attention to the necessity of so treating each sample that it may give its best results. Each coal has its "personal equation" that must be consulted in setting it to work. The treatment that gets the most out of one coal would be unjust to another. The stoker and the furnace play no unimportant parts in the so-called tests of coals. Two engineers using the same coal will give very different testimony as to its behavior. One complains of smutted flues before half his run is made, while the other declares that it always burns clear and clean. To make any such test fair, each coal should be experimented upon long enough to determine the best that can be done with it.