CHAPTER XIII.

COMPOSITION OF IOWA COALS.

INTRODUCTORY.

In beginning investigations on the composition of the Iowa coals attention has been directed chiefly to the merchantable product just as it comes from the mines and is sold on the market. As will be shown more in detail in another place there is nowhere in the state any special preparation of the coal for the different uses to which it is put. No instance is known at the present time where the slate, "sulphur" balls, ironstone nodules, or other gross impurities are systematically removed before the output is loaded for shipment. This elimination of the larger masses of impurities from the coals in other places has made some of the neighboring states formidable competitors in the Iowa home markets. With the sorting out of some of the substances detrimental to the Iowa coals quite different analyses of the commercial article would be obtained.

The chemical analyses tabulated farther on were made chiefly by Prof. G. E. Patrick, of the Iowa Agricultural College. The methods of sampling have varied somewhat in accordance with different problems which required solution, but in all cases careful checks have been kept in comparing results received in the different ways. As the discrepancies between the several methods are very small they may be for all practical purposes ignored. To be sure, many of the analyses are doubtless quite different from those made elsewhere of essentially the same coals, but it is to be remembered that in the large majority of cases the results obtained by the latter are largely from picked samples, while those here given are representative of the product as it is sold to the public. On the whole, the merchantable coals of Iowa with proper preparation would be much better than the presented analyses indicate at first glance. As it is, however, they compare very favorably with the other coals of the Western Interior basin.

KINDS OF COAL.

The commercial varieties of coal are classified principally according to the different proportions of fixed and volatile components contained. The combustible portions are made up of the lighter volatile hydrocarbons, which are driven off when the coal is moderately heated, and the fixed carbon. The proportion of the former in the total amount of combustibles determines the character of the coal. Thus of volatile matter the percentage contained is in:

Graphite	0
Anthracite	10
Semi-anthracite	20
Bituminous coal	40

Graphite, the pure massive variety of carbon so common in crystalline rocks and areas exhibiting regional metamorphism, is practically devoid of volatile matter.

Anthracite, or hard coal, contains but a small proportion of the volatile hydrocarbons. Its comparatively great hardness, weight, lustrous appearance, conchoidal fracture, difficulty of ignition, and the burning with blue flame, accompanied by little or no smoke, are characters readily distinguishing it from other varieties of coal.

Semi-anthracite possesses properties about midway between those of true anthracite and the bituminous coals. The hardness and density are less than in the former, the volatile combustibles greater. Fractured surfaces are not so glistening. When ignited a yellowish flame appears, but gradually disappears as combustion continues.

Bituminous coal is commonly quite soft, and breaks easily. It contains a large percentage of volatile matter, burns with a strong yellowish flame, and gives off in ignition a more or less dense smoke. The Iowa coals are largely of this kind. There are, however, three more or less distinct varieties. These are: (1) the dry, open burning or furnace coals; (2) cementing or coking coals; and (3) the cannel coals. "Of these the first and second varieties are sometimes classed as cubical or block coals, from their tendency to break into more or less cubical blocks. The first variety enumerated includes those that do not coke and adhere in the furnace, and such as can be used in the raw state for the manufacture of iron. They have generally a distinct laminated structure, and are composed of bituminous layers separated by thin partitions of cannel or mineral charcoal, materials which do not coke. Hence the bitumen in them—relatively small in quantity—is held in cells, and cannot flow together so as to give the mass a pasty, coherent character.

The second class, or cementing coals, are such as have few partitions, but show upon fracture broad surfaces of pitch-like bitumen. These, to a greater or less degree, melt or agglutinate by heat, forming what blacksmiths term a hollow fire. This property causes them to choke up the furnace and arrest the equal diffusion of the blast through the charge; hence they cannot be used in the raw state for the manufacture of iron, but must be coked. This process of coking consists in burning off the bituminous or gaseous portion, which leaves the coal in the condition of anthracite, except that as this change is effected without pressure, the resulting material is cellular and spongy. Coals of this character, when free from sulphur—their great contaminating impurity—are used for the manufacture of gas; the volatile portion driven off in the retorts serving the purpose of illumination, while that which remains is coke and may be used as fuel." (Newberry.)

The third class, or cannel coal, occurs rather sparingly in Iowa, and there is very little mineral fuel that can properly be called by this name, though there are a number of seams in different localities which closely approach in character. In the formation of this variety of coal there seem to have been somewhat different physical conditions than those under which the ordinary bituminous kinds originated. Newberry held the opinion that this coal formed in the lagoon of open waters in the coal marshes, and that in these lagoons the completely macerated vegetable tissue accumulated as a fine carbonaceous mud. The evidence he deduces may be summarized as follows:

First. The cannel coals in their intimate structure are more homogeneous than the cubical coals, and show nothing of the alterations of bright and dull lines to which reference has been made, and which may be considered as proofs of changing surface conditions in the coal marsh.

Second. Though laminated in the sense that the cubical coals are, the cannels are more distinctly stratified like other rocks which are deposited from aqueous suspension.

Third. The cannel coals generally contain a greater percentage of volatile matter than the cubical coals, and the gas made from them consists more largely of hydrogen, and has higher illuminating power. All of which is a natural result of their deposition in a hydrogenous medium which prevented oxidation.

Fourth. Cannel coals, as a rule, contains more ash than the cubical coals, and they frequently pass into bituminous shales. This occurs where the water from which they were deposited had a more rapid motion and greater transporting power. It then carried and mingled with its carbonaceous sediment an increasing and ultimately preponderating amount of mineral matter.

Fifth. Cannel coal contains, as characteristic fossils, aquatic animals, such as mollusks, fishes, amphibians and crustaceans. These are sometimes so abundant and of such a character as to prove conclusively that they inhabit the pools of water in which cannel coal was deposited as a sediment. Where plant remains are found in cannel they are usually floated fragments which show the effect of long maceration, fern fronds, for example, being usually skeletonized.

Sixth. In the lagoons of open water in our modern peat marshes fine carbonaceous sand accumulates, which, when dried, closely resembles in appearance and properties our cannel coal.

Lignite.—There are two other sources of mineral fuel in Iowa which require passing mention here. They form a part of the coal series. The one is lignite, or brown coal, and the other is peat. Neither of these substances come within the scope of the present work; but they will form subjects of special consideration at another time. Lignite is a compact woody or charcoal-like material having many of the properties of common bituminous coal, but is very soft, easily crumbled, and contains a high percentage of hydrocarbons and moisture. By proper preparation, and by manufacturing it into briquettes a very serviceable fuel is often obtained. Several beds of this material are known to occur in the Cretaceous deposits of northwestern Iowa, one of them being upwards of four feet in thickness.

Peat.— This is one of the first stages in coal formation. The thick matted mass of vegetable matter gradually becomes more and more compact, lose much of their hydrocarbons, and finally, with heat and pressure, may turn into coal. Extensive deposits are found in the northern portions of the state.

PHYSICAL PROPERTIES OF COALS.

In their ordinary physical properties the Iowa coals have a very considerable range of variability. The character of the fractures, hardness, specific gravity, and color of the ash when burned, all change very materially with the locality.

Fracture.— This is quite characteristic for different places. In nearly all cases ordinary breakage of the coal yields more or less cubical blocks of varying size. Sometimes the broken surfaces show glistening faces not unlike anthracite. This is notably the case with the Mystic seam of southern Iowa. Commonly, however, the fractures show alternate bright and dull bands. The tendency towards lamination is one of the most noticeable physical characters of many of the bituminous coals. This feature enables them to be broken up readily into more or less cubical masses, hence they have been called "block" or "cubical" coals. An examination of a block of ordinary bituminous coal will show an alternation of bright and dull lines. The bright lines on further examination will be found to be made up almost entirely of hardened bitumen; the dull lines to be mineral charcoal. The bright folia are very much harder than the dull plates. In striking the block of coal with a hammer it cleaves readily along the dull lines. These cleavage faces are found to be made up of a matted mass of what appears to be pressed or flattened charcoal. When the coal seam is examined in the mines before it is removed, it is found that the bright and dull lines are always parallel to the planes of sedimentation.

Recognizing the fact that the coal was originally a vegetable accumulation, and was subsequently covered by deposits of clay and sand, it will be readily inferred that, in a mass of matted plant remains on a gradually sinking shore, a constantly increasing pressure upon the beds would be the result of an increasing deposition of sediments, and that the vegetable matter would continually be made more and more compact as the overlying beds became thicker, and as time went on. Gases arising from the slow decomposition of the plant remains gradually escape. Both the pressure above and the loss of gases allow the bulk of the seams to greatly diminish. This process probably continues, though slowly, until the coal bed has become perfectly hard and massive like anthracite. When ironstone nodules and concretions are found in the coal seams the laminations are very distinct both immediately above and below the foreign mass. The thin leaves which are perfectly horizontal elsewhere in the beds bend upwards and downwards around the nodules, closely following every curve and inequality in the surface. Large nodules five or six feet across and imbedded in coal seams considerably thinner protrude above the top of the coal layers. The upper portion of the nodules, however, is commonly covered with the coal to a thickness of from one to four inches. In the immediate vicinity of the nodules the coal is so strongly laminated that it cleaves like ordinary slate into extremely thin leaves. The arrangement and position of these ironstone nodules in the coal veins leave but little doubt that the coal seams have decreased greatly in thickness since the time the concretions became thoroughly hardened.

In regard to the differences between the two kinds of laminæ, the bright and the dull, it seems probable that they may have been due to a great extent to the original condition of vegetable materials. In a swamp such as that in which most of the coal was formed there would probably be times when the woody stems of plants would accumulate in the marshes more abundantly than at other periods. There would also very likely be times when fine sediments would enter the swamps. This might have been yearly or in cycles of years when there were unusual growths, or floods.

Hardness.—With every handling of soft coal there is greater or less loss through crushing and attrition. Every degree of hardness diminishes the waste in movement from the mine and in transportation. The hardness of the Iowa coals may vary greatly according to the locality and the seam worked. This is well shown at the mines where the waste in slack and fine coal or dust is from four to fifteen per cent of the total amount taken out. Some of the Iowa coals are too soft to endure a great deal of hauling, and, consequently, the output of mines operating in such veins must be used almost entirely locally. Most of the coal of the state when not taken from faces of natural exposures or at the immediate surface, has sufficient strength to withstand considerable hauling and transportation without marked depreciation in the weight of the merchantable product.

CHEMICAL ANALYSIS.

Determinations Made.— All the tests as yet made in regard to the composition of Iowa coals have been proximate and not ultimate analyses. The ultimate analysis, while giving accurately the proportions of the different elements present, is unreliable as a basis for the computation of heat equivalents in making comparisons. The method employed in making these analyses is the one commonly used in determining the relative values of different beds. The process is much more simple than that necessary for a complete elemental determination and still serves to bring out the proportions of the various components affecting the fuel values of the coals. The determinations commonly made are:

Moisture.
Volatile Combustible Matter.
Fixed Carbon.
Ash.
Sulphur, in sulphides.
Sulphur, in sulphates.

Methods of Analysis.— The moisture is determined by heating a known weight of coal for one hour at a constant temperature of 105 degrees, Centigrade, or slightly above the boiling point of water. From the loss in weight the percentage of moisture may be calculated.

For the other components, excepting sulphur, a second weighed portion of coal is heated in a covered crucible to a dull red heat for three and a half minutes; the temperature is then raised to a bright red heat which is maintained for an equal length of time. After subtracting the amount of water previously determined, the loss in weight represents the volatile combustible matter. Longer subjection to heat would be at the expense of the fixed carbon.

The coke, which remains in the crucible after the volatile matter has been driven off, is now subjected to a high degree of heat until the remaining carbon is consumed, which may then be reckoned as fixed carbon. The weight of the residue gives the percentage of ash. The ash may also be determined separately.

The value of the investigations which have just been considered depends entirely upon the maintenance of similar conditions for each sample in the series of coals.

The estimation of the sulphur is in no sense approximate. It is made independently, both as to the sulphates and the sulphides, no attempt being made to distribute it among the factors of the previous analyses. However, that portion of the sulphur already oxidized in the coal and which is separated as sulphate will be found in the ash.

Suggestive as such an analysis is, experience has shown that too much reliance may be placed upon it as an indication of the true value of a coal for any particular purpose. The physical properties already mentioned must be also taken into consideration. Thus for metallurgical purposes analyses may point to a coal low in sulphur and ash which may be still totally unfit for use in the furnace because of its coking qualities. Such a coal, however, is worthy of fuller investigation regarding the physical properties of its coke, for at the present time very little raw coal is used in blast furnace practice since the porosity, compressive strength, energy, and intensity of heating power possessed by the better classes of coke render them superior to the best anthracite coal, regardless of the somewhat larger proportion of impurities.

For purposes of gas making a high percentage of volatile combustible constituents and at the same time low proportions of sulphur are required. In this case the adaptability of a coal for producing gas of high illuminating power can best be judged only from an ultimate analysis.

Moisture.—Water, being the product of the perfect oxidization of hydrogen, is evidently incapable of combustion. Its presence is doubly deleterious, causing a negative loss by adding to the weight without increasing the heating value, and a positive one by requiring evaporation, thus diminishing the available power of the fuel.

In the amount of moisture present in the different Iowa coals there is very considerable range, from 2.06 per cent, the lowest, to 11.72 per cent, the highest, the average probably being in the neighborhood of seven per cent. This amount compares very favorably with the Illinois coals, with which the Iowa product is brought into chief competition. It is, however, from one and one-half to three per cent higher than the average moisture found in Ohio, Missouri or Kansas coals.

Volatile Combustible Matter.—The volatile combustible matter comprises in a general way the gaseous constituents of the coal. The moderate heat employed in its determination is sufficient to expel the greater part of the various compounds of carbon and hydrogen. When their combustion is complete these gases have high calorific power, but owing to the devices in common use the volatile portions of bituminous coal are almost entirely wasted, passing off in dense black clouds of pure carbon, accompanied by the lighter gases of combustion and distillation. In this manner a very large part of the inherent virtue of the coal is worse than wasted. The introduction of automatic stokers and smoke consumers would obviate to a very large degree these disadvantages in the use of bituminous coal. So widely has this matter been considered that it is thought to be worthy of special ordinances in some manufacturing cities. Strange it is that those who use the largest quantities of coal must be forced to economize in their fuel. The attention of steam users should also be urged to the intelligent study of the proper relation of coal used to the grate employed. Coals show great individuality in their behavior, those of similar composition often showing wide differences in the same furnace, and coals whose analyses indicate a deficiency frequently giving better satisfaction than those of apparently better quality.

Fixed Carbon.—In the uncombined, or fixed, carbon lies the greatest value of a coal as now generally employed. Though in uniting with oxygen only about one-third as much heat is developed as in the union of an equal amount of the hydrocarbons, its non-volatile properties insure for this portion of the coal more complete consumption. The percentage of fixed carbon is usually the basis of comparison of coals. This is especially applicable to the valuation of steam coals, but for this use sufficient volatile matter must be present to insure easy ignition and free combustion, for quantity of heat as a desideratum here gives place to intensity. For this reason and because of the intense local heat developed by anthracite inducing rapid oxidization of the grate bars, bituminous coal is to be prefered for general use under steam boilers.

Ash.—Unlike water the residue left after combustion has no positive effect in reducing the efficiency of a fuel, but is generally an inactive addition from which nothing is realized but which must be handled, and this always at constant expense. In domestic fuels a high proportion of ash is more to be avoided than in steam coals. On locomotives, where it is possible to reduce the handling of the waste product to a minimum, coals having a large percentage of ash may be frequently used with economy. From the color of the ash an idea may often be obtained as to the amount of iron, and indirectly a rough estimation of the sulphur, since most all of the iron is in the form of the sulphide.

Sulphur.—While in a condition to be easily oxidized the injurious effects of sulphur more than offset any addition to the calorific power of the coal. The most notable influence of the presence of considerable percentages of this component is seen in the tendency of coals to slack and disintegrate upon exposure to atmospheric agencies. Even under cover sulphurous coals will not stand storing for any great length of time. Spontaneous combustion in coal mines is often due to the presence of this element. Even with all possible care in stopping old entries by means of air-tight partitions a considerable degree of heat is frequently developed, requiring a constant watching that possible fires may not gain headway. The process is one of true combustion. In the coal the sulphur is mostly combined with iron, forming pyrite or the sulphuret of the metal. This substance is ordinarily very susceptible to oxidizing influences, by means of which it is converted into other compounds, the action being accompanied by heat. The oxygen for the reaction may come from the air, or, this being excluded, may be furnished by the decomposition of percolating waters. If the heat produced in this way is in excess of radiation, the temperature of the coal may be raised to the point of ignition. High percentages of sulphur render the raw coal unfit for use in the blast furnace and forge; for here the iron must come in direct contact with the fuel. On account of its strong chemical affinity the sulphur is taken up largely by the iron.

Chemical Analyses of Iowa Coals.

LOCALITIES.	Moisture.	Total combustibles.	Ash.	Volatile combustible matter.	Fixed carbon.	Coke—Fixed carbon plus ash.	SULPHUR. In sulphides.	SULPHUR. In sulphates.	SULPHUR. Total.
ADAMS COUNTY—									
Plowman shaft, Briscoe, top	8.97	80.48	10.55	36.44	44.04	54.59	3.15	.11	3.26
Same, middle of seam	9.09	74.95	15.96	32.04	42.91	58.87	2.46	.13	2.59
Same, bottom of seam	8.72	77.39	13.89	32.01	45.38	59.27	3.67	.27	3.94
Wyles mine, Carbon, average	8.01	80.12	11.87	35.26	44.86	56.73	4.25	.11	4.36
Reese mine, Carbon, average	9.12	81.51	9.36	35.71	45.79	55.12	3.89	.18	4.07
Hinton mine, Eureka, average	8.68	81.91	9.70	33.85	47.72	57.43	4.38	.19	4.58
APPANOOSE COUNTY—									
Diamond mine, Centerville, top	9.66	82.06	8.28	34.72	47.34	55.62	2.57	.14	2.71
Same, middle of seam	10.12	83.67	6.21	35.63	48.04	54.25	2.13	.07	2.20
Same, bottom of seam	10.28	84.64	5.08	36.89	47.75	52.83	2.67	.13	2.80
Scandinavian mine, Centerville, average	9.23	40.46	6.97	36.21	47.58	54.55	2.79	.12	2.91
Appanoose mine, Cincinnati, sample of room	6.54	80.37	13.09	36.20	44.17	57.26	4.40	.13	4.53
Same, vein above clay seam	6.20	78.11	15.69	34.00	44.11	59.80	3.67	.16	3.83
Same, vein below lower clay seam	7.53	75.14	17.33	29.31	45.83	63.16	6.73	.82	7.55
Thistle mine, Cincinnati, top	3.18	85.22	11.60	36.55	48.67	60.27	3.57	.11	3.68
Same, middle of seam	5.80	90.71	3.49	37.71	53.00	56.49	2.97	.05	3.02
Same, bottom of seam	6.02	87.80	6.18	36.90	50.90	57.08	3.13	.17	3.30
Same, below sulphur band	2.88	72.69	24.43	29.03	43.66	68.09	3.61	.43	4.04
Whitebreast No. 19, Forbush, average	9.70	82.98	7.31	35.84	47.14	54.45	4.14	.27	4.41

BOONE COUNTY—									
Angus mine, Angus, average	8.62	82.75	8.64	38.33	44.41	53.05	2.59	.08	2.67
Dalby mine, Angus, top of seam	2.71	87.26	10.03	39.90	47.36	57.39	5.17	.15	5.32
Same, middle of seam	2.13	92.14	5.73	44.21	47.93	53.66	3.72	.10	3.82
Same, bottom of seam	3.69	85.70	10.61	45.12	40.58	51.19	4.10	.16	4.25
Northwestern mine, Boonesboro, top	13.23	81.21	5.56	37.52	43.69	49.25	....	...	....
Same, bottom of seam	11.51	82.60	5.89	58.86	43.74	49.63	....	...	....
DALLAS COUNTY—									
Tudor mine, Dawson, top	4.64	81.73	13.63	39.84	41.89	55.52	2.08	.13	2.21
Same, middle of seam	5.62	79.86	14.52	36.79	43.07	57.59	4.69	.24	4.93
Same, bottom of seam	6.55	84.00	9.45	37.45	46.55	56.00	3.27	.08	3.35
Keeler mine, Linden, average	7.41	67.97	24.61	27.86	40.10	64.72	6.53	.65	7.18
Redfield mine, Redfield, top	11.36	78.15	10.49	38.46	39.69	50.18	2.76	.04	2.80
Same, middle of seam	10.55	75.60	13.85	30.18	45.42	59.27	3.83	.24	4.07
Same, bottom of seam	12.76	72.94	14.30	34.72	38.22	52.52	3.01	.10	3.11
Tabor mine, Woodward, average	7.15	77.94	14.90	35.54	42.40	57.30	5.74	.69	6.44
DAVIS COUNTY—									
Dye mine, Laddsdale, bottom	4.48	87.40	8.12	44.26	43.14	51.26	4.26	.12	4.38
Sickles mine, Laddsdale, top of seam	3.06	92.34	4.60	42.82	49.52	54.12	5.19	.23	5.42
Same, middle of seam	2.06	90.66	7.28	43.84	46.82	54.10	6.51	.29	6.80
Same, bottom of seam	2.59	75.41	22.00	36.97	38.44	60.44	7.05	.22	7.27
Same, average	2.57	86.13	11.29	41.21	44.43	56.22	6.25	.24	6.49
GREENE COUNTY—									
Bussey mine, Rippey	9.92	87.92	2.16	44.39	43.53	45.69	....	...	....
Kennedy mine, Rippey, top of seam	7.01	84.08	8.91	43.94	40.14	49.05	3.62	.06	3.68
Same, middle of seam	9.40	81.64	8.96	39.76	41.88	50.84	3.39	.05	3.44
Same, bottom of seam	9.70	82.90	7.40	40.36	42.54	49.94	2.94	.06	3.00
GUTHRIE COUNTY—									
Eclipse mine, Fansler, top of seam	7.73	86.44	5.83	39.85	46.59	52.42	3.62	.05	3.67
Same, middle of seam	7.04	83.61	9.35	37.94	45.67	55.02	4.32	.07	4.39
Same, bottom of seam	6.89	76.23	16.88	32.67	43.55	60.44	9.50	.68	10.18
Reese mine, Panora, cannel	4.88	59.09	36.03	30.80	28.29	64.32	10.57	.50	11.07
Same, average, bituminous	6.41	80.39	13.19	38.07	42.32	55.51	5.59	.13	5.72
Suggett mine, Stuart, top of seam	9.61	79.19	11.20	34.63	44.56	55.76	4.01	.11	4.12
Same, bottom of seam	9.30	81.07	9.63	36.80	44.27	53.90	3.48	.05	3.53

Chemical Analyses of Iowa Coals.—Continued.

LOCALITIES.	Moisture.	Total combustibles.	Ash.	Volatile combustible matter.	Fixed carbon.	Coke—Fixed carbon plus ash.	SULPHUR. In sulphides.	In sulphates.	Total.
HAMILTON COUNTY—									
Silver mine, Webster City	9.00	84.80	6.20	34.19	50.61	56.81	3.09	1.12	4.21
Stockdale mine, bottom of seam	7.22	82.61	10.17	35.16	47.45	57.62	5.80	.21	6.01
Same, top of seam	8.01	84.96	7.03	37.99	46.97	54.00	5.28	.11	5.39
HARDIN COUNTY—									
Fuller mine, Eldora	12.45	79.37	8.18	35.73	43.64	51.82	....	....	....
Chaffin mine, Eldora, top of seam	11.32	83.52	5.16	32.69	50.83	55.99	2.02	1.47	3.49
Same, middle of seam	10.90	80.17	8.63	38.98	41.49	50.12	1.76	1.89	3.65
Same, bottom of seam	9.63	84.29	6.08	34.44	49.85	55.93	2.25	.30	2.55
JASPER COUNTY—									
Jasper mine, Colfax, top of seam	7.72	79.97	12.31	38.14	41.83	54.14	3.73	.48	4.21
Same, middle of seam	8.38	77.86	13.76	35.78	42.08	55.84	1.11	.13	1.24
Same, bottom of seam	8.88	77.66	13.46	32.21	45.45	58.91	4.87	.05	4.92
Snook mine, Newton	4.61	87.71	7.68	44.41	43.30	53.44	....	...	....
KEOKUK COUNTY—									
Pioneer mine, Thornburg, top of seam	4.78	92.65	2.57	49.17	43.48	46.05	4.38	.20	4.58
Same, middle of seam	7.79	89.83	2.38	44.05	45.78	48.16	2.06	.39	2.45
Same, bottom of seam	5.56	86.16	8.28	38.37	47.79	56.07	2.45	.07	2.52
What Cheer No. 5, What Cheer, top of seam	5.40	75.90	18.70	35.16	40.74	59.44	13.79	.92	14.71
Same, middle of seam	5.96	82.16	11.88	35.89	46.27	58.15	6.56	.29	6.85
Same, bottom of seam	7.14	76.26	16.60	33.96	42.30	58.90	6.67	.40	7.07

LUCAS COUNTY—									
Cleveland mine, Cleveland, top of seam	9.95	80.27	9.78	37.70	42.57	52.35	3.69	.07	3.76
Same, middle of seam	9.39	84.21	6.43	38.62	45.59	52.02	2.69	.06	2.75
Same, bottom of seam	7.46	82.11	10.43	36.99	45.12	55.55	2.97	.07	3.04
Same, average of seam	8.92	82.19	8.88	37.77	44.43	33.30	3.11	.07	3.18
Lucas mine, Lucas, average	11.29	79.88	8.83	37.13	42.69	51.52	2.89	.08	3.98
MADISON COUNTY—									
Clarey mine, Northbranch	6.75	77.28	15.97	31.85	45.43	61.40	...	...	....
MARION COUNTY—									
Bousquet mine, Coalport	5.69	90.79	3.32	43.25	47.54	50.84	....	...	....
Bussing mine, Knoxville	6.56	89.54	3.90	45.29	44.25	48.15	....	...	....
Clernen mine, Marysville	6.81	91.53	7.90	26.01	49.28	61.36	....	...	....
Sherwood mine, Marysville	5.62	92.58	1.80	36.61	55.97	56.77	....	...	....
MONROE COUNTY—									
Chicago and Iowa mine, Albia, average	6.09	81.20	12.67	43.19	38.04	50.71	5.54	.19	5.73
Enterprise mine, average	5.09	89.51	5.39	44.62	44.89	50.28	4.91	.29	5.20
Iowa and Wisconsin mine, Albia, top of seam	4.02	63.70	32.28	31.15	32.55	64.83	7.17	.87	8.04
Same, middle of seam	4.94	83.26	11.80	38.23	45.03	56.83	4.96	.34	5.30
Same, bottom of seam	4.00	86.45	9.55	34.95	51.50	61.05	4.09	.29	4.38
Smoky Hollow mine, Avery, average	5.05	87.57	7.38	42.64	44.93	52.30	4.20	.59	4.79
Deep Vein mine, Foster, top of seam	5.75	81.04	13.21	40.36	40.68	53.89	4.24	.36	4.60
Same, middle of seam	6.67	91.03	2.30	44.75	46.28	48.58	3.34	.10	3.44
Same, bottom of seam	5.77	79.29	14.94	35.25	44.04	58.98	5.21	.20	5.41
MAHASKA COUNTY—									
American mine, Evans, top of seam	3.55	91.84	4.61	46.43	45.41	50.02	3.48	.09	3.57
Same, middle of seam	5.16	90.71	4.13	45.42	45.29	49.42	3.65	.06	3.71
Same, bottom of seam	4.45	83.33	12.22	36.46	46.87	59.09	4.17	.06	4.23
Same, cannel-like part	5.13	84.91	9.96	42.46	42.45	52.41	4.79	.41	5.20
Griffith mine, Given, average	2.84	83.85	13.31	41.01	42.84	56.15	4.41	.08	4.49
Burns mine, Oskaloosa	4.01	93.83	2.16	47.76	46.07	50.25	....	...	....
Carey mine, Rose Hill, average	4.91	84.70	10.39	41.69	43.01	53.40	5.00	.09	5.09

Chemical Analyses of Iowa Coals.—Continued.

LOCALITIES.	Moisture.	Total combustibles	Ash.	Volatile combustible matter.	Fixed carbon.	Coke—Fixed carbon plus ash.	SULPHUR. In sulphides.	SULPHUR. In sulphates.	SULPHUR. Total.
POLK COUNTY—									
Christy mine, Des Moines, top	5.53	88.05	6.42	44.70	43.35	49.77	4.78	.09	4.87
Same, middle of seam	6.18	84.12	9.70	38.65	45.47	55.17	5.41	.15	5.56
Same, bottom of seam	6.60	75.62	17.78	33.84	41.78	59.56	4.79	.19	4.98
Gibson mine, Des Moines, average	7.04	82.89	9.72	40.06	43.17	52.89	4.09	.16	4.25
Manbeck mine, Des Moines, average	6.82	76.58	16.19	36.93	39.65	56.34	4.44	.29	4.70
POWESHIEK COUNTY—									
Smith and Barrowman mine, Searsboro, top of seam	5.41	89.30	5.29	41.39	47.91	53.20	....	...	....
Same, bottom of seam	6.28	86.67	7.05	36.51	50.61	57.21	....	...	....
SCOTT COUNTY—									
Friedley and Hoyt mine, Buffalo, top of seam	3.48	89.79	6.73	41.32	48.47	55.20	4.99	.54	5.53
Same, middle of seam	3.66	87.46	8.88	41.44	46.02	54.90	3.72	.15	3.87
Same, bottom of seam	2.89	82.03	15.08	38.09	43.94	59.02	7.80	.38	8.18
Hanlon and Blackwell mine, Buffalo, top of seam	2.66	86.66	10.68	42.10	44.56	55.24	3.11	.05	3.16
Same, bottom of seam	5.07	83.59	11.34	39.33	44.26	55.60	4.38	.22	4.60
Friedley mine, Muscatine	3.94	92.98	3.08	37.46	55.52	58.60	3.03	.07	3.10
TAYLOR COUNTY—									
Adams shaft, New Market	8.00	79.68	12.31	35.41	44.29	56.58	5.29	.59	5.88
Anderson mine, New Market, average	8.06	80.57	11.36	34.99	45.58	56.95	4.72	.45	5.17
Campbell mine, New Market, top	7.44	80.64	11.92	37.79	42.85	54.77	3.54	.14	3.68
Same, middle of seam	8.21	82.77	9.02	35.28	47.49	56.51	3.85	.43	4.28
Same, bottom of seam	7.94	79.93	12.13	37.41	42.52	54.65	4.70	.54	5.24

VAN BUREN COUNTY—									
Slaughter mine, Farmington	8.62	85.50	5.88	38.08	47.42	53.30	....	...	....
Cox mine, Hillsboro	7.92	88.50	3.58	41.74	46.76	50.34	....	...	....
Manahard mine, Selma	7.76	88.34	3.90	40.23	48.11	52.01	....	...	....
WAPELLO COUNTY—									
Whitebreast No. 22, Keb, top of seam	5.54	84.79	9.67	41.24	43.55	53.22	6.35	.11	6.46
Same, middle of seam	6.82	82.03	11.15	35.29	46.74	57.89	9.53	.16	9.69
Same, bottom of seam	7.55	79.09	13.36	33.43	45.66	59.02	6.05	.25	6.30
Same, sample of room	5.08	74.54	20.38	33.66	40.88	61.26	6.49	.28	6.77
Eldon mine, Laddsdale, top	3.81	93.39	2.80	41.69	51.70	54.50	2.57	.33	2.90
Same, middle of seam	3.72	85.37	10.91	42.88	42.49	53.40	2.93	.66	3.59
Same, bottom of seam	3.24	87.97	8.79	45.82	42.15	50.94	2.80	.56	3.36
Brown and Godfrey mine, Ottumwa	6.50	89.60	3.90	41.35	48.25	55.78	....	...	....
Evans mine, Chillicothe, top	5.35	87.65	7.00	42.41	42.41	52.24	....	...	....
Same, bottom of seam	3.89	77.77	18.34	36.94	40.83	59.17	....	...	....
Wyles mine, Eddyville	3.95	84.69	10.36	36.98	48.71	61.49	....	...	....
WARREN COUNTY—									
Dillard mine, Spring Hill, top	11.56	83.27	5.17	42.88	40.38	45.55	....	...	....
Same, middle of seam	14.13	80.60	5.27	36.59	44.01	49.28	....	...	....
Bennum mine, Summerset, top	7.31	82.09	10.60	36.63	45.46	56.06	5.02	.09	5.11
Same, bottom of seam	9.43	82.14	8.43	36.96	45.18	53.61	3.62	.16	3.78
WAYNE COUNTY—									
Frey mine, Confidence, below parting	9.26	80.45	10.29	34.21	46.24	36.53	4.71	.26	4.97
Same, above parting	9.39	78.69	11.92	34.71	43.98	55.90	2.97	.20	3.17
Same, middle of seam	8.01	75.41	16.58	37.22	38.19	54.77	3.24	.09	3.33
Same, top of seam	9.37	77.12	13.51	31.78	45.34	58.85	3.53	.37	3.90
WEBSTER COUNTY—									
Collins No. 6, Coalville, average	7.48	84.06	8.44	39.52	44.54	52.99	4.98	.26	5.24
Collins No. 4, Coalville, average	7.80	82.88	9.32	37.74	45.14	54.46	3.97	.12	4.09
Old Reese mine, Fort Dodge	9.92	48.77	41.31	29.69	22.08	63.39	....	...	....
Carlson mine, Kalo, average	10.10	76.53	13.36	32.83	43.69	57.06	1.68	.18	1.86
Craig Cannel mine, Kalo, "cannel" coal	5.87	78.26	15.87	39.04	39.22	55.09	6.87	.25	7.12
Craig slope, Kalo, bituminous	8.46	81.37	10.17	37.97	43.40	53.57	5.19	.10	5.29
Crooked Creek mine, Lehigh, top of seam	7.74	78.94	13.32	34.47	44.47	57.79	4.83	.81	5.64
Same, middle of seam	8.52	82.65	8.83	38.64	44.01	52.84	3.71	.48	4.19
Same, bottom of seam	8.57	81.86	9.57	37.57	44.29	53.86	3.47	.18	3.65
Crooked Creek shaft, Lehigh, average	6.99	76.66	16.34	34.40	42.26	58.60	5.67	.37	6.04
Corey mine, Lehigh, average	7.77	81.27	11.00	38.05	43.21	54.21	7.02	.68	7.70