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CONTENTS

[The letters in parentheses preceding titles are those used to designate the chapters as separately published]

Constitution Diagrams of Pennsylvania Anthracite

GEOLOGICAL SURVEY BULLETIN 995-A

A CONTRIBUTION TO ECONOMIC GEOLOGY

CONSTITUTION DIAGRAMS OF PENNSYLVANIA ANTHRACITE

By Holly C. Wagner

ABSTRACT

Correlation of coal beds is an important but difficult task in the intensely folded and faulted anthracite fields of Pennsylvania. Results of an effort to correlate beds of anthracite in the center of the Western Middle anthracite field by the use of diagrams showing the arrangement and percentages of the internal constituents of coal are reported in this paper.

The anthracite studied is banded coal in which the bands are classified as vitrain (brilliant luster, hackly fracture), fusain (mineral charcoal), bright attrital coal (bright luster, very fine banding), dull attrital coal (dull luster, matte surface), and impure coal (all impurities included in the coal bed). Procedures in sampling coal beds, and measuring, describing, and diagramming the coal constituents are explained.

Two premises concerning the accumulation of the coal are tested: (1) that conditions prevailing during coal accumulation were widespread; and (2) that such conditions varied during the accumulation of different coal beds. Five oriented pillar samples of the Bottom Split Mammoth coal bed were collected from carefully selected sites, reassembled in the laboratory, and the internal constituents of the coal bed were measured, percentages determined, and the results plotted. Premise 1 was verified for the area studied. Premise 2 was tested by collecting four samples of the Reliance-Skidmore coal bed and the same procedure of collection and description was followed. The constitution diagrams of this bed were similar in many respects to those of the Bottom Split Mammoth coal bed. Diagrams of two other coal beds (Top Split Mammoth and Four-Foot) revealed decided differences in pattern of ingredients. Premise 2 was therefore neither verified nor disproved.

It is concluded that accumulation of coal-forming debris was generally cyclic in nature, that coal constitution diagrams are economically useful, but that further study is necessary before the usefulness of constitution diagrams as aids in correlation of anthracite can be established.

INTRODUCTION

PURPOSE OF INVESTIGATION

The study of the lithologic constituents of anthracite was undertaken by the author as a collateral investigation in connection with the mapping of the Western Middle anthracite field in Pennsylvania begun by the United States Geological Survey in September 1947. Most former surveys of Pennsylvania anthracite record only the correlation of the coal beds made individually by each of the many mining companies. These companies correlated the coals within their respective properties but often failed to make complete correlation with adjoining properties.

Early in the present survey it was recognized that the correlation of coal beds from mine to mine and field to field throughout the anthracite region would be an important contribution from both scientific and economic points of view. The reports of the survey would not be complete without such correlations, which, in themselves, might uncover anthracite reserves that were formerly unsuspected because of faulty correlation of the coal beds. The lithologic study of coal was undertaken in the hope that it would aid in the correlations.

ACKNOWLEDGMENTS

The author wishes to express his sincere appreciation to H. E. Rothrock, Chief of Party, Pennsylvania Anthracite Project for the laboratory facilities provided under his auspices and encouragement given. He wishes also to acknowledge the many courtesies extended by personnel of the Philadelphia and Reading Coal and Iron Company, without whose permission to collect samples in the mines and help in the selection and location of accessible sites for sampling, the study would have been virtually impossible. Credit for suggestion of the study and instruction in methods of investigation is hereby acknowledged to J. M. Schopf of the U. S. Geological Survey. Assistance in collection of samples by B. R. Haley, H. H. Arndt, and J. R. Houston of the U. S. Geological Survey is also acknowledged.

COAL-CONSTITUTION STUDIES

PREVIOUS WORK

Use of the microscope on thin sections of coal was first reported in 1833 by Henry Witham and William Hutton, whose reports constitute the first investigations on the internal constitution of coal. During the next 15 years many important observations on coal ingredients were made and recorded through use of the microscope the most noteworthy of which were reports by Goeppert, Link, Rogers and Darwin on the vegetable nature of coal and the origin and nature of "mother of coal" (fusain) (see Stopes and Wheeler, 1924, pp. 179–180). Many of the earliest investigations dealt with anthracite and included articles by Bunker (1833, pp. 172–173), Bailey (1846, pp. 407–410) and Teschmacher (1847, pp. 86–90).

Except for work by Wethered (1885, p. 406) involving the separation of the different layers of a single coal bed and their separate examination, little notable work in the field of coal constitution was done during the next 50 years. Early in the 1900's, however, several coal-constitution studies were undertaken almost simultaneously in both Europe and America and, during the first 25 years of the 20th century, coal petrology and petrography became a science. The most important contributions during this period were made by Thiessen, White, Fieldner, and Sprunk in America, by Stopes, Jeffrey, Lomax, and Hickling in England, by Grand Eury in France, and by Potonie and Winter in Germany (Stopes and Wheeler, 1924, pp. 179–184, 196–200; Horton, Randall, and Aubrey, 1944, pp. 65–80, 100–109). During this period the detailed and involved coal-constitution terminology developed.

In 1930, a study of anthracite, somewhat similar to the present investigation, was reported by Turner (1930, pp. 104–107) in which about 300 pillar samples of different coal beds were collected. Each sample was sawed perpendicular to the laminations with a hack-saw, and after the face was smoothed with an abrasive wheel, the banding was brought out by charring the smooth face. Study of the banding revealed that there were variations in ingredient materials from the top to the bottom in each bed and that these variations were the same for each bed and different for different beds.

Constitution studies of coal have continued to increase in importance during the second 25 years of the 20th century largely through the efforts of the above-mentioned early workers and also such later workers as Cady, Lowry, McCabe, Dapples, and Schopf in America, and Lessing, Raistrick, Roos, Seyler, Mott, Duparque, Stach, and Marshall in Europe. Coal-constitution terminology developed further and many of the original difficulties were eliminated.

TERMINOLOGY OF COAL CONSTITUENTS

The first terminology designed to include all the ingredients of banded coal was published in England in 1919 by Dr. Marie C. Stopes (1919, pp. 470–487). At that time she presented to coal scientists her four visible ingredients of banded bituminous coal—vitrain (brilliant bands), clarain (bright bands), durain (dull bands) and fusain (mineral charcoal bands). Contemporaneously, Dr. Reinhardt Thiessen in America was preparing a report in which he proposed a nomenclature for coal also designed to cover all the constituents (Thiessen, 1920, pp. 185–209). Thiessen recognized the presence of mineral charcoal (fusain) and broke down the remainder of banded coal into anthraxylon (bright coal) and attritus (dull coal). The two terminologies were immediately controversial because Stopes' was designed for megascopic study and Thiessen's was genetic in approach and necessarily mainly microscopic in application. Also, the visual differences effected by the banding of the coal were in conflict, for neither the bright nor the dull ingredients of the two terminologies were correlatives. This was revealed in 1929 when Thiessen and Francis (1929, pp. 23–27) reported that anthraxylon (bright coal) was essentially the same as vitrain (brilliant bands) and that attritus (dull coal) was the same as clarain (bright bands). They also determined that mineral charcoal was fusain and stated that durain had no counterpart in American coals. The following year, however, Thiessen (1930, pp. 645–646) published a report showing that the splint coal in America is the correlative of British durain.

In the meantime coal investigators in Germany had devised still another terminology which consisted of glanzkohle, mattkohle, and faserkohle. Glanzkohle is the equivalent of the British vitrain and clarain and the American bright coal; mattkohle is the equivalent of the British durain and the American splint coal; faserkohle is the equivalent of fusain (see Turner and Anderson, 1931, p. 263; Thiessen, 1930, pp. 644–645; and Winter, 1924, p. 134). Nomenclatorial correlations were successful from a megascopic standpoint but a few differences still remain regarding certain microscopic characteristics of some coal constituents. General agreement in terminology was reached in 1935 when the Second International Congress for the Study of the Stratigraphy of the Carboniferous Rocks adopted Stopes' nomenclature with only slight modification (Jongmans and others, 1936, p. 15).

Stopes' terminology was specifically stated to apply only to coals of bituminous rank and therefore the terminology advocated by J. M. Schopf (unpublished field manual) for use by U. S. Geological Survey personnel is followed in this report.

DEFINITIONS OF TERMS USED IN THIS REPORT

The anthracite studied in this report falls into the category of banded-coals which are coal beds made up of alternating bands of coal material that reflect light with different degrees of brightness. (See pls. 1–4.) This characteristic of banded coals is apparently closely related to the degree of maceration and type of plant material and to the percentage of included mineral matter; the greater the amount of complexly broken and digested plant material and foreign mineral matter, the lower the reflective power of the coal band.

VITRAIN

Vitrain is the most brilliantly reflecting coal ingredient in anthracite. (See pls. 1, 2*A*, and 4*A*.) It has a jetlike appearance similar to obsidian or dark-colored broken glass, a brilliant, vitreous luster, and often breaks to a hackly surface. Vitrain occurs generally as thin (1–6 millimeters) bands within a duller matrix material, but may itself be a thick unit (as much as 200 millimeters) with only a few bands of other ingredients within it. When thin, the vitrain bands are usually short lenticular bodies that taper at one or both ends (see pl. 4*A*), although in some instances they extend for long distances. Thick bodies of vitrain, because of the inherent brittleness of the material, usually are considerably jointed or cleated (see pl. 1) and many times break to conchoidal fracture surfaces that reflect light in oval shapes giving rise to the common augen or eye structure. (See pl. 2*A*.)

In measuring sections, vitrain bands less than one-half millimeter (1/50 inch) in thickness were not recorded separately but were included as part of the enclosing bright or dull attrital coal.

FUSAIN

Fusain is a minor constituent of the coal beds sampled. In the samples used in the study, fusain consists of thin (1–4 millimeters) lenticles of dull, porous, friable material that looks much like charcoal and powders readily. Separated fragments can sometimes be seen on bedding (or banding) planes but are usually seen only as short lenses of fusain on faces that crosscut the bedding. Not more than 30 millimeters of fusain was found in any one coal sample used in the study. In general the fusain occurred near the base of the coal beds.

ATTRITAL COAL

Bright attrital coal, as used in this report, refers to the coal constituent that reflects light with considerable brightness but not with the brightness of vitrain. (See pl. 2*B* and 3.) It usually breaks to a relatively smooth, bright, shiny face, that in some places is nearly as bright as vitrain, but within which a few thin lenticles of vitrain can always be found.

As the bright attrital coal decreases in brightness, very fine banding within this constituent becomes more apparent until the dull bands become broader and the luster duller (see pl. 2*B* and 3). The brightness of this coal constituent is variable within limits but never is its luster so dull as that of the dull attrital coal nor is it ever so brilliant as the brilliant luster of vitrain.

Dull attrital coal is the coal ingredient in which the surface appearance to the naked eye is smooth matte to very finely granular, and grayish. (See pl. 4.) It is hard, tough, and compact, breaks to a more or less even surface, and usually contains thin interlaminated lenses and small flecks or chiplike fragments of vitrain scattered through it (see pl. 4*A*).

IMPURE COAL, BONE, AND OTHER IMPURITIES

As the coal material becomes more granular in appearance and loses its homogeneous dull-gray luster, it usually develops a slightly coruscate, grainy, dark-gray appearance. This material constitutes the impure coal of this report, and grades through nearly black carbonaceous claystone (bone) to light-gray carbonaceous claystone. This latter material was in very small amount.

Ironstone concretions and disseminated pyrite occur in nearly all the samples studied but are only local in extent and minor in amount.

METHOD OF STUDY

GENERAL STATEMENT

On a brief visit to the Pennsylvania Anthracite Project in 1948, J. M. Schopf, geologist U. S. Geological Survey, instructed the author in the method of coal-bed description used in this study. Schopf collected two complete pillar samples of the Four-foot coal bed from sites about 400 feet apart at the Monitor Stripping, Locust Spring mine, about 2 miles southwest of Mount Carmel, Pa. (fig. 1). He then measured and recorded the thicknesses of the banded ingredients of the coal bed and plotted the results into diagrams. The diagrams, shown in the lower half of figure 2*A*, were similar and it was decided that this method of correlation of coal beds should be further tested in anthracite.

In order that the internal constituents of coal beds may be useful for correlation purposes certain conditions must be satisfied: the various constituents of the coal must maintain approximately the same position in the coal bed over areas of wide extent so that the pattern of the constitution diagram remains constant throughout the area, and the upward arrangement of the constituents in the coal bed must differ in each, or at least several, coal beds so that the constitution diagram of the bed is different from diagrams of other beds, and thus is diagnostic for that particular bed. Such an arrangement of constituents is possible only if conditions propounded in the two following premises are valid: (1) that the conditions (climatic, botanical, chemical, geological) that prevailed during deposition of any one coal bed varied similarly throughout a large part of the area of deposition of the coal bed, and (2) that these conditions varied differently during the deposition of other coal beds. It is recognized that variations within a basin of deposition would occur but it is believed that such variations would generally be gradual and would be reflected in the constitution diagrams of a properly located series of samples, and thus permit correlation of beds far beyond an area of nearly identical diagrams.

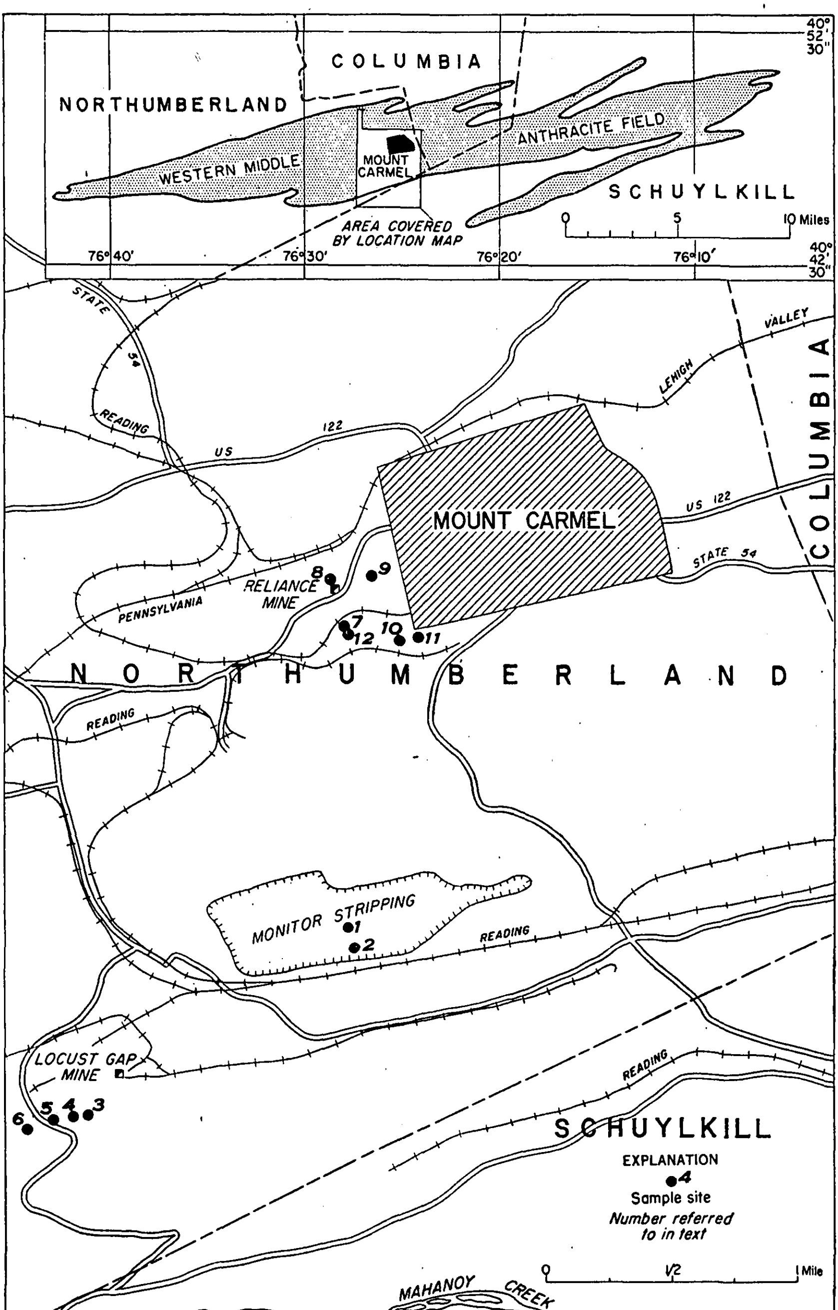


FIGURE 1.—Index map showing location of sample sites.

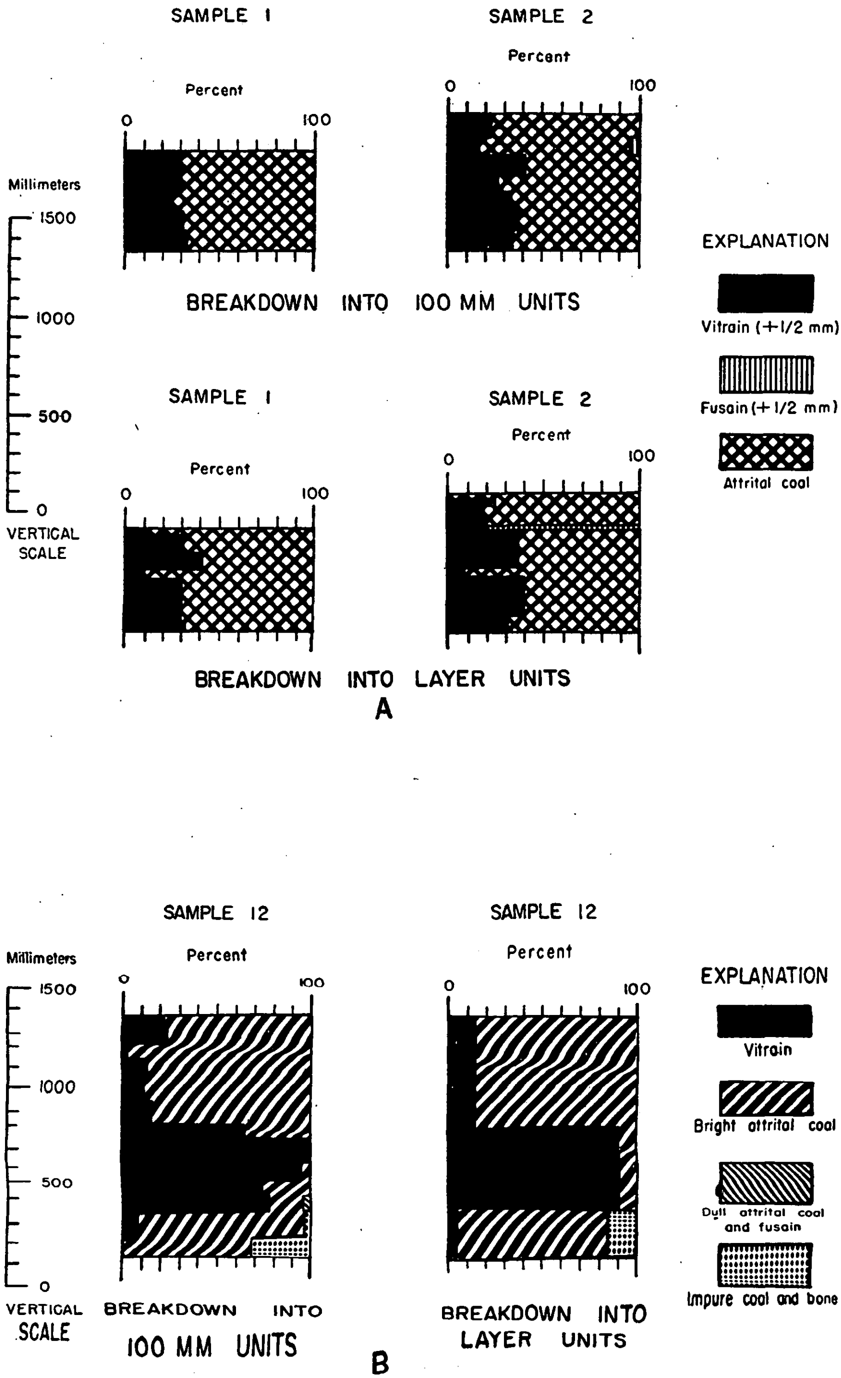


FIGURE 2.—Composite constitution diagrams of coal samples. *A*. Four-foot coal bed. *B*. Top Split Mammoth coal bed.

SELECTING THE SAMPLE SITES

In order to test the lateral continuity of the internal constituents of anthracite the Bottom Split Mammoth coal bed of middle Pennsylvanian age was selected for study and the West Bottom Split Mammoth gangway, 6th lift (elevation approximately 270 feet), in the Locust Gap mine was chosen as the sampling area. In this gangway the coal bed was but little fractured, was of relatively constant thickness, and was accessible to samplers for a distance of one-half mile along the strike of the bed. Six samples were taken but, unfortunately, two were damaged beyond use during removal to the laboratory.

Each sample site along the gangway was selected where the coal face was fairly clean, no portion of the bed was minutely sheared or fractured, and the thickness of the coal was constant for several feet in both directions away from the site.

DETERMINING THE LAYER UNITS

Layer determination consisted of the breaking down of a coal bed into gross visual units on the basis of luster variation, type and amount of coal-bed impurity, and diversity of cleat- or joint-spacing, after first cleaning the coal face with a stiff-bristle brush. These units were generally kept greater than 2 inches in thickness; units smaller than that, unless they were of distinctly different material (such as interbedded claystone), were incorporated with the enclosing type of material. Determination of layers involves a certain amount of selectiveness, and considerable experience is necessary for accurate work.

After the layer boundaries had been carefully determined, they were marked on the coal with an orange wax pencil and the layer units were measured, described and recorded. The layer unit descriptions, the total thickness of the coal bed, and the character of the "bottom-rock" and "top-rock" comprised the field description of the coal bed. Removal of the block samples from the coal face, preparatory to removal to the laboratory, followed the layer determination.

SAMPLING THE COAL BED

A coal bed was sampled by removing contiguous blocks from the coal face, from the top of the bed downward. Jointing that was not closely spaced considerably facilitated the sampling but made sampling upward in the bed hazardous because overlying (supported) blocks would have been dislodged prematurely and the continuity of the sample interrupted. Block samples, as large as could be taken from the coal face, were removed singly and each was taped and marked prior to removal of the next block. Two thin chisels made from files were very valuable instruments in the removal of some of the tightly wedged blocks, for the chisels could be inserted into the joint cracks and the blocks removed by rotating the chisels alternately.

As each block was removed, care was taken to keep it properly oriented and adhesive tape was applied, perpendicular to the banding, completely around the specimen so that one end of the tape stuck to the other end. Half-inch tape was adequate on blocks that were solid and unfractured but many blocks that were only slightly fractured prior to removal developed fractures immediately upon removal and it was necessary to use 1- to 2-inch tape on them. Orientation was accomplished by marking an arrow pointing upward on the adhesive tape in ink, along with a consecutive block number and the sample number. (See pl. 5.) It was found advisable always to mark the position of the bottom of the preceding block on the adhesive tape of each succeeding block. This practice was necessary when the blocks overlapped, so that no duplication of the bed occurred, and it also served to identify blocks when the numbers elsewhere on the tape became smudged. When blocks overlapped, a separate ingredient band was traced laterally from one block to the next, prior to removal from the coal face, and a mark was made with the orange wax pencil on the coal. This mark was transferred to the adhesive tape when the block was removed and taped.

All material encountered between the "top-rock" and "bottom-rock" of the coal bed (coal, impure coal, bone, carbonaceous claystone, ironstone concretions) was included in each pillar sample. When sampling was completed, the entire sample was removed to the laboratory and described.

DESCRIBING SAMPLES

All samples were described in detail in the laboratory under the same lighting conditions, which consisted of two gooseneck lamps. The blocks comprising each sample were arranged on a bench in the correct relationship one to another, care being taken that the "up" arrow always pointed to the top of the bed (to a lower-numbered block), that the numbers were consecutive, and that the bottoms of all blocks, marked on the adjacent block, agreed. A stiff-bristle brush was used on each block; every face of the block was brushed thoroughly and rotated until the face showing the banded constituents to best advantage was determined. If no face showed the features clearly, or only portions of a face were clear, a sharp, chisel-point hammer was used to prepare a fresh face. Usually, however, one face of the block was clear and the selected face was carefully examined and the banded ingredients were measured perpendicular to the banding and recorded. The faces of all coal samples shown in the plates in this report are natural faces.

Data were recorded in millimeters (mm), thus obviating use of fractional numbers. The lower limit of recorded data was arbitrarily set at 1 mm. Vitrain lenticles less than 1 mm in thickness but greater than ½ mm in thickness were recorded as 1 mm and attempts were made to average out thicknesses of vitrain shown in any one block. Because of the lenticular nature of the vitrain (see pls. 2*B* and 4*A*) it was felt that such generalizations did not seriously affect the observations. Vitrain lenses less than ½ mm in thickness were not recorded separately but were included as part of the attrital coal in which they occurred. Fusain was treated in the same manner as vitrain.

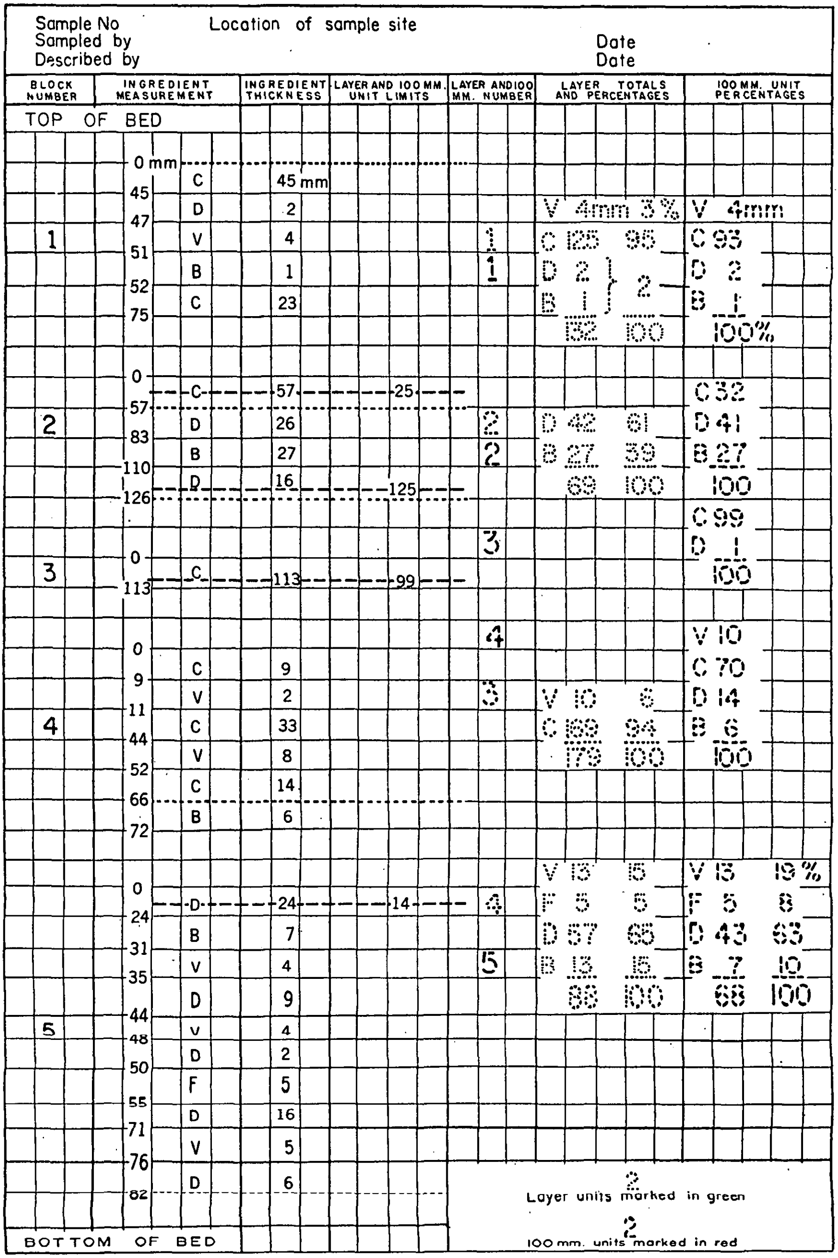
Each block was recorded as a separate unit, and the measurements of constituents of the block were recorded as a continuous series of numbers. Thicknesses of the different constituents were obtained by subtraction. It was found expeditious in recording data to use letter symbols for the coal constituents; thus, V=vitrain, C=bright attrital coal, D=dull attrital coal, F=fusain, B=bone and impure coal, and other letter symbols as needed. The method of recording the data in the notebook is shown in figure 3.

PLOTTING DATA

Following the laboratory description the thickness totals of the blocks were added together and checked to see that they agreed with the total thickness of the coal bed, as recorded in the field. Layer units of each sample, as determined in the mine, were transferred to the laboratory notes and the limits marked in green pencil. The laboratory notes were then examined and a further layer-unit breakdown was made where the more detailed examination showed definite differences in the concentration of the coal constituents.

Each coal constituent was then totaled for each layer unit and percentages determined. Constitution diagrams for each coal constituent were prepared by plotting percentages of ingredients from left to right and the layers horizontally from bottom to top of page. Fusain was so small in amount that it was included with the dull attrital coal in these diagrams. Impurities, such as ironstone concretions, and carbonaceous claystone were included with the impure coal and bone.

Similar diagrams were prepared for all the samples described, and a comparison of the vitrain constitution diagram was made. (See lower part of pl. 6*A*.) The vitrain diagrams contained certain similarities of form, as did those of other major constituents. (See pl. 6*B* and *C*.) Comparison of the constitution diagrams was made somewhat difficult by variations in thickness of layer units. This factor, combined with the fact that different persons made different layer unit determinations, influenced the author into attempting a breakdown of the coal bed into units of the same thickness. Thickness



Sample No Location of sample site
Sampled by Date
Described by Date

BLOCK NUMBER	INGREDIENT MEASUREMENT		INGREDIENT THICKNESS	LAYER AND 100 MM. UNIT LIMITS	LAYER AND 100 MM. NUMBER	LAYER TOTALS AND PERCENTAGES	100 MM. UNIT PERCENTAGES
TOP OF BED							
	0 mm						
		C	45 mm				
	45						
		D	2			V 4mm 3%	V 4mm
	47						
1		V	4		1	C 125 95	C 93
	51						
		B	1		1	D 2 } 2	D 2
	52					B 1	B 1
		C	23			132 100	100%
	75						
	0						
		C	57	25			C 32
	57						
2		D	26		2	D 42 61	D 41
	83						
		B	27		2	B 27 39	B 27
	110						
		D	16	125		69 100	100
	126						
							C 99
	0				3		D 1
3		C	113	99			100
	113						
	0				4		V 10
		C	9				C 70
	9						
		V	2		3	V 10 6	D 14
	11						
4		C	33			C 169 94	B 6
	44						
		V	8			179 100	100
	52						
		C	14				
	66						
		B	6				
	72						
	0					V 13 15	V 13 19%
		D	24	14	4	F 5 5	F 5 8
	24						
		B	7			D 57 65	D 43 63
	31						
		V	4		5	B 13 15	B 7 10
	35						
		D	9			88 100	68 100
	44						
5		V	4				
	48						
		D	2				
	50						
		F	5				
	55						
		D	16				
	71						
		V	5				
	76						
		D	6				
	82						
BOTTOM OF BED							

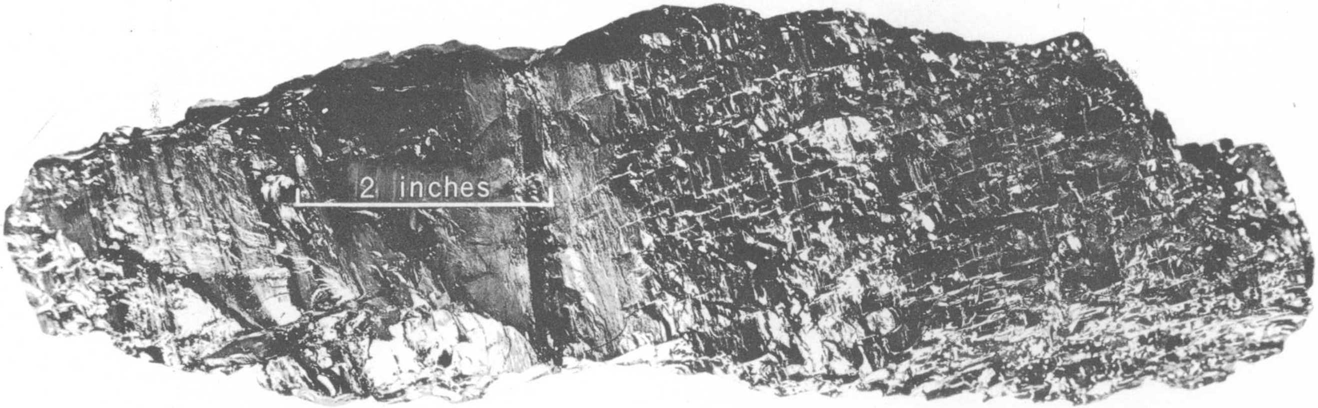
2
Layer units marked in green

2
100 mm. units marked in red

FIGURE 3.—Sample page from notebook showing method of recording data.

EXPLANATION OF PLATE 1

Vitrain comprises the right half of specimen (note how jointing is confined to this constituent).; dull attrital coal comprises the right part of the left half (note how the vitrain band cuts across the dull attrital coal) ; and bright attrital coal comprises most of the left part of the left half (note the very fine banding in this constituent).



COAL CONSTITUENTS IN BANDED ANTHRACITE

units of 25, 50, 100, and 200 mm were tried and it was found that breakdowns into units of 25 and 50 mm made curves of the ingredient percentages in the diagrams rather than definite breaks at certain definite boundaries; much detail was lost in the 200-mm-unit breakdown. The 100-mm-unit breakdown seemed to show the more salient features of the coal constituents and at the same time had the advantage of eliminating percentage calculations. Therefore, of the equal-interval-unit breakdowns, the 100-mm unit was chosen. In the notebook, starting from the bottom of the sample (the top could just as well have been used), limits of 100-mm units were calculated and marked off in red pencil with the 100-mm-unit limit figure noted on each red division line, and the ingredient totals per 100-mm-unit division recorded near the right side of the page. (See fig. 3.) These units were then numbered consecutively and plotted (pl. 6*A*, *B*, and *C*).

The form similarities shown in the constitution diagrams prepared for each separate ingredient were not decisive and certain coal-constituent combinations were plotted. The attrital-coal diagrams (pl. 6*D*) were somewhat similar for the different samples, but not until the vitrain-plus-bright-attrital-coal diagram (pl. 6*E*) was made did similarities of outline of the percentages form a diagnostic pattern. The vitrain-plus-bright-attrital-coal diagrams were used, therefore, in attempts at correlation.

Composite constitution diagrams of the samples (pl. 6*F*) were prepared by plotting all the coal constituents into one diagram. The constituents were plotted by layer units and 100-mm units separately, with the brightness of the coal type decreasing to the right; vitrain was plotted at the left and bright attrital coal, dull attrital coal, and impure coal and bone were plotted progressively to the right.

BOTTOM SPLIT MAMMOTH COAL BED

CORRELATION DISCUSSION

Comparison of the vitrain-plus-bright-attrital-coal constitution diagrams for samples 3, 4, 5 and 6 (pl. 6*E*) from the Locust Gap mine showed such decided similarities of form that the validity of the first premise propounded on page 6—that conditions prevailing during deposition of a given coal bed were similar throughout much of the area of deposition—seemed to be established for the area studied. Therefore, the study was extended about 2 miles northeast, to the Reliance mine, and another sample of the Bottom Split Mammoth was taken.

The Reliance Bottom Split Mammoth sample (sample 7) was taken in a test slant off the No. 4 Underground Slope, 4th lift (elevation 884 feet), in the Reliance mine. Methods of sampling, describing, and plotting of sample 7 were the same as those for samples 3 to 6, inclusive. Similarity in form of the diagrams continued although this similarity was not quite as pronounced as in the Locust Gap mine samples. Variation in coal constituents, such as the impure coal and bone in place of dull attrital coal in the center or the coal bed, suggests changing environmental conditions at the coal-accumulation site. In general, however, the conditions under which the Bottom Split Mammoth coal bed accumulated were essentially the same throughout the area studied. A general description of this coal bed, based upon the megascopic observations, follows in the next section.

DESCRIPTIVE SUMMARY

The Bottom Split Mammoth coal bed, in the area sampled, is banded anthracite about 8 feet in thickness. The uppermost foot of the Bottom Split Mammoth coal, missing in some samples, is mainly bright attrital coal with a few interlaminated vitrain bands from ½ millimeter (1/50 inch) to 5 millimeters thick. Dull attrital coal and impure coal and bone become abundant in the lower 4 inches of this unit and grade downward into about 3 inches of dull attrital coal. Below this layer is a thin unit consisting of about a foot of nearly pure bright attrital coal in most samples but containing considerable vitrain and impure coal and bone in others. A 7- to 10-inch unit, consisting mainly of dull attrital coal and impure coal (with many interlaminated vitrain lenses as shown in plate 4*A*) underlies the bright attrital coal unit and is followed downward by almost 2 feet of very bright coal composed of about 75 percent bright attrital coal and 25 percent thin interlaminated vitrain in which a few interbeds of dull attrital coal and impure coal occur.

A 10-inch layer of dull attrital coal, largely impure coal in sample 7, occurs immediately below this very bright unit and is underlain by the lowest 3 feet of the coal bed, which consists mainly of bright attrital coal and vitrain. Vitrain bands are more abundant and thicker in this lowest portion of the Bottom Split Mammoth than elsewhere in the coal bed and, in places, make up more than 80 percent of the coal, as is shown by the constitution diagrams of plate 6*F* (upper part of this lower unit in samples 3, 5, and 6 and lower part of sample 7). The vitrain-rich layer may be as much as a foot in thickness with only thin bands of attrital coal or impure coal and bone included. In some places sampling was difficult in this lowest unit because of the friability and cleating inherent in vitrain. A few thin fusain lenticles were noted about 2 feet above the base of the coal bed in most samples.

RELIANCE-SKIDMORE COAL BED

In order to test the premise that conditions of accumulation of each, or at least several, of the coal beds would vary, with a consequent difference in the vertical arrangement of the coal constituents, four samples of the Reliance-Skidmore coal bed were collected in the Reliance mine. Samples 8 and 9 were taken along the Skidmore East Gangway, 8th lift (elevation approximately 240 feet), at sites about 900 feet apart. Samples 10 and 11 were taken along the Skidmore Gangway 32, 4th lift (elevation 849 feet), and the Skidmore Gangway 33, 4th lift (elevation 848 feet), respectively. The greatest distance between these four samples is that between samples 8 and 11, a distance of about one-half mile. Samples 8 to 11, inclusive, were obtained, described and plotted in the same manner as the previous samples.

CORRELATION DISCUSSION

Inspection of the coal-constitution diagrams of the individual constituents of the Reliance-Skidmore coal bed (pl. 7*A*, *B*, and *C*) reveals no decided predominance of percentages of any one type over the percentages of that same type in the Bottom Split Mammoth samples. Furthermore, a comparison of the diagram of total attrital coal (pl. 7*D*) and that of vitrain plus bright attrital coal from the Reliance-Skidmore coal bed (pl. 7*E*), and the upper part of similar diagrams of the Bottom Split Mammoth coal bed (pl. 6*D* and *E*), reveals considerable similarity. The same statement is true of the composite diagrams of plates 6*F* and 7*F*. Abnormal thickening of one bed, or thinning of the other, would make correlation by use of these diagrams extremely hazardous. Thus, the validity of the premise that depositional conditions varied from one bed to another is not proven by the Reliance-Skidmore samples. The following detailed description of the Reliance-Skidmore coal bed is based upon observations of the internal constituents in the four samples from the Reliance mine.

DESCRIPTIVE SUMMARY

The Reliance-Skidmore coal bed is about 5 feet in thickness where sampled. The uppermost 30 inches consists of an upper 6-inch layer of interbedded vitrain and bright attrital coal that is separated from a similar 12-inch unit below by about a foot of coal that is largely dull attrital coal, impure coal, and bone. The lower part of this upper unit is mainly bright attrital coal with a few vitrain lenses as much as 1½ inches thick and one or two thin lenses of fusain.

The upper 15 inches of the lower half (30 inches) of the coal bed comprises a series of 2- to 5-inch alternating bright and dull layers; the bright layers are made up of vitrain and bright attrital coal and the dull layers of dull attrital coal and impure coal. This unit is underlain by about 10 inches of bright attrital coal in which thick vitrain bands are sometimes prominent in the basal portion. Fusain lenses occur locally near the top and base of this unit. About 4 inches of impure coal or 2 inches of dull attrital coal underlies this thick bright unit which is followed downward by the basal 2 to 5 inches of the Reliance-Skidmore coal bed. This basal unit is not present in sample 8 but in the other samples consists mainly of bright attrital coal with minor vitrain interlaminated.

TOP SPLIT MAMMOTH COAL BED

At the time that the Bottom Split Mammoth coal bed was sampled in the test slant at the Reliance mine (elevation 884 feet), a sample (sample 12) was taken of the Top Split Mammoth coal bed. The two splits were separated by only about a foot of carbonaceous claystone at this location but this interval increases to as much as 100 feet laterally (see Rothrock and others, 1951, sheet 3).

CORRELATION DISCUSSION

A composite constitution diagram of sample 12 (fig. 2*B*) is the only diagram included in the report because it is sufficient to show the distinctiveness of the constituent percentages of this coal bed. The composite constitution diagram shows that the combined ingredients of vitrain plus bright attrital coal cover practically the entire diagram. This is quite different from other diagrams, all of which had reentrants in the diagrams caused by increases in the dull attrital coal, impure coal, and bone constituents.

DESCRIPTIVE SUMMARY

Inspection of sample 12 shows that the Top Split Mammoth coal bed is essentially a bright coal that can be divided into three distinct units: (1) an upper unit that is nearly 2 feet thick and consists mainly of bright attrital coal with thin interlaminated vitrain, (2) a central unit consisting of about 20 inches of brilliantly lustrous, closely jointed or fractured coal (vitrain) with a few thin fusain lenticles near the base and a very minor amount of bright attrital coal interlaminated, and (3) a lower foot-thick unit consisting mainly of bright attrital coal with minor impure coal and bone near the base.

CONCLUSIONS

Lateral continuity and persistence of the different coal constituents in two different coal beds (Bottom Split Mammoth and Reliance-Skidmore) were tested and established in the area studied. Small changes in some constituents suggest that over larger areas important changes in constituent content may occur. In those cases, however, constitution diagrams of properly spaced samples of the coal bed should reflect the lateral changes, a trend could be established, and correlation of coal beds in extensive areas might be made.

Constitution diagrams of two of the coal beds sampled (Top Split

Mammoth and Four-foot) have distinctive patterns which apparently can be used to aid in correlation. The diagrams of the two more extensively tested coal beds (Bottom Split Mammoth and Reliance-Skidmore), however, are similar to one another in many respects and correlation of these beds by use of the diagrams would be difficult. The results of this study are not conclusive and suggest that generalizations concerning the value of the method for coal-bed identification should be avoided until the method is tested further.

Inspection of certain constitution diagrams (pls. 6*B*, *C*, *E*, and 7*B*, *C*, *E*) shows a definite pattern of extensions and reentrants in the percentages of constituents. This pattern may reflect cyclic changes in environmental conditions that prevailed during accumulation of coal-forming debris.

Constitution diagrams have economic importance to coal operators and coal processors in that they yield data regarding the amounts of the various constituents in coal beds. Coal operators can advantageously utilize this information because mining costs and mining methods in many cases may be affected by the internal constitution of the coal bed. A bed high in vitrain will respond more readily to cutting and shooting, but will produce a greater number of fine-sized particles (McCabe, 1942, p. 407); thus, the cost of mining is reduced but the market value of the coal is also reduced.

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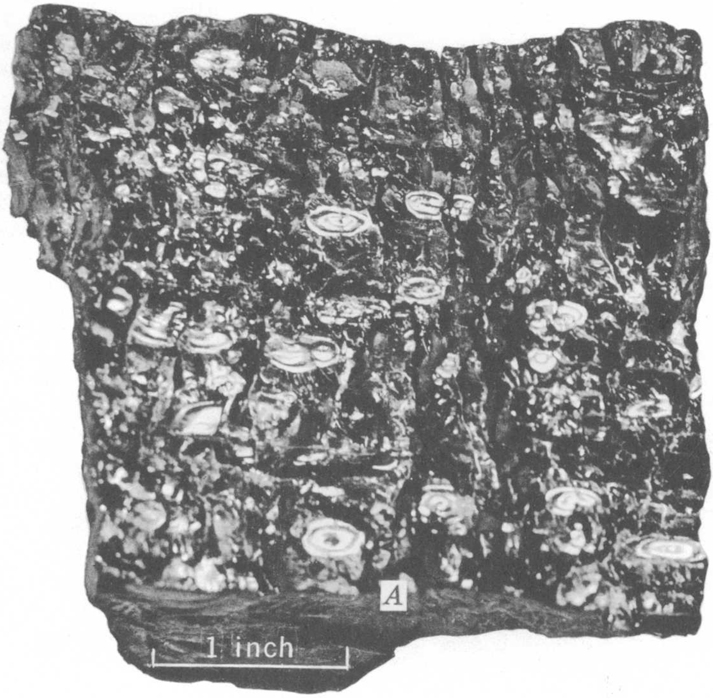
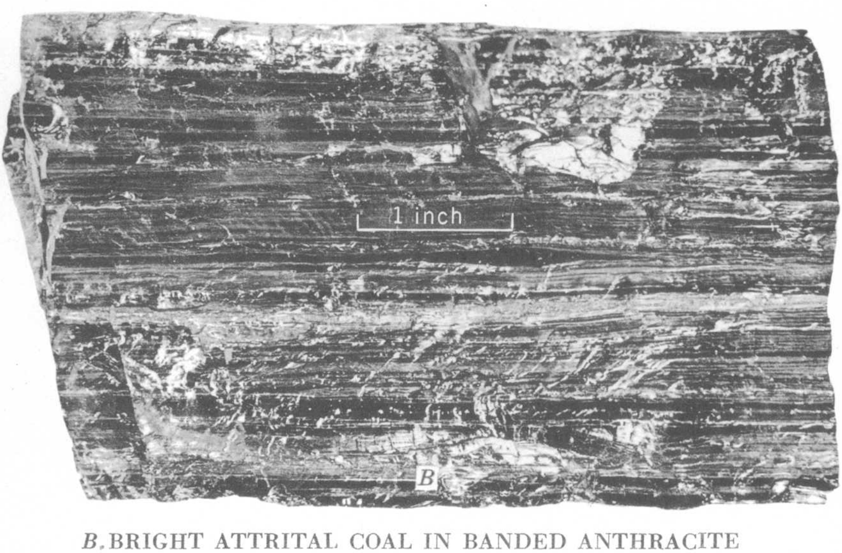


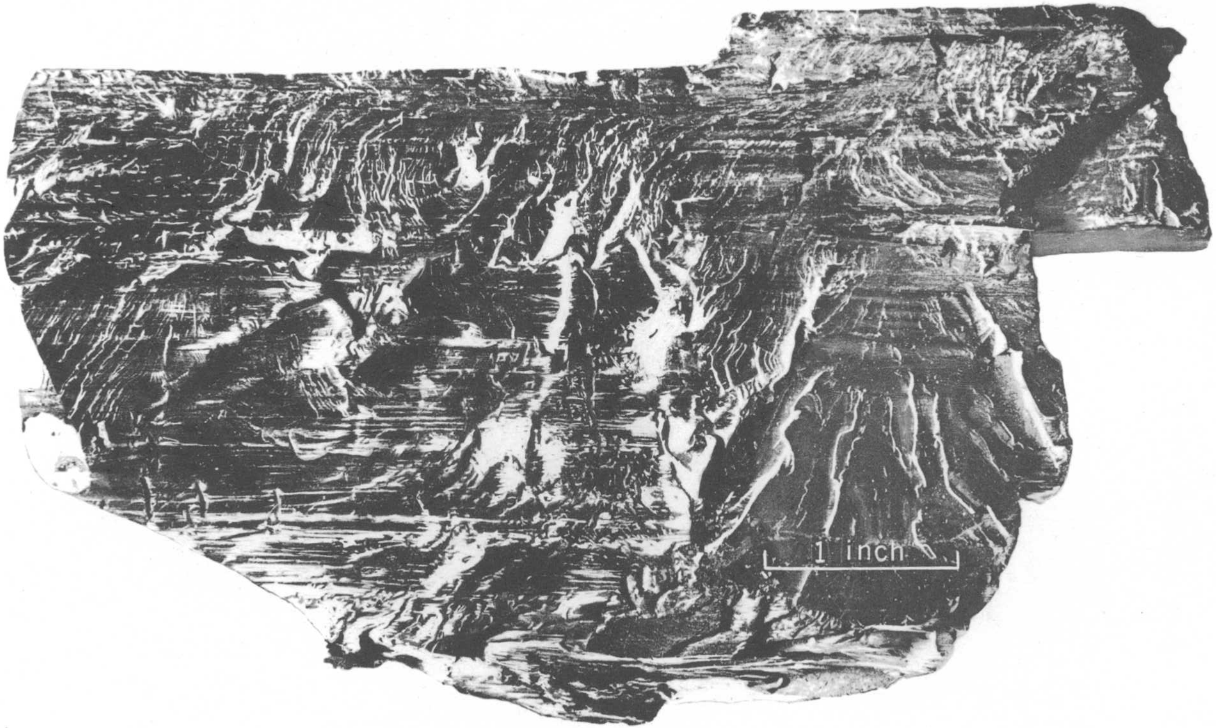
A. VITRAIN IN BANDED ANTHRACITE

Specimen shows very irregular (hackly) surface of the block, pronounced jointing, and well-developed "eye" (augen) structure.



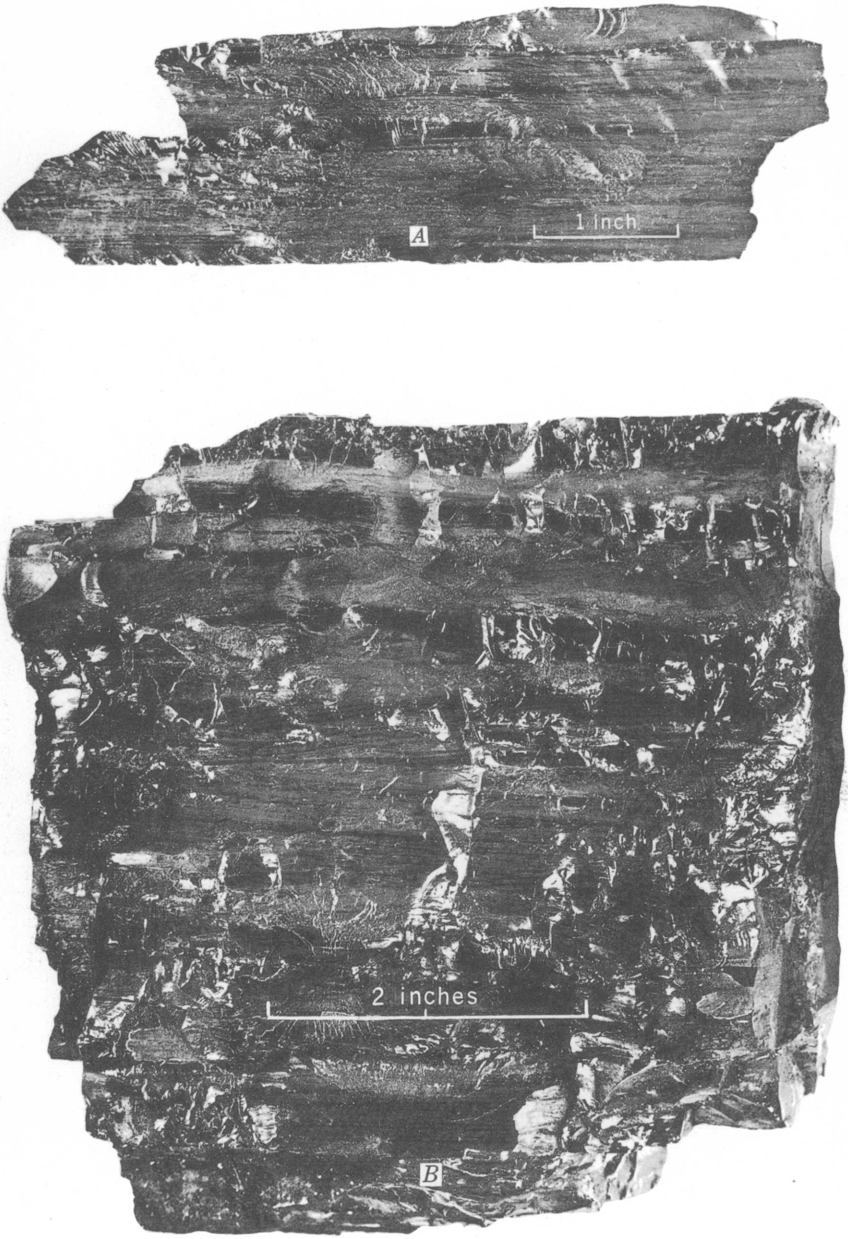
B. BRIGHT ATTRITAL COAL IN BANDED ANTHRACITE

Specimen shows very fine banding of the attrital constituent and lenticular nature of the vitrain (brilliant black) band in the center.



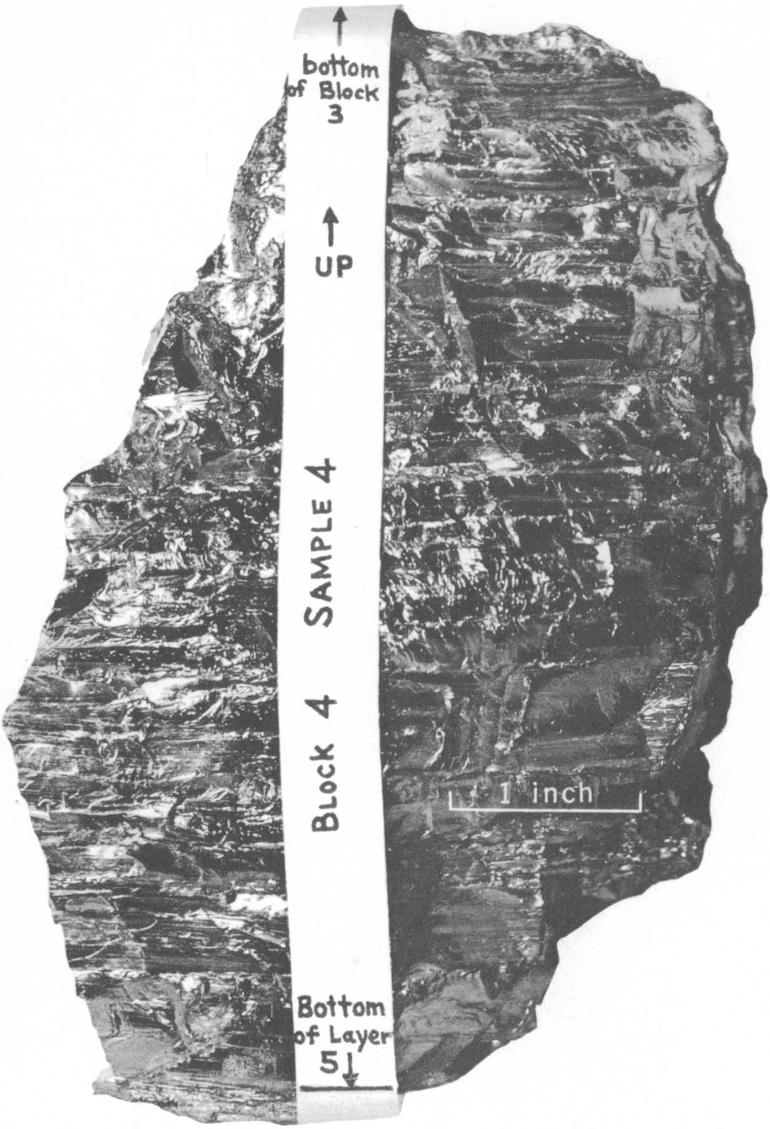
BRIGHT ATTRITAL COAL IN BANDED ANTHRACITE

Note the relatively smooth face and very fine banding.



DULL ATTRITAL COAL IN BANDED ANTHRACITE

Upper picture shows brilliant luster and irregular ends of the vitrain bands.



BLOCK OF BANDED ANTHRACITE SHOWING METHOD OF MARKING BLOCKS AT THE TIME OF SAMPLING

Mainly vitrain and bright attrital coal; a band of dull attrital coal is at the base.