

An Investigative Study of Six Indiana Coals

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Abstract

Proximate and ultimate analyses of 21 coal samples from six Indiana coals have been determined. Total sulfur in the "whole" coal is compared with the total sulfur retained in the "coke-button" after pyrolysis at 950° C and with the total sulfur retained in the ash after combustion at 750° C.

The Illinois Basin comprises portions of Indiana, Illinois, and Kentucky. The Indiana portion (Fig. 1) along the eastern edge of the basin, covers an area of approximately 6,500 square miles (5). Within this area coals of commercial value are all Pennsylvanian in age (3).

The significant coal members of the Pennsylvanian period (Fig. 2) that are considered in this paper, and in order of decreasing age are:

- (1) The Upper Block Coal of the Brazil Formation
- (2) The Seelyville Coal (III) of the Staunton Formation
- (3) The Springfield Coal (V) of the Petersburg Formation and
- (4) Coal Vb, the Hymera Coal (VI), and the Danville Coal (VII) of the Dugger Formation.

These coals are all ranked as high volatile bituminous.

In dollar value of mineral production during 1966, coal ranked first in Indiana with the approximate FOB mine value of \$65,730,000 representing a production of over 17 million tons (Hutchinson, H., and M. B. Fox, personal communication). The mining of the Springfield (V), Hymera (VI), and Danville (VII) Coals constitutes about 88% of total production in Indiana.

Coal samples collected for this study were taken from 14 active mines over a 7-county area. At the time of sampling, overburden had been removed from the various coal seams for less than a week. In all cases the samples were face channel samples and before sampling the coal face was chipped away to insure a "non-oxidized" surface. Upon collection, the samples were stored in air-tight cans to minimize the loss of moisture.

Preparation of the samples and subsequent chemical analysis followed the procedures and specifications of ASTM-D-271-58.

The analyses considered in this paper are the proximate, ultimate and calorific.

Proximate Analysis

The proximate analysis consists of the determination of moisture, ash, volatile and fixed carbon. In Table 1 moisture is on the as-received basis and the remainder of the data is on the moisture-free basis. Moisture refers only to the amount of weight loss of the coal sample when it is heated at 105° C for a period of 2 hours. It is considered to be inherent and extraneous water but does not refer to water of hydration.

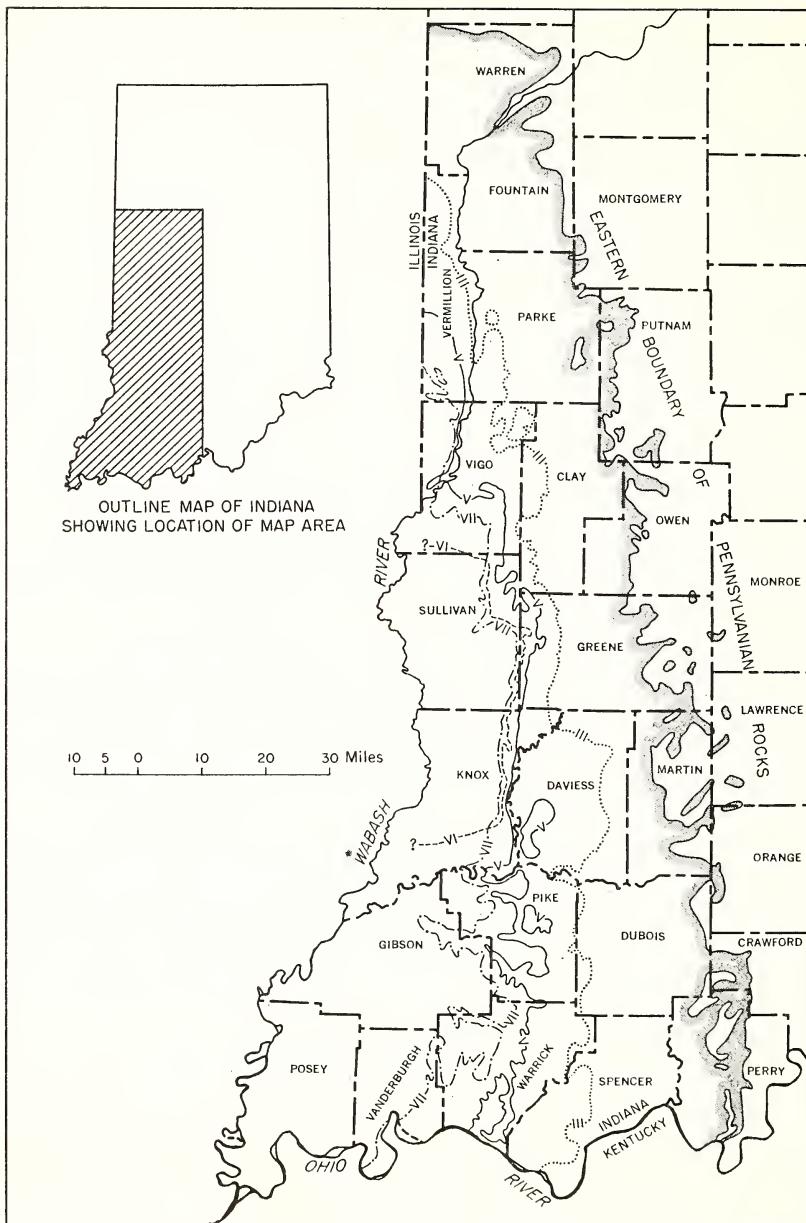


Figure 1. Map of southwestern Indiana showing eastern limits of Indiana's major coals. Roman numerals designate Seelyville Coal (III), Springfield Coal (V), Hymera Coal (VI), and Danville Coal (VII).

TIME UNIT		THICKNESS	LITHOLOGY	ROCK UNIT		
PERIOD	EPOCH			SIGNIFICANT MEMBER	FORMATION	GROUP
PENNSYLVANIAN	ALLEGHENY	230 to 345	Danville Coal (VII)	Dugger	Carbondale	
			Hymera Coal (VI)			
			Coal Vb			
			Alum Cave Limestone	Petersburg		
			Springfield Coal (V)			
			Survant Coal (IV)	Linton		
	Colchester Coal (IIIa)					
	POTTSVILLE	145 to 450	Seelyville Coal (III)	Staunton	Raccoon Creek	
			Perth Limestone	Brazil		
			Minshall Coal			
Upper Block Coal						
MISS.				Mansfield	Stephensport	
						Glen Dean Ls.

Figure 2. Column showing stratigraphic position of important Indiana coals.

Ash is the non-combustible residue resulting from the burning of coal. As determined, ash is not present in the coal (2); iron, for example, that is present as the oxide in the ash may be present as the sulfide (pyrite) in the coal.

The volatile determination, an empirical test, is the percent weight loss of the coal when it is pyrolyzed in the absence of air at 950° C for exactly 7 minutes (1).

Fixed carbon on the as-received basis is the difference between 100 and the sum of moisture, ash, and volatile material and is the recipient of all errors.

Ultimate Analysis

Ultimate analysis refers to the determination of carbon, hydrogen, nitrogen, oxygen, sulfur, and ash.

Carbon, hydrogen, and oxygen exist in both the organic and inorganic substances of the coal. Little is known about the mode of occurrence of nitrogen except that it is a part of the organic fraction of the coal substance (4) and is probably present in cyclic structures.

Sulfur in coal occurs in three forms—pyritic, organic, and sulfate. Pyritic and organic sulfur comprise a major portion of the total sulfur.

Ash was defined in the proximate analysis but must be considered as part of the total for ultimate analysis.

Oxygen is the difference between 100 and the sum of carbon, hydrogen, nitrogen, sulfur, and ash; and as for fixed carbon in the proximate analysis, oxygen is the recipient of all errors.

The calorific value refers to the heating value and is expressed here as British thermal units per pound or Btu.

TABLE 1
Proximate and Ultimate Analysis

Coal	Seelyville Springfield		Hymera Danville			
	U. Block Coal (III)	Coal (V)	Coal Vb Coal (VI)	Coal (VII)		
	% As Received					
Moisture	16.2	11.8	11.7	13.8	11.1	12.9
	% Moisture Free					
Ash	5.6	17.2	10.2	12.8	13.4	11.4
Volatile	38.9	40.3	40.9	39.8	39.6	41.0
Fx. Carbon	55.5	42.5	48.8	47.3	47.0	47.6
Carbon	76.3	63.6	*71.1	68.2	68.6	69.1
Hydrogen	5.27	4.78	*4.93	4.85	4.76	4.92
Oxygen	9.5	7.6	*8.6	8.6	7.8	9.5
Nitrogen	1.56	1.23	1.54	1.54	1.55	1.61
Sulfur	1.8	5.6	3.9	4.1	3.8	3.5
BTU	13,740	11,720	12,670	12,230	12,040	12,490
No. of Samples	1	2	7	2	4	5

* Average for 6 samples only.

As one observes the data in Table 1 it must be kept in mind that the collected channel samples were from the face and may include some impure materials that would increase the ash and sulfur values and lower all other values. Cleaned or tippie samples would show a lower ash and sulfur value and consequently would increase all other values.

The data in Table 1 are not meant to categorize any one coal member but rather to show a slight trend within the range of analysis. These data do not indicate any specific entity that could be used to identify or delineate the various coal members. It will be shown in Table 2 that the range of analyses, from highest to lowest value, could change values of one coal member to within the range of values of another—thus making identification difficult if not impossible.

The data in Table 1 are the averages of the number of samples represented at the base of the table. Certainly, the sample population is too small to make any valid statistical analysis for identification

purposes. These data need to be compared and included with the data from a larger suite of samples.

The data in Table 2 illustrate the difference between the highest and lowest values for the number of samples of each coal member. The great variance, not only within the same coal member, but also between coal members, would certainly confirm the fact that coal is a heterogeneous material and that these variances would negate categorizing these coal members on the basis of proximate and ultimate analyses alone.

TABLE 2. Range of Analyses

Coal	Seelyville Coal (III)	Springfield Coal (V)	Hymera Coal Vb Coal (VI)	Danville Coal (VII)	
	% As Received				
Moisture	1.5	1.7	2.0	1.8	5.6
	% Moisture Free				
Ash	0.8	7.3	3.8	6.0	1.9
Volatile	0.6	4.1	0.9	6.0	1.6
Fx. Carbon	1.4	6.0	3.0	6.3	3.2
Carbon	0.1	*7.0	4.2	9.8	2.4
Hydrogen	0.16	*0.60	0.30	1.02	0.10
Oxygen	1.0	*2.4	0.6	7.9	0.9
Nitrogen	0.02	0.67	0.01	0.16	0.34
Sulfur	1.63	3.33	1.27	2.23	2.46
BTU	180	1,270	840	960	650
No. of Samples	2	7	2	4	5

* Range for 6 samples only.

Table 3 illustrates the sulfur retention in the ash and in the "volatile coke button" during and after pyrolysis of the various coal members. These data, too, show a variability, especially so with regards to the percent of sulfur that is retained in the ash. Analysis of the ash might possibly reveal some material that would have an affinity for the sulfurous gases that are given off during combustion and explain the high retention of sulfur in the ash of the Springfield (V) and Hymera (VI) Coals and conversely the lower percentages in the Seelyville (III) and Danville (VII) Coals and Coal Vb. The ash was not analyzed for other elements but certainly needs to be.

If one considers the average sulfur retention in the ash of all coals (53.4%) and the average total sulfur for all coals then one must realize that upon combustion approximately 46.6% of the total sulfur is exhausted into the atmosphere as sulfurous compounds. Putting this information into more elemental terms, one can say that on the average basis and with the number of samples and analyses considered here that from this uncleaned coal approximately 38 pounds of sulfur for each ton

TABLE 3. Sulfur Retention During Pyrolysis

Coal No.	Whole Coal % Total Sulfur Moisture Free	% Total Sulfur Retained in "Vol. Button"	% Total Sulfur Retained in Ash	% Whole Coal Sulfur Retained in "Vol. Button"	% Whole Coal Sulfur Retained in Ash
Danville					
Coal (VII)	3.5	2.9	1.2	82.8	34.3
Hymera					
Coal (VI)	3.8	3.7	3.4	97.4	89.5
Coal					
Vb	4.1	3.8	1.4	92.7	34.1
Springfield					
Coal (V)	3.9	3.1	2.6	79.5	66.7
Seelyville					
Coal (III)	5.6	4.8	2.4	85.7	42.8
U. Block					
Coal	1.8	1.6	*	88.9	*
Avg. (excluding U. Block Coal)	4.1	3.6	2.2	87.6	53.4

* Not determined.

of coal burned would be exhausted into the atmosphere—providing, of course that no sulfur recovery from exhaust gases was applied.

The method used for the determination of the volatile material is essentially the equivalent of the coking process—the heating of coal in the absence of air. When considering the retention of sulfur in the "volatile coke button," one can readily realize why Indiana coals, which are all relatively high in sulfur, cannot be used in metallurgical coke and especially so when the specifications for coke require a coal with a sulfur content of one percent or less. Not only that, the by-product gases and volatile organics would contain 12.4% of the total sulfur of the whole coal which could be disadvantageous in some systems of by-product recovery.

Literature Cited

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