ANALYSIS OF CERTAIN COALS OF ILLINOIS

AND THEIR RELATION TO EACH OTHER.

A THESIS

PRESENTED TO THE FACULTY OF THE UNIVERSITY OF ILLINOIS

By

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History of Coal.

Coal or coke, originally meant any substance that was used as fuel.

The ancients appear to have been acquainted with coal, and with the fact that it would burn, but they do not seem to have turned their knowledge to much practical use. Theophrastus, a Greek writer who flourished about two hundred years before the Christian era, in a work entitled, "The Book of Stones," describes an earthy substance which would kindle and burn, and which was used by smiths. There can be no doubt that he referred to coal, and this is the first passage in which that substance is expressly mentioned.

There is no good evidence of the employment of English coal earlier than 853 A.D. In 1239 the king granted license to the good men of New-Castle
to dig for coal in neighborhood of their town and it is said that in 1287 New castle had a considerable trade in coal. But mineral fuel did not however come into general use without meeting with great opposition.

In 1306 Parliament petitioned King Edward I to prohibit the use of coal in London. The citizens were so offended at the sulphurous smoke and savour of the firing that the King complied with their request, and a penalty for the use of coal was the destruction of the furnaces or kilns in which it was used.

We are also told that many years afterwarde the nice dame of London would not come into a house or room where sea coal was used nor willingly eat of the meat that was either sod or roasted with sea coal fire. Sea Coal was the
name given to coal that was brought from New-
castle by sea.
The same thing happened in France as late as
1714. The Parisians refused to allow coal to be
used in Paris. But in 1769, a little more than a
hundred years ago—when wood was very dear
in Paris, coal was shipped in by English merchants.
The coal was mostly used by the poor people and
used by higher classes in the stoves and fire places.
The unfortunate mineral fuel was accused of
vitiating the air, of soiling the linen when drying
and of causing effect on the chest. Complaints
were steadily increasing and once more the mineral
fuel was expelled. In spite of all these difficulties
it came into use, more and more. In 1879 the first
government tax was laid on coal.

In the reign of Edward VI an English writer
Speaks of, that things that France can live no more without, than the fylke without water; that is to say, Newe-castel cole, which without that they can neither make steel worke, nor metall worke, nor gusses, nor us manner of thirlines that faceeth the fire.

Many problems arose as to the employment of coal instead of charcoal in the process of iron smelting. The quantity of wood used for this purpose was so great that in the reign of Elizabeth four acts were passed to check its consumption. Under these circumstances it is evident that he who could successfully introduce the use of sea coal into the manufacture, which was thus devastating the forests, would not only confer a great benefit upon the country, but would reap a rich reward.

Many attempts were made. One of the earliest of these speculators, Simon Sturtevant, announced
that he had discovered a method by means of which the smelting of as much iron as had hitherto required an outlay of 500 s for charcoal could be accomplished with from 30 2 - 50 2 worth of sea coal. His method, however, does not seem to have realized his expectations. The difficulties to be overcome were very great. Iron had previously been smelted in small quantities, and to substitute coal for charcoal successfully it would have been necessary to employ larger furnaces, and more powerful bellows than were used then. The sulphur too, of which coal contains a small proportion, injuriously affected the quality of the iron produced. The device now employed of getting rid of part of the sulphur by converting the coal into coke was not at that time resorted to. The above is a brief
history of coal, from the earliest time to the present. A period has now been reached in which there is a great demand for coal for domestic and industrial purposes. The very existence of coal is now considered essential.
Economic Geology.

The Illinois coal fields, cover more than thirty six thousand square miles.

The coal business has been rapidly developed during the past ten years. The production in 1870 having been 262,416 tons while in 1872 it was 179,499 tons. This rapid increase has been made possible by the abundance of coal, the wide area over which it extends, the facility with which it can be mined and our unusual railroad facilities which have enabled the miner to place his product on the market at an extremely low price and has stimulated a rapid growth in our manufacturing industries.

There is perhaps no equal area in the U.S. where coal can be obtained with so moderate an expenditure of capital as in the Illinois coal fields.
Illinois has about three times the coal area of Pennsylvania and Ohio combined. There are many places in Illinois where coal was laid down, but can not now be found by boring or other means on account of it being washed out by means of streams or other erosive agents, while in many other places coal never was deposited because these island or ridge-like areas were so much above the general level that coal plants could not grow on them. Examples of the first are the borings in Tuscola, Douglas Co. and Champaign, Champaign Co. Examples of the second are the artesian wells at Canton, Fulton Co. and the shaft at Chenoa, McLean Co. The man who undertook to sink a shaft at Chenoa, being certain of finding coal on account of many coal shafts being on every side, had the misfortune of striking one of
of these island above mentioned.
The dip of the coal from the western border of the coal field is to the eastward about seven feet to the mile. A knowledge of the dip is of great value as it enables us to find the depth we would have to go in any part of the country to reach the coal.

There is no anthracite coal in Illinois because there never was any great disturbances to make so much heat as to drive off the volatile matter. Anthracite coal is nothing more than bituminous coal which has been subjected to metamorphic action which has expelled the volatile matter. It belongs to the same geological period as the common coal and is only found in those regions where the strata have been greatly disturbed.

It is said that in Wales the same bed may
be traced from a bituminous to a true anthracite coal and the same is true in Pennsylvania. All the gradations of the change can be distinctly seen.

The usual method used in mining, to estimate the productive capacity of a coal seam is that one square mile will yield one million tons of coal for every foot in thickness, so that a seam six feet thick would yield six million tons. This method will generally give a result much too large, for there are areas in each horizon of every coal field, which were islands in the old coal marshes on which coal plants never grew, and as we have no means of knowing how many such islands existed in any given area, or what may have been their area, it is impossible to make a reliable estimate until
the field has been thoroughly prospected with the drill. A few estimates can be made for a space of a few hundred feet on each side of a shaft, or boring, but estimates covering larger areas should not be attempted until sufficient data are accumulated.

The largest portion of this State Illinois is prairie land. In it all kinds of prairies may be seen, such as the highland prairies, the river bottom or alluvial prairies and the low wet swamp lands.

One theory attributes them to the annual fires sweeping through the grass killing every tree and germ almost before they could take root. In some places the fires are supposed to have encroached year by year upon the forests, in the deep hollows, or in the wet places, were the fires would be checked, the timber
would spring up and displace the prairies. Some other theories account for the treeless character of these plains, from the lacustrine origin and nature of the prairie soils and subsoils. Trees would not naturally grow in this sedimentary finely comminuted prairie soil, according to this theory. Lesquereux supposes prairies to have been formed by water covering the earth or place, and then receding and making a sort of swampy land, then at last becoming dry. These are the leading theories that have been advanced.

Theory of the formation of Coals

Most coals were formed on the place where they are now found, in basins more or less extensive. The materials to make this coal were accumulating for many years. They consist of peat mosses
and other swamp-loving plants, which have decayed under water. There are at present peat bogs forming in this very way, plants grow very dense in marshy places and accumulate to a great thickness. They sink below the surface by their own weight and are thus kept from the oxygen of the air. By this means much of their carbon escapes oxidative and is retained in the form of coal.

But we must understand that the peat bogs that formed the coal were more extensive, and plants then grew more luxuriously and that material accumulated for years and years.

At the time coal was formed, and after, the surface of the earth changed very often from a higher to a lower level and "vice versa". This explains why our coal horizons are not found in a horizontal position, but often tilted or
inclined at different degrees. The coal must have
been laid down horizontally, that is generally
speaking, of course it was not laid down perfectly
level, so one would understand it so. The disturb-
ances in Illinois were not great and so we do not
find the coal horizons very far from the level, al-
though a person visiting a mine, can often see
a dip of 6-8 degrees. In the Alleghany Mountains
where the disturbances were greater the coal beds
are found sometimes in a perpendicular con-
dition or folded one upon the other.

Vegetation grew luxuriantly and rank beneath
the surface and by its weight kept weighing
until the whole surface was covered with water,
to that extent when rocks and shales began to form.
This formed a deposit of rock on the coal and
then at sometime after the land rose again and
conditions were such that vegetation grew again and made a thick deposit, and sank again, and rock was formed upon it. This went on in the same way until as many as 29 strata of coal were formed and at this epoch, in which coal was laid down was called the Carboniferous age which has an aggregate thickness, in Illinois, of about twelve hundred feet.

But we must not understand by this that coal was not formed in any other age. The rocks of many carry more or less. Those of the Jura Trias contain strata forty feet in thickness, while the Cretaceous rocks of the great West probably carry more coal than the entire Carboniferous formation of America.

The coal-bearing strata are divided into the upper and the lower coal measures. The di-
riding line in this State being the Shoal Creek limestone
Composition of Coal.

Coal contains mainly, carbon, hydrogen, oxygen and nitrogen accompanied by a few other elements in less proportions, such as sulphur, phosphorus, iron etc. These last mentioned are not essential elements of coal but come under the head of impurities. The hydrogen and oxygen are supposed to be combined with a part of all of the carbon, so that coal consists mostly of oxygenated hydrocarbons. When coals are heated, they afford much volatile matter, although containing more, this arising from the decomposition by heat of some of the hydrocarbons present. The volatile matter is mostly hydrocarbon oils, or gas with a little water. Bitumen is mainly an oxygenated hydrocarbon and coals rich in these oxygenated hydrocarbons have received the name of bituminous coal.
Constitution of Coal.
Attempts have been made to dissolve out the
bituminous matter of coal.
Many chemists have succeeded in dissolving out
small quantities of bituminous matter from coal
by means of ether, benzene, carbon bisulphide, and chloro-
form. C. Guignet, in the Journal of Chemical Society
of 1879, Page 602 says he has obtained better results
with phenol. The coal was dried at 110°C reduced
to the finest possible state of subdivision by grind-
ing with water until it assumes a clear brown
color and is quite soft to the touch, yields as much
as four o/s of its weight to dry boiling phenol.
The filtrate is brown and on the addition of alcohol
deposits the dissolved matter in brown flocs, which
were put on a filter and washed with alcohol
until free from phenol. Nitric acid attacks this
substance with some difficulty forming a yellow product. On repeatedly treating the original coal with nitric acid and filtering, evaporating to dryness taking up with water, boiling the solution with barium carbonate and filtering, precipitating the barium salts by means of sulphuric acid a solution is obtained containing trinitroresorcinol (dynamite acid). The barium carbonate precipitate contains barium oxalate besides sodium sulphate and ferric hydrate. The coal residue insoluble in nitric acid contains nitro products similar to nitro-celluloses and on heating decomposes with explosion or evolution of red fumes. It also contains products giving a brown solution with sodium hydrate and even with ammonia. The original coal treated with strong sodium hydroxide, evaporated to dryness and then distilled at 400°C in an iron retort.
yields a clear yellowish liquid containing among other things, ammonia, and aniline, but no resorcinol. The distillation residue treated with water gives a deep brown solution which neutralized with an acid deposits a large quantity of brown substance, resembling ill-defined compounds comprised under the name, ulnin, humin, acid etc. By treating the coal with concentrated sulfuric or nitric sulfuric similar products are obtained, in the latter case mixed with nitro products.

The constitution of coal is a subject which has not yet been thoroughly investigated, and much could be found on this subject.
Sulphur in Coal.

Sulphur is known to exist in coal in three conditions: as metallic sulphides such as pyrites; as sulphate of calcium or barium; and as a sulphuretted hydrocarbon. In approximate analysis of coal about one half of the sulphur in any pyrites present and all the sulphur existing as a sulphuretted hydrocarbon, are probably driven off with the Volatile Combustible Matter. The rest of the sulphur is driven off during the burning off of the fixed Carbon (Sulphate of iron being easily decomposed at a bright red heat). When an alkali or an alkaline earth is present (the sulphuric acid formed from the oxidation of the pyrites is taken up by the alkali or alkaline earth.

To find in what form sulphur exists in
coal (as sulphate or sulphides) one finds the sulphur in the ash and subtract this from the total amount of sulphur found. This difference represents the sulphur in the form of sulphides, and the sulphur in the ash, i.e., in the form of sulphates. These results would be correct if the coal contain no free alkali or alkaline earths to retain the sulphur. But the above mentioned method is the nearest approach we can make. All coals hitherto examined contained a certain amount of sulphur—that is sulphur not combined with calcium, Barium, or iron. The percent varies greatly; some figures have been attained varying from 1.25 to 75.00 of the total sulphur present. Experiments have been made and conclusions reached that the condition of the sulphur in coal bore little or no relation to the % of it, which was volatilized in coking.
Moisture.

All coal contains more or less water. This is not only a diluent of the coal but is in itself an obstacle to its effectiveness. The vaporization of the moisture causes a serious loss of heat. Heat is taken up to make steam and keep it in that form till it passes off. Water is contained in coal as hygroscopic water.

Many methods have been used to find the amount of moisture in coal. The one used for a long time was to heat a definite weighed quantity till it lost no more in weight, but this method gave no uniform results, on account, that some of the coal was oxidized and increased in weight for a certain length of time, and then decreased again, and every time it was weighed it would have either increased or decreased and no constant weight could be obtained.
so experiments were made and from these the conclusion drawn that the best way to get at the percentage of moisture is to heat for one hour at a temperature of 105°–110°. This temperature was chosen because 100° did not drive off all of the moisture, some of the moisture being held to firmly mechanically.

Method used.

One gram of the finely pulverized coal was weighed out into a platinum crucible and heated in an air bath, kept at the temperature of 105–110° C., for one hour. Allowed the crucibles to cool in a desiccator and then weighed. The loss in weight divided by the amount taken and the result multiplied by 100 gave the percentage of moisture. The coal used for this was ground so fine so as to pass through a sieve having ninety meshes to the inch.
Volatile Combustible Matter.

This was determined by means of the method given in Blaine Chemical Analysis of Iron. Second edition. It is as follows. One gram of the powdered coal was weighed in a platinum crucible and the cover placed on and heated by means of a Bunsen burner for three and one half minutes, then without allowing it to cool, it was heated next three and one half minutes more by means of a bunsen lamp. Cooled in a desiccator and weighed. Divided the loss in weight by the amount taken multiplied by one hundred subtracted the percentage of moisture and the remainder being the percentage of Volatile Combustible Matter. This determination was always made on a fresh sample and never on the portion used for the determination of moisture. The necessary precautions being that the lids
fit tight, and to heat each one of them the same number of minutes, also that the crucible was put in the desiccator, immediately after heating, for if this was not done it was noticed, the coke would absorb moisture from the air very rapidly and in this way cause an error.

By knowing the percentage of Volatile Combustible Matter we can form some judgement as to the amount of gas the coal will yield.

All the coal used in analysis was powdered so as to pass through a sieve ninety meshes to the square inch and in this way a homogeneous mixture was obtained.
Fixed Carbon.

After weighing the crucible for the determination of volatile combustible matter, it was placed over a lamp and the carbon allowed to burn off. The burning off of the carbon was hastened by breaking up and stirring the mass from time to time with a platinum rod. When all the particles of carbon were burnt off, the crucible was allowed to cool and then weighed. The difference between the above weight and this, divided by the weight of the coal taken and multiplied by 100 gave the percentage of fixed carbon.

The fixed carbon is the constituent of the coke which gives it the heating power, for this reason it is of great value to know the per cent of fixed carbon.

The amount of coke a coal will yield is equal to the sum of the fixed carbon and ash.
Ash.

To know the amount of ash in a coal is of great importance. If coal contains a large percent of ash it is unfit for the use in the manufacture of iron since the percentage is about double in the coke. The tendency of a coal to "clinker" (that is, the ash fusee and forms a "slag") is caused by the presence of certain substances in the ash. A glassy slag is formed by the combination of silica with potassium, sodium, calcium or iron. Generally the amount of iron contained is in the form of a sulphide. A large percent of ash is also objectionable on account of the large amount of heat it retains. A large amount of heat is lost when the ash falls through the grate or when the ash collects and must be removed and with it a large amount of unburnt coal is removed.
Method used for Sulphur.

The sulphur in the coal was determined by means of Echik's method, and is as follows: One gram of the finely powdered sample was weighed out and mixed thoroughly with one and a half gram of a mixture consisting of one gram of magnesium oxide and one half gram of Potassium Carbonate, transferred the mixture to a large crucible, and heated it over a Bunsen burner, having the crucible inclined in such a manner that the flame could be applied to the bottom of the crucible, so that the dull red heat extended only about one third up from the bottom. The mixture was stirred every few minutes with a platinum wire until the carbon was burned off and the ash was of a dull yellow color. This required about an hour or a little longer. The crucible was allowed to
cool, added to the mixture one gram of nitrate of ammonia, mixed in thoroughly, placed the lid on the crucible and heated cautiously until all the nitrate of ammonia was decomposed and at last the crucible was brought to a dull red heat. Now allowed to cool, treated with hot water in a beaker and allowed to come to a boil, filtered from the insoluble matter, acidulated with hydrochloric acid and determined sulphur as barium sulphate by precipitating with barium chloride. The weight of barium sulphate multiplied by 13736 gives the amount of sulphur.
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Moisture Average:

1. Breuggerman Coal Co.
2. Chas. Hartmann " "
3. Willstadt Coal Co.
4. Bennett " "
5. John Kloess " "
6. Fred Murphy " "
7. West End " "
8. Trenton " "
10. Mentor " "
11. Eastern " "
12. Darrow " "

Specific Gravity:

1.25
1.24
1.23
1.22
1.21
1.20
1.19
1.18
1.17
1.16
1.15
1.14
1.13
1.12
1.11
1.10
1.09
1.08
1.07
Volatile Matter Average.

Sulphur Average.

Ash Average.
Plate showing situation of the Coal Mines in the County

Scale: 5 miles = 1 inch

M & P
St. Clair County
<table>
<thead>
<tr>
<th>Name of Mine</th>
<th>Depth in Feet</th>
<th>No. of Seam Mined</th>
<th>Name of County</th>
</tr>
</thead>
<tbody>
<tr>
<td>Breugeman coal co.</td>
<td>60</td>
<td>6</td>
<td>St. Clair County</td>
</tr>
<tr>
<td>Chas. Hartman coal co.</td>
<td>85</td>
<td>&quot;</td>
<td>&quot;</td>
</tr>
<tr>
<td>Millstadt coal co.</td>
<td>48</td>
<td>&quot;</td>
<td>&quot;</td>
</tr>
<tr>
<td>Benett Coal co.</td>
<td>203</td>
<td>&quot;</td>
<td>&quot;</td>
</tr>
<tr>
<td>John Knoes coal co.</td>
<td>110</td>
<td>&quot;</td>
<td>&quot;</td>
</tr>
<tr>
<td>Fred Murphy coal co.</td>
<td>70</td>
<td>&quot;</td>
<td>&quot;</td>
</tr>
<tr>
<td>West End coal co.</td>
<td>130</td>
<td>&quot;</td>
<td>&quot;</td>
</tr>
<tr>
<td>Trenton coal co.</td>
<td>320</td>
<td>7</td>
<td>Clinton County</td>
</tr>
<tr>
<td>Wildermans Mine</td>
<td>122</td>
<td>6</td>
<td>St. Clair County</td>
</tr>
<tr>
<td>Mentor Mine</td>
<td>208</td>
<td>6</td>
<td>&quot;</td>
</tr>
<tr>
<td>Eastern Mine</td>
<td>70</td>
<td>&quot;</td>
<td>&quot;</td>
</tr>
<tr>
<td>Darrow Mine</td>
<td>185</td>
<td>&quot;</td>
<td>&quot;</td>
</tr>
</tbody>
</table>
Method used for the determination of H. and C.
The coal used was pulverized and dried at 100°C for six hours. The combustive was carried on in the ordinary way for the determination of H and C.

The tube contained besides copper oxide also lead chromate, this being present to retain the oxides of sulphur. A reduced copper gauge was placed in the tube to decompose all oxides of N. that might form. Sulphuric acid was used to absorb the water formed and potassium hydroxide for the absorption of carbon dioxide formed.

About 2 of a gram of the dried pulverized coal was weighed out and then mixed with a mixture of copper oxide and pulverized lead chromate, two of copper oxide to one of lead chromate. This lead chromate was also present to absorb the oxides of sulphur. This mixture
was then placed in the combustion tube and then a copper gauge was placed in the same end of the tube and proceeded with the combustion in the ordinary way. The usual precautions were observed.

After having heated the mixture for about one hour and a half at a dull red heat, dried oxygen was allowed to pass through the tube for a half hour, then the heat was turned off and dry air passed through for fifteen minutes.

From these data the heating power was calculated as given on the sheet containing the results.
<table>
<thead>
<tr>
<th>Designation</th>
<th>1st.</th>
<th>2nd.</th>
<th>Average</th>
<th>Average in Calories</th>
</tr>
</thead>
<tbody>
<tr>
<td>Breuggerman Coal</td>
<td>5.54</td>
<td>68.40</td>
<td>5.70</td>
<td>68.53</td>
</tr>
<tr>
<td>Hartman Coal Co.</td>
<td>5.82</td>
<td>68.66</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Millstadt Coal Co.</td>
<td>5.37</td>
<td>69.08</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Benett Coal Co.</td>
<td>5.74</td>
<td>68.55</td>
<td>5.77</td>
<td>68.93</td>
</tr>
<tr>
<td>Fred Murphy Mine</td>
<td>5.63</td>
<td>70.28</td>
<td>5.74</td>
<td>69.54</td>
</tr>
<tr>
<td>Next End Mine</td>
<td>5.76</td>
<td>69.70</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Wildermans Mine</td>
<td>5.97</td>
<td>54.26</td>
<td>59.7</td>
<td>54.26</td>
</tr>
<tr>
<td>Eastern Mine</td>
<td>4.50</td>
<td>52.41</td>
<td>4.57</td>
<td>52.41</td>
</tr>
<tr>
<td>Darow Mine</td>
<td>4.67</td>
<td>63.04</td>
<td>4.67</td>
<td>63.04</td>
</tr>
</tbody>
</table>

Calculated heating power in Calories:

\[80 \times 68.53 = 5482.42\]
\[34460 \times 0.0570 = 1964.22\]
Total 7601.64

Total 7491.87

7507.37

6164.27

7582.79

6495.26

5785.42

6782.16

6704.91
The Object of this Thesis

The object of this thesis is to get the analysis of the coal and show the relation which exists between coal from the same horizon taken from mines in the near vicinity of each other.

It has been said that the coal varies greatly in different parts of the same County. All the samples of coal, but one were from St. Clair Co. This County leads in the production of coal in Illinois, and the amount is increasing every year, and it is of great importance to know what relation the coal from different parts of the County bear to each other.

The statement has been made by many that the coals from the Northern and most Southern parts of the County were better than those in the Eastern and Western parts of the County.
This theory also throws some light on the deposition of coal, that is, if it was laid down of a homogeneous composition. As can be seen by the analysis, not such a great difference is noticeable as might be expected.

The coal having the lowest % of volatile matter is from Darrow mine, the one with the highest from West End mine. The Trenton coal has the highest % of fixed carbon 45.03 and coal from John Kloess' mine the lowest 41.04.

Darrow mine coal has the highest % of moisture 10.25 and West End the lowest 5.88. The average is 7.74. Mentor mine coal has the lowest % of ash 7.04 and Eastern mine coal has the highest 11.43. Average % of ash 8.96.

The lowest % of sulphur is in Trenton coal 0.55. The highest in West End 2.05. Average 2.34.
Willetadt coal has the lowest specific gravity 1.07, Murphy coal the highest 1.25+, the average is 1.11. The specific gravity does not vary much. All further relations can be seen on the sheet containing the results of the analysis.

It is said that Illinois coal is of poor quality but judging from my analyses I see no truth in the statement. Illinois has just as good a bituminous coal as can be found anywhere especially in the southern part of the state. Dunrovin and Trenton considered among the best. All the coals analysed were from St. Blais Co. except one, the Trenton from Clinton Co.