AN ANALYSIS OF SELECTED INDIANA COALS
BY THE PARTICLE COUNT METHOD

by

RANARD JACKSON PICKERING

Indiana Department of Conservation
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Report of Progress No. 6

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AN ANALYSIS OF SELECTED INDIANA COALS
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ABSTRACT

The bituminous coals of Indiana show a characteristic bright and dull banding which is due to alternating bands of five distinct physical constituents, namely, vitrain, clarain, durain, fusain, and mineral matter. A petrographic analysis of Indiana Coals V, VI, and VII was made to determine whether any appreciable variation in the content of these ingredients occurred. The "particle count method" was used in analyzing the coals.

In order to establish a standard for comparing Coals V, VI, and VII, an index number was determined for each sample by dividing the combined clarain-durain content by the vitrain content. These index numbers are the most reliable and satisfactory basis for the comparison of coals, and they maybe used to some extent in coal correlation.

Because vitrain has the most desirable combustion properties, a coal that has a high - vitrain content may be more desirable commercially. Coals VI and VII were found to have a distinctly higher vitrain content than Coal V. Localities of high-vitrain content within the various coal beds in Indiana are outlined in this report.

Suggestions for further use of the particle count method in coal analysis are made.

INTRODUCTION

Purpose and scope

The bituminous coals of Indiana are characterized by a distinct banding of alternating bright and dull layers (pl. 1, A). The bright layers are composed of vitrain, and the duller layers are chiefly clarain, durain, and fusain. The relative amount of each of these ingredients varies from coal to coal, and to a lesser amount within a particular coal bed. The individual constituents react somewhat differently when the coal is burned because of their different chemical and physical properties. Thus a coal that has a relatively higher concentration of a particular constituent may be more desirable for certain commercial uses. Because of this fact and because of the possibility of using petrographic analysis in coal correlation, samples of Indiana Coals V, VI, and VII2 which are important commercially, were analyzed to determine the relative amounts of the ingredients which these coals contained. These coals are included in the Petersburg and Dugger formations of the Alleghenian series of Pennsylvanian age (fig. 1).

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The petrographic analysis of coals as described in this report is much like that method which is widely used to test performance of ore-dressing operations, and has been termed the "particle count method" (Parks, 1949, pp. 376-424). In addition to outlining the procedure that was used, this report discusses the commercial application and the possibility of correlation of coal beds.

Acknowledgments

The writer made the laboratory analysis during the summer of 1951 while he was employed by the Coal Section of the Geological Survey. This report was written under the direction of P. D. Proctor, Professor of Economic Geology, and was submitted to the Faculty of the Graduate School in partial fulfillment of the degree, Master of Arts, in the Department of Geology, Indiana University, June 1952. The author gratefully acknowledges the assistance of Charles E. Wier, Head of the Coal Section, under whose direction the work was done, and of G. K. Guennel, paleobotanist in the Coal Section.

DESCRIPTION OF SAMPLES

Samples of 33 benches from 25 localities were analyzed. Samples from 12 of these localities were obtained from Coal V, five from Coal VI, four from Coal VII, and four from the Millersburg coal.

The localities from which samples were obtained were selected so that they followed a general north-south line which ran through the area in which coal is found in the state. Moreover, they were spaced as regularly as possible for each coal. (See fig. 2.) This pattern of sampling was used in order to determine whether any definite north-south linear variation in the relative abundance of the coal constituents existed in the various coals.

The samples which were analyzed were complete channel samples. These channel samples, which had been collected from underground and strip mines, had a cross -sectional area of approximately 1 square inch and a vertical extent equal to the thickness of the coal bench. The specimens which the writer studied were, with two exceptions, splits from samples which had been analyzed previously for spore content. Whenever distinct and persistent shaly partings divided a bed of coal into two benches or more (pl. 1, B), separate samples were collected from each bench.
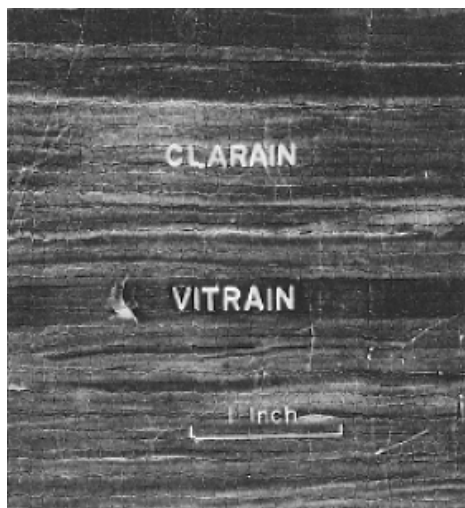
A. POLISHED SECTION OF COAL IV SHOWING BANDING OF
THE PHYSICAL CONSTITUENTS
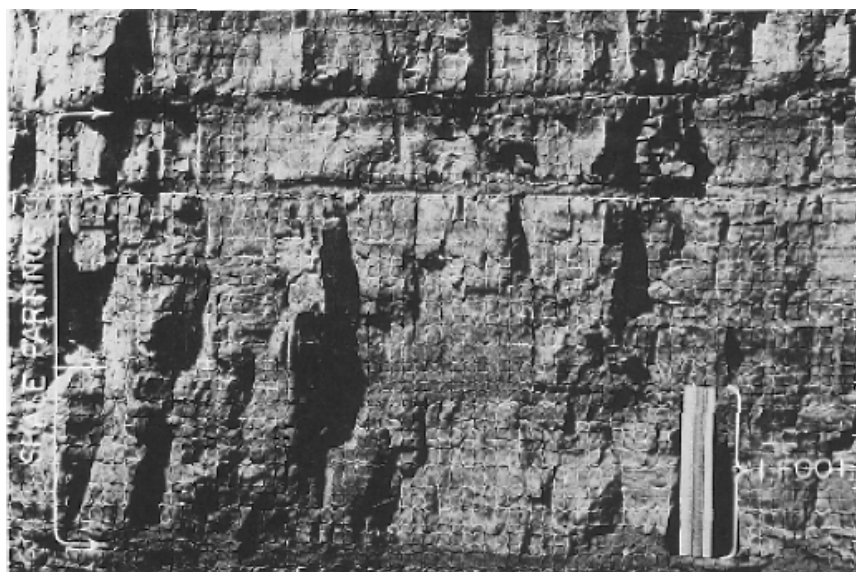
B. OUTCROP OF COAL VI SHOWING SHALY PARTINGS.
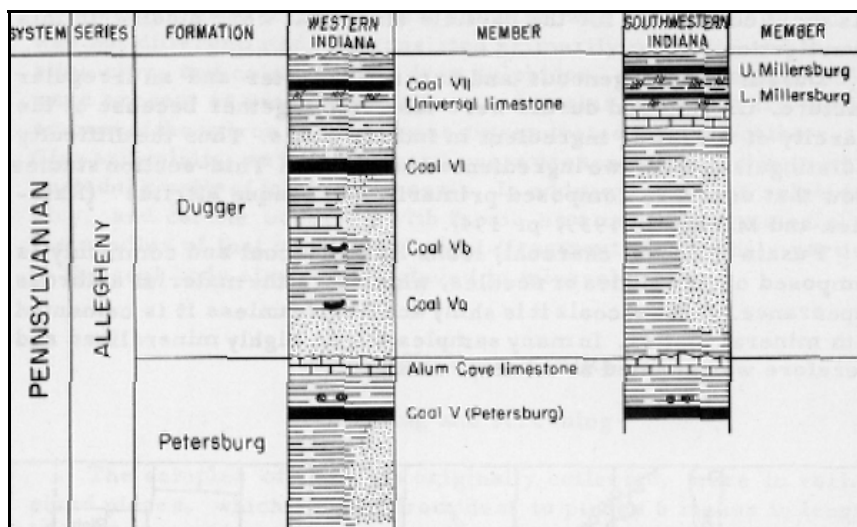
BANDING IN INDIANA COALS.

Figure 1. *Generalized stratigraphic column showing position of Coals V, VI, and VII.*

PHYSICAL CONSTITUENTS

Because much has been written on the nature of the ingredients of which coal is composed, only a brief description of each ingredient is given in this report. The various ingredients appear much the same under low magnification as they do to the unaided eye. The main characteristics of these physical constituents are summarized in the table on page 12.

Vilrain was formed mainly from the woody parts of trees, such as trunks and branches. Vitrain bands of varying thicknesses occur in the Indiana coals. These bands are distinguished by their massiveness, bright vitreous luster, and fracture. A few pieces of vitrain in the samples which were analyzed appeared to be composed of consecutive layers of microvitrain (microscopic-sized vitrain).

Clarain is composed of alternating bands and fragments of microvitrain and a dull ingredient which is called "translucent attritus" (Raistrick and Marshall, 1939, p. 193)."Translucent attritus" contains cuticles, spores, resin bodies, and fragments of plant tissues in various stages of disintegration. The brightness of clarain. increases with the amount of microvitrain present. No definite thickness has been set as a basis for a distinction between microvitrain and vitrain. A width of one-tenth inch (approximately 2 mm), however, was assumed by the writer as the minimum thickness for a vitrain band, and thus bands less than 2 mm thick in clarain were counted as clarain. This width was used by Parks (1949, p. 381) and

was most convenient for the particle sizes that were studied in this investigation.

Durain is homogeneous and has a dull luster and an irregular fracture. Clarain and durain were tabulated together because of the scarcity of the latter ingredient in Indiana coals. Thus the difficulty of distinguishing the two ingredients, was avoided. Thin-section studies show that durain is composed primarily of "opaque attritus" (Raistrick and Marshall, 1939, p. 194).

Fusain (mineral charcoal) looks like charcoal and commonly is composed of f ine blade s or needles, which give the material a fibrous, appearance. In most coals; it is shiny and friable unless it is cemented with mineral matter. In many samples it was highly mineralized and therefore was counted as mineral matter.
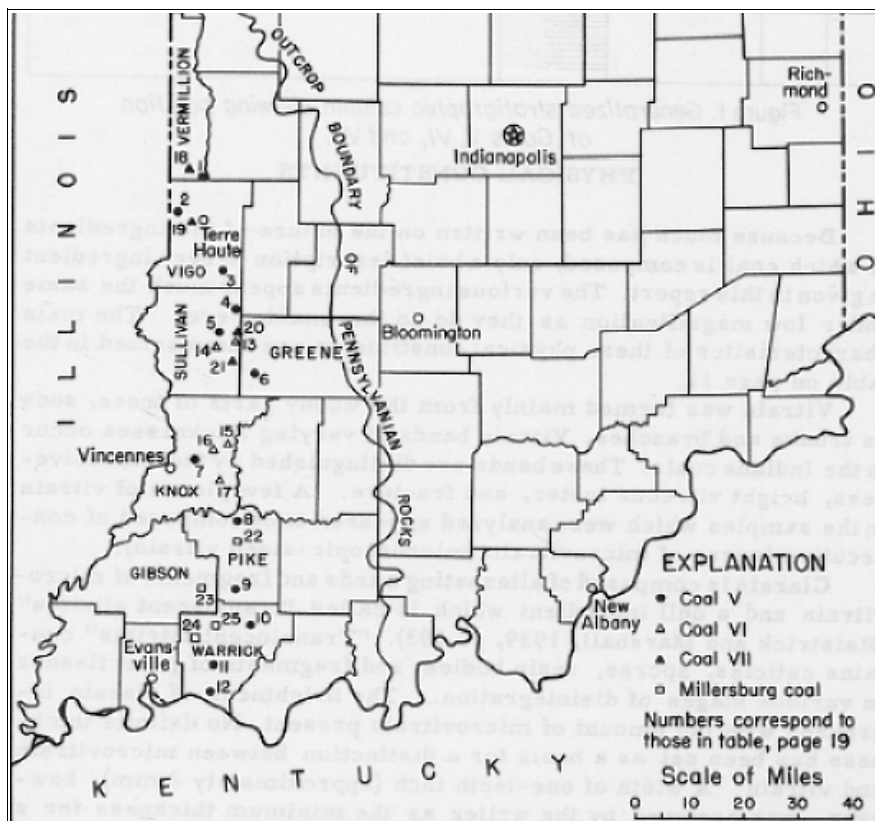

Figure 2. *Map of southern Indiana showing location of samples of coals.*

Mineral matter in the coal samples was readily identified and was not differentiated. It consisted primarily of pyrite and marcasite, clay, and calcite. The iron sulphides, pyrite and marcasite, were present as small concretions and grains. Moreover, a slight amount of these iron sulphides was disseminated throughout the coals. Clay and calcite, on the other hand, were present as thin sheets which coated the walls of joints in the coals. In addition, the iron sulphide s, clay, and calcite occurred with fusain as a cementing material for the needles of that constituent. Shale fragments from shaly partings in the coal beds also were included in mineral matter.

ANALYSIS PROCEDURE

Crushing and screening

The samples of coal, as originally collected, were in various sized pieces, which ranged from dust to pieces 6 inches in length. Most of the coal, however, was in fragments of 2 to 3 inches in length.

The coal was crushed in a Braun Chipmunk model WD64 crusher with the jaws set at a distance of one -eighth inch minimum and three -eighths inch maximum. The sample then was passed through a Jones sample splitter until approximately 1,500 grams remained. Next, the sample was passed through a Tyler 8-mesh sieve (8 meshes per inch, with a mesh opening of 0. 0937 inch) in order to eliminate the oversized fragments. The material which remained on the sieve was rerun through the crusher and sieved again (fig. 3). As oversized fragments from this second run were absent or negligible, any fragments that remained were discarded.

The 1,500 -gram sample of crushed coal then was split to obtain a sample which weighed exactly 500 grams. This 500-gram sample next was passed through Tyler sieves of the following mesh sizes: 10, 14, 20, 28, 352 48, 65, 100, 150, 200, 270, and 325. The amount of coal which was retained on each screen was weighed and placed in bottles for analysis.

The material which passed through the 325-mesh sieve was discarded. Because of these rejected fines and a slight loss in screening, the final sample weighed slightly less than 500 grams.

Particle count

A Bausch and Lomb wide-field stereoscopic microscope was used in counting the coal particles. A magnification of 6.6X was used for observing the 8 by 10-mesh (the particles which passed through the 8-mesh and were caught on the 10-mesh sieve) and 10 by 14-mesh par-

CHARACTERISTICS OF THE BANDED INGREDIENTS

DISTINGUISHING CRITERIA FOR IDENTIFICATION OF THE PHYSICAL CONSTITUENTS

PHYSICAL CONSTITUENTS	CHARACTERISTICS OF BED-COAL AND LUMPS	CHARACTERISTICS OF SMALL PARTICLES - 1/10" DIMENSION	CHARACTERISTICS OF POLISHED SURFACES
VITRAIN	BANDS JET-BLACKS GLOSSY; SMOOTH-TEXTURED; CONCHOIDAL FRACTURES; OFTEN PROMINENT VERTICAL FRAC-TURES FILLED WITH MINERAL MATTER IN THE THICKER LAYERS; BRITTLE.	IRREGULAR PARTICLES TENDING TO BE LENS-SHAPED; CONCHOIDAL FRACTURE; THIN EDGE; BLACK TO GRAYISH; BRILLIANT LUSTER; SMOOTH-TEXTURED. AT LOW MAGNIFICATION THIN EDGES AND THE ENTIRE PARTICLES IN VERY FINE SIZES MAY SHOW ORANGE-COLORED TRANSLUCENCY.	JET- TO GRAYISH BLACK; HOMOGENEOUS TEXTURE; BRILLIANT LUSTER; HIGH REFLECTANCE.
CLARAIN	BRIGHT TO GRAYISH; STREAKED OR SILKY LUSTERED; FRACTURE UNEVEN AND CONCHOIDAL; HARDER' THAN VITRAIN BUT SOMETIMES BRITTLE.	IRREGULARLY SHAPED PARTICLES; LESS LENTICULAR THAN VITRAIN BUT SOME SHOW CONCHOIDAL FRACTURE; STREAKED APPEARANCE CHARACTERISTIC OF ALL PARTICLES LARGER THAN ONE-FIFTIETH INCH; SMALLER PARTICLES SHOW ONLY A VARYING PROPORTION OF DULL COAL ATTACHED TO VITREOUS COAL.	BRIGHT, STREAKED, AND SILKY LUSTERED; SOMETIMES DULL-GRAY.
DURAIN	DULL-GRAY; EVEN-TEXTURED: MAT SURFACE; GRAINY FRACTURE: HARD.	PARTICLES TEND TO BE PLATY WITH FRAC-TURE PLANES NEARLY AT RIGHT ANGLES IN LARGER PARTICLES; GRAINY SURFACE; DULL-GRAY; VERY IRREGULAR AND GRAINY, WITH SPORES AND RODLETS 114BEDDED IN SURFACE.	DULL-GRAY; EVEN-TEXTURED; MAT SURFACE.
FUSAIN	JET-BLACK TO GRAYISH BLACK; SOMETIMES BRILLIANT; OFTEN HAS LOOSE SPLINTERY APPEAR-ANCE; USUALLY VERY SOFT BUT SOMETIMES FIRMLY CEMENTED WITH MINERAL MATTER.	NEEDLE-SHAPED AND PLATY: JET-8LACK, GRAYISH, AND SOMETIMES BRILLIANT; SURFACE PUNCTATE AND SHOWS EVIDENCE OF CELLULAR STRUCTURE; USUALLY VERY SOFT AND POWDERY BUT SOMETIMES HARD AND BRITTLE.	DARK-GRAY; POROUS.

¹MODIFIED AFTER PARKS, 1949, P. 380.

ticle sizes. On the other hand, magnification of 13X was found most suitable in working with the 14 by 20-mesh and 20 by 28-mesh sizes. The coal was placed on a sheet of white paper and moved with a dissecting needle. Each piece was pushed aside as it was counted. A Stocker and Yale fluorescent laboratory lamp that uses two 4-watt bulbs provided illumination. A Clay-Adams multiple laboratory counter was used to record the particle count. This is a finger-manipulated counter that has five recording units, a continuous totalizer, and a bell which rings at the end of every 100 objects counted.

In an experiment on size distribution, Parks (1949, p. 406) determined that the weight of broken coal which was retained on each of the set of sieves showed essentially a straight line relationship when the se weights were plotted on a graph of the type which was devised by Geer and Yancey (1938, pp. 250-269) and which used Bennett's modification (Parks, 1949, p. 406) of the Rosin and Rarnmler formula. Developed after extensive research, the Rosin and Rammler formula (Parks, 1949, p. 406) relates the weight percentage of a coal sample which is retained on a set of test sieves to the size of the sieve openings. Geer and Yancey's graph enables one to plot cumulative weight percentages of coal which is retained on a set of sieves in relation to the screen size. Parks (1949, p. 395) also stated that "investigation showed that the size-frequency distribution of handpicked vitrain, clarain, and durain, when crushed under identical conditions, conformed essentially in terms of weight percentages retained on standard scale sieves. This discovery provided the basis for the assumption that when a mixture of the banded ingredients was crushed, the size-frequency distribution of the different ingredients would be essentially uniform, provided that undersized particles were readily freed from the crusher and that the grinding action of particle against particle was reduced to a minimum."

Only the four largest screen sizes of particles were counted manually. The percentage of each ingredient in the smaller screen sizes was determined by extrapolation from Parks' modification of the graph which was described in the previous paragraph. The use of extrapolation eliminated the tedious and time-consuming task of counting the very small particle sizes.

In order to facilitate plotting the calculations, the writer used weight in grams for the ordinate of the graph, rather than cumulative weight percentages, and a direct plot in place of a cumulative plot.

Five hundred particles were counted in each of the four largest particle sizes. This number of grains was considered to represent the average composition of the broken coal which was retained on each screen. A total of 2,000 particles thus was counted for each sample, and the percentage of the various ingredients was calculated for each of the four largest screen sizes.

Calculation of results

After the percentage content of each ingredient in the four largest particle sizes was determined, these percentages were retabulated for plotting on the graph (fig. 4). Graph data were plotted and read to the nearest half a gram. The tabulation consisted of multiplying the percentage of each ingredient in a given particle size by the total weight of particles of that size.[1] The results of this tabulation were the number of grams of each constituent contained in each of the four screen sizes of coal that had been counted. The number of grams of each constituent then was plotted directly on the graph, and these amounts were compared with the plot of the total weight of coal that was retained on each screen.

The sample graph (fig. 4) demonstrates that below the 20 by 28 mesh particle size, the curve for the total sample is essentially a straight line. Because of the discarded fines, however, this curve does not reach zero in the finest particle size. As the weight of the discarded fine coal was always less than 5 grams (or 1 percent) of the entire sample, the weight of each ingredient could be interpolated in the smaller sizes with little error. The weights of the constituents were interpolated for the 270 by 325-mesh size by a comparison of their relative amounts in the larger particle sizes. These interpolated weights were connected with those which had been determined by actual count in the 20 by 28-mesh size by a straight line. Thus the extrapolated curves for the distribution of the various constituents in the finer screen sizes were established.

The weight in grams of each constituent in all the particle sizes was taken from the graph and totaled. These amounts represented the total weight of each constituent in the entire sample. These weights then were added together to obtain a weight for the total sample. Finally, the percentage of the various ingredients which were contained in a sample was computed by dividing the calculated weight of each constituent in the total sample by the total weight of the sample. Each of these percentages then was entered in the proper blank on the graph. In this analysis, clarain and durain were listed together. The amount of durain, however, was small.

The percentages of mineral matter could not be used as a satisfactory criterion because of a variation in sampling procedure. In some localities the entire parting was included in the sample of one bench and none was included in the other. A reference ratio which could be used to compare the coals, and which would minimize the variability of the mineral matter and the possible concentration of fusain in the smaller particle sizes, was obtained by dividing the

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[1] The constituents have nearly the same density and thus were assumed to be of the same density.
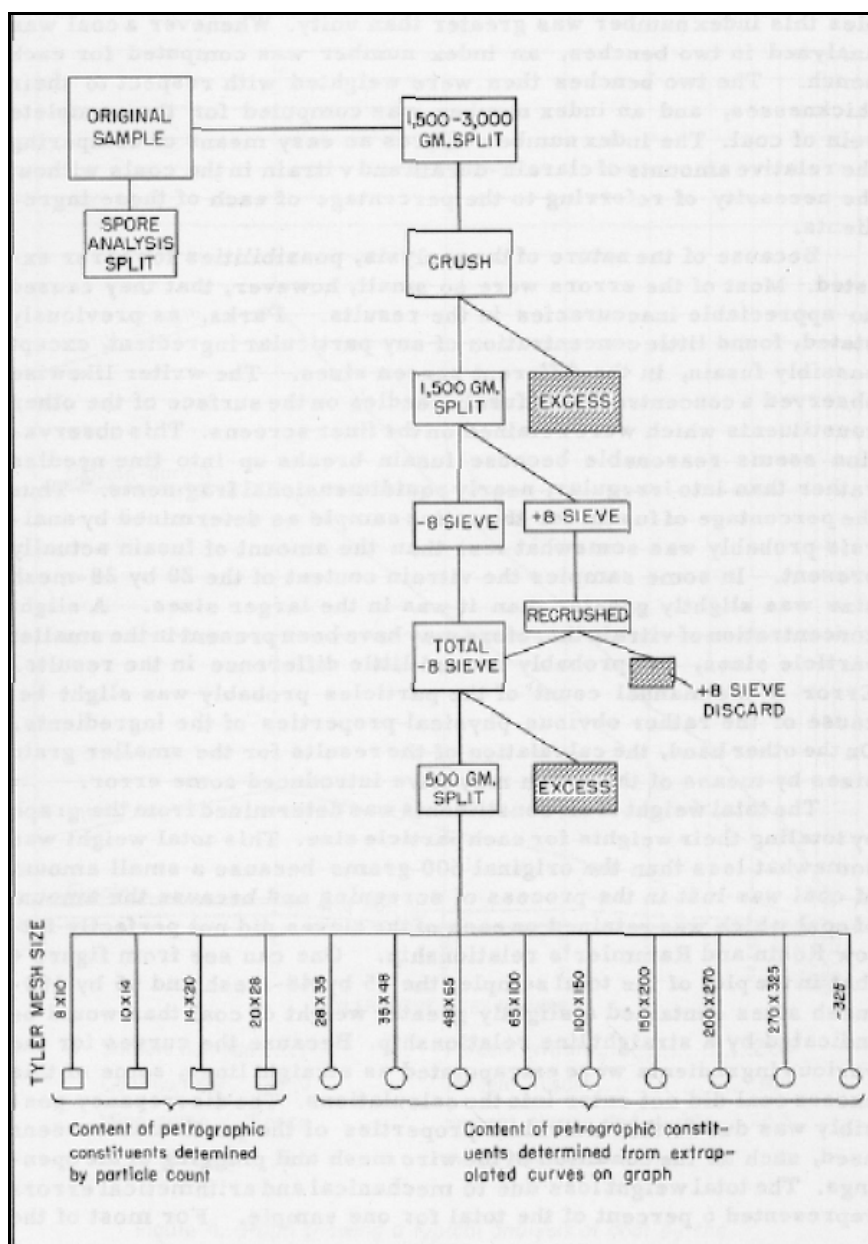
Figure 3. *Flow sheet showing the procedure used to prepare samples
of coals for analysis.*

clarain-durain content of the coal by the vitrain content. In all samples this index number was greater than unity. Whenever a coal was analyzed in two benches, an index number was computed for each bench. The two benches then were weighted with respect to their thicknesses, and an index number was computed for the complete vein of coal. The index number affords an easy means of comparing the relative amounts of clarain-durain and vitrain in the coals without the necessity of referring to the percentage of each of these ingredients.

Because of the nature of the analysis, possibilities for error existed. Most of the errors were so small, however, that they caused no appreciable inaccuracies in the results. Parks, as previously stated, found little concentration of any particular ingredient, except possibly fusain, in the different screen sizes. The writer likewise observed a concentration of fusain needles on the surface of the other constituents which were retained on the finer screens. This observation seems reasonable because fusain breaks up into fine needles rather than into irregular, nearly equidimensional fragments.[2] Thus the percentage of fusain for the entire sample as determined by analysis probably was somewhat less than the amount of fusain actually present. In some samples the vitrain content of the 20 by 28-mesh size was slightly greater than it was in the larger sizes. A slight concentration of vitrain therefore may have been present in the smaller particle sizes, but probably caused little difference in the results. Error in the manual count of the particles probably was slight because of the rather obvious physical properties of the ingredients. On the other hand, the calculation of the results for the smaller grain sizes by means of the graph may have introduced some error.

The total weight of all constituents was determined from the graph by totaling their weights for each particle size. This total weight was somewhat less than the original 500 grams because a small amount of coal was lost in the process of screening and because the amount of coal which was retained on each of the sieve a did not perfectly follow Rosin and Rammler's relationship. One can see from figure 4 that in the plot of the total sample, the 35 by 48-mesh and 65 by 100mesh sizes contained a slightly greater weight of coal than would he indicated by a straight line relationship. Because the curves for the various ingredients were extrapolated as straight lines, some of this excess coal did not enter into the calculations. The discrepancy possibly was due to the individual properties of the particular screens used, such as the condition of the wire mesh and plugging of the openings. The total weight loss due to mechanical and arithmetical errors represented 6 percent of the total for one sample. For most of the

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[2] A concentration of fusain was noted in the fines from commercial coal preparation tipples.
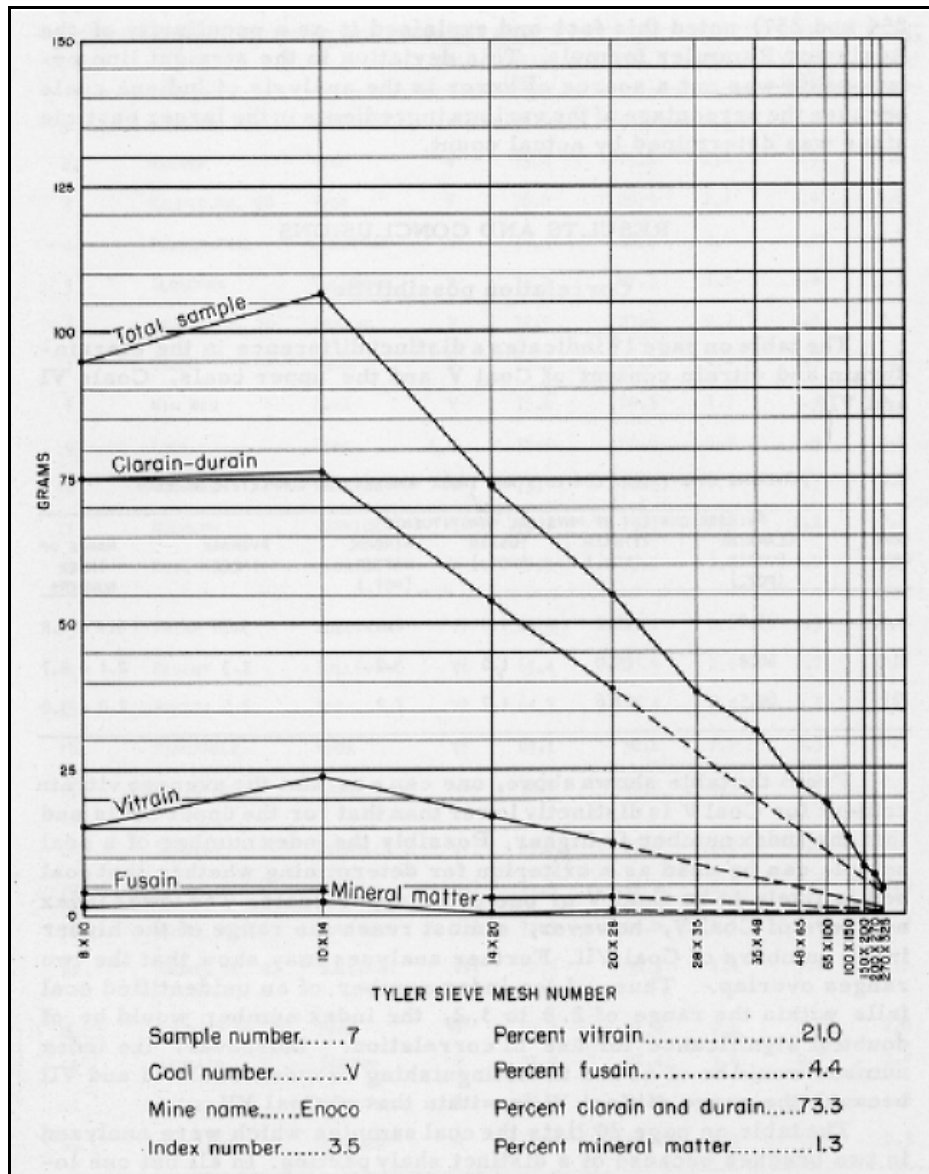
Figure 4. *Graph showing a typical analysis of coal by the particle count method.*

The largest particle sizes in all samples did not follow the straight line relationship mentioned on page 13. Geer and Yancey (1938, pp. 254 and 257) noted this fact and explained it as a peculiarity of the Rosin and Rammler formula. This deviation in the straight line relationship was not a source of error in the analysis of Indiana coals because the percentage of the various ingredients in the larger particle sizes was determined by actual count.

RESULTS AND CONCLUSIONS

Correlation possibilities

The table on page 19 indicates a distinct difference in the clarain-durain and vitrain content of Coal V and the upper coals, Coals VI and VII.

AVERAGE CONSTITUENT CONTENTS AND INDEX NUMBERS FOR COMPLETE COAL BEDS

COAL BED	AVERAGE CONTENT OF PHYSICAL CONSTITUENTS					
	CLARAIN-DURAIN (PCT.)	VITRAIN (PCT.)	FUSAIM (PCT.)	MINERAL MATTER (PCT.)	AVERAGE INDEX	INDEX NUMBERS
V	73.2	20.2	1.8	2.8	3.7	3.1 - 4.8
VI	66.8	29.0	1.0	3.2	2.3	2.1 - 2.7
VII	68.5	27.6	1.7	2.2	2.5	2.0 - 3.0

From the table shown above, one can see that the average vitrain content for Coal V is distinctly lower than that for the upper coals and that the index number is higher. Possibly the index number of a coal sample can be used as a criterion for determining whether that coal bed is likely to be Coal V or one of the upper coals. The lower index numbers of Coal V, however, almost reach the range of the higher index numbers of Coal VII. Further analyses may show that the two ranges overlap. Thus, if the index number of an unidentified coal falls within the range of 2.8 to 3.2, the index number would be of doubtful significance for use in correlation. Moreover, the index number would be of no use in distinguishing between Coals V1 and VII because the range of Coal VI is within that of Coal VII.

The table on page 20 lists the coal sample s which were analyzed in two benches because of a distinct shaly parting. In all but one locality, the upper bench had a higher vitrain content than the lower. This consistency in the relative composition of the two benches may reflect a standard environmental condition in the coal swamp.

PERCENTAGE OF CONSTITUENTS AND INDEX NUMBERS OF SAMPLES OF INDIANA COALS

SAMPLE NUMBER	NAME OF MINE	COUNTY	COAL BED	CLARAIN-DURAIN (PCT.)	VITRAIN (PCT.)	FUSAIN (PCT.)	MINERAL MATTER (PCT.)	INDEX NUMBER
I	STANDARD No. 2	VERMILLION	V	74.6	18.3	2.1	5.0	4.1
2	WABASH	VIGO	V	75.4	15.7	2.4	6.5	4.8
3	MAUMEE No. 20	VIGO	V	76.2	20.3	2.1	1.4	3.8
4	POWDER MILL	SULLIVAN	V	77.4	20.8	0.6	1.2	3.7
5	GLENDORA	SULLIVAN	V	74.7	22.7	1.0	1.6	3.3
6	MAUMEE No. 30	GREENE	V	72.9	23.6	0.7	2.8	3.1
7	ENOCO	KNOX	V	73.3	21.0	4.4	1.3	3.5
8	MIN WIN	PIKE	V	75.6	20.3	1.7	2.4	3.7
9	ENOS	PIKE	V	76.4	20.0	0.8	2.8	3.8
10	TECUMSEH	WARRICK	V	73.4	22.7	1.2	2.7	3.2
11	RUDOLPH	WARRICK	V	75.1	19.8	2.9	2.2	3.8
12	ROSE HILL	WARRICK	V	77.2	17.2	1.6	4.0	4.5
13	FRIAR TUCK	SULLIVAN	VI	68.5	29.4	0.6	1.5	2.3
14	REGENT	SULLIVAN	VI	65.4	29.9	2.0	2.7	2.2
15	SHASTA	KNOX	V1	64.7	28.4	0.4	6.5	2.3
16	PANHANDLE	KNOX	A	63.1	30.2	1.2	5.5	2.1
17	WHITE ASH	KNOX	V1	72.1	26.9	0.9	0.1	2.7
18	SUNSPOT	VERMILLION	VII	65.8	29.0	2.8	2.4	2.3
19	SUPERIOR	VIGO	VII	71.9	26.2	1.6	0.3	2.7
20	ROBIN HOOD	SULLIVAN	VII	73.5	24.8	1.1	0.6	3.0
21	MAUMEE No. 27	SULLIVAN	ViI	62.6	30.4	1.4	5.6	2.1
22	LANDREY No. I	PIKE	M¹	64.3	31.4	2.6	1.7	2.0
23	KINCAID	GIBSON	M	75.9	22.4	1.0	0.7	3.4
24	DITNEY HILL	WARRICK	M	63.4	34.0	1.1	1.5	1.9
25	SUNLIGHT	WARRICK	M	65.2	28.6	0.8	5.4	2.3

¹MILLERSBURG COAL

As shown below, the lower bench sample from the Ditney Hill mine contained more vitrain than the upper bench sample. In mining coal at this mine, the operators have had to leave a roof of good quality coal which the writer did not sample. If this coal roof has a high enough vitrain content, the complete upper bench likewise would have more vitrain than the lower bench, as analysis of the other samples indicated.

CONSTITUENT CONTENTS AND INDEX NUMBERS OF SAMPLES ANALYZED IN TWO BENCHES OF COAL

MINE NAME	COAL BED	CLARAIM-DURAIN (PCT.)		VITRAIN (PCT.)		INDEX NUMBER	
		UPPER BENCH	LOWER BENCH	UPPER BENCH	LOWER BENCH	UPPER BENCH	LOWER BENCH
MAUMEE NO. 30	V	72.3	73.2	25.5	22.6	2.8	3.2
TECUMSEH	V	75.3	72.4	23.6	22.2	3.2	3.3
FRIAR Tucx	VI	66.9	70.0	31.7	27.4	2.1	2.6
REGFNT	VI	63.7	66.5	34.5	27.0	1.8	2.5
SHASTA	VI	63.7	76.2	29.2	19.7	2.2	3.9
PANHANDLE	VI	58.6	65.6	37.4	26.2	1.6	2.5
DITNEY HILL	M	64.5	60.8	33.4	35.3	1.9	1.7
SUNLIGHT	M	64.4	70.2	29.9	20.3	2.2	3.5

MILLERSBURG COAL

Possibly some samples of doubtful correlation maybe identified on the basis of an analysis by benches rather than by analysis of the complete bed. One bench of a coal bed may be similar to a whole bed of coal elsewhere. Samples from the Kincaid and Sunlight mines illustrate this fact. Field evidence suggests that the lower bench of coal at the Sunlight mine corresponds to the entire vein mined at the Kincaid mine (Wier, personal communication). This evidence is based upon the fairly continuous tracing of the lower bench (Lower Millersburg coal) between the two mines. Although the results of spore analysis do not completely support such a conclusion (Guennel, 1952, p. 30), the results of the particle count do. The index number for the Kincaid mine is 3.4 and that for the lower bench of the Sunlight mine is 3.5. This similarity of index numbers may or may not be significant for the correlation of coals, but it is at least noteworthy.

Commercial application of data

The physical and chemical composition of the individual ingredients influences the manner in which they burn. Vitrain burns with little ash. On the other hand, clarain and durain burn with a greater amount of ash. A high content of vitrain thus is desirable in order to lessen the amount of ash that is formed when a coal is burned. Research carried on by the Illinois Geological Survey (Helfinstine and Boley, 1946, p. 29) has indicated that a high-vitrain content in coal also produces greater uniformity in its combustion. Because Coals VI and VII are notably higher in vitrain content than Coal V, they would produce less ash and burn with greater uniformity. This conclusion seems to be supported by the limited number of available analyses of Indiana coals. In general, the average ash content of Coals VI and VII is from I to 2 percent lower than that of Coal V.

If the index numbers of all samples of a specific coal bed are compared as to the location of the beds within the state, certain areas of high-vitrain content can be outlined. For Coal V, two such areas exist. The first includes Sullivan, Greene, and Knox Counties, and the second is in the northern part of Warrick County. The vitrain content of Coal VI in the northern part of Knox County appears to be higher than that of Coal VI in the southern part and is approximately the same as the vitrain content in central Sullivan County. For Coal VII, the areas of higher vitrain content are southern Vermillion County and southern Sullivan County. Most of the few available analyses of high-vitrain coals indicate a slightly lower ash content than that of low-vitrain coals.

Such high-vitrain areas may be desirable localities in which to prospect for coal because the coal from these areas would burn with greater efficiency, and because it might command a better price. The mineral matter content of the coal must be considered, however, in selecting areas of high-vitrain content. Although the proportion of vitrain to clarain-durain maybe higher at one locality than at another, the content of mineral matter also may be high enough to nullify the advantage gained by the high-vitrain content.

Further studies

A limited number of samples were analyzed, particularly in Coals VI and VII. The most significant information that was obtained from the analysis was the relative percentages of clarain-durain and vitrain in each coal. The index number, therefore, is the most accurate and satisfactory basis for comparing the coals. Further investigation is needed to determine whether correlation possibilities do exist, or whether they are merely false indications which resulted from in-

sufficient data.

As little is known about the durain content of Indiana coals, the writer suggests that further analyses should include a count of durain as a separate constituent. Combustion tests of Indiana coals should be made to determine whether enough difference in the burning qualities of the high- and low-vitrain coals exists to have any real commercial significance.

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