State of Iowa
1929

Analyses of
IOWA COALS

Issued by the
Iowa Geological Survey

George F. Kay, Director
James H. Lees, Assistant State Geologist

Published by
THE STATE OF IOWA
Des Moines

FOREWORD

Coal is a very important natural resource of Iowa. It is known to underlie an area of approximately twenty thousand square miles within the state, and it occurs at sufficiently shallow depths beneath the surface to permit mining without great difficulty. The quantity of coal in Iowa has been estimated to be nearly thirty billion tons, an amount which at the present annual rate of production should last more than twenty-five hundred years.

Information with regard to the coal of Iowa has been published in several of the volumes of the Iowa Geological Survey. Volume II of the reports of the Survey appeared in 1894. This report on coal was superseded by a more comprehensive report, Volume XIX, distributed to the people of the state in 1908. In this report the distribution, the geological relationships, the characteristics of the coal beds, the chemical composition and other features of the coals were discussed. Proximate analyses of sixteen Iowa coals were given, including a statement of the methods used in making the analyses, and a discussion of the physical and chemical properties of the coals from the industrial standpoint.

Recently it has seemed desirable to give further study to the coals of the state, particularly with reference to their chemical properties. Samples were collected carefully by Dr. James H. Lees, Assistant State Geologist, in accordance with the most modern methods now being used for sampling coals for chemical analysis. These coals have been studied by Dr. H. L. Olin and his assistants in the laboratory of the Department of Chemical Engineering of the University of Iowa. The methods of analysis employed were the standard methods adopted by the American Society for Testing Materials.

The results of the investigations of Doctor Olin and his coworkers are herewith made available to all persons interested in the chemical qualities of the coals of the state. In comparing these analyses with the analyses of Iowa coals published elsewhere it must be kept clearly in mind that the values of analyses must be judged in relation to whether or not the samples analyzed were collected in such ways as to represent the average of the coal being mined, and whether or not the most modern scientific methods were employed in ascertaining the chemical characteristics of each of the constitutents of the coal.

Respectfully submitted,

G. F. KAY, *State Geologist.*

In Table I are given the names and locations of the mines covered in this report. Although in a general way it includes the most important coal producing areas of the state and possibly most of the larger mines it is nevertheless incomplete and data on other coals will be collected as opportunity offers.

Geographical positions of the mines included in this survey are shown in Plate I.

Table I, Names and Location of Mines Sampled

No.
1—Des Moines Ice & Fuel Co., Des Moines, Polk Co.
2—Bennett Bros. Coal Co., Mine No. 2, Des Moines, Polk Co.
3—Economy Coal Co., Des Moines, Polk Co.
4—Des Moines Coal Co., Mine No. 4, Des Moines, Polk Co.
5—Urbandale Coal Co., Des Moines, Polk Co.
6—Beck Coal & Mining Co., Des Moines, Polk Co.
7—Shuler Coal Co., Waukee, Dallas Co.
8—Gibson Coal Co., Rider, Polk Co.
9—Great Western Coal Co., Orillia, Warren Co.
10—Indian Valley Gloss Coal Co., Hartford, Warren Co.
11—Norwood White Coal Co., No. 8, Herrold, Polk Co.
12—Norwood White Coal Co., No. 7, Moran, Dallas Co.
13—Scandia Coal Co., No. 4, Madrid, Boone Co.
14—Scandia Coal Co., No. 6, Madrid, Boone Co.
15—Dallas Products Co., Granger, Dallas Co.
16—Benson Coal Co., No. 1, Boone, Boone Co.
17—Boone Coal Co., No. 1, Boone, Boone Co.
18—Old King Coal Co., Centerville, Appanoose Co.
19—Center Coal Co., Centerville, Appanoose Co.
20—Superior Coal Co., No. 19, Bucknell, Monroe Co.
21—Pershing Coal Co., No. 12, Pershing, Marion Co.
22—Numa Coal Co., Numa, Appanoose Co.
23—Appanoose Co. Coal Co., Centerville, Appanoose Co.
24—Armstrong Coal Co., Cincinnati, Appanoose Co.
25—Iowa Block Coal Co., Exline, Appanoose Co.
26—Violet Valley Coal Co., Seymour, Wayne Co.
27—Central Iowa Fuel Co., No. 5, Williamson, Lucas Co.
28—Central Iowa Fuel Co., No. 4, Williamson, Lucas Co.
29—Red Rock Coal Co., Melcher, Marion Co.
30—Consolidated Indiana Coal Co., No. 2, Melcher, Marion Co.
31—Liberty Coal Co., No. 3, Mystic, Appanoose Co.
32—Pearson Coal Co., No. 2, Clarinda, Page Co.
33—New Market Coal Co., New Market, Taylor Co.
34—John G. Henton Mine, R. F. D. No. 1, Carbon, Adams Co.
35—Ruth Coal Co., Carbon, Adams Co.
36—Oskaloosa Coal & Mining Co., Oskaloosa, Mahaska Co.

In presenting Table II, which gives analytical data on the so-called "as received" basis, we wish first to call attention to the moisture content column. As explained above, in collecting the sample the water in the coal is carefully conserved so that it may be measured in the laboratory, but it should be clearly understood that in no wise does this figure represent the moisture percentage of the coal delivered to the consumer after having been in contact with drying air for days or weeks while in transit or storage. The actual moisture value of a coal at a given time is of course dependent upon the humidity of the air and upon the time of exposure to it. It is difficult therefore to estimate how much moisture

these coals would contain under marketing conditions, but it is safe to say that the percentages are vastly lower than those given for mine conditions. With lower total moisture values the percentage contents of the other constituents, and also the thermal values, increase in proportion.

Table II, Results of Analyses of Iowa Coals

	As Received					
No.	Moisture	Ash	Volatile	Fixed carbon	Thermal values (B. t. u.)	Sulfur
1.	16.0	8.7	37.3	37.9	10,820	5.3
2.	16.8	14.5	35.0	33.7	9,190	5.8
3.	15.9	9.2	37.1	37.7	10,530	5.0
4.	13.8	16.9	34.3	34.9	9,040	5.6
5.	14.2	13.0	36.3	36.5	10,220	5.2
6.	16.7	15.5	33.0	34.7	9,660	3.8
7.	14.2	12.7	34.7	38.3	10,450	3.9
8.	13.7	6.5	39.5	40.3	11,450	3.7
9.	13.1	14.6	35.4	36.8	10,210	6.3
10.	14.6	10.6	39.1	35.7	10,830	4.8
11.	13.6	14.6	36.8	35.0	10,050	5.2
12.	16.9	12.3	33.9	36.9	9,920	3.1
13.	14.9	10.3	36.9	37.8	10,450	3.5
14.	15.1	12.5	36.9	35.5	10,050	4.1
15.	16.2	14.0	34.5	35.3	9,690	3.8
16.	20.9	8.5	33.8	36.7	9,430	4.0
17.	19.7	9.3	36.3	34.7	9,740	4.8
18.	18.1	8.6	33.9	39.4	10,050	3.7
19.	18.0	6.5	35.7	39.7	10,430	2.7
20.	14.8	9.8	35.0	40.4	10,700	2.1
21.	17.1	9.4	34.9	38.6	10,490	3.5
22.	17.6	11.0	36.7	34.7	9,880	4.5
23.	15.3	12.2	34.6	37.9	9,960	3.9
24.	13.4	10.3	35.6	40.7	10,490	4.9
25.	14.9	9.7	36.3	39.1	10,750	3.4
26.	16.7	8.3	34.1	40.8	10,350	3.9
27.	15.8	14.0	33.6	36.5	9,950	5.3
28.	19.8	12.8	32.7	34.6	9,460	2.0
29.	18.5	10.4	32.6	38.5	10,000	2.6
30.	18.6	9.2	31.9	40.2	10,030	2.6
31.	15.6	11.0	35.2	38.2	9,800	3.3
32.	18.4	13.7	35.3	32.6	9,440	3.4
33.	20.2	13.3	33.6	32.9	9,080	5.5
34.	21.1	9.9	32.9	36.1	9,280	3.5
35.	20.6	12.3	33.0	34.1	9,270	3.1
36.	18.1	10.0	33.5	38.4	10,610	2.0
Mean	16.6	11.4	35.0	37.0	10,040	3.9

Table IV, in which the results of the preceding table are calculated to the dry basis, needs no comment except perhaps in explanation of the term "unit coal." This in brief is a hypothetical material intended to represent the pure or actual coal substance calculated from analytical data after taking into consideration corrections for moisture and ash. As developed by Parr the formula is

$$\text{Unit coal} = 1.00 - (W + 1.08\ A + \frac{22}{40} S)$$

where W, A and S are total water, ash as weighed and sulfur respectively.

This "unit coal" value which represents the decomposition residue of

a flora characteristic of a given period and region should, if the history of the seam formation is normal, be fairly constant for that given seam. This has proved to be the case particularly where the coal measures are of comparatively large area, as in Illinois. A tabulation of unit coal values of the three beds represented in this study (see tabulation by Lees in the following paper) shows rather wide variation and it is evident that calculated heating values of a sample from the given bed, based on average unit coal value for that bed, would not be highly accurate. The mean values of the figures in question are given in the following table.

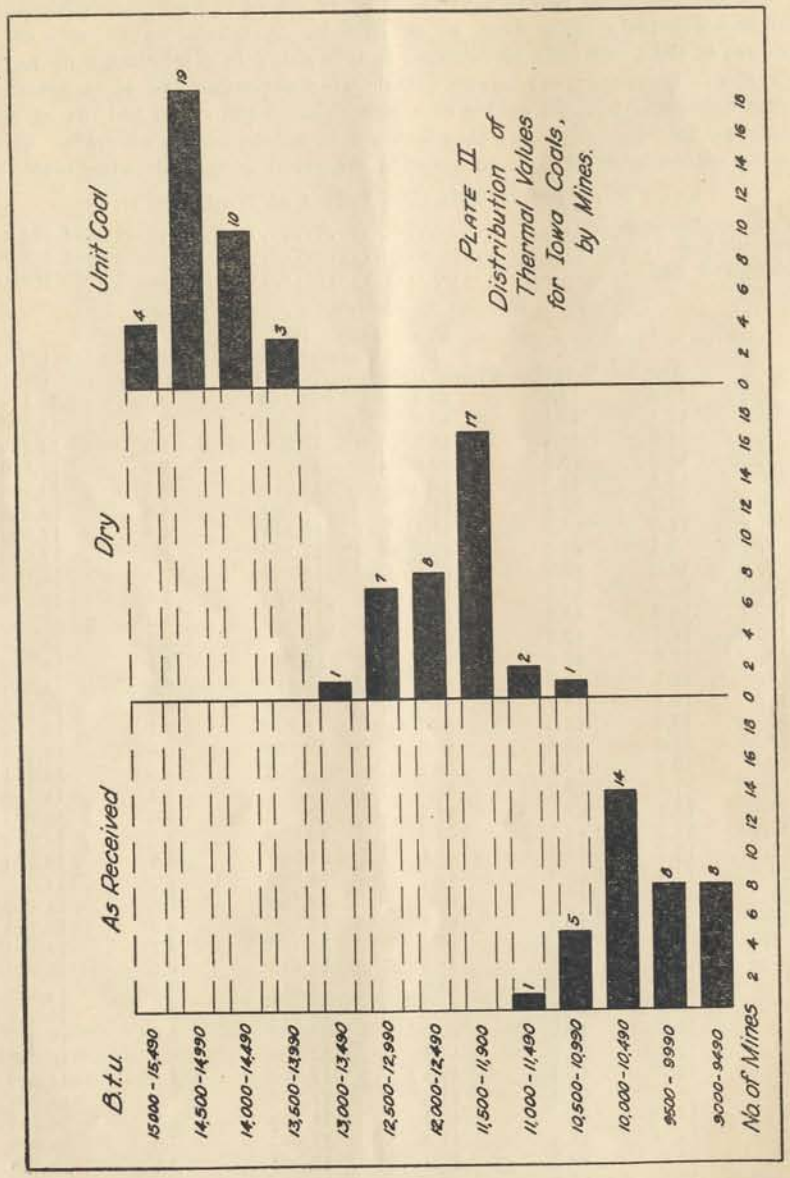
Table III, Average Unit Coal Values of Iowa Coal Beds

Lower Cherokee bed	14,671 B.t.u.
Mystic bed	14,345 B.t.u.
Nodaway bed	14,365 B.t.u.

Table IV, Results of Analyses of Iowa Coals

	Dry Basis					
No.	Ash	Volatile	Fixed Carbon	Thermal Values (B.t.u.)	Sulfur	Unit Coal
1.	10.4	44.5	45.4	12,900	6.3	15,110
2.	17.4	42.1	40.5	11,050	7.0	14,290
3.	11.0	44.2	44.9	12,550	5.9	14,730
4.	19.6	39.8	40.6	10,500	6.5	13,950
5.	15.2	42.3	42.5	11,910	6.1	14,760
6.	18.6	39.7	41.7	11,600	4.6	14,970
7.	14.8	40.5	44.7	12,200	4.6	14,950
8.	7.5	45.8	46.7	13,260	4.3	14,830
9.	16.8	40.8	42.4	11,750	7.3	15,100
10.	12.4	45.8	41.8	12,620	5.6	15,110
11.	16.9	42.6	40.5	11,630	6.0	14,850
12.	14.8	40.8	44.4	11,940	3.7	14,560
13.	12.1	43.4	44.5	12,300	4.1	14,550
14.	14.7	43.5	41.8	11,840	4.8	14,530
15.	16.7	41.2	42.1	11,560	4.6	14,550
16.	10.8	42.8	46.4	11,950	5.1	13,990
17.	11.6	45.2	43.2	12,130	6.0	14,430
18.	10.5	41.4	48.1	12,270	4.5	14,270
19.	7.9	43.6	48.5	12,730	3.3	14,210
20.	11.5	41.1	47.4	12,550	2.5	14,550
21.	11.3	42.1	46.6	12,650	4.2	14,800
22.	13.3	44.6	42.1	11,990	5.5	14,520
23.	14.4	40.9	44.7	11,750	4.7	14,360
24.	11.9	41.2	46.9	12,120	5.6	14,430
25.	11.5	42.6	45.9	12,630	4.0	14,790
26.	9.9	40.7	49.4	12,420	4.7	14,330
27.	16.6	39.9	43.5	11,810	6.3	15,020
28.	15.9	40.6	43.5	11,810	2.5	14,510
29.	12.8	39.9	47.3	12,260	3.1	14,510
30.	11.3	39.1	49.6	12,330	3.2	14,330
31.	13.0	41.7	45.3	11,620	4.0	13,870
32.	16.7	43.2	40.1	11,560	4.2	14,500
33.	16.7	42.0	41.3	11,380	7.0	14,570
34.	12.5	41.6	45.9	11,760	4.5	14,000
35.	15.5	41.6	42.9	11,680	3.9	14,390
36.	12.2	40.9	46.9	12,960	2.4	15,140
Mean	13.6	42.0	44.4	12,045	4.8	14,555

Plate II gives a graphical analysis of all the preceding data wherein thermal values are plotted as ordinates against the number of mines from which samples having these thermal values were obtained.



It is interesting to compare the results of this and of Hixson's survey with those of a similar one from an adjoining state. From a list compiled by Parr from Bull. No. 29, Illinois State Geological Survey, which gives figures on 36 samples of coal from 29 different counties, we have calculated the Illinois data given in the table below.

Table V, Comparative Data on Iowa and Illinois Coals

MEAN VALUES (DRY BASIS)

	Volatile matter	Ash	Sulfur	Thermal value
Iowa (36 samples)	42.0	13.6	4.8	12,045 B.t.u.
Iowa (16 samples)	40.1	13.7	4.9	12,552 B.t.u. (Hixson)
Illinois (36 samples)	37.3	11.0	3.7	12,725 B.t.u.

Total moisture contents on the wet basis were for the Iowa and Illinois coals 13.6, 15.1 and 12.4 respectively. It may be seen, therefore, that so far as proximate analyses can be relied upon to distinguish them, the difference is much less than is often popularly supposed.

Fusion Temperatures of Iowa Coal Ash

Because of the important bearing ash fusion temperatures have on the formation of slag and clinker in the coal furnace a systematic study was made of this phase of the problem.

The samples tested were from the coals described above. Quantities of the coal, 50 to 100 grams in weight, were ground to 60 mesh and burned in a gas fired muffle furnace. The ash was ground in an agate mortar and again heated to 1600°F. in a stream of oxygen to insure the highest oxidation of all the mineral constituents. The finished material was then fashioned into small cones and heated in a special gas fired furnace under reducing conditions up to the softening points of the ash. Temperatures were measured by means of an optical pyrometer of modern design.

Table VI, Melting Points of Iowa Coal Ash Degrees Fahrenheit

Numbers refer to samples as listed in Table I. Tests made with a standard gas furnace under reducing conditions and temperatures were measured with an F. and F. optical pyrometer.

Number	Temperature	Number	Temperature
1	2063	19	2023
2	1981	20	2168
3	1940	21	1937
4	2035	22	1930
5	1935	23	2000
6	2063	24	1930
7	1947	25	1998
8	2033	26	1945
9	2025	27	1946
10	2193	28	2055
11	2177	29	2000
12	2192	30	1957
13	1960	31	2148
14	2353	32	2253
15	2005	33	2237
16	2037	34	2238
17	1889	35	1985
18	1980	36	2040

A final word may be said concerning the comparison of the values obtained in this work with those based on the analysis of the same, or similar coals made at other laboratories.

As we have already explained, all sampling for these studies was made by a member of the Geological Survey acting of course as an unbiased referee. The method used is both the most fair and the most severe, inasmuch as it provides for the inclusion of impurities in their proper proportions and precludes the possibility of either premeditated or unconscious "handpicking", which is a major factor in vitiating results. It follows, therefore, that comparisons between our figures and others can be made fairly, only when all are reduced to a common standard of sampling, analysis and calculation.

DESCRIPTION OF MINES SAMPLED

JAMES H. LEES

The samples of coal herein discussed were collected in the early part of 1928 by the method approved by the U. S. Bureau of Mines. A fresh working face was cleaned and a cut was made from roof to floor about four inches wide and two inches deep. Bony or pyritic bands over one-fourth inch thick were rejected. The coal fell on a canvas cloth and was broken into small fragments, mixed and quartered and alternate quarters were rejected until about a gallon remained. This was put in a tin can with a tight cover which was further sealed with friction tape. The sample was mailed to the chemical laboratory at Iowa City.

Samples numbered 1 to 17, 20, 21, 27 to 30, 36 are from various horizons in the Lower Cherokee sub-stage, the lowest member of the Des Moines series. Samples 18, 19, 22 to 26, 31 are from the coal called by Bain the Mystic bed, which is now classified as Upper Cherokee. Samples 32 to 35 come from the Nodaway seam of the Shawnee stage of the Missouri series. All of these formations belong in the Pennsylvanian system of strata.

Notes on Mines Sampled

Sample Number 1, Collected February 4

Operator, Des Moines Ice and Fuel Co., Des Moines. Mine located near SW. cor. sec. 26, T. 79, R. 23, Delaware Tp., Polk Co. Top of shaft about 850 feet above sea level, shaft 120 feet deep. Sample taken from 9th SW. entry, room 3. Coal 3 feet, 9 inches thick, ranges from 2 feet, 10 inches to 4 feet, 6 inches thick. No bony coal or pyrite bands. Some streaks of pyrite fill cracks. Roof is black shale with some boulders. Fireclay underlies the coal.

Sample Number 2, Collected January 26

Operator, Bennett Bros. Coal Co., Des Moines. Mine No. 2. Mine located near SE. cor. SW. ¼ sec. 17, T. 78, R. 24, Des Moines Tp., Polk Co. Top of shaft about 900 feet above sea level. Shaft 212 feet deep to top of coal. Sample taken from 3d A entry, about 2,100 feet from shaft. Coal 4 feet, 6 inches thick. Has 4 inch sulphur band about two feet from top. Coal lies unevenly, hills are as much as 42 feet above swamps. Coal 6½ to 7 feet thick in swamps. Mine opened in 1916.

Sample Number 3, Collected February 15

Operator, Economy Coal Co., Des Moines. Mine No. 1; located in SE. ¼ NW. ¼ sec. 5, T. 78, R. 23, Lee Tp., Polk Co. Altitude top of shaft 800 feet. Depth of shaft 145 feet. Sample taken from 3d north entry, about 2,000 feet north of shaft. Coal 3 feet, 5 inches thick. No pyrite bands and no bony coal; one inch to three inches of cannel coal at top of bed. The roof is "slate", about 16 feet thick and the bottom is shale, locally sandy. Another bed lies 7 to 20 feet above this one, but it has been worked out here.

Sample Number 4, Collected January 26

Operator, Des Moines Coal Co., Des Moines. Mine No. 4; located near NW. cor. NE. ¼ sec. 19, T. 78, R. 24, Des Moines Tp., Polk Co. Altitude top of shaft about 840 feet. Depth of shaft 175 feet. Sampled at face of back east entry, about 1,800 feet from shaft. Coal 5 feet, 10 inches thick where sampled, with one inch pyrite band two feet from top. No other impurities.

Sample Number 5, Collected March 17

Operator, Urbandale Coal Co., Des Moines. Mine located near SW. cor. SE. ¼ sec. 26, T. 79, R. 25, Walnut Tp., Polk Co. Altitude top of shaft 850 feet. Depth of shaft 175 feet. Sample taken from 3d entry south off main west entry. Coal is 22 inches thick above an 8-inch band of bony coal, then 34 inches below; a total of 4 feet, 8 inches of workable coal. There are no other impure bands. Roof is shale, floor is hard sandy shale for two feet, then sandstone. From 250 to 300 tons of coal is raised daily. The mine was opened 10 years ago.

Sample Number 6, Collected March 30

Operator, Beck Coal and Mining Co., Des Moines. Mine is in SE. cor. NE. ¼ sec. 24, T. 79, R. 25, Webster Tp., Polk Co. Altitude of shaft 940 feet; depth of shaft 190 feet. Sample taken from 14th south entry. Coal 50 inches thick. Roof shale, floor fireclay. Hoist 350 to 450 tons daily. Mine opened July, 1921. Sampled in 1921 for ash and sulphur determinations (Iowa Geol. Survey, Vol. XXXI, pp. 157-165).

Sample Number 7, Collected April 4

Operator, Shuler Coal Co., Des Moines. Mine in SW. ¼ sec. 23, T. 79, R. 26, Walnut Tp., Dallas Co., 2 miles east, 1 mile north of Waukee. Altitude top of shaft about 1,000 feet; depth of shaft 387 feet. Mine sampled in room 6, NE., 1st E., 11th S. entry, about one-half mile from shaft. Coal 4 feet, 10 inches thick, about the average of the mine. A two inch pyrite band lies about 18 inches from the top; no other impurities. The roof is black clay shale, the floor "false bottom", four inches, then coal and shale, then fireclay. Mine hoists about 900 tons daily. Opened in 1921.

Sample Number 8, Collected March 30

Operator, Gibson Coal Co., Des Moines. Mine in NE. cor. NW. ¼ sec. 21, T. 79, R. 25, at Rider, Webster Tp., Polk Co. Top of shaft 970 feet above sea; depth of shaft 330 feet. Coal sampled from 8th west entry,

northeast course. about 2,500 feet from shaft; here 62 inches thick. No pyrite bands or balls, only usual films of selenite. Roof is bony shale; floor, 6 inches blackjack, then shale.

Sample Number 9, Collected April 4

Operator, Great Western Coal Co., Des Moines. Mine in SW. ¼ sec. 4, T. 77, R. 25, near Orillia, Linn Tp., Warren Co. Altitude at shaft 960 feet; depth of shaft 312 feet. Sample taken from face of main west entry, 3,000 feet in from shaft, about 350 feet below top of shaft. Coal is here 3 feet, 10 inches thick, about average from mine. No pyrite or dirt bands. Roof is black shale, floor sandy shale. Mine was opened in April, 1923; hoists 900 to 1,000 tons per day.

Sample Number 10, Collected March 30, 1929

Operator, Indian Valley Gloss Coal Co., Des Moines. Mine located in center of NW. ¼ NW. ¼ sec. 17, T. 77, R. 22, near Hartford, Richland Tp., Warren Co. Altitude top of shaft 850 feet; depth of shaft 85 feet to top of coal. Took samples from main west entry, 3d southwest entry, 1st northwest entry, 2d northwest entry. Coal about 4 feet thick; in places a one inch pyrite band one foot above base. The bed worked is the "2d vein;" 1st vein is about 6 inches thick. Below the bed worked are 5 beds within 150 feet. Mine opened in 1922.

Sample Number 11, Collected April 18

Operator, Norwood-White Coal Co., Des Moines. Mine No. 8; located in NW. ¼ SW. ¼ sec. 27, T. 80, R. 25, near Herrold, Jefferson Tp., Polk Co. Shaft top is 890 feet above sea level; shaft 210 feet deep. Sample taken from main east entry on north side, about 2,300 feet in. Coal is 3 feet, 8 inches thick, its average thickness; has no important pyrite bands or other impurities. A two-foot bed lies 18 to 22 feet above the one being mined. Steep local dips, up to 20 degrees. Mine hoists about 500 tons per day.

Sample Number 12, Collected April 19

Operator, Norwood-White Coal Co., Des Moines. Mine No. 7; located in NW. ¼ NW. ¼ sec. 29, T. 81, R. 26, at Moran, Des Moines Tp., Dallas Co. Shaft mouth 890 feet above sea; shaft 285 feet deep. Sample taken from face of main east entry, about 1¼ miles southeast of shaft. Coal 6 feet thick as mined, in addition to 18 to 24 inches left as roof. No dirt or pyrite bands. Coal lies in long narrow basin extending northwest to southeast. Where prospected this valley lies 630 to 670 feet above sea, with thicker coal in lower parts. Mine began hoisting in 1919; hoists about 500 tons daily. Sampled in 1921 for ash and sulphur determinations (Iowa Geol. Survey, vol. XXXI, pp. 157-165).

Sample Number 13, Collected April 23

Operator, Scandia Coal Co., Des Moines. Mine No. 4; located in SE. ¼ sec. 36, T. 82, R. 26, a mile south of Madrid, Douglas Tp., Boone Co. Altitude of mouth of shaft 1,020 feet; depth of shaft 306 feet. Sample from room 4 on 3d B entry, about 1¾ miles southeast of shaft and 50 feet lower than shaft bottom. Coal is here 4 feet, 1 inch thick, averages

3 feet, 10 inches; has no pyrite or dirt bands. Shaft reaches to upper vein, 3 feet to 3 feet, 8 inches thick, which has been nearly worked out. From this bed a 5° slope reaches the lower bed, which is being worked. Mine opened in 1917; hoists 1,300 to 1,500 tons daily. Roof is black shale.

Sample Number 14, Collected April 23

Operator, Scandia Coal Co., Des Moines. Mine No. 6; located in NE. ¼ SW. ¼ sec. 29, T. 82, R. 25, near Madrid, Garden Tp., Boone Co. Altitude of shaft top about 1,000 feet; depth of shaft 340 feet. Took sample from face of 10th south entry, 2,000 feet southeast of shaft; thickness of coal, 4 feet, 7 inches. Thickness ranges up to 6 feet, 8 inches. No pyrite or dirt bands. Bed is fairly level. Mine opened 1921; hoists 550 tons daily. Sampled in 1921 for ash and sulphur determinations (Iowa Geol. Survey, vol. XXXI, pp. 157-165).

Sample Number 15, Collected April 21

Operator, Dallas Products Co., Des Moines. Mine located in SW. ¼ NE. ¼ sec. 26, T. 81, R. 26, near Granger, Des Moines Tp., Polk Co. Altitude of shaft 1,000 feet; depth 340 feet. Sample taken from 13th east entry, about 1¼ miles from shaft. Coal was here 4 feet 3 inches thick; averages about 4 feet; has some undulations, ranges up to 4 feet, 10 inches in swamps and thins to 3 feet on hills. No pyrite or rock bands. Mine opened in 1915. hoists about 450 tons per day.

Sample Number 16, Collected April 28

Operator, Benson Coal Co., Boone. Mine No. 1; located in SW. ¼ SW. ¼ sec. 20, T. 84, R. 26, at Boone, Des Moines Tp., Boone Co. Altitude of shaft, about 1,100 feet; depth 235 feet. Sample taken from 1st west entry, on south side of mine, 400 feet from shaft. Coal is 3 feet thick, has one inch pyrite band about 10 inches from bottom. A cap rock 3 to 18 inches thick overlies the coal and above it is 8 to 10 inches of poor coal. Mine opened July, 1926; hoists about 150 tons daily; operates longwall system.

Sample Number 17, Collected April 28

Operator, Boone Coal Co., Inc., Boone. Mine No. 1; located in NE. ¼ sec. 30, T. 84, R. 26, at Boone, Des Moines Tp., Boone Co. Altitude of shaft 1,100 feet; depth 250 feet. Took sample from longwall face off 3d north entry, about 2,000 feet east of shaft. Coal 3 feet, 7 inches thick; averages about 2 feet 8 inches; other beds similar to those in Benson mine. An irregular bed of coal 20 to 48 inches thick lies one to five feet below the one being worked. The intermediate layer is in places shale, elsewhere sandstone. Mine opened in 1911; hoists up to 300 tons daily.

Sample Number 18, Collected June 12

Operator, Old King Coal Co., Centerville. Mine in NW. ¼ sec. 33, T. 69, R. 18, near Centerville, Bellair Tp., Appanoose Co. Altitude of shaft 1,000 feet; depth 120 feet. Sample taken from main south entry about 200 feet in. Coal 35 inches thick, with 3 inch clay band in middle. Roof is black slate, about a foot, then an inch or so of clay, then "cap rock" of limestone. Floor is fireclay, about a foot, then limestone below. Mine opened in 1927; hoists about 50 tons per day.

Mines of the Centerville district all work in the same bed of coal, most of them by longwall system. The median dirt band is everywhere present. A three-eighths inch pyrite band is common in the lower coal about 8 inches below the clay band. Exceptionally a one-eighth inch pyrite band is found about the middle of the upper coal. Roof and floor conditions everywhere are quite similar.

Sample Number 19, Collected June 13

Operator, Center Coal Co., Centerville. Mine located in NE. cor. sec. 12, T. 68, R. 18, two miles south of Centerville court house. Altitude of top 1,000 feet; depth of shaft 132 feet. Sampled from face of 1st north entry off east entry, about 1,000 feet from shaft. Mine in operation 24 years; hoists 200 tons per day.

Sample Number 20, Collected June 11

Operator, Superior Coal Co., Gillespie, Illinois. Mine No. 19; located in NW. ¼ SW. ¼ sec. 8, T. 72, R. 19, at Bucknell, Wayne Tp., Monroe Co. Elevation shaft top 820 feet; depth of shaft 133 feet. Took sample from 8th north entry off main west entry. Coal 6 feet, 6 inches thick, no rock or pyrite, averages 6 feet over the mine, thickens locally to 13 feet. Above coal is a few inches of rather dirty coal, then gray shale. Floor is "false bottom", 6 inches, then fireclay. Mine hoists 1,660 tons per day.

Sample Number 21, Collected June 11

Operator, Pershing Coal Co., Des Moines. Mine No. 12; located in NW. ¼ sec. 36, T. 75, R. 19, at Pershing, Knoxville Tp., Marion Co. Altitude of shaft top 900 feet; depth of shaft 191 feet. Took sample from 11th northwest entry. Coal is here 6 feet thick, has a few pyrite nodules, otherwise clean. Has 4 inches blackjack at top, left for roof; then gray shale. At the bottom of coal is 3 inches dirty coal, then fireclay. Mine opened 1911; hoists about 1,000 tons per day.

Sample Number 22, Collected June 12

Operator, Numa Coal Co., Numa. Mine located in NW. ¼ SW. ¼ sec. 17, T. 68, R. 19, one mile east of Numa, Bellair Tp., Appanoose Co. Altitude of shaft 1,030 feet, depth 155 feet. Sample taken from face of main north entry, 1,600 feet from shaft. Coal 29 inches thick. Mine operated 5 years; hoists 300 tons per day.

Sample Number 23, Collected June 13

Operator, Appanoose County Coal Co., Centerville. Mine located in SE. ¼ SW. ¼ sec. 21, T. 69, R. 18, three miles west of Centerville. Altitude of shaft 1,020 feet; depth 120 feet. Took sample from face of 4th right entry on north side, about 600 feet in. Coal 33 inches thick. Mine opened 1917; hoists 250 tons per day.

Sample Number 24, Collected June 13

Operator, Armstrong Coal Co., Kansas City. Mine No. 1; located in NW. ¼ sec. 9, T. 67, R. 18, one mile from Cincinnati, Pleasant Tp., Appanoose Co. Altitude of shaft 1,035 feet; depth of shaft 132 feet. Took sample from 3d room on entry side, 2d south entry off west entry, 1,500 feet from shaft. Coal is 32 inches thick; worked room and pillar system. Mine opened 22 years, now hoisting 60 tons per day, capacity 200 tons per day.

Sample Number 25, Collected June 13

Operator, Iowa Block Coal Co., Exline. Mine located in NE. ¼ sec. 32, T. 68, R. 17, at Exline, Caldwell Tp., Appanoose Co. Altitude of shaft 1,010 feet; depth of shaft 150 feet. Took sample from 6th room off 2d south entry off 1st west entry on south side of mine, about 2,500 feet in. Coal is 34 inches thick; in addition to main clay band has local bands an inch or so thick. Mine operating 24 years, capacity 300 tons per day.

Sample Number 26, Collected June 14

Operator, Violet Valley Coal Co., Seymour. Mine located in SE. ¼ sec. 1, T. 68, R. 20, 3 miles NE. Seymour, Walnut Tp., Wayne Co. Altitude of shaft 1,000 feet, depth of shaft 150 feet to coal. Sampled mine at face of south entry off main east entry, 450 feet in. Coal 29 inches thick, conditions similar to those near Centerville. Rarely roof slate and clod are absent and limestone cap rock rests directly on coal. Fireclay thinner than near Centerville. Has a few pyrite lenses in upper coal but no regular bands as farther east. Mine operated since 1922, capacity 60 tons daily.

Sample Number 27, Collected June 9

Operator, Central Iowa Fuel Co., Des Moines. Mine No. 5; located in NW. ¼ SW. ¼ sec. 1, T. 72, R. 21, 3 miles SE. Williamson, Lincoln Tp., Lucas Co. Altitude shaft mouth 940 feet; depth of shaft 186 feet. Took sample from 1st west entry off main south entry, about 600 feet from shaft. Coal 4 feet, 8 inches thick; no pyrite seams of importance; some boulders of limestone present in coal. Mine operated since 1927.

Sample Number 28, Collected June 9

Operator, Central Iowa Fuel Co., Des Moines. Mine No. 4; located in NW. ¼ sec. 24, T. 73, R. 21, 3 miles NE. Williamson, English Tp., Lucas Co. Elevation shaft mouth 1,004 feet; depth of shaft 286 feet; altitude of coal 718 feet. Took sample from back south, 12th east, 3d south entry, 3,000 feet in. Coal is 4 feet, 5 inches thick; a few limestone boulders in some places, rolls considerably; roof and floor gray slate. Mine hoists 1,300 tons per day.

Sample Number 29, Collected June 9

Operator, Red Rock Coal Co., Des Moines. Mine No. 1; located in NW. ¼ sec. 14, T. 75, R. 21, at Melcher, Dallas Tp., Marion Co. Altitude shaft 940 feet; depth of shaft 285 feet. Took sample from room 1, main north entry, 13th east entry, about 1½ miles in. Coal 4 feet, 7 inches thick; no pyrite bands; rolls a good deal, about 40 feet higher where sampled than at bottom. Roof black shale; floor shale or sandstone. Mine opened 11 years, capacity 850 tons per day.

Sample Number 30, Collected June 8

Operator, Consolidated Indiana Coal Co., Chicago. Mine No. 1; located in NW. ¼ sec. 10, T. 75, R. 21, one mile west of Melcher, Dallas Tp.,

Marion Co. Altitude top of shaft 940 feet; depth of shaft 256 feet. Took sample from 8th north entry on west side, about two-thirds mile in. Coal 5 feet, 6 inches thick, with about 2 inches fine-grained cannel-like coal and one or two pyrite bands up to an inch in thickness. Roof is black slate, floor sandstone. Coal is quite level but thins locally to a foot or less. Mine opened 5 years previously, hoists 1,500 tons per day.

Sample Number 31, Collected June 14

Operator, Liberty Coal Co., Mystic. Mine No. 3; located in NE. ¼ sec. 16, T. 69, R. 18, about a mile east of Mystic, Walnut Tp., Appanoose Co. Slope mine; altitude at mouth 890 feet, altitude of face 860 feet. Took sample from longwall face on 1st road off 1st right entry off 1st left entry, 1,600 feet in. Coal 35 inches thick. Mine operated 10 years, output 150 tons per day.

Sample Number 32, Collected July 28

Operator, Pearson Coal Co., Clarinda. Mine No. 2; located in SE. ¼ sec. 2, T. 68, R. 37, a mile west of Clarinda, Harlan Tp., Page Co. Altitude of shaft mouth 1,080 feet; depth of shaft 159 feet. Sample taken from longwall face in 2d room off main west entry, 250 feet from shaft. Coal is 15 inches thick, splits into three layers—top 4 inches, middle 5 inches, bottom 4 to 6 inches; no clay in partings; very little pyrite in coal. Top is mostly "bastard rock," clayey, hard, gray. Floor is gray shale. Mine operated 2 years, hoists 50 tons per day in summer.

Sample Number 33, Collected July 27

Operator, New Market Coal Co., New Market. Mine No. 2; located in SE. ¼ sec. 32, T. 69, R. 35, at New Market, Dallas Tp., Taylor Co. Elevation shaft mouth 1,200 feet; depth of shaft 210 feet. Took sample from longwall face on main north entry, about 600 feet in. Coal averages 18 inches in thickness; splits into two seams—upper 10 inches, lower 8 inches, no clay band between; a few thin pyrite streaks, a few masses in bottom, otherwise coal is clean. Roof is slate 1 to 3 feet thick, then limestone above. Floor is fireclay with streaks of sandstone. About 2 feet is taken up. Mine operated since November, 1924; hoists 60 to 80 tons per day.

Sample Number 34, Collected July 30

Operator, John G. Henton, Carbon, R. F. D. Mine located in NE. ¼ sec. 25, T. 73, R. 35, Lincoln Tp., Adams Co. Altitude shaft about 1,200 feet; shaft 90 feet deep. Took sample from southwest face, about 400 feet from bottom. Coal averages 18 inches, splits in three layers—top 4 inches, lower two 7 inches; has a little pyrite in streaks and balls, otherwise clean. Mined longwall. Roof, shale and bastard 4 to 30 inches then limestone cap rock; floor, fine, smooth gray shale. Mine opened 1911, takes out 10 to 15 tons daily in summer.

Sample Number 35, Collected July 28

Operator, Ruth Coal Co., Carbon. Mine located in center SE. ¼ sec. 2, T. 72, R. 35, a mile NW. Carbon, Douglas Tp., Adams Co. Altitude of shaft 1,090 feet; depth of shaft 57 feet. Took sample from face of longwall at end of west entry, 60 feet in. Coal is 18 inches thick, top layer

4 to 6 inches thick, lower about 12 inches; no pyrite, coal very clean. Roof and floor similar to those in other mines in the Nodaway bed. Mine opened spring of 1928, hoists 16 tons in summer.

Sample Number 36, Collected September 10

Operator, Oskaloosa Coal & Mining Co., Oskaloosa. Mine No. 1; located in NE. ¼ SE. ¼ sec. 12, T. 75, R. 16, at north city limits of Oskaloosa, Mahaska Co. Slope mine, altitude of top about 820 feet, bottom of slope 780 feet. Took sample from room off 1st east entry, about 300 feet in from mouth of slope. Coal is here 47 inches thick, ranges up to 4 feet, 8 inches in hollows; clean, no pyrite bands, an occasional boulder. Roof gray shale, 2 to 4 inches shoddy above coal; floor fireclay, with a local "false bottom" of shale a few inches thick. Mine opened January, 1927, hoists 50 to 70 tons daily.

Geographic Distribution of Samples

In the following table the mines which were sampled are arranged geographically from north to south so that the analyses of coals from different districts and from different beds can be more readily compared. The mines in the Mystic (or Centerville) bed are arranged from east to west; those in the Nodaway bed from north to south. Compare also Plate I. The first line following each mine number is the analysis "as received"; the next line represents the analysis "bone dry."

TABLE I—COMPOSITION OF IOWA COALS TABULATED BY BEDS

No.	Moisture	Ash	Volatile	Fixed Carbon	B. T. U.	Sulfur	Unit Coal
			Lower Cherokee Beds				
16	20.98	8.5	33.8	36.7	9,430	4.0	
		10.8	42.8	46.4	11,950	5.1	13,990
17	19.72	9.3	36.3	34.7	9,740	4.8	
		11.6	45.2	43.2	12,130	6.0	14,430
13	14.97	10.3	36.9	37.8	10,450	3.5	
		12.1	43.4	44.5	12,300	4.1	14,550
14	15.11	12.5	36.9	35.5	10,050	4.1	
		14.7	43.5	41.8	11,840	4.8	14,530
12	16.94	12.3	33.9	36.9	9,920	3.1	
		14.8	40.8	44.4	11,940	3.7	14,560
15	16.24	14.0	34.5	35.3	9,690	3.8	
		16.7	41.2	42.1	11,560	4.6	14,550
11	13.64	14.6	36.8	35.0	10,050	5.2	
		16.9	42.6	40.5	11,630	6.0	14,850
7	14.25	12.7	34.7	38.3	10,450	3.9	
		14.8	40.5	44.7	12,200	4.6	14,950
8	13.74	6.5	39.5	40.3	11,450	3.7	
		7.5	45.8	46.7	13,260	4.3	14.830
5	14.24	13.0	36.3	36.5	10,220	5.2	
		15.2	42.3	42.5	11,910	6.1	14,760

TABLE I—COMPOSITION OF IOWA COALS TABULATED BY BEDS —Continued

No.	Moisture	Ash	Volatile	Fixed Carbon	B. T. U.	Sulfur	Unit Coal
			Lower Cherokee Beds				
6	16.78	15.5	33.0	34.7	9,660	3.8	
		18.6	39.7	41.7	11,600	4.6	14,970
9	13.17	14.6	35.4	36.8	10,210	6.3	
		16.8	40.8	42.4	11,750	7.3	15,100
4	13.89	16.9	34.3	34.9	9,040	5.6	
		19.6	39.8	40.6	10,500	6.5	13,950
2	16.82	14.5	35.0	33.7	9,190	5.8	
		17.4	42.1	40.5	11,050	7.0	14,290
3	15.99	9.2	37.1	37.7	10,530	5.0	
		11.0	44.2	44.9	12,550	5.9	14,730
1	16.05	8.7	37.3	37.9	10,820	5.3	
		10.4	44.5	45.4	12,900	6.3	15,110
10	14.6	10.6	39.1	35.7	10,830	4.8	
		12.4	45.8	41.8	12,620	5.6	15,110
30	18.65	9.2	31.9	40.2	10,030	2.6	
		11.3	39.1	49.6	12,330	3.2	14,330
29	18.52	10.4	32.6	38.5	10,000	2.6	
		12.8	39.9	47.3	12,260	3.1	14,510
28	19.89	12.8	32.7	34.6	9,460	2.0	
		15.9	40.6	43.5	11,810	2.5	14,510
27	15.88	14.0	33.6	36.5	9,950	5.3	
		16.6	39.9	43.5	11,810	6.3	15,020
21	17.12	9.4	34.9	38.6	10,490	3.5	
		11.3	42.1	46.6	12,650	4.2	14,800
20	14.80	9.8	35.0	40.4	10,700	2.1	
		11.5	41.1	47.4	12,550	2.5	14,550
36	18.1	10.0	33.5	38.4	10,610	2.0	
		12.2	40.9	46.9	12,960	2.4	15,140
			Mystic Bed				
19	18.09	6.5	35.7	39.7	10,430	2.7	
		7.9	43.6	48.5	12,730	3.3	14,210
25	14.94	9.7	36.3	39.1	10,750	3.4	
		11.5	42.6	45.9	12,630	4.0	14,790
24	13.42	10.3	35.6	40.7	10,490	4.9	
		11.9	41.2	46.9	12,120	5.6	14,430
22	17.62	11.0	36.7	34.7	9,880	4.5	
		13.3	44.6	42.1	11,990	5.5	14,520
18	18.14	8.6	33.9	39.4	10,050	3.7	
		10.5	41.4	48.1	12,270	4.5	14,270
23	15.32	12.2	34.6	37.9	9,960	3.9	
		14.4	40.9	44.7	11,750	4.7	14,360
31	15.61	11.0	35.2	38.2	9,800	3.3	
		13.0	41.7	45.3	11,620	4.0	13,870
26	16.76	8.3	34.1	40.8	10,350	3.9	
		9.9	40.7	49.4	12,420	4.7	14,330

TABLE I—COMPOSITION OF IOWA COALS TABULATED BY BEDS —Continued

No.	Moisture	Ash	Volatile	Fixed Carbon	B. T. U.	Sulfur	Unit Coal
			Nodaway Bed				
34	21.1	9.9	32.9	36.1	9,280	3.5	
		12.5	41.6	45.9	11,760	4.5	14,000
35	20.6	12.3	33.0	34.1	9,270	3.1	
		15.5	41.6	42.9	11,680	3.9	14,390
33	20.2	13.3	33.6	32.9	9,080	5.5	
		16.7	42.0	41.3	11,380	7.0	14,570
32	18.4	13.7	35.3	32.6	9,440	3.4	
		16.7	43.2	40.1	11,560	4.2	14,500

CHEMICAL AND THERMAL VALUES OF IOWA COALS

H. L. Olin, R. C. Kinne and N. H. Hale

In Volume 19 of the Iowa Geological Survey Hixson reported the results of proximate analyses of sixteen coal samples collected at mines located in ten of the principal coal producing counties of the state. This report was followed in 1914 by a paper in which the previous figures were republished but amplified by additional data on ultimate analyses of the same samples, together with tables showing the compositions of the ash.

In the space of twenty years since these coal samples were collected many changes have taken place in the coal mining industry of the state. Many of the mines that were the leading producers in 1909 have long since passed their peak of production or have been abandoned altogether. In any case it seemed wise to make a new survey of Iowa's coal to bring this information up to date not only with respect to the location of leading production centers, but also with respect to quality. The direct incentive for undertaking such a study was the initiation of a comprehensive program of Iowa coal research by the Department of Chemical Engineering at the University which required in preparation, accurate analytical data on present supplies.

The tables given in this bulletin are based upon the analyses of samples collected under the direct supervision of the Assistant State Geologist, Dr. James H. Lees. The method he used in taking face samples is fully described in Iowa Geological Survey 24, 692 (1914) and in his contribution to this report, and those specially interested in its details are referred to those sources of information. In brief it involves the cutting of the face of the seam in such a way as to insure the inclusion of the varying components of the seam in their true proportions with respect to the entire face, and thus it affords the means for collecting a sample that most nearly approaches the average composition of the output of the mine as a whole. Moreover, a sample secured in this way and immediately sealed in an airtight container provides the analyst with material for determining the natural moisture content of the coal in place. This value, while not of great significance commercially because of immediate drying losses that take place after the coal is exposed to the air, has great scientific importance in its bearing on coal classification. Thus Campbell of the U. S. Geological Survey proposes a system for ranking coals based solely on the percentage of this initial moisture.

Methods of Analysis

Laboratory methods and apparatus employed were in all cases those adopted by the American Society for Testing Materials and described in the Proceedings for 1924 under the serial number D-22-24, and in U. S. Bureau of Mines Technical Paper 76. These specifications designate as official instruments the A. S. T. M. constant temperature coal moisture oven, the Fieldner electric furnace for volatile matter and the oxygen bomb calorimeter for thermal values, with all of which the Fuel Laboratory of the University is equipped.

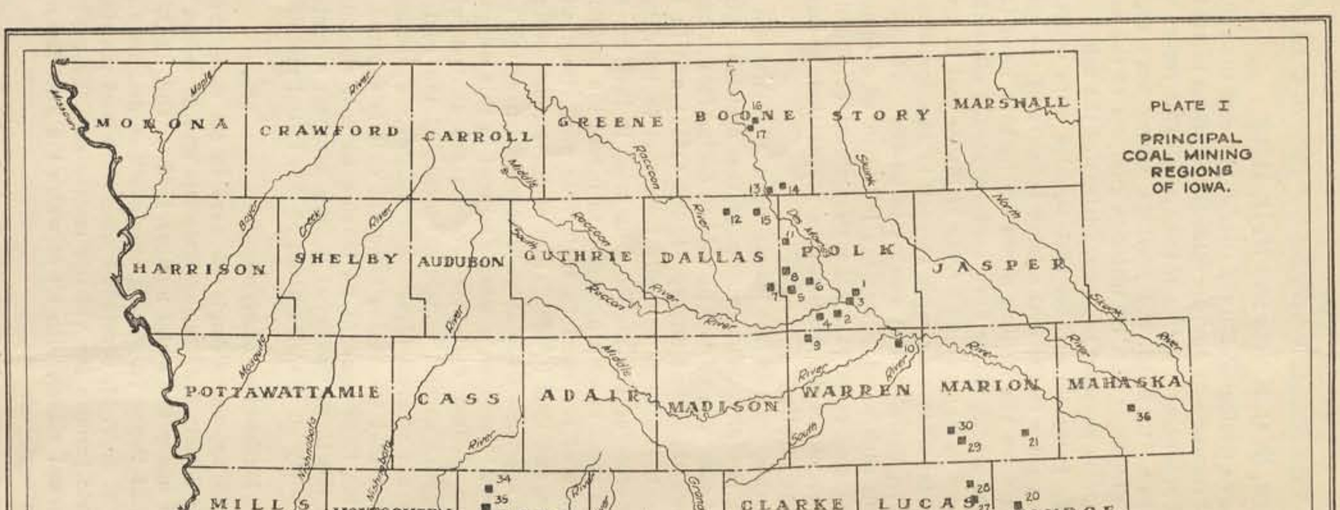


PLATE I
PRINCIPAL COAL MINING REGIONS OF IOWA.
MONONA
CRAWFORD
CARROLL
GREENE
BOONE
STORY
MARSHALL
HARRISON
SHELBY
AUDUBON
GUTHRIE
DALLAS
POLK
JASPER
POTTAWATTAMIE
CASS
ADAIR
MADISON
WARREN
MARION
MAHASKA
MILLS
MONTGOMERY
ADAMS
UNION
CLARKE
LUCAS
MONROE
FREMONT
PAGE
TAYLOR
RINGGOLD
DECATUR
WAYNE
APPANOOSE