

PETROGRAPHIC CONSTITUTION OF THE MEIGS CREEK NO.9 COAL BED

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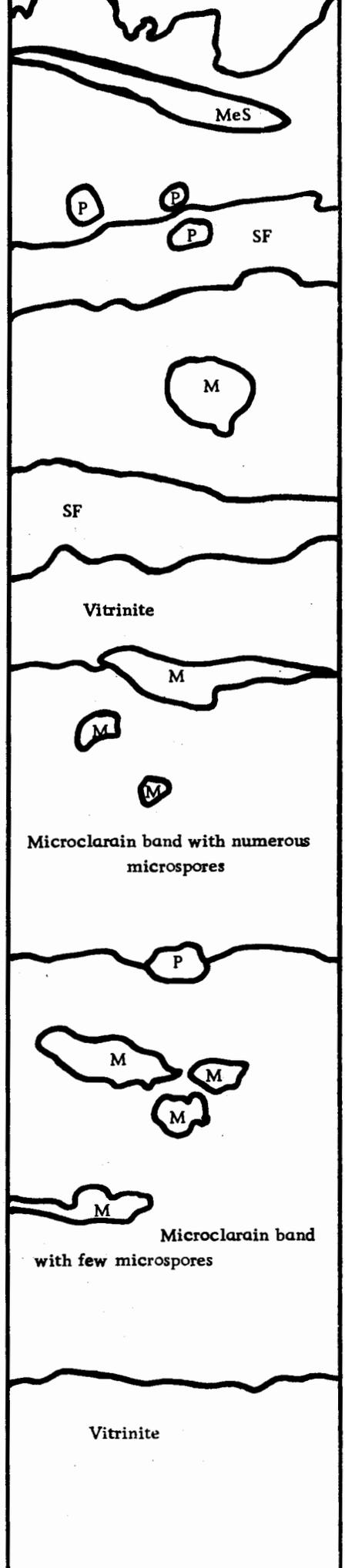
PETROGRAPHIC CONSTITUTION OF THE MEIGS CREEK NO. 9 COAL BED

AN EXPLORATORY STUDY OF THE PETROGRAPHIC CONSTITUTION OF THE
MEIGS CREEK (NO. 9) BED COAL OF OHIO WITH AN INTRODUCTORY
DESCRIPTION OF THE PREVAILING METHODS OF COAL MICROSCOPY

BY
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COVER. Reflected light photomicrograph showing the complex structure of the microbands in a piece of coal. (SF is semi-fusain, P is pyrite crystals, M is micrinite, and MeS is a megaspore.) Magnification is 250X as it is for all other photographs in this publication unless otherwise noted. All photographs by Gilbert E. Smith.

FOREWORD

The present report is the first to describe the petrographic characteristics of Ohio banded bituminous coal. The report is particularly directed to the citizens of the State interested in the coal resources of Ohio and in the use of these resources to the fullest advantage. Such realization cannot be expected without a comprehensive understanding of the composition of the coal both physically and chemically. The chemical characteristics of coal have been and are being explored in great detail by chemists, particularly those associated with the steel, coking, and chemical industries and with certain government agencies; the investigation of the physical composition particularly of Ohio coals has been largely neglected. This report deals with these physical characteristics which are related to the banded structure of the coal bed and to the various coal components which are responsible for this structure.

The nature of the physical heterogeneity of coal is not generally well understood, although the derivation of coal from accumulations of plant material such as compose peat bogs is a matter of common knowledge. It is less commonly realized that a bed of coal consists of a variety of coalified substances of different types and in different stages of coalification. The chemical character of an average sample of coal from a coal bed is an average of the various types and ranks of coal representing the various coalified plant substances found in the bed. It is quite uncertain how much of the variation in the chemical character of an individual coal bed is due to variations in the types of coal material composing the bed. Before this question can be answered or thoroughly investigated, it is necessary to demonstrate that the coal in a coal bed actually contains various types of coal material due to its diverse plant derivation.

The present exploration of the Ohio coals is mainly for the purpose of demonstrating that this diversity exists and to explain the microscopic procedure whereby such demonstration is possible.

The investigation of the physical make-up of coal is the purpose of coal microscopy; hence the techniques of two phases of this field of investigation, thin-section and polished surface techniques, will be described; and finally in the last part of the report, consideration will be given to the description of the petrographic characteristics of the Meigs Creek (No. 9) bed coal as determined mainly by the polished surface procedure. It is hoped that the relatively brief description provided will be convincing of the fact of the physical heterogeneity of the coal as well as give a good idea of its manner of expression.

Although some consideration will be given to the extent to which preparation procedure may modify the type of coal in the different sizes as compared with the coal in the bed, this is only a more or less incidental purpose of the investigation, which is primarily for the purpose of demonstrating the fact of physical variability, which in turn, is definitely a consequence of the initial variability of the material composing the different types of coal found in the bed. The fact of such variability once established is a challenge to those concerned with the investigation of the chemical variability of coal since there is a possible source of variability in the various types of coal material whereby one type of such substance can be compared with another, both of which have been subjected to the same geological vicissitudes.

Chemical investigations of this type into the nature of coal material composing a bed of coal have not been extensive, and knowledge in regard to the chemical variation among the coal types composing individual coal beds is exceedingly meager in this country and particularly for Ohio coals. It is hoped that the present investigation of the petrographic characteristics of Ohio coals will stimulate such chemical investigations to be carried on in cooperation with coal petrography.

John H. Melvin

ACKNOWLEDGMENTS

This report of investigation is the result of a grant from the National Science Foundation for fundamental research on the petrographic constitution of Ohio coals. Although this is a pioneering attempt at such studies of Ohio coals, we feel that a pattern has been established which can be followed in future fundamental as well as applied research. For the opportunity to make these studies we are sincerely grateful to the National Science Foundation. Without its financial support this work could not have been accomplished.

The authors desire to make grateful acknowledgment of the continued support to this investigation supplied in numerous ways by Mr. John H. Melvin, Chief, and Mr. Ralph Bernhagen, Assistant Chief, Ohio Division of Geological Survey. We are indebted to the United States Bureau of Mines and particularly to Mr. Bryan C. Parks and Mr. Hugh J. O'Donnell of the Bureau staff of the Central Experiment Station at Pittsburgh for the preparation of a set of thin sections of the Meigs Creek bed coal which was made available for study, for providing the result of the microscopic analysis of these sections, and for assisting in setting up these results in graphic form. We also gratefully acknowledge the services of the Ohio State University Engineering Experiment Station in supplying numerous coal analyses made under the direction of Dr. Peter O. Krumin and in supplying samples of float and sink fractions of coal for use in the study of broken coal. For the helpful cooperation of representatives of various mining companies in the collection of coal samples used in these studies, we are especially grateful. Finally our thanks to the various members of the Ohio Division of Geological Survey who helped in the collection and initial preparation of the coal samples, and particularly, for assistance in various phases of the work by Mrs. Marian S. Klein, statistician, and Mr. Tom Gallagher, laboratory assistant and draftsman.

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INTRODUCTION

A. Nature and Purpose of the Exploration Project

Because the petrographic composition of Ohio coals has never received special attention, this is called an exploration project. However, general knowledge concerning the petrographic character of Ohio coals is available from microscopic studies that have been made of some of these coal beds using samples collected from their extensions in the neighboring states of Pennsylvania and West Virginia. Hence it is not expected that they will prove remarkably different from most banded bituminous coals found in this general area with respect to petrographic composition. It is desirable, nevertheless, to obtain some specific information concerning the petrographic composition of these coals in Ohio since coal beds rarely maintain close similarity in petrographic make-up from place to place and beds differ one from another.

To make this report on the petrography of Ohio coals more understandable to the general reader will require preliminary explanation of the more elementary aspects of coal microscopy, with description and illustration of the general petrographic characteristics of a few Ohio coals.

The benefits that might accrue from an understanding of the petrographic composition of these relatively low grade coals must be looked for mainly in the use of such knowledge in the control of quality and maintenance of uniformity of composition in coal produced mainly for steam production. Such use will depend partly upon the character of the data provided or accessible and also in good measure upon the understanding and imagination of these engaged in the solution of coal mining and preparation problems especially the latter. A little realized potential capacity for variation exists in these banded coals due to differences in composition rather than simply to variations in ash content.

The assumption that Ohio coals are entirely unsuitable for use in the manufacture of metallurgical and chemical cokes may be found incorrect should full advantage be taken of the petrographic heterogeneity of these coals. For the same reasons it may be possible to prepare special varieties of coal adapted to special uses. An imaginative understanding of the nature of coal petrology and petrography and a realization that in the physical variability microscopically visible there may reside a greater or less degree of chemical variability, will determine the extent to which coal petrography will be employed in the arts and manufactures.

The benefits, if any, that may accrue from a better understanding of the physical constitution of Ohio and similar bituminous coals cannot be fully foreseen in an age such as the present in which conditions affecting the use of coal are constantly changing. Even more because of this fact, every possible means of improving our understanding of this important energy and chemical resource should be explored and developed.

MEIGS CREEK COAL

B. Limitations of the Investigation

The funds made available for the project restricted the character of the laboratory facilities and equipment, the number of the personnel engaged in the studies, and the scope of the investigation. There are a considerable number of workable coal beds in the State of Ohio, but with the means available it was believed necessary to restrict the studies to not more than four coal beds. These beds, selected more or less at random but representing the two more important coal-bearing formations of the Pennsylvanian System, the Allegheny, and the Monongahela were the Meigs Creek (No. 9) (Monongahela), Pittsburgh (No. 8) (Monongahela), the Middle Kittanning (No. 6) (Allegheny), and Clarion (No. 4a) (Allegheny) (1).

Whether or not detailed petrographic study of the last two coals named will be possible in the time remaining is uncertain, but at least megascopic examinations have been made and the general characteristics of these coals have been determined.

C. Objectives

The general objectives of the project have already been stated. The first immediate objective with respect to the study of the four coals selected for special investigation is the determination of the general aspects of the megascopic petrography of these coals. This was possible, however, only on the basis of information that could be supplied by a very few samples. Further studies must be made to determine the facts in regard to local variability. The number of samples were too few to determine the extent to which the four beds are characterized by geographically distributed variations in their petrographic composition. Nevertheless megascopic surveys or profiles of coal beds commonly provide important information concerning the size, quantity, and distribution in the bed of the banded constituents, technically referred to as "ingredients" (5) or "lithotypes" (6) and also provides some indication of their importance in determining the character of the various sizes of prepared coal.

The second objective is the determination of the microscopic composition of the coal beds, for coal petrography is fundamentally based upon microscopic components, and, as will be shown, visual inspection without the microscope is inadequate for an understanding of coal constitution. The coals were examined in serial order as listed on page 3, the first study being made of the Meigs Creek (No. 9) bed coal. A general microscopic examination of the coal was made by using polished surfaces, for reasons which will be explained ahead, but one complete suite of thin sections of this coal has been made available for examination through the courtesy of the United States Bureau of Mines. The usual practice in the present studies has been to select for microscopic study those portions of the bed which in the megascopic profile were characterized by relatively dull luster and commonly designated as durain. From past experience it is known that such bands consist of a relatively high percentage of microscopically fine material of diverse character. Much less uncertainty exists concerning the composition of the bright bands of coal.

One column of the Meigs Creek coal was analyzed chemically in eight successive sections separated largely on the basis of differences in megascopic appearance. Detailed microscopic examination was made of this entire column, but this was the only column so handled. The main purpose of the microscopic study was the determination of the nature and cause of the petrographic variability as shown in the megascopic profile.

The third phase of the exploration was concerned particularly with the composition of different sizes of broken or "sized" coal such as is produced for the market or as produced by controlled breakage. The possibility of differential breakage and subsequent concentration of different ingredients in different sizes merits consideration in view of the variations in the physical properties such as specific gravity, hardness, brittleness, toughness, resilience, elasticity, etc., commonly assigned to the different components of the coal. Much remains to be known about the extent and character of these differences.

This third phase of the exploration suffers like the others from the limitations imposed on the scope of the investigation, so that it is impossible to reach a comprehensive and conclusive understanding of the full extent to which mining and preparation processes may bring about differential breakage, segregation, and concentration of the coal constituents or ingredients. Only brief laboratory study of breakage on a small sample of coal such as a drill core, when this is dropped from a height of 5 to 6 feet on a steel plate, could be made of each coal (see Appendix I). A somewhat similar study was made of the petrographic composition of screen sizes obtained from one sample of mine-run coal representing both benches of Meigs Creek (No. 9) bed coal obtained in the course of float-and-sink studies concurrently carried on by the Engineering Experiment Station of Ohio State University.

D. Chemical Analyses of The Meigs Creek No.9 Bed Coal

Chemical analyses have been made of the coal used in the petrographic studies of the Meigs Creek (No. 9) bed coal. These analyses consisted in the main of data presented in the "proximate" form, including B. t. u. determinations, and in some cases the values for the three forms of sulphur were reported, namely, pyritic sulphur, organic sulphur, and sulphate sulphur. Most of the analyses were made in the laboratory of the Engineering Experiment Station of Ohio State University under the direction of Dr. Peter O. Krumin. There are also available two sets of proximate and ultimate analyses made by the United States Bureau of Mines, one set representing the upper bench and the other set representing the lower bench of the Meigs Creek bed and made from channel samples collected in the mine of the Electrometallurgical Division of the Union Carbide and Carbon Company near Dexter City, Jefferson County, May 7, 1952. At the time this channel sample was collected a column or pillar of coal was obtained at the same locality which was used by the Bureau of Mines in making a suite of thin sections representing the two benches of this bed at this place.

The source and character of the samples and the character of the information supplied by the analyses made in the laboratory of the Engineering Experiment Station, and those made by the United States Bureau of Mines, are shown in the accompanying table (Table 1). The chemical determinations made on the various sizes of broken coal consisting only of ash and sulphur values appear in Table 10 in Appendix II.

The proximate and ultimate analyses of face samples, columns and diamond drill cores used in the petrographic studies including the two analyses supplied by the United States Bureau of Mines are also given in Appendix II.

Of these analyses only those made by the Bureau of Mines represent standard face samples so collected and packaged that the mine moisture was retained in the coal at its arrival at the laboratory. The values given in these analyses therefore can be used for determining the rank classification of the coal as indicated by the B. t. u. value of the coal on a moist, mineral-matter-free basis. This value for the upper bench is determined as 14,252 and for the lower bench as 14,382. The number of analyses, however, are inadequate for definitely establishing the rank of the coal. On the basis of this inadequate information, the Upper Bench coal is classified as High Volatile C and the Lower Bench coal as High Volatile B bituminous coal. An average of three or more analyses of standard face samples would probably change this classification somewhat but it seems probable that the coal lies near

MEIGS CREEK COAL

Table 1. Source and Character of Samples and Character of Information Supplied by Analyses of Ohio Meigs Creek, No. 9, Bed Coal.¹

Sample number	Kind	Number of benches analyzed	Character of information				Source ¹	
			Proxi- mate	Ulti- mate	Sulphur forms	Ash and sulphur only	U.S.B.M.	E.E.S., O.S.U.
584	Channel	Composite (Upper).....	x	x	x	-	x	-
		Composite (Lower).....	x	x	x	-	x	-
597-A	Core	Composite.....	x	x	x	-	-	x
		8.....	x	-	x	-	-	x
597-B	Core	Composite.....	x	x	x	-	-	x
		Upper 4½".....	x	-	x	-	-	x
		Next 6¼".....	x	-	x	-	-	x
597-C	Core	Composite.....	x	x	x	-	-	x
		4.....	x	-	x	-	-	x
598-A	Core	Composite.....	x	x	x	-	-	x
		5.....	x	-	-	-	-	x
598-B	Core	Composite.....	x	x	x	-	-	x
		4.....	x	-	-	-	-	x
598-C	Core	Composite.....	x	x	x	-	-	x
		4.....	x	-	x	-	-	x
		6 screen sizes, dropped core	-	-	-	x	-	x
		6 screen sizes, composite...	-	-	-	x	-	x
600	Channel	Composite.....	x	x	x	-	-	x
		9 screen sizes.....	-	-	-	x	-	x
		9 screen sizes, composite...	-	-	-	x	-	x
601-B	Core	Composite.....	x	x	x	-	-	x
		4.....	x	-	-	-	-	x
601-C	Core	Composite.....	x	x	x	-	-	x
		4.....	x	-	x	-	-	x
		6 screen sizes, dropped core	-	-	-	x	-	x
		6 screen sizes, composite...	-	-	-	x	-	x
601-D	Core	Composite.....	x	x	x	-	-	x
		4.....	x	-	-	-	-	x
603-A	Channel	Composite (Upper).....	x	x	x ²	-	-	x
		Composite (Lower).....	x	x	x ²	-	-	x
603-B	Run-of- mine	Upper Bench						
		Composite.....	x	x	x	-	-	x
		10 screen sizes.....	-	-	-	x	-	x
		10 screen sizes, composite..	-	-	-	x	-	x
		4 screen sizes.....	-	-	-	x	-	x
		4 screen sizes, composite...	-	-	-	x	-	x
		Lower Bench						
		Composite.....	x	x	x	-	-	x
		10 screen sizes.....	-	-	-	x	-	x
		10 screen sizes, composite..	-	-	-	x	-	x
4 screen sizes.....	-	-	-	x	-	x		
4 screen sizes, composite...	-	-	-	x	-	x		

1. The Ohio State University Engineering Experiment Station, 1953-1955 and the United States Bureau of Mines, 1952.

2. Grindability.

the border of Bituminous B and C coals.

The available analytical data represent samples of too generalized or average character to provide good correlation with variations in petrographic composition. It was thought necessary to have some chemical information about the coals studied, but it was realized, in view of the fact that usually the coal analyzed was not fresh, that only a rough approximation to the actual composition of the fresh coal was possible. Sulphur and ash values give some idea of the relative purity of the coal in the columns and cores petrographically studied. One of the cores of the No. 9 bed (No. 597-A) was divided into eight parts each part being separately analyzed. These parts are not strictly benches as this is not a systematically benched bed, except for the possibly local subdivision into upper and lower parts separated by a shale or clay parting. The subdivision of this core was made with some consideration of the distribution of petrographic variations suggested by the megascopic profile. That is, certain of the parts individually analyzed consisted of relatively dull coal other portions having a brighter luster. Since it was necessary to restrict the number of portions individually analyzed to relatively few, none of the portions consisted entirely of one type of coal, although there may have been a predominance of one type. In general the "bench" analyses indicated that dullness of certain portions of the bed was mainly owing to relatively high ash content of such portions, the variations in ash tending in general to obscure the effect of petrographic variations. More discriminating preparation of samples and analytical data of elementary as well as proximate character are believed necessary to demonstrate correlation between chemical and petrographic composition. Such work can be best carried on after a knowledge of the petrographic constitution of the coal is available rather than while such data are being assembled.

Those interested in obtaining more information concerning the chemical character of the Meigs Creek (No. 9) bed coal in Ohio and also information concerning the geological occurrence and the reserves in this bed are invited to refer to Ohio Division of Geological Survey Report of Investigations No. 17 or Ohio State University Engineering Experiment Station Bulletin No. 151 entitled "The Meigs Creek No. 9 coal bed in Ohio": Part I. Geology and reserves by William H. Smith, Russell A. Brant, and Fred Amos; Part II. Washability characteristics and other properties by Peter O. Krumin, 163 pp., 1952. A supplementary bulletin with additional data on the washability characteristics of the Meigs Creek coal is soon to be distributed.*

E. Source of Coal Samples

The four beds selected for the exploratory study, as previously stated, were the Meigs Creek (No. 9), Pittsburgh (No. 8), Middle Kittanning (No. 6), and the Clarion (No. 4-A) (1).

From these four beds a total of thirteen bed column sections have been made, megascopic logs of which are shown in Plate I. The thirteen samples consist of four diamond drill cores (Nos. 597A, 597B, 598A, and 601D) and three column or pillar samples (Nos. 584, 600, and 603A) of the No. 9 bed, two column (Nos. 604 and 605) of the No. 8 bed, one core (No. 606) and one column (No. 602) of the No. 6 bed and two columns (Nos. 607 and 608) of the No. 4-A bed.

Although it was planned to investigate only two samples from each bed, use was made of an additional five diamond drill cores of the No. 9 bed which happened to be available from experimental drilling carried on by the Ohio Division of Geological Survey in 1953. Concurrently with the petrographic studies chemical studies of the Meigs Creek (No. 9) bed coal were underway by the Engineering Experiment Station of the Ohio State University (2) and these provided a convenient and timely means of exploring the possibility of correlating the results of chemical and petrographic studies. A fourth column sample of the No. 9 bed (No. 603B) was added from collections made by the Engineering Experiment Station.

*At the publication of this manuscript no title was available for this forthcoming bulletin by Peter O. Krumin of the Engineering Experiment Station.

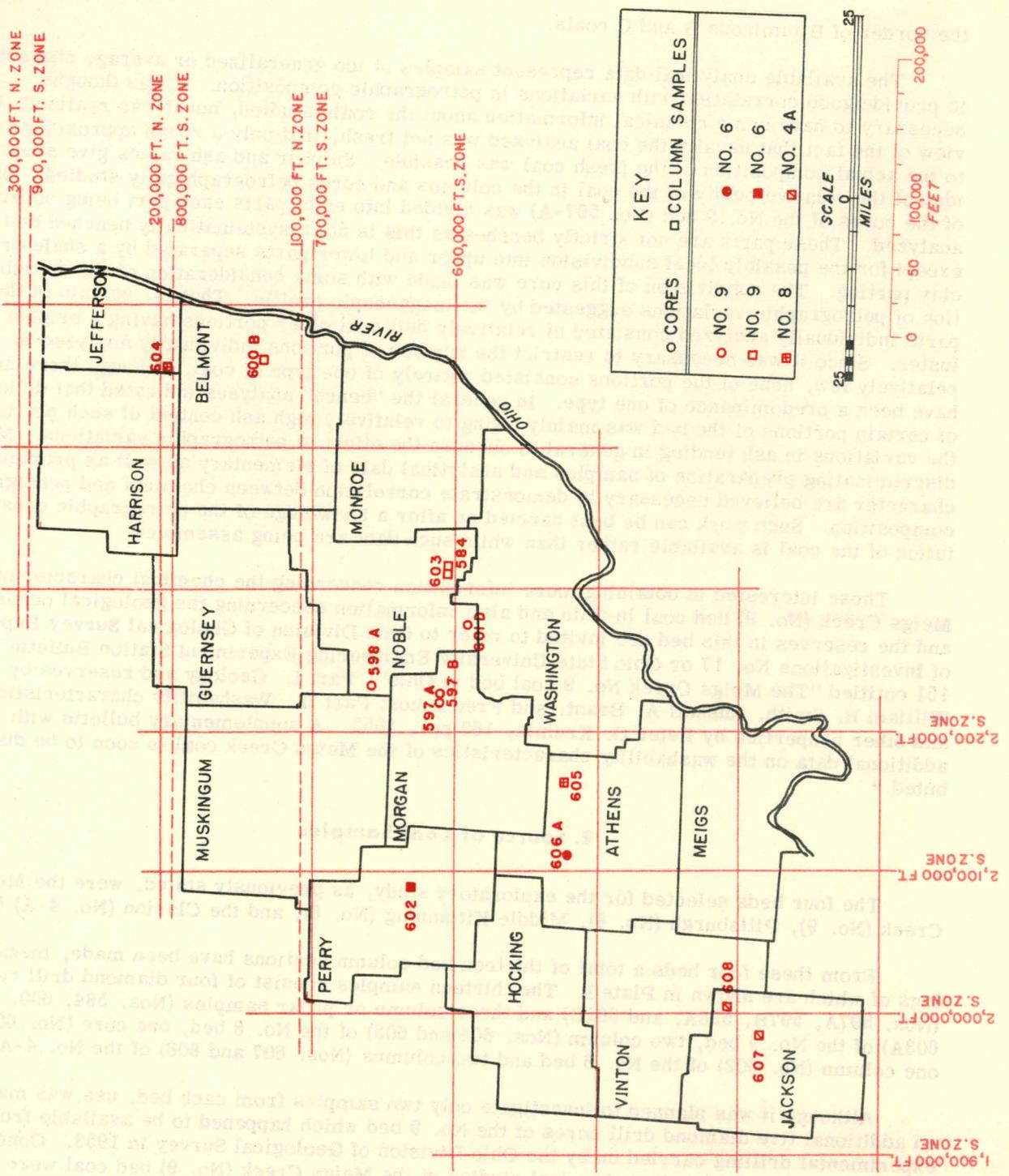
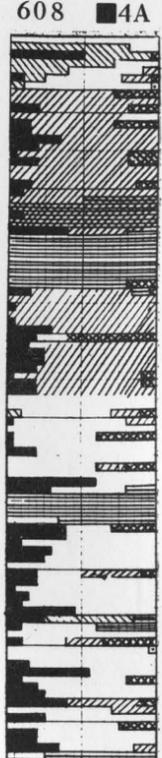
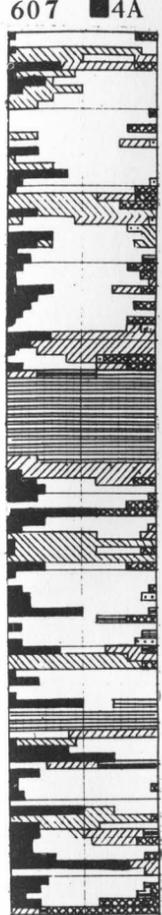
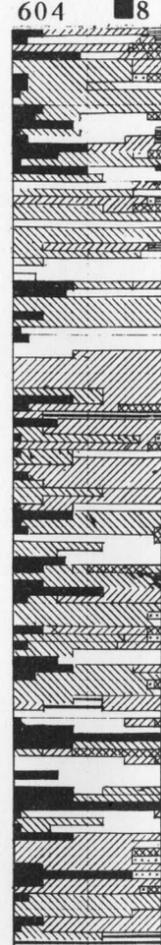
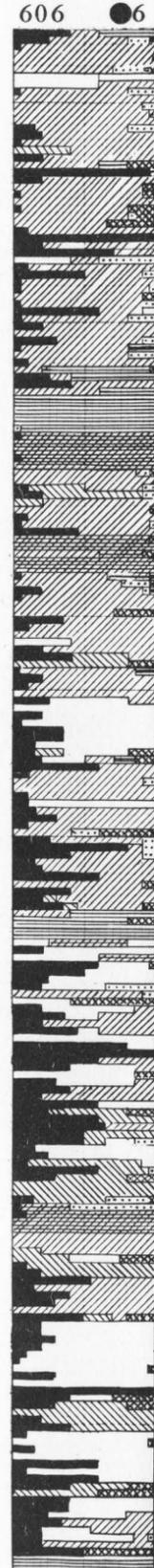
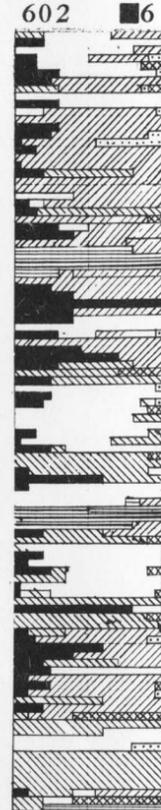
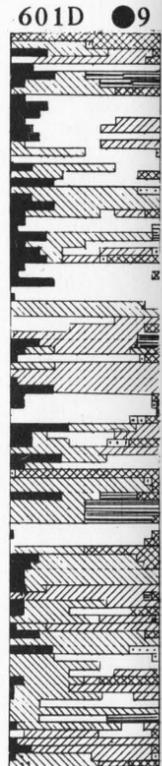
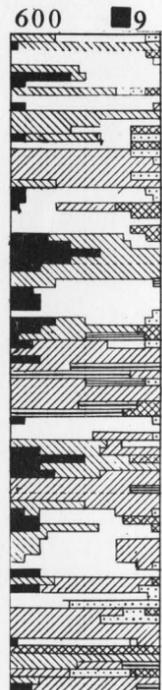
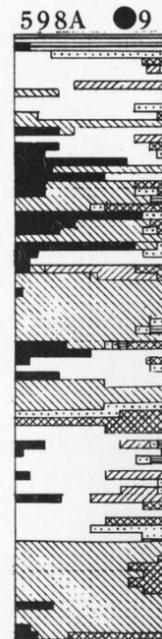
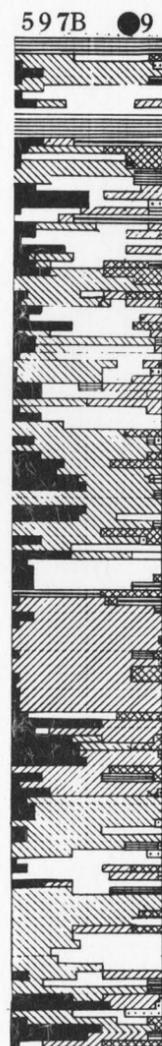
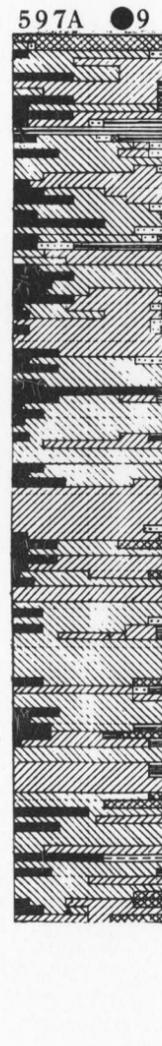
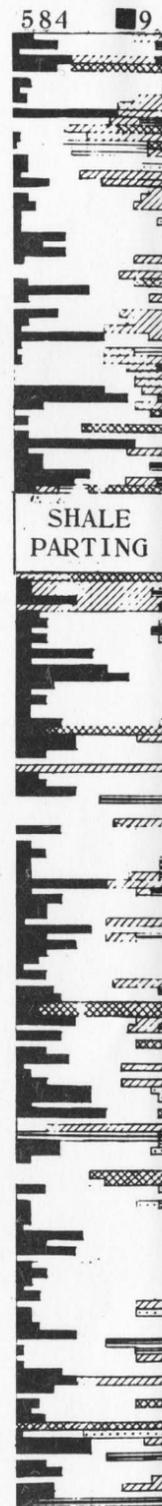


Figure 1. Outline map of eastern and southeastern Ohio showing locations where column, core, and run-of-mine samples were collected.

PLATE I. GRAPHIC SUMMARY MEGASCOPIC PROFILES OF MEIGS CREEK (No.9), PITTSBURGH (No.8), MIDDLE KITTANNING (No.6), AND CLARION (No.4A) COAL BEDS OF OHIO



● Cores ■ Columns

- VITRAIN
- ▨ CLARAIN
- ▤ CLARO-DURAIN
- ▧ DURAIN
- ▩ FUSAIN
- PYRITE
- MINERAL MATTER
- ▬ BONE
- ▮ GAPS

The locations of the channel and core samples used in this study will be described bed by bed as follows:

(1) MEIGS CREEK (NO. 9) COAL BED

No. 584 is a column sample collected by R. A. Brant and Lee Sprout in May 1952, one year prior to the inauguration of the project. This column was obtained in the Cornetta Farm strip mine operated by the Electrometallurgical Division of the Union Carbide and Carbon Company at the north edge of the NW $\frac{1}{4}$, NW $\frac{1}{4}$, Section 4, Jefferson Township, Noble County (Macksburg Quadrangle). Coordinates of the location are X-2, 301, 250, Y-606, 100 (Fig. 1). The No. 9 bed here has a total thickness of 114 $\frac{7}{8}$ inches with 29 $\frac{1}{8}$ inches in the top bench, 28 inches of clay parting, and 57 $\frac{3}{4}$ inches in the bottom bench. Of this 86 $\frac{7}{8}$ inches were studied, the parting not being included. (Plate I, No. 584).

Nos. 597A, 597B, and 597C, are three diamond drill cores drilled by John Hyland and James Reynolds of the Ohio Division of Geological Survey in June 1953, the coal drilled consisting of a single bench. These holes, 50 feet apart, are located along an east-west county road in the SE $\frac{1}{4}$, SW $\frac{1}{4}$, Section 35, Bristol Township, Morgan County (Caldwell Quadrangle). No. 597A is the westernmost with coordinates X-2, 215, 100, Y-610, 000, Nos. 597C and 597B lying consecutively to the east (Fig. 1).

Petrographic studies were made of only two of these cores No. 597A and No. 597B, the study of No. 597A being much more complete. The coal obtained from the third hole, No. 597C, was used as a sample for chemical analysis. Core No. 597A has a total length of 57 inches with only minor partings, which were included in the petrographic study. Core No. 597B has a length of 78 $\frac{1}{4}$ inches in which 7 $\frac{1}{4}$ inches of pyritic partings are not included. Core No. 597C has a length of 65 $\frac{1}{8}$ inches in which 8 inches of pyritic shale partings were not included in the sample provided for chemical analysis.

The three cores Nos. 598A, 598B, and 598C, are from holes drilled by John Hyland and Lee Sprout for the Ohio Division of Geological Survey in June 1953 on the property of the Moscrip Mining Corporation. Each consists of a single bench. Hole 598A was located 20 feet north of State Route 215, 9 miles east of its junction with State Route 76 in the SE $\frac{1}{4}$, SE $\frac{1}{4}$, Section 8, Brookfield Township, Noble County (Cumberland Quadrangle). The coordinates of 598A are X-2, 236, 000, Y-661, 100. No. 598B is 100 feet north of No. 598A and hole No. 598C is 200 feet east of No. 598A (Fig. 1).

No. 598A was logged megascopically (Plate I) and microscopically for its entire length of 38 inches. No. 598C was broken by dropping and studies made of the resulting screen sizes. This core was 48 inches in length. Only ash and sulphur determinations were made of the coal from core No. 598B. This core was 51 inches long.

No. 600 is a 42-inch column sample of a single bench collected by W. H. Smith and P. O. Krumin in July 1953 from the Malik strip mine in the center of Section 24, Richland Township, Belmont County (St. Clairsville Quadrangle). The coordinates are X-2, 464, 300, Y-740, 000 (Fig. 1). The entire thickness was used for petrographic study (Plate 1, 600) with an additional sample taken for chemical analysis.

Nos. 601B, 601C, and 601D are cores of three diamond drill holes drilled by John Hyland and James Reynolds in June, 1953, on the Gore Farm Strip Mine of the Baker and King Coal Company, and each consists of a single bench. They were drilled along a 150 foot east-west line starting in the NE corner of the field 1,000' NW of a farm house in the SE $\frac{1}{4}$, SE $\frac{1}{4}$, Section 9, Jackson Township, Noble County (Caldwell Quadrangle) (Fig. 1). No. 601B was drilled in the NE corner of the field, coordinates C-2, 272, 300, Y-599, 900, and provided a sample only for chemical analysis and consisted of 39- $\frac{3}{8}$ " of coal. No. 601D

was 50' west and was petrographically studied (Plate I, 601D) for its entire length of 46" No. 601C, another 100' west, was broken by regulated dropping and sized for natural breakage petrographic studies. The sample represented 43-1/8" of coal.

Nos. 603A and 603B are coal samples taken from the underground mine of the Electro-metallurgical Division of the Union Carbide and Carbon Company. The entrance of this mine is in the NW $\frac{1}{4}$, SW $\frac{1}{4}$, Section 33, Enoch Township, Noble County (Macksburg Quadrangle) at the coordinates X-2, 301, 500, Y-608, 000, (Fig. 1). 603A is a face sample taken by G. H. Cady, R. A. Brant and R. Lehman in January, 1954, 600' along the west entry from the entrance of the mine. This sample was used for petrographic study and consists of a lower bench of 46" and the upper bench of 30-1/2". The clay parting of 8-3/4" between the two benches was discarded. No. 603B is a run-of-mine sample of about 2 tons collected by R. A. Brant, R. Weiss, and P. O. Krumin in March 1954 at a point 200 feet east of No. 603A and used for the petrographic study of various screen sizes produced by natural breakage in the operation of a mechanical miner. The sample was taken from the conveyer belt in two parts each representing a single bench. The upper bench sample (No. 603B-2) represents 27 $\frac{1}{2}$ inches of coal and the lower bench (No. 603B-1) represents 47 3/4 inches.

The clay parting of 10 inches which separated the two benches was discarded.

Some of the columns and cores of No. 9 coal bed consist of two benches and some of only one. It is not always certain whether the single bed represents both benches present elsewhere or only one of these benches, and which one, if only one.

(2) PITTSBURGH (NO. 8) COAL BED

No. 604 (Plate I) is a channel sample collected by R. A. Brant and R. Lehman in January, 1954, from the underground Dun Glen mine of the Hanna Coal Company, located in the SE $\frac{1}{4}$, SW $\frac{1}{4}$, Section 34, Mt. Pleasant Township, Jefferson County (St. Clairsville Quadrangle), at coordinates of X-2, 454, 400, Y-184, 900 (Fig. 1). The bed is in a single bench at this locality and the entire 60" were used for petrographic study. A representative sample of the bed was also broken by regulated dropping and various screen sizes thus produced will be studied for natural breakage petrographic characteristics.

No. 605 (Plate I) is a channel sample of the two benches of Pittsburgh coal characteristic of the Federal Creek Field in Southeastern Ohio and was taken by G. E. Smith, R. Lehman, and R. Weiss in February 1954, in the 2nd N. room off the last W. entry in the A. W. Gilchrist mine near Sharpsburg in the NE $\frac{1}{4}$ of Section 29, Bern Township, Athens County (Chesterhill Quadrangle) at coordinates X-2, 167, 500, Y-524, 600 (Fig. 1). The upper bench (605-1) is 46" thick. Including the parting of 12 $\frac{1}{2}$ " of clay between the benches, the bed has a total thickness of 109-1/2".

(3) MIDDLE KITTANNING (NO. 6) COAL BED

Nos. 602A and 602B are channel samples collected from strip pits of the Sunny Hill Coal Company near New Lexington. Sample No. 602A was collected by G. H. Cady and G. E. Smith in December 1953 in the South Center, NE $\frac{1}{4}$, Section 17 (coordinates X-2, 080, 050, Y-647, 400); No. 602B was collected by W. H. Smith and G. E. Smith in April 1954 in the SW $\frac{1}{4}$, NW $\frac{1}{4}$, Section 16, Clayton Township, Perry County (Zanesville Quadrangle) (Fig. 1).

Macroscopic petrographic studies (Plate I, 602) have been made of each of the three benches, excluding the two partings between them, of 602A. The lower bench has 18" of coal with a 2" clay parting on top. The middle bench has 14 $\frac{1}{2}$ " of coal, with 2 $\frac{1}{2}$ " clay parting

on top, while the upper bench has 14" of coal, the total thickness being 51".

No. 602B, also in three benches, was broken by regulated dropping for natural breakage petrographic studies. The total thickness of this coal bed sample was 58" consisting of 18" in the lower bench with a 1-1/2" parting on the top, 16-1/2" in the middle bench with a 1-1/2" parting on the top, and 20-1/2" in the upper bench.

No. 606 is a diamond core supplied by the Dry Dock Coal Company of Nelsonville. This core was from a prospect hole put down under contract by the Mott Core Drilling Company in September, 1953, and has a length of 103" of coal. The hole was located in the SE $\frac{1}{4}$, Section 17, Dover Township, Athens County (Athens Quadrangle) at the coordinates of X-2, 112, 100, Y-522, 900 (Fig. 1). The core shows the typical three benches with 42" in the lower bench with 2-1/2" of parting on top, 31" in the middle bench with 2-1/2" of parting on top, and 25" in the upper bench. Megascopic petrographic logs were compiled of the entire thickness (Plate I, 606). Other petrographic studies are planned.

(4) CLARION (4A) COAL BED

No. 607 is a channel sample taken by G. E. Smith, L. Sprout, and R. Weiss in April, 1954, from the stripping operations of the Broken Aro Coal Company near Wellston in the NW $\frac{1}{4}$, Section 29, Milton Township, Jackson County (Jackson Quadrangle) at the coordinates X-1, 993, 500, Y-388, 500 (Fig. 1). The thickness of the bed here is 56-1/2" including two clay partings with a combined thickness of 9-1/2". Megascopic petrographic studies have been made of the entire column (Plate I, 607) and a matching sample broken by regulated dropping with the resulting natural breakage sizes screened and studied.

No. 608 is another channel of Clarion coal taken by G. E. Smith, Lee Sprout, and R. Weiss in April, 1954, from the Horse Hollow (underground) Mine of the Kriebel Brothers Coal Company of Wellston. This mine, coordinates X-2, 011, 600, Y-407, 050, is in the SE $\frac{1}{4}$, NW $\frac{1}{4}$, Section 2, Milton Township, Jackson County (Wilkesville Quadrangle) (Fig. 1). The bed here is 48" thick including two clay partings totaling 8". Megascopic studies were made of this bed (Plate I, 608) with microscopic studies planned.



NATURE AND CONTENT OF COAL MICROSCOPY

A. The Physical Heterogeneity of Coal

Coal petrography is that branch of coal petrology or anthracology dealing with the description and classification of coal as a rock or rock-like material. It attempts to provide an intelligent understanding of the physical heterogeneity of coal.

To coal mining and coal preparation engineers the phrase "physical constitution of coal" is likely to denote simply the variations in size and in mineral matter or ash content of coal as prepared for the market, toward the control of which variables their interest is very largely directed. To the geologist, and particularly to the coal petrographer, physical heterogeneity has more intrinsic connotations related to the fundamental composition of the coal material. To such persons coal is usually regarded as a rock or rock-like substance of organic origin composed of a variety of components mainly of plant origin, the kind, distribution, and degree of modification of which determine the characteristics of the coal.

The organically derived components of coal consist of various parts of plants, tissues, organs, secretions, and derivatives thereof, including degradation products, along with various amounts of mineral particles of primary or secondary origin, all generally so arranged as to give the bed of coal a laminated or banded structure. Such laminated structure, in the case of more massive appearing coal like cannel coal, may be apparent only by microscopic examination.

In inorganic rocks the constituent components are called minerals. The components of coal may be called phyterals (3) if the organic identity of the component is regarded as the important consideration, or they may be called macerals (4) if the petrographic or rock-like aspect of the material is emphasized. Coal is a closely knit mixture of some relatively large and many small units or phyterals of diverse plant origin. The size of the units is in part determined by the size of the original organ, tissue, or secretion, and in part by the degree of degradation of the plant material brought about in the various stages of accumulation, degradation, and burial. Before burial the plant tissues were commonly broken up and disintegrated into units or fragments of very small size and redistributed irrespective of their original associations. In the case of some coals only the relatively remote products of plant degradation by bacterial, fungal, and other diagenetic activities, including any processes of decay or weathering remain, the actual initial source of which may be difficult to determine. But this, in general, is not the case with respect to the common variety of banded bituminous coal found in Ohio.

B. Resolution of the Heterogeneity of Coal Composition by the Methods of Paleobotany and Coal Petrography

To achieve a satisfactory description of coal it is necessary to resolve the complexity of its component parts in terms either of phyterals (paleobotanical entities) or of macerals (petrographic components). Thus the compressed, solidified; and otherwise coalified plant material may be regarded in either or in both of two ways; that is, (1) paleobotanically, as

plant material uniquely fossilized in a manner which varies progressively from rank to rank; or (2) physically, as a petrographically distinctive rock-like material likewise varying progressively from rank to rank.

(1) RESOLUTION OF THE HETEROGENEITY OF COAL IN TERMS OF PHYTERALS

Paleobotanically coal may be regarded, as suggested above, as an accumulation of much compressed fossil plants, plant parts, organs, secretions, and degradation products. The resolution of the heterogeneity of coal then becomes very largely a matter with which paleo- is concerned, with emphasis on coal genesis, plant identification, morphology, and classification. The fossilized coalified plant components may be conveniently referred to as phyterals so long as they can be recognized as more or less definite organic entities. The nomenclature associated with the paleobotanical composition is described ahead under Terminology of thin section practice.

(2) RESOLUTION OF THE HETEROGENEITY OF COAL IN TERMS OF THE MACERALS

The first modern attempt at coal description and classification on a strictly petrographic basis was that of Stopes (5) who in 1919 introduced the petrographic names vitrain, clarain, durain, and fusain for the four main rock types of banded bituminous coal (Fig. 2). These are the four banded ingredients, as they were called by Stopes, recently designated lithotypes (5), readily identified and differentiated with the unaided eye on the basis of luster, structure, texture, and other aspects of their general appearance. These names were introduced in England about the same time as the terms anthraxylon, attritus, and fusain were given out in America by Thiessen (7) who pursued a line of research mainly based on Microscopic observations. Vigorous adherence by individuals to one or the other of these two terminologies has marked the recent history of coal petrology, but mainly in different regions, with the Thiessen terminology winning most approval in America.

a. Macerals

Pursuant to the idea that the banded ingredients of coal, or lithotypes, are suitably regarded as varieties of rock material and that the coalified botanical constituents composing the ingredients are analogous to minerals in inorganic sedimentary and igneous rocks the term maceral was proposed by Stopes (5) as a name for such primary petrographic components. Each banded ingredient or lithotype is therefore regarded as being composed of one or more, mainly microscopic macerals.

Inasmuch as maceral names had been applied to the discrete structural components making up the more or less complex lithotypes clarain and durain, consistency called for a hypothetical substance which would serve as an analogous structural unit of the commonly more massive vitrain. The same logic applied to fusain. Hence we have the terms vitritinite and fusinite, which, although possibly convenient, since their use often shortens the labor of repetitious description, do not refer to any definite substances of fixed chemical composition like a mineral, except as it is represented by the lithotypes vitrain and fusain or by any other coal material having the general appearance of vitrain or fusain in thin sections or polished surfaces.

The terminology of coal petrography, which will be discussed in greater detail in a later section of this report, is equipped, if not actually burdened, with a large variety of names, a number of which have specific application to specific botanical entities and are, to all intents

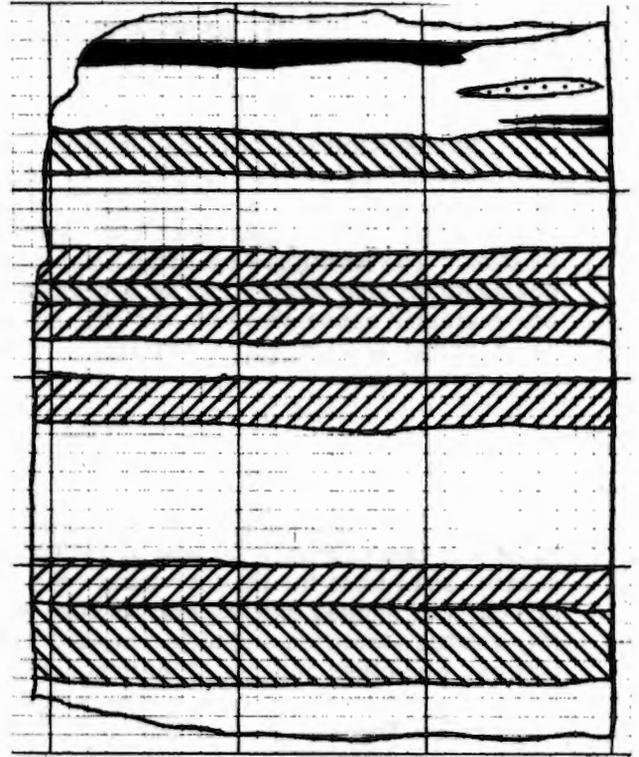


Figure 2. Natural size photograph of a lump of Meigs Creek (No.9) bed coal showing the four banded ingredients or lithotypes and one mixed variety, vitrain, clarain, durain, fusain, and claro-durain. Column No. 600, photo 84.

and purposes, equivalent to the names of phyterals. Other names have more recently been proposed which represent an effort to classify and group together certain varieties of coal with the intent of simplifying description and classification. There is now favored by some petrographers and others (8) a simplified basis of description and classification of coal substances, namely vitrinite representing all coal material of humic or woody or other origin having the characteristics of vitrain, exinite, representing all of the so-called "bituminous" components such as spore exines, cuticles, and miscellaneous resinous and waxy constituents, and inertinite which includes highly carbonized materials such as fusain and the opaque components or micrinite. In the present report this vitrinite is referred to as "total vitrinite"¹

Vitrinite consists of at least 95% vitrinite. This vitrinite includes all material having the petrographic appearance of vitrain with or without evidence of having plant structure. The thickness of vitrinite must exceed 50 microns (1/20 mm.)

Clarite consists of bands of coal material exceeding 50 microns in width with more than 10% vitrinite, more than 5% exinite and resinite, and less than 5% inertinite (micrinite, semi-fusain, fusain, sclerotinite).

Durite consists of bands of coal material exceeding 50 microns in width with not more than 10% vitrain and vitrain like material, with the ratio of exinite plus resinite to inertinite varying between 10 to 90 and 90 to 10. Durite rich in inertinite is to be called Durite I and durite rich exinite Durite E.

Fusite consists of fusain, semi-fusain, and sclerotinite (fungal sclerotia) having a thickness exceeding 50 microns (1/20 mm.). Hard and soft varieties of fusite are recognized determined by the amount of mineral matter present, but no quantitative differentiation in terms of mineral matter content are given.

Shaly coal is a term to be used to designate microlithotypes containing 20 to 60% by volume of mineral impurities (clay, mica, quartz, etc.), otherwise called carbonaceous shale (bone ? G H C) and Brandschiefer. Vitritic clayey coal, claritic clayey coal and fusitic clayey coal are varieties that might be recognized. (Presumably when the mineral matter content exceeds 60% the material is no longer regarded as coal. G H C)

These proposals are of very recent date and have not been followed in the present report. They have not yet been shown to be of practical value although they may very well be. In general on this report the terms microvitrinite, microclarite, and microdurite have essentially the meaning of the proposed terms "vitrite", "clarite", and "durite".

C. Microscopic Methods of Coal Petrography

(1) BOTANICAL COAL MICROSCOPY

A certain amount of subdivision and classification of coal material is possible without the use of the microscope, as is evident from the subdivision of coal material proposed by Stopes previously referred to. However, a comprehensive understanding of the physical constitution of coal requires the use of the microscope sooner or later.

In exploring the botanical constitution of coal various methods have been used either for actually liberating the individual plant entities or for making them more clearly visible under the microscope. The identifying structures of the plant fossils found in coal are generally of microscopic size and require the use of the microscope for their discovery and identification.

¹ It has recently (6) been proposed to designate as microlithotypes components of coal exceeding 50 microns (1/20 mm.) in width composed of "typical associations of macerals". The microlithotypes proposed are named vitrite, clarite, durite, fusite, claro-durite, duro-clarite, and vitrinertite, the names all ending in -ite.

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One method of resolution of the botanical constituents of coal is by maceration, which depends upon the differential solubility of components of the coal in an alkaline solution after preliminary oxidation by a strong oxidizing agent. The more resistant components such as spores, cuticles, and other waxy substances, resins, fusain, and some mineral matter furnish a residue insoluble in alkaline solutions and hence a source of small plant fossils. Some of these fossils, the spore exines in particular, in recent years have been very useful in the identification and correlation of coal beds (9), (10), (11).

Exploration of the botanical structures in coal may also be carried on by etching polished surfaces of coal, particularly vitrain. This procedure is largely restricted to the study of the wood structures in vitrain in the high rank coals such as low volatile bituminous coals and anthracite from which it is difficult to make thin sections (11), (12), (13), (15).

The most favored means of studying the organic structures in coal, at least in America, is by the use of thin sections. In such studies the lead taken by the U. S. Bureau of Mines in the Central Experiment Station at Pittsburgh, where for many years the coal microscopy investigations were under the guidance of Dr. Reinhardt Thiessen, is recognized. Other laboratories where paleobotanical work on coal is being carried on are the Illinois State Geological Survey, Urbana, West Virginia State Geological Survey, Morgantown, Pennsylvania State College, and U. S. Geological Survey, Columbus, Ohio.

(2) USE OF THIN SECTIONS IN SYSTEMATIC COAL PETROGRAPHY

Thin sections of coal have been widely used in America not only as a medium for carrying on botanical studies but as a basis for systematic investigations in coal petrography. On the basis of a classification of coal material founded on microscopic observations R. Thiessen and other coal petrographers of the Bureau of Mines have provided several hundred petrographic analyses of American and other coals in terms of a standard system of petrographic description (16). This must be regarded as a notable achievement in the quantitative assessment of the petrographic characteristics of American coal. Because of the large volume of these data it is important that any other system of quantitative petrographic analysis be correlated as precisely as possible with that expressed by the Thiessen system. However, such correlation between thin section and polished surface technology is incompletely achieved and remains one of the outstanding problems of coal petrology with respect to the European and American systems. It is next to impossible at the present time to translate the quantitative values of one system exactly into terms used by the other.

(3) TERMINOLOGY OF THIN SECTION PRACTICE

When small pieces of coal, one surface of which has been specially prepared for such use by grinding and smoothing or polishing, are mounted individually on glass slides and then ground down to a condition of translucency, microscopic examination commonly reveals many details not previously apparent of the organic structures present in the coal (17). Such thin sections, as has previously been pointed out, also provide a means for the more or less systematic classification of the coal material as such into useful categories, largely on a botanical or genetic basis (18), (21).

When viewed in a microscopic both the heterogeneous and homogeneous aspects of the different megascopic banded ingredients of the coal are revealed, and description and classification on the basis of microscopic characteristics becomes not only possible but essential. Thin section practice recognizes only four primary microscopic components of coal, namely anthraxylon, translucent attritus, opaque attritus, and fusain or mineral charcoal. This

classification is based upon the valid assumption that the common varieties of bituminous coals are composed partly of wood, bark, and some leaf material which coalifies in the form of bright, lustrous, megascopically homogeneous bright black bands, the anthraxylon; partly of heterogeneous plant debris of all kinds but generally of relatively small size which forms bright to dull coal having megascopically a striated or laminated structure, the attrital coal; and partly of charcoal-like substance, the fusain. Viewed microscopically in thin sections the striated or attrital coal may contain considerable amounts of opaque material, which seems to be other material than fusain; thus are differentiated the translucent and opaque attritus. In thin section technique and quantitative measurements anthraxylon is differentiated down to widths of 14 microns ($14/1000$ mm.). Hence the bright striated coal may consist of much anthraxylon as well as of translucent attritus. In the duller striated coals usually there is some fine anthraxylon present, but usually there is more attrital material with more or less opaque matter. Coal with as much as 30% opaque matter is called splint (21), but such coal may be restricted to certain benches of a coal bed. If there is between 20 and 30% of opaque matter present the coal has been called semisplint (21).

Anthraxylon, which microscopically generally reveals more or less cellular structure varies in width from bands several inches wide to those that can be distinguished only with the aid of the microscope. They may be so small as to constitute only a minor constituent of the attrital matrix.

a. Description of Attrital Material

In general not more than one-quarter of a bed of banded bituminous coal consists of anthraxylon (vitrain) of megascopic width. Therefore the character of the remaining 75% of the coal is of much importance in determining the constitution of the bed. Commonly as much as one-half of this remaining 75% consists of anthraxylon of microscopic width greater than about 14 microns ($14/1000$ mm.) and about one-half of coal of attrital composition. The so-called attritus may occur in fairly coarse bands or laminae between bands of either megascopic or microscopic anthraxylon. Attrital coal containing but little anthraxylous humic material is likely to be dull.

The two varieties of attrital coal, translucent and opaque, can be differentiated only by the use of the microscope. Although it was formerly thought (23) that opaque attritus could be recognized only by the use of thin sections, which accounts for its name, it is now known that the material producing opacity in thin sections can be readily identified in polished surfaces of coal, using an oil immersion objective, by its characteristic high reflectivity (24). Coal beds or layers of coal containing considerable amounts of opaque matter, that is splint coals, tend to have a dull luster; but dullness of luster of these and other "dull" coals or durains is owing very largely to absence of anthraxylon in thin bands and other coalified humic matter. The major part of dull coal or durain may consist of opaque matter, spores, cuticles and other waxy and resinous material, small fragments of fusain, and mineral matter in all possible proportions.

It should be pointed out that the opacity produced by the opaque components in splint coal operates whether the opaque component lies on the upper surface of the thin section, lies within the section, or lies on the lower surface (18), (19), (20), (21), (22), (25), and (26). It is obvious that the amount of opacity is greater than it would be if only surface opaque material produced the opacity, hence those components producing opacity appear to occur in greater quantity in thin sections than in polished surfaces, but the degree of difference has not been resolved. Of course, if the opaque matter appears in greater quantity in thin section than in polished surfaces there must be a relative decrease in other components concealed by the opaque matter.



b. Phyteral Differentiation In Thin Section Coal Petrology

By the use of thin section microscopic technique the petrographic composition of a coal may be described in a more or less general way in the terms of the four components anthraxylon, translucent and opaque attritus, and fusain, with separate consideration of mineral matter. But a more elaborate quantitative analysis is possible in terms of the phyterals or plant entities or secretions. In a recent publication Schopf and Gray (27) have differentiated and determined the volume percent of the following components of a lignite coal from Dakota:

Anthraxylon, coarse (> 0.5 mm.); fine 0.5 mm. to 14 microns).

Translucent attritus:

Subanthraxylon, less than 14 microns wide,
Humic matter,
Red attrital resin,
Spores, pollen, and cuticle,
Yellow amorphous waxy matter,
Fungus spores,
Fungal sclerotia,
Brown matter (with traces of semifusain).

Opaque attritus (granular and amorphous varieties commonly recognized).

Fusain (fusain, semifusain commonly recognized).

Mineral impurities:

Pyrite, transparent minerals, and clay minerals.

Details may be elaborated to a greater length depending upon the knowledge and skill of the investigator in the discrimination of components and the importance he may place upon such discrimination.

The nature of the translucent cell wall or humic degradation matter and certain of the other components listed in the preceding table has been briefly explained by Hacquebard (28):

"Thiessen regarded the translucent cell wall or humic degradation matter and anthraxylon as consisting essentially of the same material with only a size distinction between the two. Anthraxylon occurs in larger units, usually as bands; the translucent humic matter occurs in smaller units oftentimes as the ground mass of the attritus. The brown cell wall degradation matter was thought to have been derived from tissues of bark. The spores, cuticles, and resinous bodies need no further explanation. They are translucent under transmitted light. Regarding the opaque matter or opaque attritus Thiessen and Sprunk (20), (29), have shown that when it occurs in finely divided or granular form it probably originated from highly decomposed wood fibres, mostly of coniferous wood."

(4) THIN SECTION MICROSCOPIC ANALYSIS OF MEIGS CREEK (NO. 9) BED COAL

There follows a petrographic analysis of the upper and lower benches of the Meigs Creek (No. 9) bed coal compiled from a microscopic examination of a suite of thin sections representing practically the entire thickness of the coal bed. Quantitative measurements are given in terms explained in the immediately preceding pages. The thin sections and analyses were made at the Central Station Laboratory of the United States Bureau of Mines, Pittsburgh, Pennsylvania.

COAL MICROSCOPY

Table 2. Microscopic Petrographic Analysis of the Two Benches of Ohio Meigs Creek, No. 9, Bed Coal.¹
(Percent)

Petrographic component	Upper Bench 2' 5-1/4"		Lower Bench 4' 10-5/8"	
	As measured	Mineral-matter-free	As measured	Mineral-matter-free
Anthraxylon	49.2	58.9	47.3	54.9
Translucent attritus	28.1	33.6	27.0	31.4
Opaque attritus	4.7	5.6	8.0	9.3
Fusain	1.6	1.9	3.8	4.4
Translucent mineral matter	9.3	-	4.0	-
Pyrite	7.1	-	9.9	-
Total	100.0	100.0	100.0	100.0

1. Based on a suite of thin sections made from a column cut by R. A. Brant and Lee Sprout of the Ohio Division of Geological Survey in the NW 1/4, NW 1/4, Sec. 4, T. 5 N., R. 8 W., Noble County, Ohio, in the mine of the Electrometallurgical Division of the Union Carbide and Carbon Company, April 1, 1952. The thin sections were prepared during June, 1952 and the microscopic analysis was made in July of that year. Pet. Lab. No. P 3090A. Reported by Mr. Bryan C. Parks, Coal Technician, May 26, 1953. The coal in both benches is described as 100% xylloid, that is woody.

Besides providing over-all analyses in terms of the components the U. S. Bureau of Mines usually furnishes data in graphic form showing the components and types of coal (Fig. 3) compiled from the microscopic examination of individual thin sections. In the accompanying diagram which is based upon analyses made in the coal microscopy laboratory of the Bureau of Mines at Pittsburgh by H. J. O'Donnell and B. C. Parks, the component composition of each thin section unit, representing a thickness of about 1 centimeter of the coal bed, is shown to the right in terms of anthraxylon, translucent and opaque attritus, and fusain on a mineral-matter-free volume percent basis. The thin sections are numbered consecutively from bottom to top of each of the two benches. These measurements do not include the shale parting between the two benches. A scale in inches on the left margin makes it readily possible to determine the distance above the base of the bench of any point in the respective bench. In Bureau of Mines terminology of coal microscopy (21), the term components refers to the anthraxylon, attritus (translucent and opaque), and fusain. Type classification assigns the coal to one of following five categories: Cannel coal, boghead coal, bright coal, semisplint coal, and splint coal. It will be noted from the illustration (Fig. 3) that the Meigs Creek coal is very predominantly of the type of "bright coal" with a minor amount of semisplint coal in which thin sections 20 to 30 percent of opaque attritus was found. It will be observed that such coal occurs only in thin bands in the order of 1 to 2 centimeters, in no case as much as 1 inch thick. Splint coal contains 30 percent or more of opaque matter. It has been found in the Meigs Creek bed.

MEIGS CREEK COAL

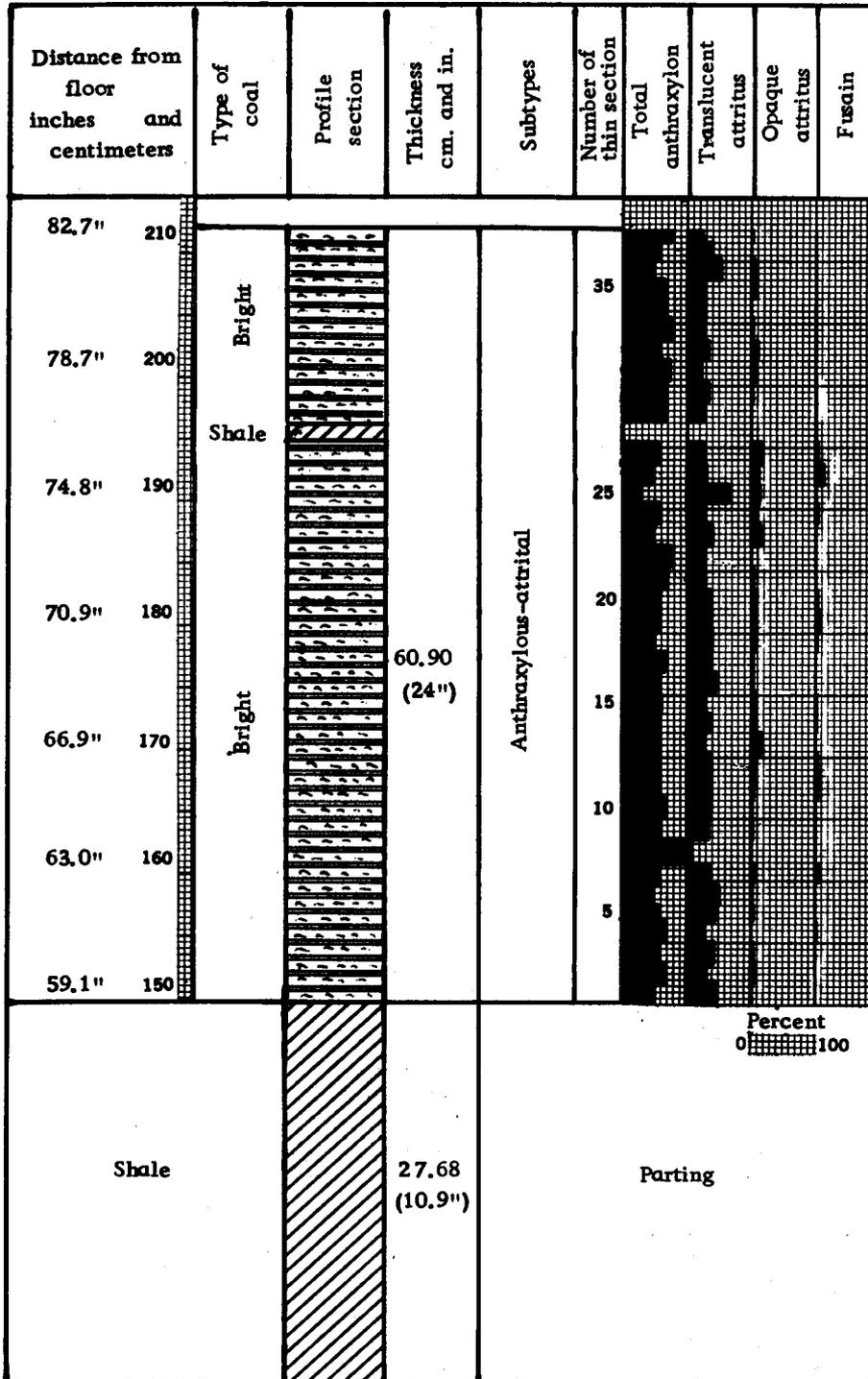


Figure 3a. Profile analysis of the upper bench of Column 584 of the Meigs Creek (No.9) coal bed, showing types of coal and percentages of components based upon thin section examination according to a system used by the United States Bureau of Mines. Analysis made by the Bureau of Mines, Pittsburgh, illustration prepared by Gilbert E. Smith, Ohio Division Geological Survey.

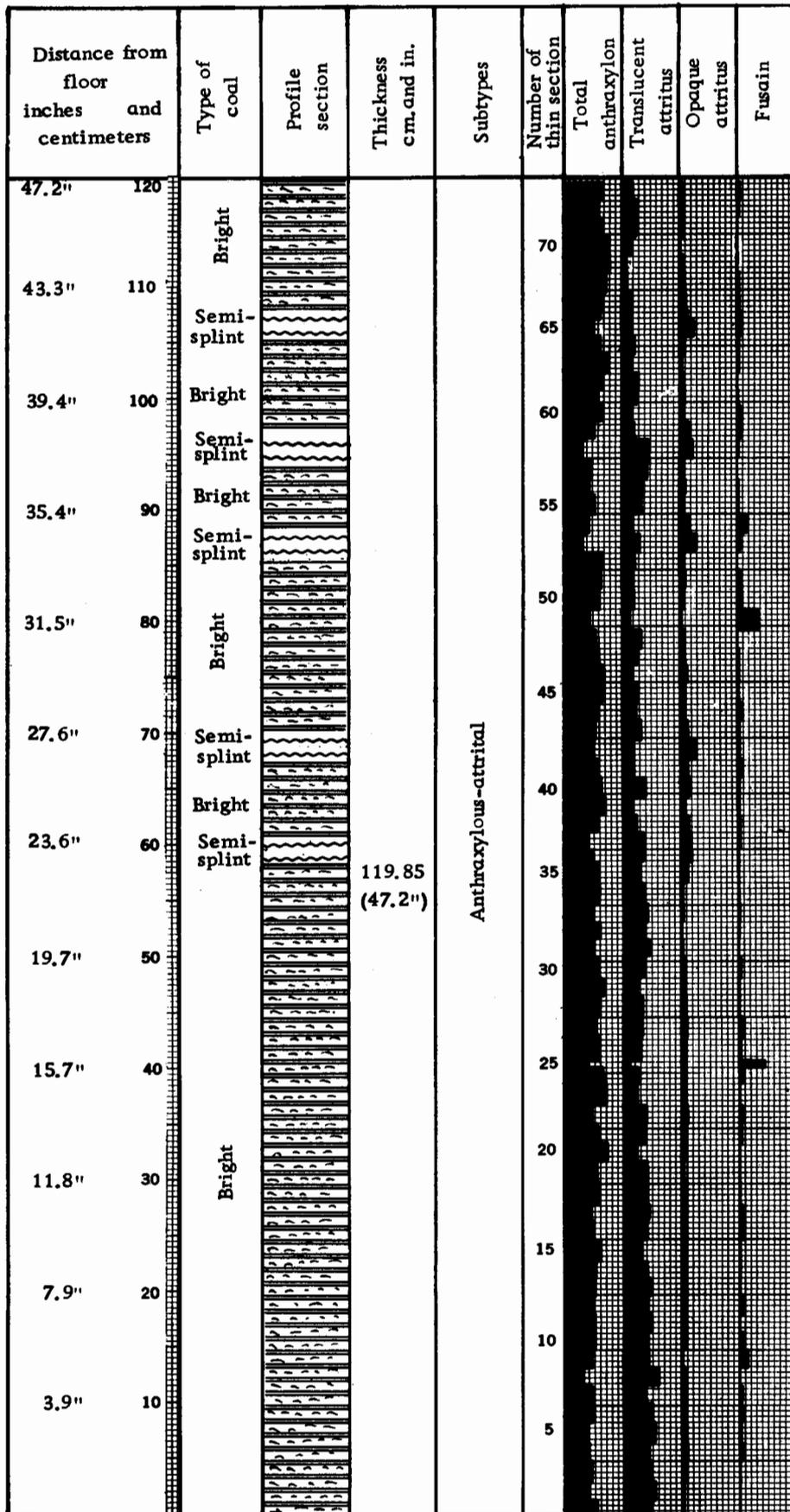


Figure 3b. Profile analysis of lower bench Column 584.

Percent
0 100

The sub-type nomenclature serves to describe the structure of the coal in somewhat greater detail. Parks and O'Donnell say: "Subtype designations are used to distinguish varieties of coal that have mixed characteristics of the main types such as boghead-cannel and bright attrital."

It will doubtless be noted by the reader that although the Bureau of Mines methods of analysis and description show the great importance of attrital material in the bright coal making up the Meigs Creek bed, little or no information is provided concerning the composition of the attrital matter except as it may consist of fusain and the so-called opaque matter. The so-called translucent attritus is known to be made up of what has been called the humic degradation matter, spore exines, cuticular matter, waxes and resins. The character of the attritus may or may not be stated in the graphic form of the bed analysis. The information was not provided in the analyses of the thin sections of the Meigs Creek coal from which the graphic analysis was prepared.

In some analyses the structure of the bright coal is differentiated as coarse or fine depending mainly upon the width of the anthraxylon or vitrain bands. This was not done in the case of the thin sections from column No. 584. Had it been done the coal in all probability would have been described as finely banded.

(5) METHODS OF COAL PETROGRAPHY WITH POLISHED SURFACES

a. Nomenclature

In the early days of modern polished surface coal petrography a primary subdivision of bituminous coal on a megascopic basis into the four ingredients, recently designated as lithotypes (6), vitrain, clarain, durain, and fusain, was made by Stopes (5). As has become fairly common knowledge among those working with coal these names refer respectively to the brilliantly black unstriated coal bands of high luster which are largely responsible for the banded appearance of coal beds; to similarly bright but less uniform, striated coal; to striated coal with a dull luster; and to mineral charcoal. It seems possible to classify all bituminous coal lying in beds into one or another of these ingredients or lithotypes. This constitutes the megascopic subdivision of coal material as a rock-like substance, with mineral matter being regarded as a fifth components of coal beds.

The coal paleobotanists were quick to point out, as a result of their studies of thin sections of coal, of the plant fossils found in coal-balls, and the residues of maceration, that the ingredients or lithotypes are of varied botanical composition and that the differences in the initial plant material from which the coal was formed produced the difference among and within the ingredients or lithotypes.

The invention and use of the maceral system of nomenclature with reference to the components of the lithotypes is explained in page 11.

"Opaque Matter" In Polished Sections.

Although the discovery of the importance of opaque matter in splint coals was first made by the use of thin section, its identity with certain of the very highly reflective material consisting of small particles or more massive areas in some durains has been established in polished surfaces of such coals particularly with the aid of the oil immersion objective (24). Opaque matter has much the same properties as fusain with respect to composition and to behavior in carbonization and hydrogenation, being essentially inert. As it appears to make little practical difference whether the inert material is fusain or the opaque matter,

called micrinite in polished surface practice, these materials have been broadly designated under the general term inertinite, a term which in some classifications may include mineral matter (8).

Vitrinite, Exinite, Inertinite.

In the present report some use will be made of the terms vitrinite, exinite, and inertinite (8). Vitrinite, that is, total vitrinite, (see p. 13), as a more or less generalized maceral representing the hypothetical substance of vitrain and other coal originating from wood, certain types of leaves, other humic material such as humic degradation matter comprises much of clarain. Exinite is a generalized maceral representing the substance of coalified bituminous components such as spores, cuticles, pollens, resins, etc. The meaning of inertinite is explained in the preceding paragraph. When there is need for such reference spore exines will be definitely referred to as such or simply as spores, and similarly there may be reference to cuticles, resins, waxes, etc., using the phyteral names. These objects are almost as readily seen in polished surfaces under oil immersion as they are in thin sections, although by no means displaying such strong contrasts in color with the surrounding material. A proposed modification of the use of vitrinite is advanced later in the report, the use of the term vitrinite being restricted to apply to such structureless groundmass as is represented by humic degradation matter found in clarain and to a limited extent in durain.

b. Methods of Polished Surface Coal Petrography

The methods employed in polished surface coal petrography have been described in great detail particularly in German literature (30, 31). Recently a description of the technique, presented in English, has been published by Hacquebard (28). The method of preparation of polished surfaces of Ohio coal used during the present investigations is described in Appendix I by the junior author who has been mainly responsible for the preparations of the specimens used.

It should be pointed out that the technique of the preparation of polished surfaces of coal changes almost from day to day with the discovery of new polishing cloths and powders. The requirements consist in the production, first, of a very fine grained scratch-free surface and, second, the avoidance of the use of a lap or polishing powder that will cause any scratching during the polishing procedure. It seems quite probable if the use of polished sections of coal increases to any extent that the preparation of specimens will become mechanized so that it can proceed with almost complete elimination of personal attention.

By a recently developed technique of preparing polished thin sections, Teichmuller and Parks (22), (25), (26), provide an excellent means of correlating thin section and polished surface observations. Thus the character of the opaque matter seen in transmitted light is more clearly shown by reflected light, and a better resolution of the vitrinite is possible with transmitted than with reflected light. No such polished thin sections have been made of the Meigs Creek (No. 9) bed coal in connection with this investigation.

c. Megascopic Description of Coal

The prevailing system of description and classification of bituminous coal rests primarily upon the recognition of the four coal ingredients or lithotypes vitrain, clarain, durain, and fusain plus mineral matter.

Importance of Clarain and Durain.

Among the banded ingredients vitrain and fusain are regarded as essentially homogeneous substances. Clarain and durain on the other hand are, in comparison, heterogeneous in composition, being composed of minute components, macerals or phyterals, variable in kind and amount. In clarain the macerals are predominantly bright, in durain predominantly dull. Differences in the physical appearance of coal result from variations in the proportions of the four ingredients and additional possibilities of variation resides in the varying composition of the attrital clarain and durain. Because banded bituminous coals such as those composing the coal beds of Ohio consist of 75 percent or more of clarain and durain, the composition of these ingredients as previously stated is of much importance in determining the character of a coal.

The primary differentiation of clarain and durain is based on megascopic difference in luster as between bright and dull striated coal. It has been learned through a study of thin sections that many of the coals with a dull luster possess the characteristics of splint coals in view of their content of opaque matter above the critical 30 percent. In this country it has come to be the general practice to identify as durain only those dull coals classified as splint. The semisplints with 20 to 30 percent opaque matter appear to be intermediate between durain and clarain. This practice is rather unfortunate as a certain amount of dull coal not containing more than 20% opaque matter must be either unclassified or be included with clarain. Actually the luster of clarain and durain is determined mainly by the amount of vitrain, micro-vitrain or vitrinite in other forms that may be present, brightness increasing with increase in the quantity of total vitrinite. The dull luster of such coals may, be due to mineral matter, to a relatively high content of exinite (spores, cuticles, resins, etc.), to the presence of opaque matter in varying quantities, or to fusain, or to various combinations of these components, but the main consideration is lack of vitrinitic material in one form or another. The determination of the maceral composition of the clarain and durain is one of the important objectives of coal petrography.

Micrinite or Opaque Matter in Attrital Coal.

Micrinite, a maceral observed in polished surfaces and the equivalent of the opaque matter of thin sections, because of its high carbon content, appears opaque in transmitted light and has high reflectivity in polished surfaces. Fusain is similarly bright in polished surfaces but is usually distinguishable by its slightly yellowish tint and the shard-shaped fragments. The two components are commonly difficult to differentiate when they occur in small fragments.

Sclerotia.

Evidence of the presence of fungi in the initial plant material is thought by some to be indicated by the presence of round or elliptically shaped small bodies thought to represent fungal sclerotia (32). Some uncertainty exists concerning the identity of these elliptical bodies seen in Carboniferous coals although no question has been raised concerning the identity of such bodies in Mesozoic and younger coals. Irrespective of the validity of the botanical identification of these substances, which are opaque in transmitted light and very bright in reflected light, coal components similar to components in European bituminous Carboniferous coals which have been called sclerotia are occasionally found in Ohio coals, illustrations of which will be found in a later section of this report (Fig. 9). Sclerotia and associated coal material possibly of similar origin forms part of the inertinite along with fusain, semifusain, and micrinite. It is quantitatively of small importance in the coals studied in this investigation.

Vitrain and Microvitrain.

Description in coal petrography suffers from a lack of general agreement in regard to minimum thickness of vitrain bands. It has been pointed out that clarain commonly consists

of many fine bands of vitrain-like material which resemble vitrain in every way except that they are not readily distinguishable except with the aid of a microscope. These thin bands of vitrain-like coal have been called microvitrain (3). In the present studies all vitrain-like bands less than 1/2 mm. thick have been called microvitrain so long as they can be distinguished at the degree of magnification used. A previously suggested boundary of 1/10-inch (3) is now thought to be too wide for practical purposes. With the magnification generally employed in this investigation of between 200 and 300 times microvitrain bands can be readily identified when no thicker than 10 microns (1/100 mm.) but it is probably desirable to have established standard maximum and minimum widths for microvitrain.

Clarain and Durain in Meigs Creek (No. 9) Bed Coal.

Analyses based upon the megascopic coal bed profiles of the Meigs Creek (No. 9) coal bed indicate that about 80 percent of this bed is composed of bright or dull striated attrital coal, that is of clarain and durain. Little if any of the dull coal or durain contains as much as 5 percent of micrinite in the polished surfaces. In the coal studied by the U. S. Bureau of Mines 4.7 and 8.0 percent of opaque matter was found in the upper and lower benches respectively of the Meigs Creek coal. There is no evidence to indicate that any important portion of the Meigs Creek coal in the columns and cores examined contains sufficient opaque matter to be regarded even as semisplint. However, it should be noted again, at the risk of unnecessary repetition, that the quantitative criteria for determining semisplint and splint coal in terms of micrinite have not been worked out.

Clarain in the Meigs Creek coal varies greatly in its petrographic composition. In some sections this lithotype consists of many thin bands of microvitrain. These are more or less separated from one another by a fine debris of attrital material here frequently designated as microclarain that has apparently generally been subjected to extensive degradation producing what has been called by R. Thiessen "humic degradation matter" (18), (23), (29). In this there are commonly embedded spores, resins, and other organic entities more resistant to the processes of degradation than the humic substance.

Spores or other exinite may be composed 50% or more of the microclarain bands lying between the bands of microvitrain. On the other hand little or no exinite may be present, this being the usual case with respect to Meigs Creek (No. 9) bed coal. As the number and thickness of the microvitrain bands and the quantity of the humic degradation matter decreases in luster and may even become dull, thus grading into durain. Other factors such as increase in mineral matter or in opaque matter (micrinite) may also result in a dull luster.

Bright clarain may also consist of a succession of thin microvitrain bands or sheets separated by thin irregular lines of cuticle. This "cuticular" coal appears to consist of impacted layers of coalified leaves (33) or thin stems, each leaf surface having a cuticular layer. Such clarain is very bright because of the high content of microvitrain as compared with the amount of exinite represented by the cuticle. Not uncommonly both cuticles and spores are found in the bands between the microvitrain. In this case the intermediate bands cannot be regarded as leaf coal.

(6) ILLUSTRATIONS OF THE PETROGRAPHIC COMPONENTS OF THE MEIGS CREEK (NO. 9) BED COAL

It is the purpose of the present section of the report to present illustrations of characteristic petrographic aspect of the megascopic and microscopic constituents of the Meigs Creek (No. 9) bed coal. These are presented accompanied by comments in the general order of the four ingredients or lithotypes vitrain, clarain, durain, and fusain and mineral matter.

a) Vitrain

The megascopic appearance of vitrain in the polished surfaces of coal varies but little from coal to coal of the same general rank except in width of the band. Since the terms thick and thin have only relative significance the following schedule of variation in thickness has been tentatively adopted for the present studies:

Massive or extra thick	- greater than 1 inch (approximately 25 mm.)
Very thick	- 0.5 to 1.0 inch (12.5 to 25.0 mm.)
Thick	- 0.25 to 0.5 inch (6 to 12.5 mm.)
Medium thick	- 0.10 to 0.25 inch (3 to 6 mm.)
Thin	- 0.05 to 0.10 inch (1 to 3 mm.)
Very thin	- 0.02 to 0.05 inch (0.5 to 1 mm.)
Microvitrain	- less than 0.02 inch (less than 0.5 mm.)

The microscopic appearance of vitrain varies considerably largely because some vitrain exhibits cell structure (Fig. 4) the structure being more evident when the cells have been filled with wax or resin as in the illustration shown. In European practice vitrain showing cell structure has been called telain and the substance telinite, telinite obviously being a variety of total vitrinite. Similarly vitrain not showing cell structure has been designated collain and the substance collinite, collinite also being a variety of total vitrinite (4), (5). The difficulty with this procedure is that thin section microscopy reveals very little vitrain that does not show cell structure and the term collinite becomes strictly applicable only to the humic degradation matter as noted in the final paragraph of the preceding and here called vitrinite section. When European coal petrographers refer to collinite it is not clear whether the reference is to structureless vitrain or microvitrain or to the more restricted vitrinite of the humic degradation matter.

b) Clarain

It has been pointed out that the two main types of clarain in the Meigs Creek (No. 9) bed coal consist of the spore clarain and the cuticular clarain.

Spore Clarain.

The spore content of the clarain in the four Ohio coals that have been examined varies through about the full range of possible variability. In the samples of the Meigs Creek coal that have been examined, however, the spore content of the clarain tends to be small, in general less than 10 percent. Many clarain or microclarain bands contain less than 5 percent of spores and it is quite unusual to find bands with as much as 25-30 percent of spore exines.

The effect upon the appearance of the clarain or microclarain of different amounts of spore exines is shown by the accompanying illustrations showing a fairly complete series of variations in spore content up to about 35 percent. In order to show this series of spore frequencies it was necessary in most cases to use photographs of clarain from other Ohio coals than Meigs Creek, particularly coal from the Pittsburgh (No. 8) bed. A single illustration (Fig. 5) shows three clarain bands showing 7, 12, and 27 percent respectively of spore content. There are grouped together (Fig. 6a-e) illustrations showing clarain with spore exine contents varying from 9 to 35 percent.

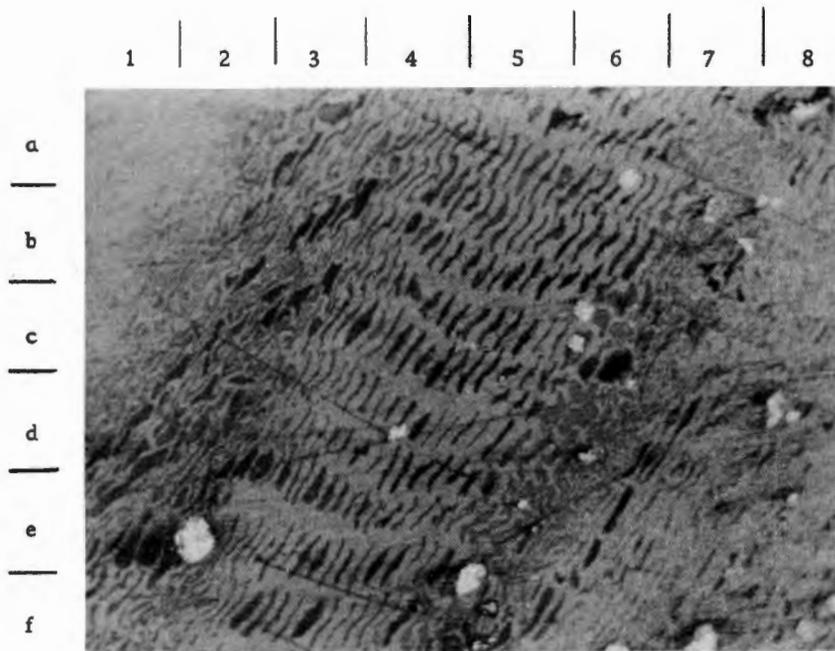


Figure 4a. Vitrain band showing cell structure. Coal No. 9, sample 603B-1, run-of-mine size 1/8" x 28 mesh. Photo 31.

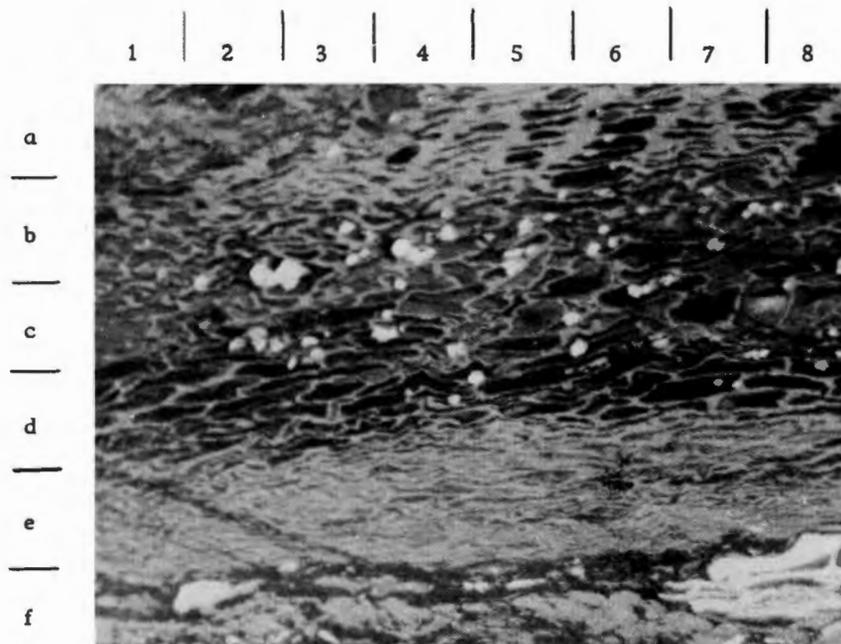


Figure 4b. Vitrain band with cell structure, showing resinous fillings and numerous small pyrite nodules. Coal No. 9, column 603A-1, block 5. Photo 63.



Figure 5. Microclarain bands with 7% (top), 12% (center), and 27% (bottom) of spore exinite. Coal No. 8, column 604, block 2. Photo 70.



Figure 6a. Microclarain band showing 9% spore exinite. Coal No. 8, column 604, block 2. Photo 71.

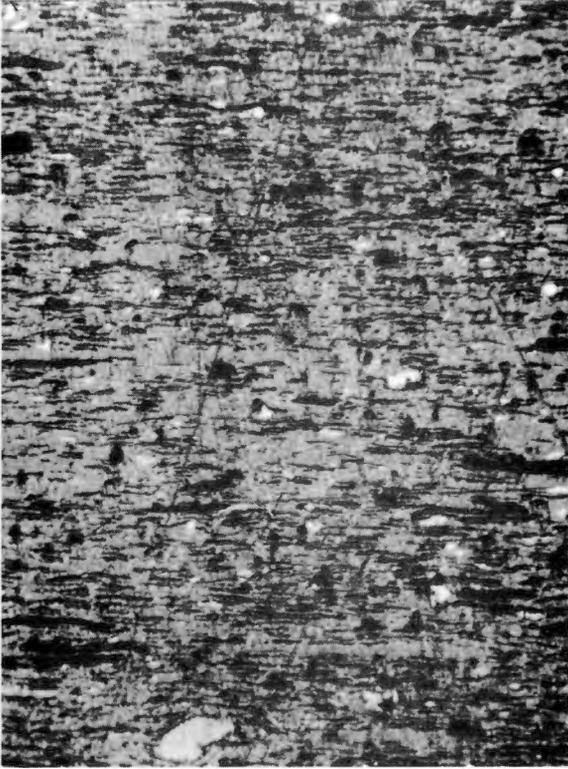


Figure 6b. Microclarain band showing 25% spore exinite. Coal No.8, column 604, block 2. Photo 67.



Figure 6c. Microclarain band showing 28% spore exinite. Coal No.8, column 604, block 2. Photo 75.

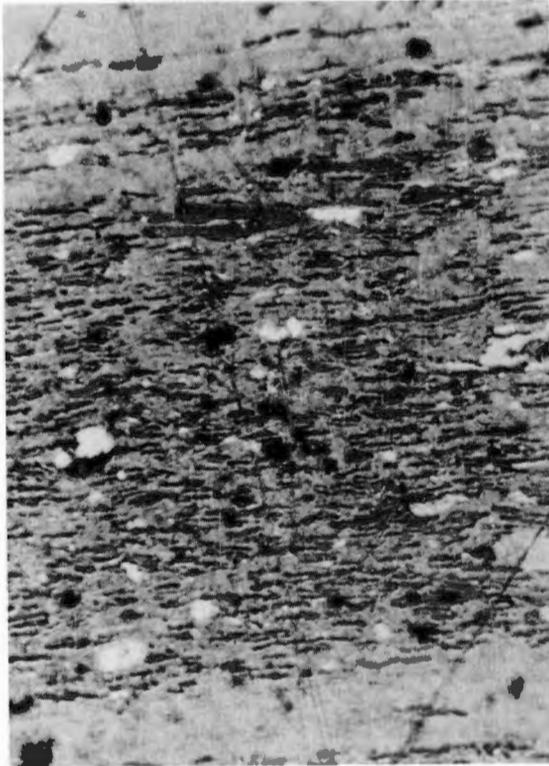


Figure 6d. Microclarain band showing 30% spore exinite. Coal No.8, column 604, block 2. Photo 26-21.

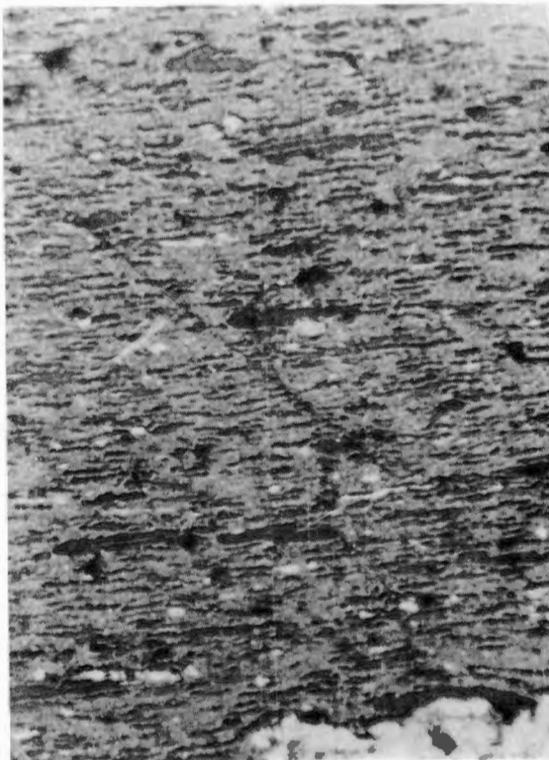


Figure 6e. Microclarain band showing 35% spore exinite. Coal No.8, column 604, block 2. Photo 26-22.

Such illustrations provide a convenient means of estimating by comparison the approximate spore content of clarain bands as seen under the usual magnification of between 200 and 300 times, since the illustrations show the features of the polished surfaces approximately as they appear in the field of the microscope. The various features appear in the field essentially in black and white or in gray tones, there being very little color evident except for the slightly yellowish tint of fusain. In this respect they are very different from the appearance of thin sections which are commonly brilliantly colored in various tones of red, orange, yellow, and black. In general the clarain bands of the Meigs creek coal have a spore content of low frequency, as has previously been stated. Because of the uncommon occurrence of clarain with many spores it seems adequate for the needs of petrographic analysis of this coal at least to classify the spore content in four categories: less than 5 percent, 5-10 percent, 10-25 percent, and more than 25 percent. This is about equivalent to saying that the vitrinite content of the clarain bands varies from not less than 95 percent to not less than 75 percent.¹

Cuticular Clarain.

The Meigs Creek (No. 9) coal is characterized by a fairly great abundance of cuticles. These are found in greatest abundance in bright clarain and serve to separate thin microvitrain bands. The amount of such cuticular exinite is difficult to determine at the magnification commonly used. The individual cuticle is commonly very thin, generally thinner than the individual spore exine, but has much greater lateral extension. The thin wavy cuticles (Figs. 7a and 7b) may lie between contiguous bands of microvitrain and between microvitrain or vitrain and thin band of clarain with spores. Closely spaced bands of microvitrain and bands of cuticle have on an earlier page been referred to as leaf coal, that is coal composed of compacted leaves of certain type.

It does not appear that cuticles impart the same degree of toughness to clarain bands as is imparted by spore exines (34) but this matter has not received sufficient investigation to completely establish the validity of the idea.

c) Durain

There are fairly frequently occurring bands of dull coal in the Meigs Creek (No. 9) bed. Microscopic resolution, however, indicates that the dullness is almost always due to the presence of mineral matter. Spore exines rarely occur in sufficient quantity to impart a dull luster to the coal. None of the bands which are not largely mineral matter contain as little as 10 percent total vitrinitic material.²

¹Methods of measurement of spore content. The possible methods of measurement of the spore content of clarain bands are quite varied. The ocular micrometer, the ocular step micrometer, the Whipple disc, and the integrating stage, and very recently the integrating ocular are available for making such measurements, but because of the high magnification required for accurate measurement and the considerable time required none of these methods seems completely practical. It was found that by using photographs such as those reproduced the amount of spore material could be determined by running 5 to 10 traverses vertically across the photographs measuring and recording the thickness of the individual spore exines intersected. This can be done graphically in a reasonable length of time. Determination of the quantity of the exines was also possible fairly quickly by using a dot survey system with a closely spaced dot pattern (100 evenly spaced dots per square inch) on a cellophane overset. Such determinations were found to agree closely with those obtained by the more elaborate traverse measurements on photographs. The photographs were also used in applying the dot system. An equally satisfactory method, in fact one that is less laborious than any of those mentioned above, is that of the point survey system directly applied to the field of the microscope with vertical determinations made at 1/3 mm. spacing of the stage micrometer and horizontal spacing as desired, that is 1, 2, or 3 mm. or more. This latter system was not used in connection with examination of the Meigs Creek coal but has been used in studies made of the other three Ohio coals.

²See footnote on vitrite, clarite, durite, etc., p. 13.

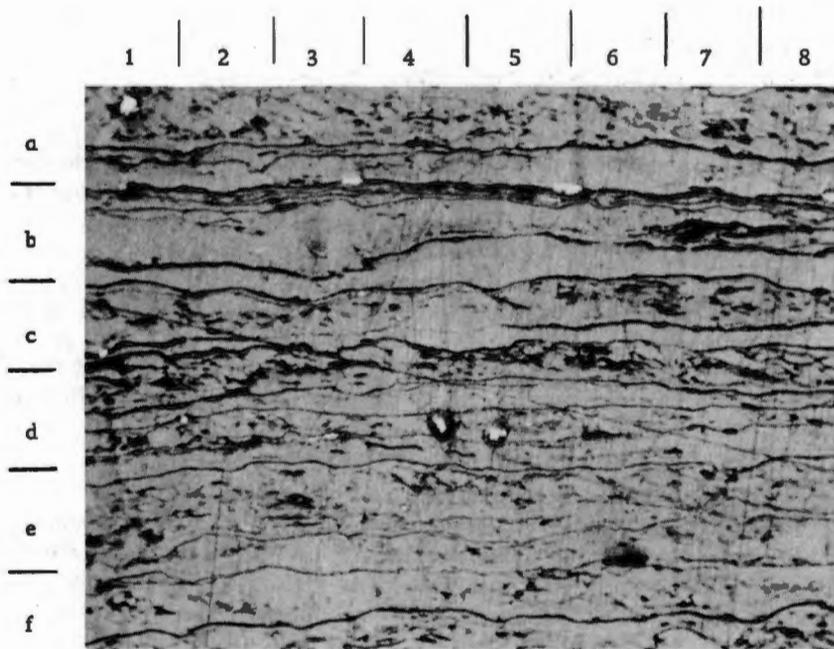


Figure 7a. Cuticles separating bands of microvitrain and microclarain (with spores). Coal No. 9, core 597-A, block 9. Photo 79.

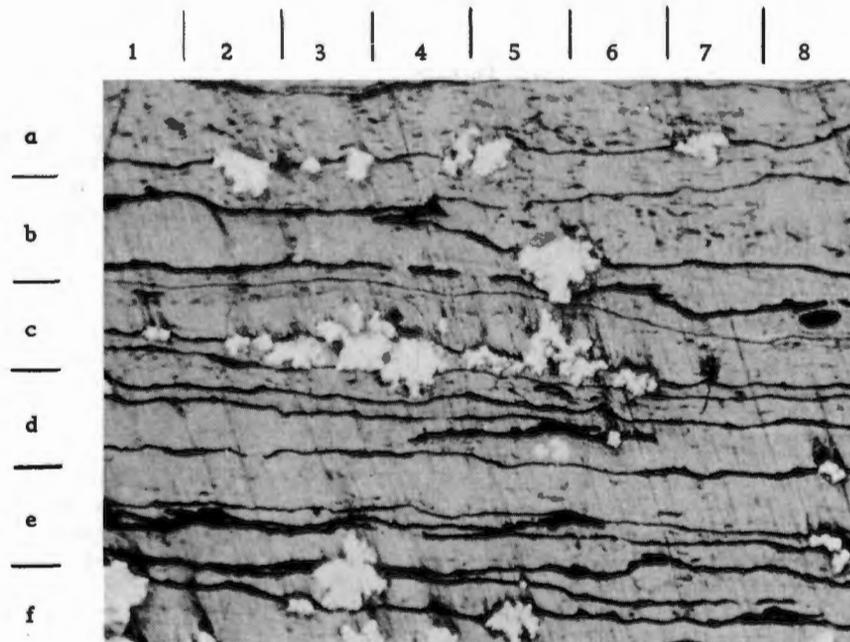


Figure 7b. Cuticles separating bands of microvitrain and microclarain with pyrite crystals commonly found along cuticles. Coal No. 9, core 597-A, block 9. Photo 83.

Illustrations in the section on Mineral Matter show the microscopic appearance of this dull heavily mineralized coal.

d) Fusain and Semifusain

Semifusain is a transitional material intermediate between fusain and vitrain. The boundary between fusain and semifusain is probably less definite than that between vitrain and semifusain but it is indefinite at both limits. In general fusain appears to have a slight yellowish tint that semifusain lacks, but undoubtedly there will be gradations in this tint. It is believed that in the accompanying illustration (Fig. 8a) the very bright honeycombed elliptical area (1-8:e-d) is fusain with elongated areas above and below of semifusain (3-8:c-d); (1-8:f). Above the upper semifusain band is a band of microvitrain and barely showing at the top of the picture (1-6:a) is a second lens of fusain which appears very white. The next illustration (Fig. 8b) shows a particle of fusain in which there is an unusual development of thick cell walls with the middle lamellae between cells strongly developed.

e) Micrinite or Opaque Matter

Micrinite or opaque matter does not occur in the Meigs Creek (No. 9) bed coal in sufficient quantity to materially affect the character of the coal, at least not in sufficient quantity as to make up as much as 20 percent of the total content of bands of megascopic width that is durain bands. It is not always possible to differentiate micrinite and fusinite with certainty in small particles, although broken fragments or shards of froth-like structure will generally be regarded as fusain particularly if they have a yellowish tint. Rather infrequently there appear carbonized bright particles round or elliptical in shape, variously identified as resin rodlets and sclerotia (Fig. 9). Micrinite and pyrite may have somewhat similar appearance in photographs that do not show the difference in color (Fig. 10), although there is usually no difficulty in differentiating the two. In the accompanying illustration pyrite crystal produce the high luster of the cluster of objects in the microvitrain band.

The fairly large amount of micrinite shown in the next illustration (Fig. 11) is exceptional. There is a lens of cellular fusain in the lower left hand side of the picture (d-e:3-4) but other white objects are thought to represent micrinite with sclerotia or carbonized resin rodlets at the top of the microvitrain band (e-f: 1-2, 6-8).

f) Mineral Matter

A very common and easily identified mineral in the Meigs Creek (No. 9) and other Ohio coal bed is pyrite. Marcasite has not been definitely identified in these coals. The pyrite commonly occurs as scattered crystals in the vitrain (Figs. 10 and 12). Such pyrite has a high brassy luster and commonly consists of aggregates of small pyrite cubes and pyritohedrons. Pyrite is by no means restricted in occurrence to vitrain. A common but peculiar mode of occurrence is in association with cuticles (Figs. 13 and 14). Pyrite also quite commonly occurs in fairly solid bands or lenses (Fig. 15) and fills cellular cavities in fusain (Fig. 16).

Finely disseminated pyrite particles in the coal are the source of considerable trouble in the preparation of polished surfaces and thin sections as they are readily loosened from the coal during grinding and polishing and because of their superior hardness are likely to scratch the surface of the coal and to leave cavities difficult to eliminate.

Other common mineral impurities in the Ohio coals consist mainly of clay minerals, with much less amount of calcite and quartz. In general shaly or "bony" coal, the so-called "Brandschiefer" as it is known in Germany, consists of coal with up to about 60 percent of impurities.* In polished surfaces clay minerals do not acquire a polish and hence appear

¹ See note on shaly coal p. 13.

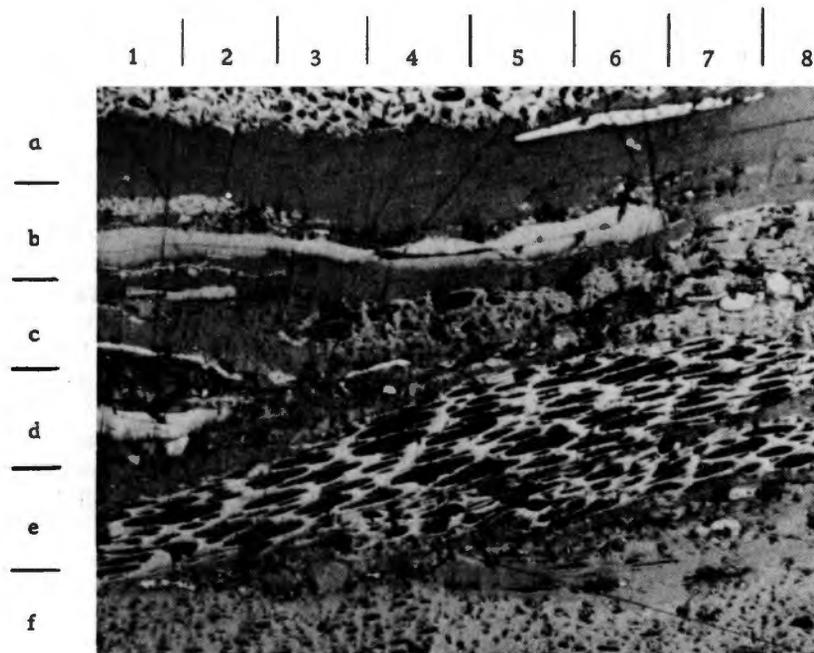


Figure 8a. Fusain lenses, 1-8; a; 1-8: d, e; and semifusain lenses at 1-8: c; 1-8: f. Coal No. 9, core 597-A, block 8. Photo 78.

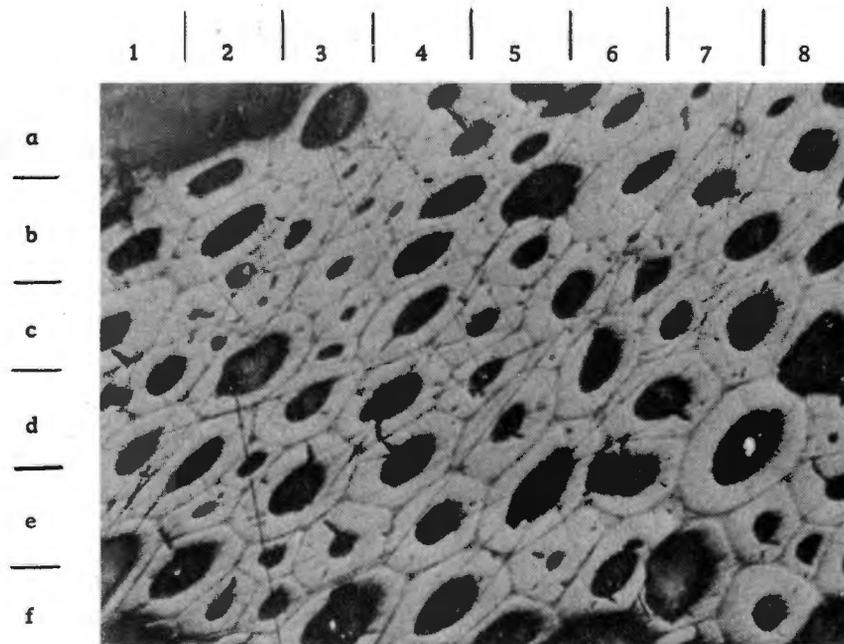


Figure 8b. Fusain with thick cell walls, black cell cavities with position of middle lamellae separating cells strongly accentuated. Coal No. 9, column 584, block 10. Photo 51.

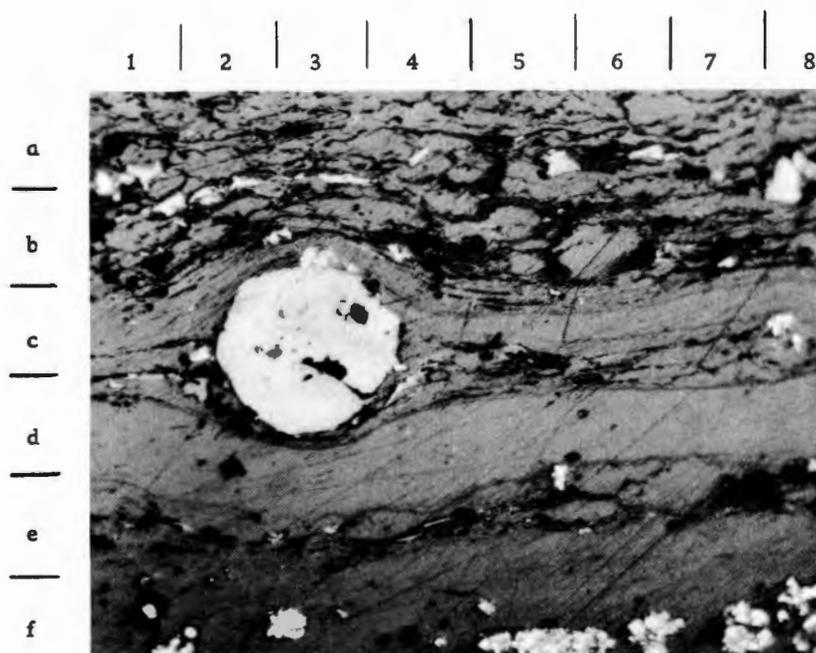


Figure 9. Carbonized resin rodlet or fungal sclerotia. Coal No. 9, sample 603B-1, run-of-mine size 1-1/2" x 1". Photo 93.



Figure 10. Pyrite in microvitrain. Coal No. 9, column 603-1, block 4. Photo 101.

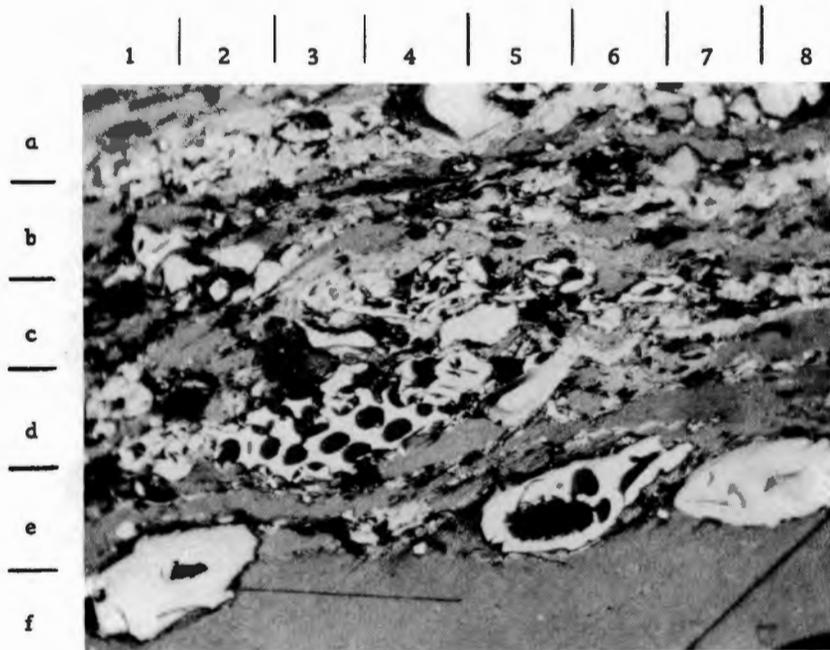


Figure 11. Micrinite in microclarain. Coal No. 9, sample 603B-2, run-of-mine size 1" x 3/4". Photo 99.

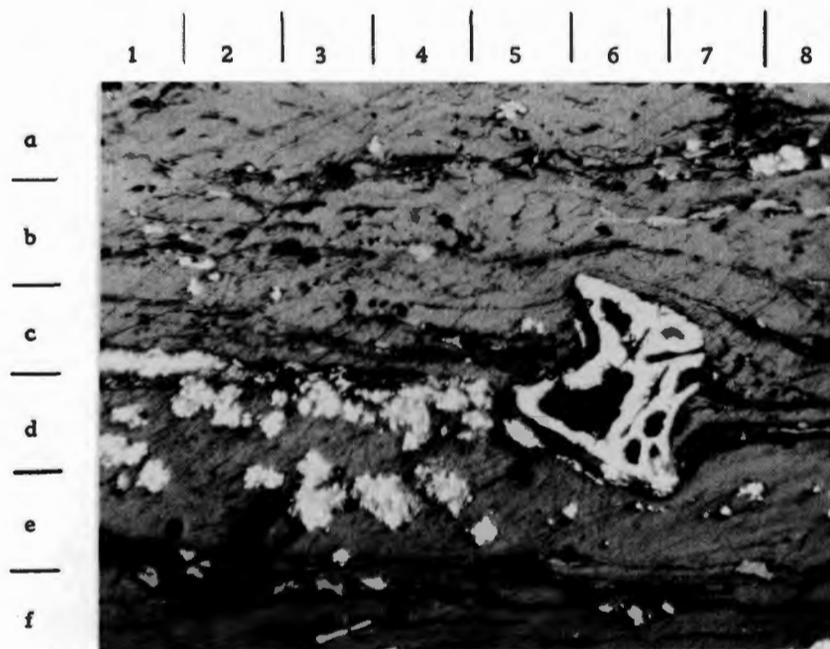


Figure 12. Pyrite crystals scattered in a microvitrain band at 1-8; d,e. Irregular mass of fusain at 6; d. Coal No. 9, sample 603B-1, run-of-mine size 1-1/2" x 1". Photo 94.

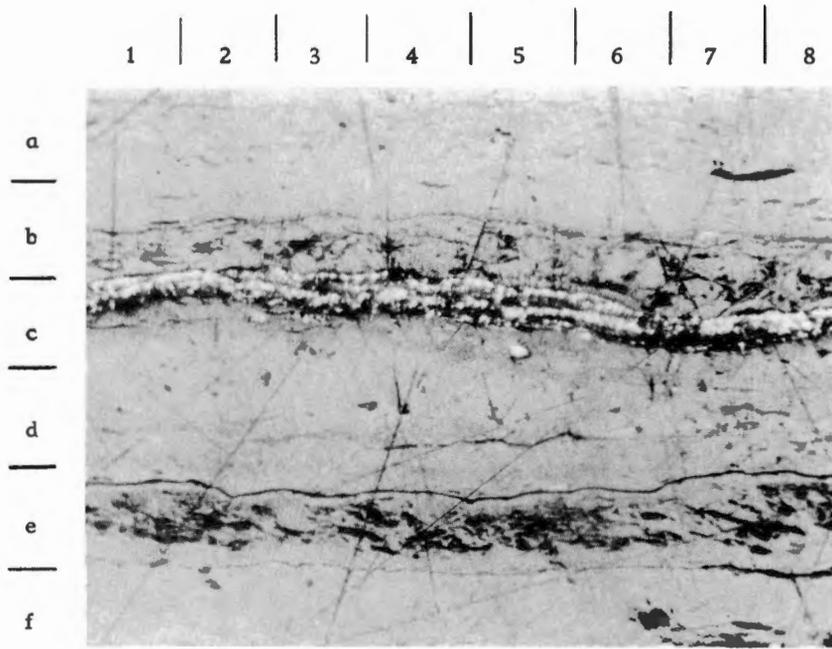


Figure 13. Small pyrite crystals closely scattered along a band of cuticle. Coal No. 9, core 597-A, block 9. Photo 58.

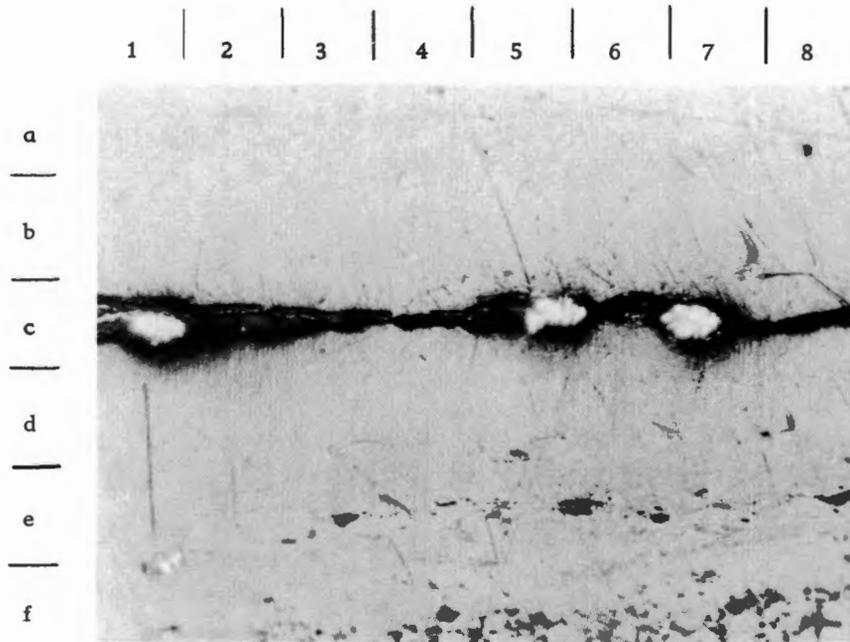


Figure 14. Three pyrite crystals arranged along a band of cuticle. Coal No. 9, core 597-A, block 9. Photo 60.

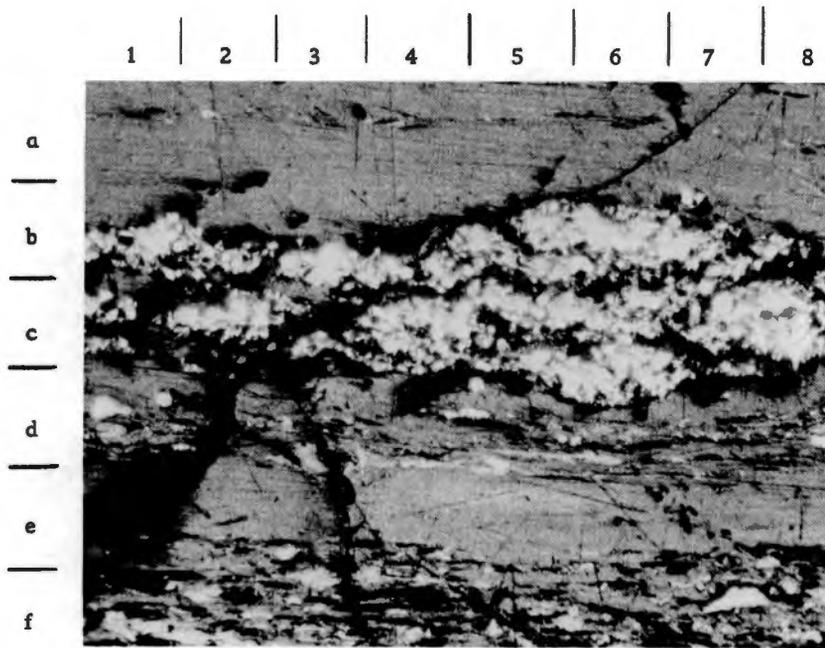


Figure 15. Solid band of crystalline pyrite. Coal No. 9, core 597-A, block 9. Photo 80.

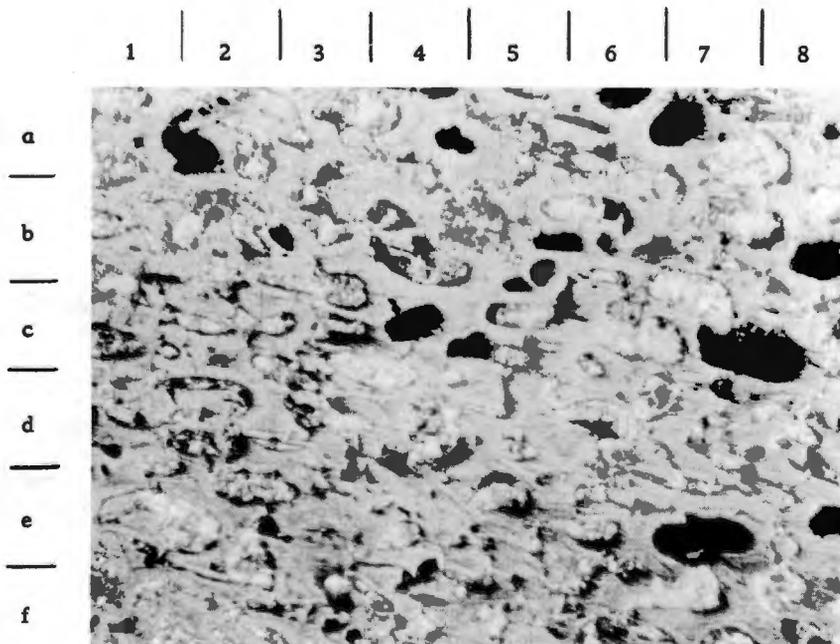


Figure 16. Pyrite filling most of the cell cavities in a piece of fusain. Coal No. 9, core 597-A, block 9. Photo 81.

black; for this reason it is not always possible to differentiate clay minerals and microspores. It seems possible, therefore, that the identification of spores in thin sections is more accurate than in polished surfaces unless the amount of opaque matter is sufficient to block out the spores. Clay minerals being relatively soft erode readily from the surface being ground or polished, producing holes which are generally more or less aligned in the direction of the bedding. It is customary, therefore, in the present investigation to regard dull coal bands containing only small shreds and lenses of coal and much black material as clay material (Fig. 17). The amount of shaly or bony coal in some parts of the Meigs Creek coal bed may be considerable, but there are no persistent bands of such material.

(7) RANK AND TYPE OF COAL

Two causes of variability that characterize all coals are represented by the concepts of type and rank. Coal varies in type because of the character of its component macerals and phyterals. Thus a coal composed largely of vitrain (anthraxylon) is of different type than one composed largely of exinite. It is apparent therefore that there can be great variability of type particularly with respect to small portions of coal bed. Actually, however, a complete bed or important benches in a bed are usually considered as a unit, so that type is usually represented by a few common varieties, namely common banded bituminous coal, cannel coal, and splint coal with gradations between (21). When type differentiation is applied very meticulously, each of these major types may be subdivided into sub-types depending upon detailed quantitative occurrence of individual macerals.

Rank is the expression of the extent of geological metamorphism to which the coal has been subjected. The full range of rank in coal runs from peat to anthracite. This may be expressed chemically by carbon content which in general increases with rank, by volatile matter content which in general decreases with rank, in coals of certain ranks by calorific value, which in general increases with rank, and by other means. In general the reflectivity of coal increases with rank as does also the specific gravity. Although Seyler (14) on the basis of measurements of the reflectivity of vitrain maintains that rank progresses by steps, it is the general opinion in this country, at least, that progression is gradual so that rank subdivision must be made at arbitrary positions. As in the case of type, it is usual to rate the rank of a coal as an average for a bed or important bench of a coal bed. Actually on the basis of any criterion used for determining rank either chemical or physical the individual macerals or phyterals making up a coal bed do not have the same rank. It has been pointed out that the reflectivity of vitrain varies progressively with rank, but so likewise does the reflectivity of spore exines, as shown by Schopf (36) and by Stach (34). The reflectivity of spore exines is lower than that of vitrain in low rank coals but becomes equal to or greater than that of vitrain in high rank coals. Other macerals also display individual peculiarities in reflectivity. Similarly the chemical properties of the different macerals show individual progressive changes with advance in rank so that if the same criteria for differentiating rank was similarly applied to the individual macerals these would be found to vary greatly in rank even for the same coal. Hence in general the rank designation of a coal from a particular bed represents the average value for the bed. However, occasional discrepancies may exist because of local increase in the quantity of some particular maceral such as fusain, micrinite, exinite, etc., in greater than average quantity hence anomalous rank values may occasionally be expected. This is particularly likely to be the case for the different size fractions of coal made during coal preparation procedures if maceral concentration results from such procedures. Thus the different sizes of coal may not appear to have the same rank based upon standard criteria.



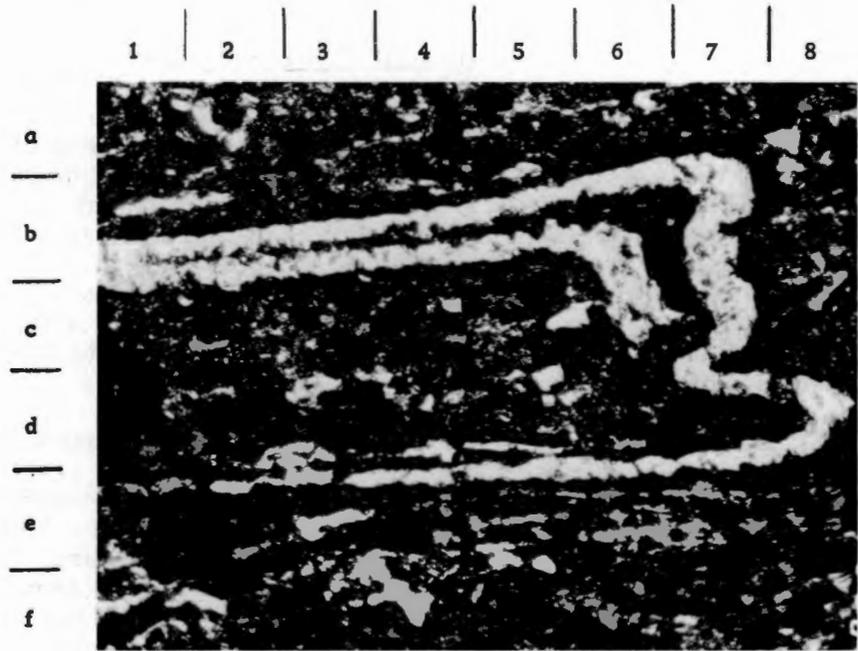


Figure 17. Highly mineralized coal, mainly with clay minerals.
Coal No. 9, core 598-B, block 12. Photo 20.

PETROGRAPHIC CHARACTERISTICS OF THE MEIGS CREEK No.9 BED COAL**A. Methods of Exploration****1) MEGASCOPIC PROFILE**

The two preceding chapters provide an introduction to the methods of studying and describing coal both megascopically and microscopically. A complete full scale diagrammatic profile of the bed on the basis of megascopic observation of polished blocks is usually first prepared whether the microscopic examination is made of thin sections or of polished surfaces. Photography can also be used for recording the megascopic appearance of the bed (Fig. 18). Such diagrammatic or photographic profiles provide a generalized picture of the distribution and thickness of the megalithotypes or ingredients vitrain, clarain, durain, and fusain and bedded and secondary mineral impurities. They may reveal the existence of persistent petrographically unusual bands or benches which may be of importance in their influence upon mining and preparation processes.

2) SUMMARY PROFILES

Since the Meigs Creek (No. 9) coal bed is generally 4 feet or more in thickness summary profiles (Pl. I) are necessary as a matter of convenience and to simplify illustration. Such graphic summaries may help to bring out more clearly concentrations of petrographic components and benched arrangements of the bed.

3) IMPORTANCE OF VITRAIN BANDS

The texture of the coal, determined largely by the thickness and distribution of the vitrain bands down to a thickness of 1/2 mm. (see p. 22) is commonly important in its effect upon breakage. Coarsely banded vitrain (thick to extra thick, (see p. 24) because of the usual brittleness of the material generally tends to break out of the coal bed and concentrate in the small sizes, but it should not be assumed that this tendency is invariable or equally applicable to all ranks of coal. On the other hand relatively thick dull coal or durain bands may because of their toughness (34) tend to concentrate in the larger nut sizes of prepared coal. It might reasonably be desirable, therefore, for cleaning procedures to vary more or less in response to variations in the petrographic profile. This may be a fundamental basis for the common preference of coal mining companies to restrict operations to a single bed to avoid the cleaning problems that may arise when coal from two or more beds having different profiles are put through the same preparation procedure. There is so very little known about the relationship of coal preparation to the petrographic profile of coal beds that it is possible to do little more than speculate on the possibilities.

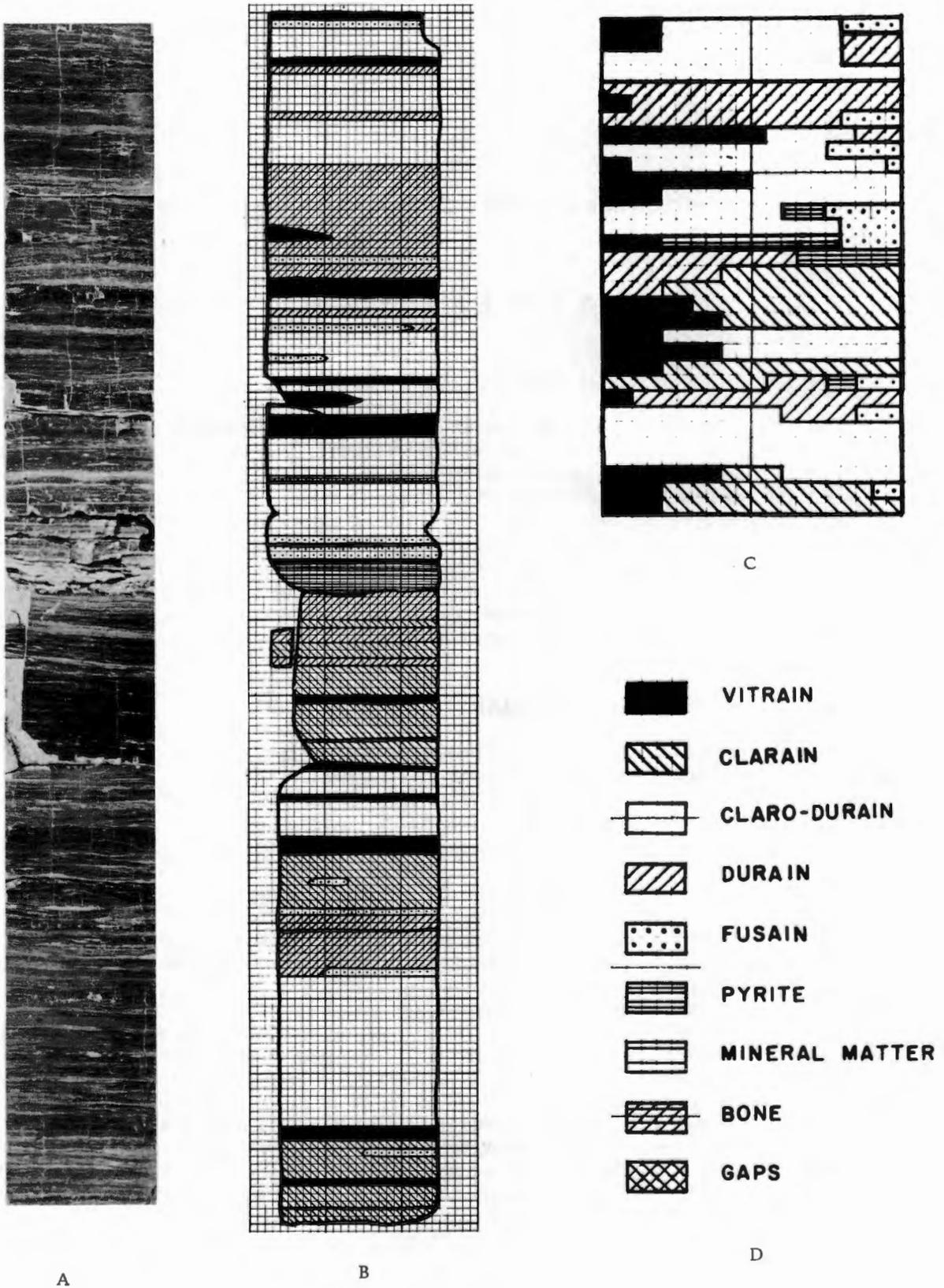


Figure 18. Photograph, one-half natural size (a), megascopic graphic profile (b), and summary profile (c), of blocks 3 through 8 of core 597-A of the No. 9 coal. The key (d) is that used for all further illustrations where megascopic profiles are shown.

4) IMPORTANCE OF FUSAIN BANDS

Fusain layers or lenses often determine the position of persistent benches in a coal bed as well as providing a source of dust produced in the mining and preparation processes. Persistent bands of fusain are, however, not characteristic of the Meigs Creek (No. 9) coal bed.

5) MICROSCOPIC PROFILES

The attrital coals clarain and durain, and particularly the latter, cannot be satisfactorily described as megascopic ingredients or lithotypes. The extent to which the bright luster of clarain is due to microvitrain or to vitrinite (humic degradation matter) can be determined only by the aid of the microscope. Which aid is also necessary to determine to what extent spore exines or other exinite, micrinite, or mineral matter contributed to the dullness of durain. Coal bed or coal bench profiles provide the microscopic information concerning the composition of the attrital bands necessary to understand the petrographic composition of these bands.

6) BROKEN COAL STUDIES

The practical value of coal petrography rests to a large extent upon its usefulness or potential usefulness in determining and controlling the character of broken coal as prepared for the market. Size and ash and sulphur content and heat value are the usual criteria employed in describing a prepared coal. Petrographic differences are almost certain to characterize the different sizes of coal, but the significance of such differences in producing variations in the properties of the different sizes is generally unrealized. Coal petrography to be of practical value must therefore be able to determine the petrographic composition of the broken coal.

7) USE OF POLISHED SURFACE TECHNIQUE

For the petrographic analysis of broken coal, particularly broken coal in sizes of less than 1/2-inch maximum diameter, the use of polished surface technique is almost essential because of the difficulty of preparing thin sections of such material. This is one of the main reasons why this technique has been employed in preparing coal bed profiles, since interpretation of the results of such examination is somewhat simpler than if one technique is used for coal bed examination and another for broken coal samples.

8) QUANTITATIVE PETROGRAPHIC ANALYSIS

Three aspects of quantitative coal analysis have been recognized particularly in Europe (31). These consist of the megascopic coal bed analysis, the microscopic coal bed analysis, and the microscopic analysis in terms of the coal macerals or phyterals. To make a coal bed analysis in terms of the macerals blocks of coal, representing in sequence the continuous profile of the bed, may be used, or the coal sample may be carefully crushed, to reduce as much as possible the quantity of extremely fine coal, and analyzed as broken coal. In the case of mine produced broken coal, quantitative petrographic analysis in terms of the macerals is generally necessary for an accurate description of the material, but microscopic profile methods can be used for the analysis of large and nut sizes of such coal provided the number of such pieces is reduced by valid sampling.

MEIGS CREEK COAL

B. Megascopic Bed Profiles of the Meigs Creek No.9 Bed Coal

1) GRAPHIC PROFILES

Full scale manually prepared graphic profiles of seven columns of the Meigs Creek coal bed reproduce the structural pattern of the bed in terms of the banded ingredients or lithotypes shown in different colors. The surface of the coal was prepared for examination by grinding and rough polishing according to procedure described in Appendix I.

The colors used in showing the structural pattern were red for vitrain and microvitrain, purple for clarain, brown for durain (dull attrital coal), green for fusain, yellow for pyrite, blue for mineral matter other than pyrite, and gaps in the section were indicated by an orange color. In some profiles claro-durain, that is attrital coal intermediate between clarain and durain was left uncolored. For reproduction in black and white (Fig. 18) special symbols were used as shown in the legend of the illustration. The patterns were shown in natural size on strips of cross section paper (Fig. 18c). The strips were cut into lengths of 10 to 12 inches and hinged together to provide a continuous profile for the thickness of the bed or bench involved.

The preparation of such a profile assures a careful preliminary megascopic examination of the bed prior to the microscopic study. This usually reveals any significant evidence of benches of coal of distinct petrographic character and position. It also reveals major structural features produced by distribution of vitrain, fusain, pyrite, and clay or shale bands. The balance of the coal consists of the attrital coal, clarain and durain. In preparing the megascopic profile of Column 584 the attrital coal was separated into clarain and durain. In other columns three grades of luster were generally recognized, that is clarain, claro-durain, and durain, but differentiation is not precise because of the lack of standards of differentiation of brightness or dullness. In general it may be assumed that clarain is bright because of the presence of microvitrain. Claro-durain and durain presumably contain little or no microvitrain, but the composition of these lithotypes require microscopic examination for an understanding of the character of the luster.

2) PHOTOGRAPHIC PROFILES

Some of the coal bed columns or cores have been photographed completely block by block and full scale prints made. These when consecutively mounted end to end provide a full scale reproduction of the column (Fig. 18). Such a photograph provides a means of checking the accuracy of a graphic log and often makes unnecessary the inconvenience of referring to the original bulky mounted specimens. Photographically there is a somewhat greater contrast between the grayish tones of clarain and durain than appears to the eye in the coal itself. Clarain containing much vitrain appears almost as black as vitrain, whereas the durain varies from dark gray to almost white. Thus in general clarain appears fairly brilliant black and durain gray, both however having striated texture.

3) SUMMARY PROFILES

There are presented in Plate I graphic summary profiles of seven columns of the Meigs Creek (No. 9) coal bed, as well as summary profiles of columns of beds No. 8, No. 6, and No. 4A. The first seven profiles on the left: Nos. 584 (two benches), 597-A and 597-B, 598-A, 600-B, 601-D; and 603 (two benches), represent the No. 9 coal bed. The geographic distribution of these columns is described on pp. 5-9 of the Introduction.

The scale of the summary profiles is one-fifth of the natural scale and they are compiled by determining the amount of lithotype transected by a single vertical line crossing the graphic megaprofile. A one-tenth-inch band across the summary profile corresponds to one-half inch of the coal as measured along a selected vertical line, usually located at the mid-point of the graphic log. The summary profile therefore represents the petrographic structure of the bed in half-inch units. If the vitrain entirely occupies one of these half-inch units, it will be shown on the summary profile as a one-tenth-inch band extending entirely across the summary profile.

It may be noted that only in column No. 597-A (Plate I) does a vitrain band extend entirely across the profile diagram. However this does not necessarily mean that there are no other half-inch wide vitrain bands present in these coals, since in some cases such bands may be partly in one and partly in another of two adjacent half-inch units as described in the preceding paragraph. It is apparent from the summary profiles, however, that the number of such wide bands is small.

4) THE MEGASCOPIC PETROGRAPHIC PATTERN OF THE MEIGS CREEK (NO. 9) COAL BED

The petrographic pattern of the Meigs Creek (No. 9) coal bed has certain aspects of possible significance. The summary profiles show a considerably less even distribution of the ingredients or lithotypes in columns Nos. 598-A and 600 than in the other five columns. The pattern of distribution of vitrain in columns Nos. 601 and 603 is somewhat intermediate in character. From (Fig. 1) it may be noted that column No. 600 is from Belmont County whereas all other columns are from Noble or an adjacent part of Morgan County. Column No. 598-A is from a locality somewhat removed from the localities where other columns were collected in Noble and Morgan Counties. There appears to be some suggestions of geographic variability in the petrographic pattern of this coal. This will require additional sampling and examination to substantiate or disprove.

If the petrographic pattern of the Meigs Creek (No. 9) coal bed actually varies systematically in the manner and to the extent indicated this is important to know. In general Meigs Creek coal bed appears to contain vitrain only in thin bands, bands as thick as one-half inch being rare and even those one-quarter-inch thick (one-half the width of the summary profile diagram) being fairly uncommon. There are 17 one-quarter-inch bands in column 584; 4 in column 597-A; 7 in 597-B; 5 in 598-A; 2 in 600; none in 601-D; and 8 in 603. Columns Nos. 603 and 584 are from essentially the same locality, and it may be significant of local regularity that both contain relatively numerous vitrain bands and that these are somewhat thicker than in other columns.

Next to the occurrence of vitrain the quantity and distribution of the dull coal or durain deserves consideration. The pattern designating durain occurs so irregularly that it may be suspected that the dullness is owing mainly to the presence of extraneous mineral matter rather than to any systematic regional change in the character of the organic matter, conditions of accumulation, or of diagenesis.

The number of occurrences of durain is small and minor similarities may have significance. The thickest zone of durain in the seven columns is recorded in column No. 597-B about one-third of the way up from the bottom. There is some suggestion of the presence of a similar dull coal zone about the same position in columns Nos. 597-A, 600, and 601-D. It is more faintly shown in the lower bench of column No. 603. The possibility of there being a fairly widespread durain zone at this general position should not be disregarded in future petrographic examinations of this bed.

There are uncertainties in comparisons such as these with respect to the Meigs Creek (No. 9) bed because of its definite separation locally at least into two benches. Where the

column or core represents only a single bench it is commonly uncertain whether such a single bench represents both benches where two benches are present, or only one, and, if only one, which one. It is generally assumed that only the lower bench is continuous but proof of this seems to be commonly lacking. The available megascopic or microscopic profiles throw no definite light on this problem but additional profiles might do so.

5) PETROGRAPHIC COMPOSITION BY MEGASCOPIC ANALYSIS

The megascopic petrographic analysis of the Meigs Creek (No. 9) bed coal involves determination of the constitution of the coal in the simple terms of banded ingredients or lithotypes, mineral matter other than pyrite, and pyrite. No differentiation of the clarain and durain into maceral composition is possible megascopically. Vitrain is all placed in a single category. It is understood that clarain owes its bright luster mainly to the presence of microvitrain which is present in much less amount in claro-durain and is largely lacking in durain. In claro-durain and durain luster varies because of varying amounts of vitrinite (representing humic degradation matter), microvitrain, spores and cuticles and other exinite, micrinite (opaque matter), and mineral matter. The quantity of such material can be determined only microscopically.

In the accompanying charts reference to intermediate and dull clarain should be understood to mean claro-durain and durain.

The graphically arranged petrographic megascopic analyses of the seven columns of Meigs Creek (No. 9) coal bed (Fig. 19a and b) are based upon data shown in the summary megascopic profiles (Plate I). They show the volumetric composition of the columns and the mineral-matter-free composition on a calculated weight percent basis. The analyses cannot show the manner of distribution of the ingredients as indicated by the profile and as described in the preceding section. Because the amount of apparent mineral matter is small, as reported for the No. 9 coal bed, the values for the lithotypes appear in about the same relationship on both the volumetric and mineral-matter-free weight percent basis. Comparison with coals Nos. 8, 6, and 4A is best made on a mineral-matter-free weight basis (Fig. 20b) since some of these coals contain a considerable amount of mineral matter and pyrite.

There appears to be fair agreement in the vitrain content in all columns of the Meigs Creek (No. 9) coal bed except for column No. 584. In four of the columns the vitrain content varies between 10.6 and 13.4 percent; two columns (600 and 601-D) show 8.3 and 9.5 percent respectively; but the two benches of 584 show 17.5 percent for the upper bench and 18.7 percent for the lower bench. This is in considerable contrast within the values 10.6 and 13.5 percent for the upper and lower benches of column No. 603 collected in close proximity to the locality where column No. 584 was obtained. Column No. 584 seems to have been collected in an area where an unusual abundance of woody material was contributed to the coal bed.

For column 584 the durain was rather strictly differentiated as dull coal, the remaining brighter striated coal being all called clarain. No material of intermediate luster (claro-durain) being differentiated. Clarain appears to be more abundant than in the other columns but this is not necessarily the case. It does show very clearly the relatively great importance of the clarain portion of the coal, the exact petrographic character of which can be determined only by microscopic examination.

6) COMPARISON OF THE MEGASCOPIC COMPOSITION OF MEIGS CREEK (NO. 9) WITH THAT OF THE NO. 8, NO. 6, AND NO. 4-A BED COALS

Greater differences are found among the different coal beds, Meigs Creek (No. 9), Pittsburgh (No. 8), Middle Kittanning (No. 6), and Clarion (No. 4-A), with respect to mega-

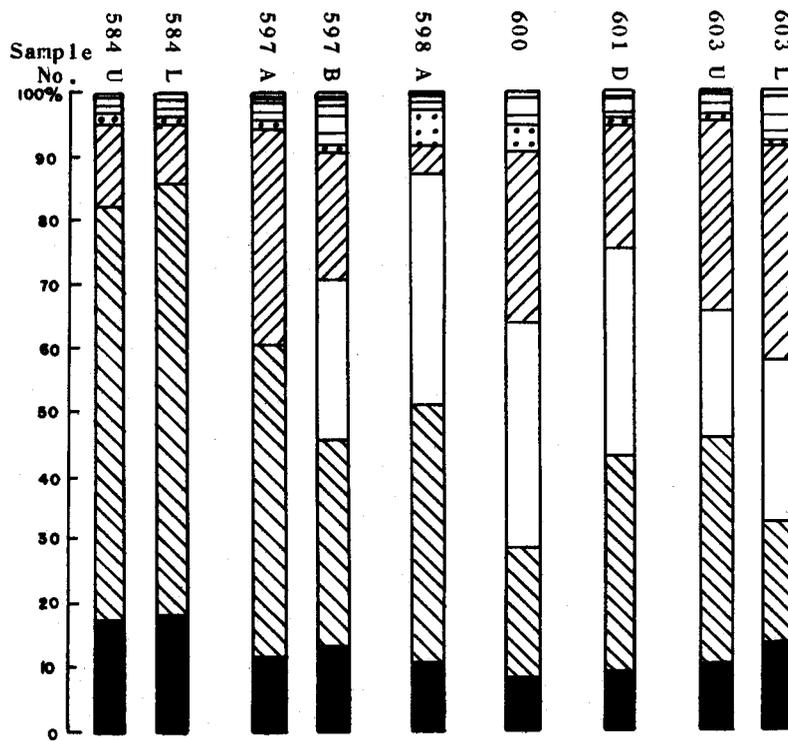


Fig. 19a. A graphic megascopic petrographic analysis of 7 columns of core sections of No. 9 coal bed on a volume-percent basis.

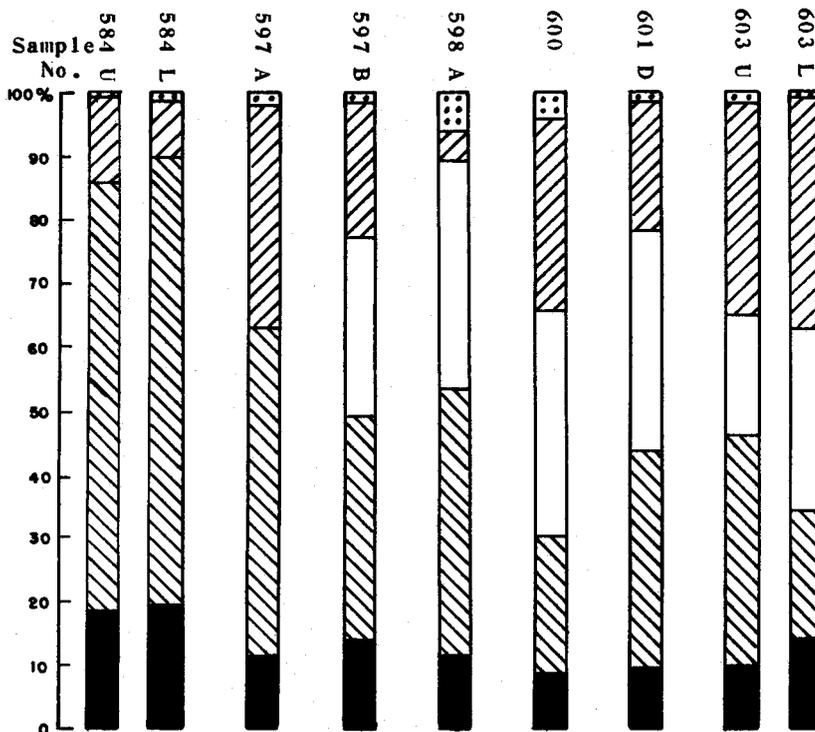


Fig. 19b. A graphic megascopic petrographic analysis of 7 columns or core sections of No. 9 coal bed on a mineral-matter-free weight-percent basis.

scopic petrographic composition than appears to exist among the various columns of the Meigs Creek bed. One column of No. 6 bed and one column of No. 8 bed have in each case a very low vitrain content, on a weight percent mineral-matter-free basis, 4.1 and 1.5 percent respectively; much lower than the vitrain content in any column of No. 9 bed. This particular column of No. 6 bed is also characterized by a very low clarain content of 1.17 per cent. Relatively small quantities of clarain also characterizes the upper bench of column No. 605 (10.9 percent) and column No. 608 (4.8 percent), representing No. 8 and No. 4-A beds respectively. Although the exact composition of the clarain cannot be determined megascopically the megascopic analysis indicates differences appropriate for microscopic investigation.

7) GENERAL SUMMARY OF MEGASCOPIC PETROGRAPHY OF THE MEIGS CREEK (NO. 9) BED COAL

1. Summary profiles indicate that the coal from the Meigs Creek bed contains very little vitrain as much as one-half-inch thick and in general not more than a total of 2 to 3 inches of vitrain in bands as much as one-quarter-inch thick.
2. One column contains about double this thickness of vitrain in one-quarter-inch bands (column No. 584).
3. Summary profiles indicate that variations in the vitrain content of the columns may have systematic geographic distribution.
4. Locally the amount of vitrain may increase 50 to 75 percent above the average.
5. Clarain and claro-durain make up 80 to 90 percent of the Meigs Creek (No. 9) bed coal and of this clarain appears to comprise about one-third.
6. On a mineral-matter-free weight percent basis there are distinct differences in the megascopic petrographic composition of the four coal beds under investigation; differences are also apparent in the summary profiles of the coal columns (Plate I).
7. Because of the relatively high total clarain, claro-durain, and durain content of the four coals being investigated, it is evident that megascopic analyses are inadequate for determining the true petrographic composition of the coals as determined by the maceral components.

C. Microscopic Bed Profile of the Meigs Creek No.9 Coal Bed

1) MACERALS RECOGNIZED IN MICROSCOPIC PROFILE ANALYSIS

Importance of Magnification.

In making a microscopic bed profile petrographic analysis of a column of coal representing a bench or a bed certain decisions must be made as to choice of components suitable for differentiation and measurement. For megascopic analysis visibility establishes limitations in the selection of such constituents. As magnification increases, more and more components, that is macerals or phytals, become visible, thus small magnification often reveals large spores, large resinous bodies, and occasionally the cellular structure of vitrain, but there are still large areas of the coal that have to be classified in general terms comparable to those used in megascopic analysis.

A fairly satisfactory discriminating resolution of much of the coal material into constituent entities or substances (phytals or macerals) results when polished surfaces of coal are

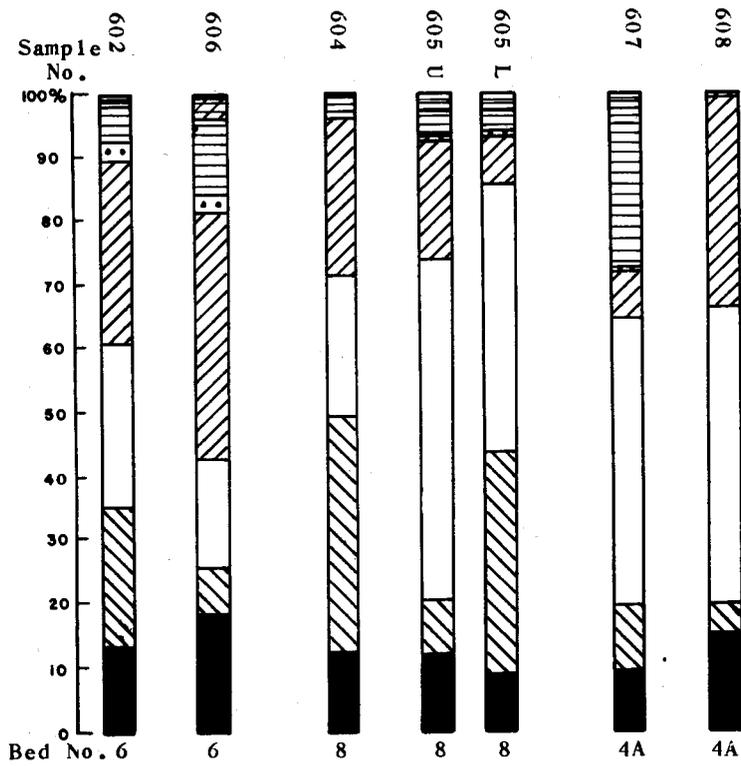


Fig. 20a. Graphic megascopic petrographic analyses of columns or cores of No. 8, No. 6, and No. 4-A coal beds on a volume-percent basis.

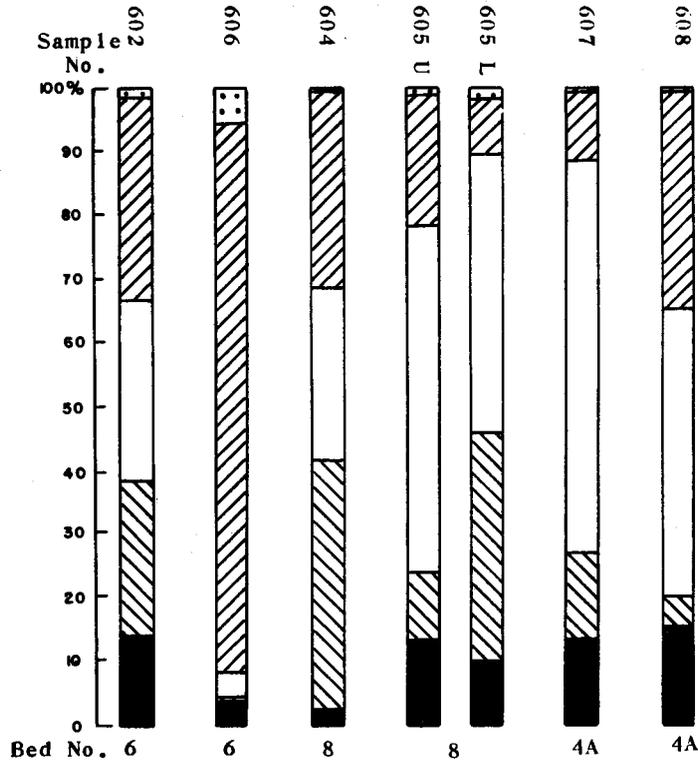


Fig. 20b. Graphic megascopic petrographic analyses of columns or cores of No. 8, No. 6, and No. 4-A coal beds on a mineral-matter-free weight-percent basis.

examined under a magnification of between 200 to 300 times, particularly when an oil immersion objective is used. At this magnification the field of observation extends across a distance of one-third to one-half millimeter (approximately 1/100 to 1/50-inch). This is the usual range of magnification used in the present studies. At this magnification it is possible to differentiate vitrain bands exceeding one-half millimeter in width and microvitrain bands as thin as two to three microns, fragments and lenses of fusain and semifusain, pyrite nodules or crystals down to a few microns in width or diameter (1 micron (μ) = 1/1000 mm.), fragments of micrinite, resin rodlets, sclerotia or sclerotia-like bodies, micro-spores, strips of cuticle, and mineral substances, having dimensions, - width or diameter, - in the order of 1 to 2 microns. However, although macerals or phyterals of this size may be distinguishable measuring them is a matter of considerable difficulty at the indicate magnification, precision generally being attainable only at still higher magnification.

a) VITRAIN, MICROVITRAIN, AND CLARAIN

The microscopic bed profile analysis is designed to provide a picture of the coal bed based upon more discriminating categories than those used in the megascopic profile analysis with greater precision in identification and additional details. In the case of vitrain a width of 0.5 mm. has been tentatively adopted in connection with these studies as the minimum width of this lithotype. No distinction is made between vitrain showing cell structure and that which does not, since it is believed impossible to make valid differentiation of this sort using only polished surfaces. Very little so called "structureless" vitrain seen in polished surfaces will probably prove to be structureless viewed in thin sections with transmitted light.

It is generally recognized that clarain usually consists in considerable part of microvitrain bands less than one-half (0.5) millimeter in width. Hence microvitrain, under the customary magnification of the coal noted above, occupies a relationship to the intervening material similar to that occupied by vitrain to the rest of the coal material in the bed as a whole. Since in the procedure of microscopic profile analysis the microvitrain is separately differentiated and measured there remains no clarain the luster of which is dependent upon microvitrain. There is therefore a microclarain (for note on microlithotypes see page p. 13) the microscopic appearance of which depends upon the amount of bright (translucent) ground mass or vitrinite (humic degradation matter) present and the amount of embedded small macerals such as spore exines (specially microspores), cuticles, resins, fragments of fusain, waxes other than exines, and micrinite of various kinds. Thus the microclarain may appear predominantly translucent (bright) if composed predominantly of a bright humic ground mass (vitrinite) or relatively dull if exinite or some other dull or opaque constituent predominates. Thus the microclarain grades into a micro-claro-durain or even into a microdurain.

b) MICRINITE OR OPAQUE MATTER

Determination of the quantity of micrinite or opaque matter in a coal is regarded as important because it has a critical relationship to the coking and hydrogenation capacity of a coal. However, as has already been pointed out (p. 15), although a smaller amount of micrinite observed in polished surfaces is equivalent to the critical 30 percent of opaque matter observed in thin sections it is not yet known how much smaller. It is tentatively thought desirable to regard as little as 10 percent micrinite in clarain or durain bands as at least worth noting. In general the micrinite in the bands of attrital coal in the Meigs Creek (No. 9) bed does not attain this level even in the few bands that have been classified as durain.

c) FUSAIN AND SEMIFUSAIN

In addition to vitrain, microvitrain, clarain, claro-durain, and durain the profile analysis records the amount of fusain and the transitional material intermediate between fusain and the vitrain called semifusain. Because of its intermediate character precision in identification is impossible as there is no standard basis of separation. In general it is believed that in the present studies there has been a tendency to assign too small an amount of material to this transitional category and too large an amount to fusain.

d) MEGASPORES

Megaspores are quite commonly of sufficient size so that they can most conveniently be considered as individual units rather than as part of clarain or durain.

e) PYRITE AND OTHER MINERAL MATTER

Pyrite and other mineral matter must be taken into consideration in compiling the microscopic coal bed profile. In Ohio coal beds, including Meigs Creek (No. 9) the minerals other than pyrite appear to consist mainly of clay minerals, although it is acknowledged that precise identification has received little more than casual consideration.

f) "VITRINITE"

Among the materials having a vitrain-like aspect viewed either in polished surfaces or in thin sections the so-called humic degradation matter (18, 23) is the only material which seems to be in the nature of a fundamental substance similar to that which composes vitrain and microvitrain and hence might be appropriately designated vitrinite as suggested by Hacquebard (35). In the present studies, therefore, this term is in general used as a substitute for the concept indicated by the phrase "humic degradation matter" referring to all material in clarain or durain having the general appearance of vitrain but not resolvable into maceral units, that is into microvitrain. When a more general meaning is employed the phrase "total vitrinite" will signify the substance composing vitrain, microvitrain, and vitrinite (restricted) (see also p. 50).

g) EXINITE

Evaluation of the petrographic characteristics of clarain and microclarain for the purposes of applied petrography involves quantitative resolution and determination of the elements of exinite. Megascopic analysis has shown that a large part of the Meigs Creek (No. 9) bed coal consists of clarain. A large part of the megascopic clarain consists of microvitrain. The microclarain bands intervening between the microvitrain bands consist of vitrinite in large part in which is embedded various components but consisting mainly of microspores and cuticles. In general in Ohio coals the amount of such exinite present in the attrital bands varies from bench to bench in the same bed and from bed to bed. Undoubtedly there are variations from place to place in the same bed. It is probable that the coal will vary to a greater or less extent both in composition and in the way in which it will respond to handling depending upon the amount and distribution of the exinite. It is therefore a matter of importance to have some method of describing not merely the amount of exinite present in the coal but the character of the clarain and durain bands in terms of the exinite content.

The use of photographs illustrating various measured frequencies of spore occurrence has been previously explained (see p. 24). Such photographs should prove useful for estimating the quantity of spore exines present in clarain and durain bands (see Fig. 5, 6).

At least reference to such illustrations may prevent extravagant statements in regard to the amount of spore exinite present. Inasmuch as the amount of spore exinite in the Meigs Creek (No. 9) bed coal is generally small, it seems probable that it will be adequate for practical purposes to recognize four categories of quantity, viz., less than 5 percent, 5 to 10 percent, 10 to 25 percent, and more than 25 percent. Very little clarain in this coal bed seems to contain more than 25 percent of spore exinite.

In the No. 9 bed cuticular exinite is much less important than spore exinite, but some parts of the bed contain considerable amounts of this material. Additional investigations will have to be made before quantitative categories of reasonable reliability can be established. Here also it is believed that photography will be of service.

2) DETAILED PETROGRAPHIC ANALYSIS

Graphic microscopic petrographic profiles of Meigs Creek (No. 9) coal bed were prepared for only one complete core (No. 597-A) and for selected portions of core No. 603. In each case the profiles were prepared block by block, the blocks not exceeding $6\frac{1}{2}$ inches in length, generally not being over 4 inches long.

For most blocks the analysis involved construction of a graphic log based upon a single detailed transect of the block. Most of the transects were made using an oil immersion objective (12.5:1 or 25:1); others were made using a dry objective (16.5:1). An eight-power ocular containing a micrometer reading to 100 parts was used throughout. This gave a series of magnifications such that by the lowest power objective the total length of the ocular micrometer extended over about one-half millimeter (0.44 - 0.45 mm.) of the coal specimen, by the intermediate power dry objective over about one-third millimeter (0.34 mm.), and by the objective of the highest power over about one-fifth millimeter (0.21 mm.).

On the same type of well-logging form used in the preparation of graphic megascopic profiles each one-tenth-inch row across the two-inch column was used to record the petrographic constituents crossed by the transect of the coal block measured in units of the micrometer scale. The coal specimen was then moved up or down on the stage, depending upon the direction of measurement, so that the next adjacent portion was covered by the micrometer scale. This step by step procedure provided a detailed record in steps of 0.45 mm., 0.33 mm., or 0.50 mm., lengthwise of the specimen. The data for each micrometer measurement were recorded in successive one-tenth-inch rows each one-tenth-inch small square on the profile representing 5 micrometer units, that is one-twentieth (5 percent) of the total length of the ocular micrometer scale. For a block 10 cm. long (approximately 4 inches) the resulting profile was 20, 30, or 50 cm. (8, 12, or 20 inches) long depending upon the power of the objective used.

A scheme of colors and patterns was used to designate the various lithotypes, "micro-lithotypes", and macerals which included the following: vitrain, microvitrain, clarain, megaspores and sporangia, individual resin bodies, fusain, semifusain, mineral matter, and pyrite. Clarain was differentiated into clarain with no exinite, clarain containing cuticle, clarain with less than 5 percent spores, clarain with between 5 and 10 percent spores, clarain with between 10 and 25 percent spores, and clarain with more than 25 percent spores. Clarain containing mineral matter, but less than 10 percent, was distinguished from "bony" clarain containing more than 10 percent mineral matter. Fusain with 10 percent or more of mineral matter was also similarly differentiated. The differentiation of "bony" clarain and fusain was based upon rough estimates only.

The general character of one of these profile graphic diagrams is illustrated by the accompanying figure (Fig. 23) with a black and white symbols substituted for the original colored pattern, as explained in the legend.

The advantage of the graphic profile lies in its reproduction in great detail of the structure of the coal in terms of ingredients or lithotypes and "microlithotypes" and to a considerable extent even in terms of the macerals or phyterals. It is evident that some components occur in fairly wide bands and that others are of very small dimensions. Measurement expressed simply in terms of percentages for the whole block fail to provide this important information concerning the coal structure and texture. Because the procedure is very time consuming it probably should not be employed except in the initial exploration of a coal bed. Thereafter for the same bed, so long as it maintains essentially the same characteristics more rapid methods should be used.

a. Analysis Based Upon Petrographic Profiles

Conversion of the data provided by the petrographic diagrammatic bed profile described above is a matter of counting the smallest squares (one-tenth-inch) represented by each variety of constituent recorded. The volume percent is then readily obtained from the total area of the diagram. To obtain the weight percent the original areas or volume values are corrected in according with the specific gravity of the different materials: vitrain and microvitrain, 1.30; fusain and micrinite, 1.35; pyrite 5.0; mineral matter, including bone, 2.6 (32). From the weight percent values mineral-matter-free (free of mineral matter, pyrite, and "bone coal") can be readily calculated.

3) PETROGRAPHIC ANALYSES OF COLUMN NO. 597A

The petrographic composition of the Meigs Creek (No. 9) bed coal based upon microscopic examination so far as this is represented by the coal of column No. 597-A is presented in Table 3 and graphically in Figs. 22a and 22b.

In gathering the data for Table 3 the prime purpose was to break down the megascopic clarain (see Pl. I and Fig. 19) into microvitrain and microclarain, or that part of the clarain consisting of vitrinite (humic degradation matter), exinite, etc. Hence the analyses show both vitrain and microvitrain. The quantity of the vitrain is a little higher (see Fig. 19, 597-A, and Fig. 22a, Average), but the quantity of clarain (microclarain) is considerably less because of the elimination of microvitrain which does not appear in the megascopic analysis. Since the exinite does not generally exceed 10 percent of the microclarain this clarain is in the order of 90 percent vitrinite. Thus if as in Block No. 1 (Table 3) the total clarain exclusive of the microvitrain is 33 percent of the block, the block then contains approximately 30 percent vitrinite. This amount added to the percent of vitrain and microvitrain gives a total of nearly 86 percent of total vitrinite.

So far as the vitrain content affects the character of the coal in utilization, it will be the total vitrinite content rather than just the vitrain that will be effective. With respect to coal preparation, however, it is the number and size of the vitrain bands that may be of importance.

From the data presented it is evident that the amount of exinite in the clarain in column No. 597-A is small, rarely exceeding 25 percent, generally being less than 10 percent. The balance of the clarain consists very largely of vitrinite (humic degradation matter). The amount of micrinite is very small being considerably less than one percent of most individual blocks.

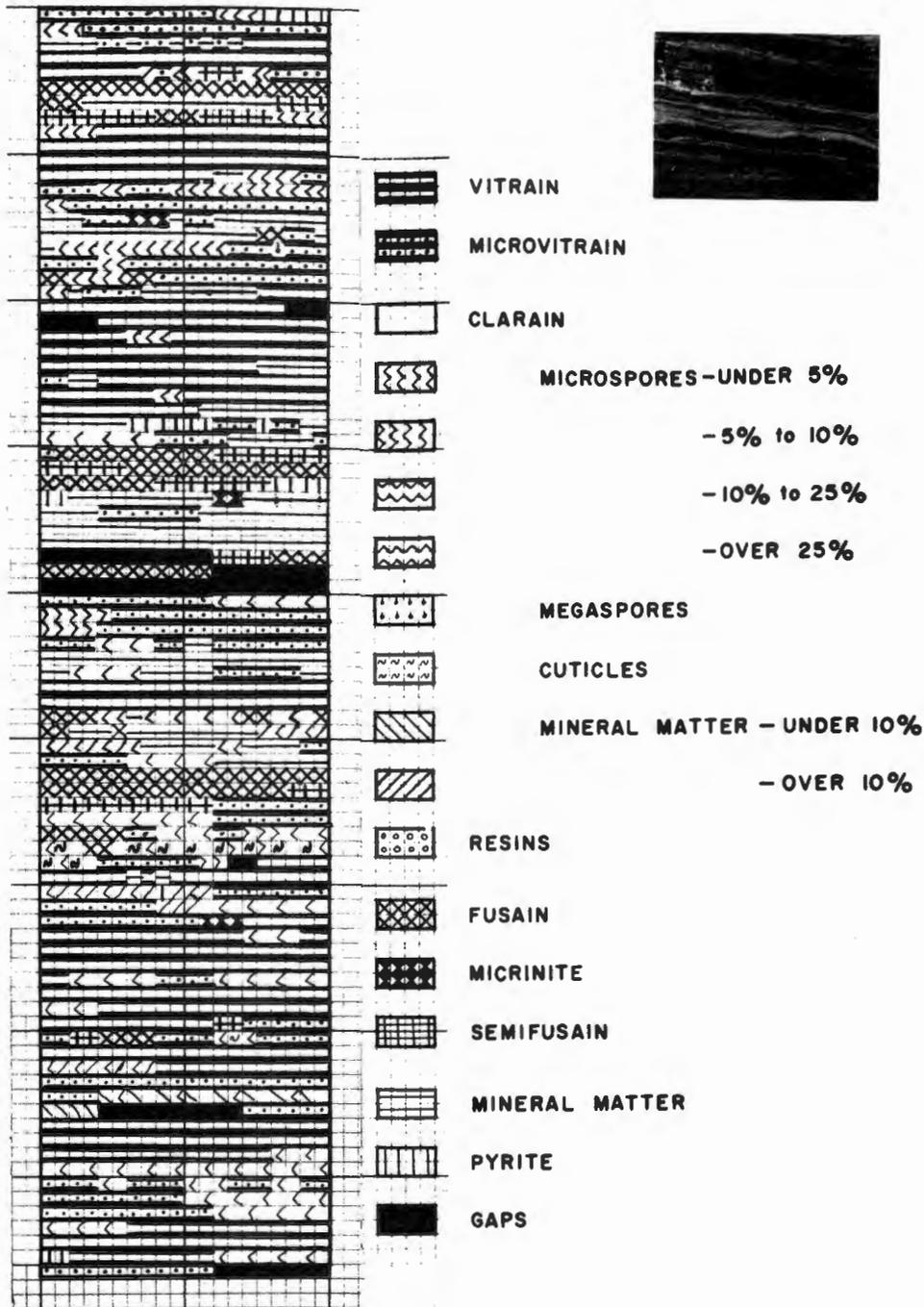


Fig. 21. Natural size photograph of the upper part of block 7, column 603, No. 9 coal (a), with the microscopic graphic profile (b) made at 125X. The key (c) is that used for all illustrations of microscopic graphic profiles.

PETROGRAPHIC CHARACTERISTICS

Table 3. Microscopic Petrographic Analysis of Core No. 597-A, Ohio Meigs Creek, No. 9, Bed Coal.

Block number	Thickness and percent of total thickness	Condition	Vitrain				Clarin				Inerts					Mineral matter				
			Vitrain	Microvitrain	Total	Spores under 10%	Spores 10% to 25%	Spores over 25%	Total	Mega-spores	Fusain			Total	Pyrite	Other mineral matter	Bone	Total		
											Fusain	Semi-fusain	Total							
1	3.5" 6.14%	1	21.73	34.02	55.75	26.35	7.13	-	33.48	0.71	-	-	3.95	0.21	4.16	1.59	3.11	1.20	5.90	100.00
		2	20.09	31.45	51.54	24.36	6.59	-	30.95	0.65	-	-	3.79	0.20	3.99	5.65	5.75	1.45	12.85	99.98
		3	23.05	36.09	59.14	27.95	7.56	-	35.51	0.75	-	-	4.35	0.23	4.58	-	-	-	-	99.98
		4	1.32	2.09	3.41	1.62	.44	-	2.06	0.04	-	-	.24	.01	.25	.10	0.19	.07	.36	6.12
2	2.6" 4.56%	1	23.75	18.27	42.02	27.45	-	-	27.45	-	1.17	3.01	4.18	.49	4.67	.85	17.59	7.27	25.71	99.85
		2	19.38	14.95	34.33	22.45	-	-	22.45	-	0.99	2.54	3.53	0.42	3.95	2.68	28.80	7.77	39.25	99.98
		3	31.90	24.61	56.51	36.96	-	-	36.96	-	1.62	4.18	5.80	0.69	6.49	-	-	-	-	99.96
		4	1.08	0.83	1.91	1.25	-	-	1.25	-	0.05	0.14	0.19	0.02	0.21	0.04	0.80	0.33	1.17	4.54
3 & 4	2.4" 4.21% 2.6" 4.56%	1	19.27	30.33	49.60	-	-	-	40.23	0.41	-	-	4.67	1.02	5.69	1.95	2.11	-	4.06	99.99
		2	17.86	28.12	45.98	-	-	-	37.30	0.38	-	-	4.49	0.98	5.47	6.95	3.91	-	10.86	99.99
		3	20.04	31.54	51.58	-	-	-	41.84	0.43	-	-	5.04	1.10	6.14	-	-	-	-	99.99
		4	1.69	2.66	4.35	-	-	-	3.53	0.04	-	-	0.41	0.09	0.50	0.17	0.19	-	.36	8.78
5	2.1" 3.68%	1	28.40	15.59	43.99	9.55	-	-	9.55	-	15.99	-	15.99	-	15.99	19.41	2.63	8.43	30.47	100.00
		2	17.63	9.69	27.32	8.93	-	-	8.93	-	10.30	-	10.30	-	10.30	46.35	3.27	6.84	56.46	100.01
		3	40.49	22.26	62.75	13.62	-	-	13.62	-	23.66	-	23.66	-	23.66	-	-	-	-	100.03
		4	1.05	0.57	1.62	0.35	-	-	0.35	-	0.59	-	0.59	-	0.59	.71	.10	.31	1.12	3.68
6	2.3" 4.04%	1	35.82	19.00	54.82	19.20	0.55	0.64	19.79	0.09	-	-	9.28	0.21	9.49	0.60	13.97	1.24	15.81	100.00
		2	30.77	16.32	47.09	16.49	0.47	0.03	16.99	0.08	-	-	8.29	0.18	8.47	1.98	24.00	1.39	27.37	100.00
		3	42.37	22.47	64.84	22.70	0.65	0.04	23.39	0.11	-	-	11.41	0.25	11.66	-	-	-	-	100.00
		4	1.45	.77	2.22	0.76	0.02	-	0.78	-	-	-	0.37	0.01	0.38	0.02	0.56	.05	0.63	4.01
7	1.5" 2.63%	1	29.36	21.42	50.78	22.98	0.87	0.13	23.98	0.50	10.74	7.06	17.80	0.69	18.49	0.38	2.01	3.81	6.20	99.95
		2	27.98	20.42	48.40	21.90	0.83	0.12	22.85	0.48	10.63	6.99	17.62	0.68	18.30	1.39	3.83	4.75	9.97	100.00
		3	31.08	22.68	53.76	24.33	0.92	0.13	25.38	0.53	11.81	7.76	19.57	0.76	20.33	-	-	-	-	100.00
		4	0.77	0.69	1.46	0.60	0.02	-	0.62	0.01	0.28	0.19	0.47	0.02	0.49	0.01	0.05	0.10	.16	2.74
8	4.3" 7.54%	1	31.45	20.06	51.51	22.66	0.79	-	23.45	0.49	6.11	7.64	13.75	1.50	15.25	2.91	1.42	4.97	9.30	100.00
		2	28.12	17.94	46.06	20.26	0.71	-	20.97	0.44	5.68	7.09	12.77	1.40	14.17	10.01	2.54	5.81	18.36	100.00
		3	34.44	21.98	56.42	24.82	0.87	-	25.69	0.54	6.96	8.66	15.62	1.71	17.33	-	-	-	-	99.98
		4	2.37	1.51	3.88	1.71	0.06	-	1.77	0.04	0.46	0.58	1.04	0.11	1.15	0.22	0.11	0.37	0.70	7.54
9	3.8" 6.67%	1	50.76	15.66	66.42	29.92	0.15	-	30.07	0.04	0.33	0.28	0.61	0.04	0.65	0.90	1.79	0.15	2.84	100.02
		2	48.55	14.97	63.52	28.60	0.14	-	28.74	0.04	0.34	0.27	0.61	0.04	0.65	3.40	3.42	0.19	7.01	99.96
		3	52.21	16.10	68.31	30.76	0.15	-	30.91	0.04	0.37	0.29	0.66	0.04	0.70	-	-	-	-	99.96
		4	3.39	1.04	4.43	2.00	0.01	-	2.01	-	0.02	0.02	0.04	-	0.04	0.06	0.12	0.01	0.19	6.67
10	3.3" 5.79%	1	25.60	24.16	49.76	38.32	1.12	-	39.44	0.29	2.53	-	2.53	0.16	2.69	5.55	2.01	0.26	7.82	100.00
		2	21.69	20.47	42.16	32.47	0.96	-	33.43	0.25	2.23	-	2.23	0.15	2.38	18.09	3.41	0.29	21.79	100.01
		3	27.73	26.17	53.90	41.52	1.23	-	42.75	0.31	2.85	-	2.85	0.19	3.04	-	-	-	-	100.00
		4	1.48	1.40	2.88	2.22	0.06	-	2.28	0.02	0.15	-	0.15	0.01	0.16	0.31	0.12	0.02	0.45	5.79
Upper 11	3.2" 5.62%	1	4.62	16.20	20.82	-	-	-	67.47	-	-	-	0.77	-	0.77	0.93	9.97	-	10.90	99.96
		2	4.10	14.39	18.49	-	-	-	59.92	-	-	-	0.70	-	0.70	3.18	17.71	-	20.89	100.00
		3	5.18	18.19	23.37	-	-	-	75.74	-	-	-	0.88	-	0.88	-	-	-	-	99.99
		4	0.26	0.91	1.17	-	-	-	3.80	-	-	-	0.04	-	0.04	0.05	0.56	-	0.61	5.62
Lower 11	.80" 1.40%	1	25.32	23.44	48.76	-	-	-	-	-	-	-	-	-	-	1.31	49.91	-	51.22	99.98
		2	16.48	15.26	31.74	-	-	-	-	-	-	-	-	-	-	3.28	64.98	-	68.26	100.00
		3	51.92	48.08	100.00	-	-	-	-	-	-	-	-	-	-	-	-	-	-	100.00
		4	.36	.32	.68	-	-	-	-	-	-	-	-	-	-	0.02	0.70	-	.72	1.40
12	4.6" 8.07%	1	23.83	20.65	44.48	17.56	0.05	-	17.61	0.45	4.68	0.41	5.09	0.14	5.23	2.22	8.11	21.88	32.21	99.98
		2	19.65	17.03	36.68	14.48	0.03	-	14.51	0.37	4.00	0.35	4.35	0.12	4.47	7.05	13.38	23.56	43.99	100.02
		3	35.08	30.41	65.49	25.85	0.05	-	25.90	0.66	7.14	0.62	7.76	0.21	7.97	-	-	-	-	100.02
		4	1.92	1.67	3.59	1.42	-	-	1.42	0.04	0.38	0.03	0.41	0.01	0.42	0.18	0.65	1.77	2.60	8.07
13	4.5" 7.89%	1	10.63	30.89	41.52	39.86	-	-	39.86	0.06	10.53	1.20	11.73	1.39	13.12	0.32	1.82	3.27	5.41	99.97
		2	10.19	29.63	39.82	38.24	-	-	38.24	0.07	10.49	1.20	11.69	1.39	13.08	1.20	3.49	4.11	8.80	100.01
		3	11.17	32.49	43.66	41.93	-	-	41.93	0.08	11.50	1.32	12.82	1.52	14.34	-	-	-	-	100.01
		4	0.84	2.44	3.28	3.15	-	-	3.15	-	0.83	0.09	0.92	0.11	1.03	0.02	0.14	0.26	.42	7.88
14	3.4" 5.96%	1	18.84	26.09	44.93	43.06	1.02	-	44.08	-	5.00	1.41	6.41	0.51	6.92	3.09	0.39	0.60	4.03	100.01
		2	17.20	23.80	41.00	39.29	0.92	-	40.21	-	4.73	1.32	6.05	0.48	6.53	10.83	0.71	0.71	12.25	99.99
		3	19.61	27.13	46.74	44.79	1.05	-	45.84	-	5.39	1.50	6.89	0.55	7.44	-	-	-	-	100.02
		4	1.12	1.56	2.68	2.56	0.06	-	2.62	-	0.30	0.08	0.38	0.03	0.41	0.18	0.02	0.04	0.24	5.95
15	4.2" 7.37%	1	-	-	36.00	-	-	-	52.41	1.86	-	-	3.88	0.91	4.79	3.50	1.44	-	4.94	100.00
		2	-	-	32.27	-	-	-	46.97	1.66	-	-	3.61	0.84	4.45	12.07	2.58	-	14.65	100.00
		3	-	-	37.81	-	-	-	55.03	1.94	-	-	4.23	0.98	5.21	-	-	-	-	99.99
		4	-	-	2.65	-	-	-	3.86	0.14	-	-	0.28	0.07	0.35	0.26	0.11	-	0.37	7.37
16	3.3" 5.79%	1	19.89	26.13	46.02	-	-	-	45.64	0.46	-	-	2.18	-	2.18	0.42	5.28	-	5.70	100.00
		2	18.67	24.52	43.19	-	-	-	42.83	0.43	-	-	2.12	-	2.12	1.52	9.91	-	11.43	100.00
		3	21.08	27.68	48.76	-	-	-	48.36	0.49	-	-	2.39	-	2.39	-	-	-	-	100.00
		4	1.15	1.51	2.66	-	-	-	2.64	0.03	-	-								

MEIGS CREEK COAL

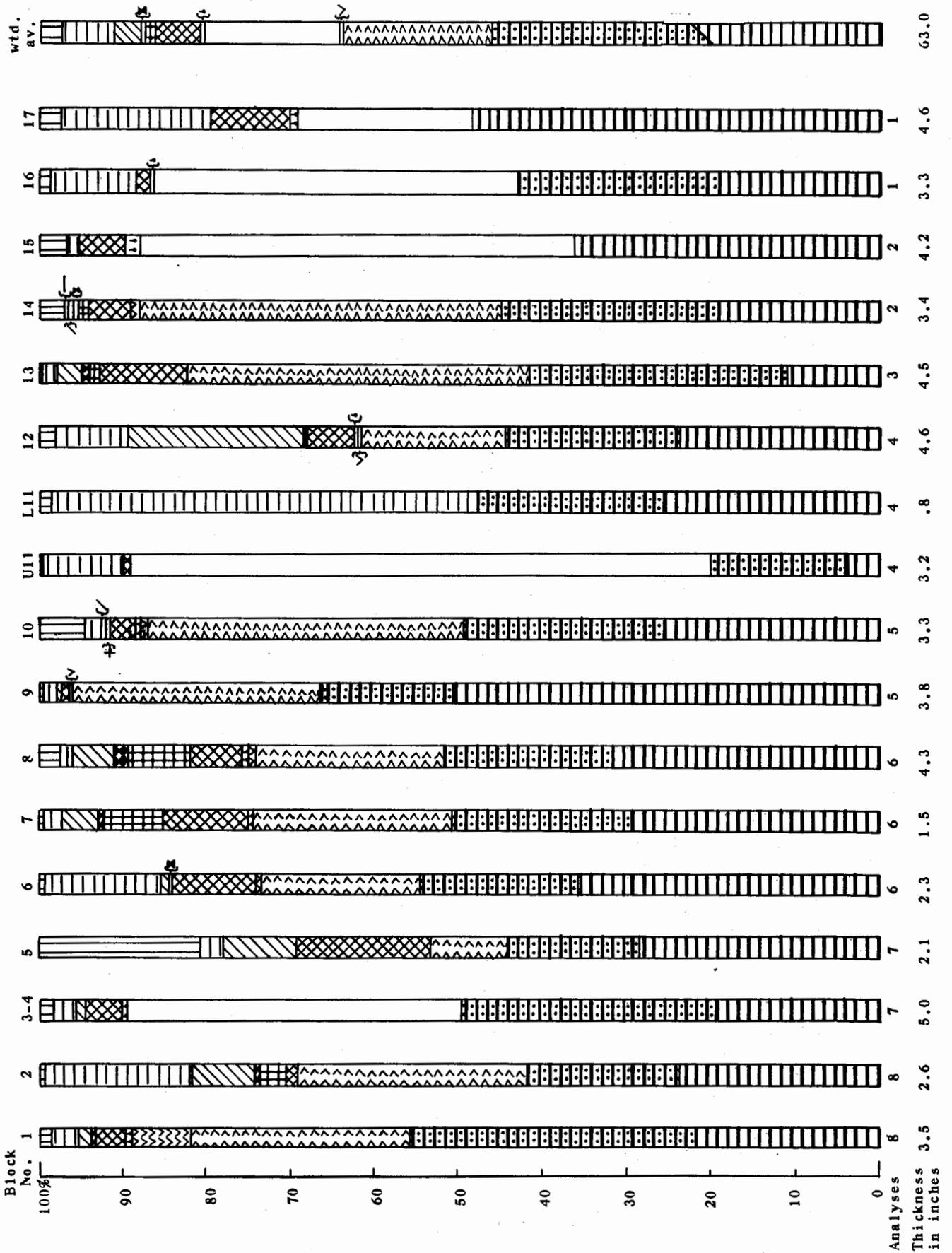


Fig. 22a. Graphic microscopic petrographic analysis of blocks of column No. 597A block by block on a volume-percent basis.

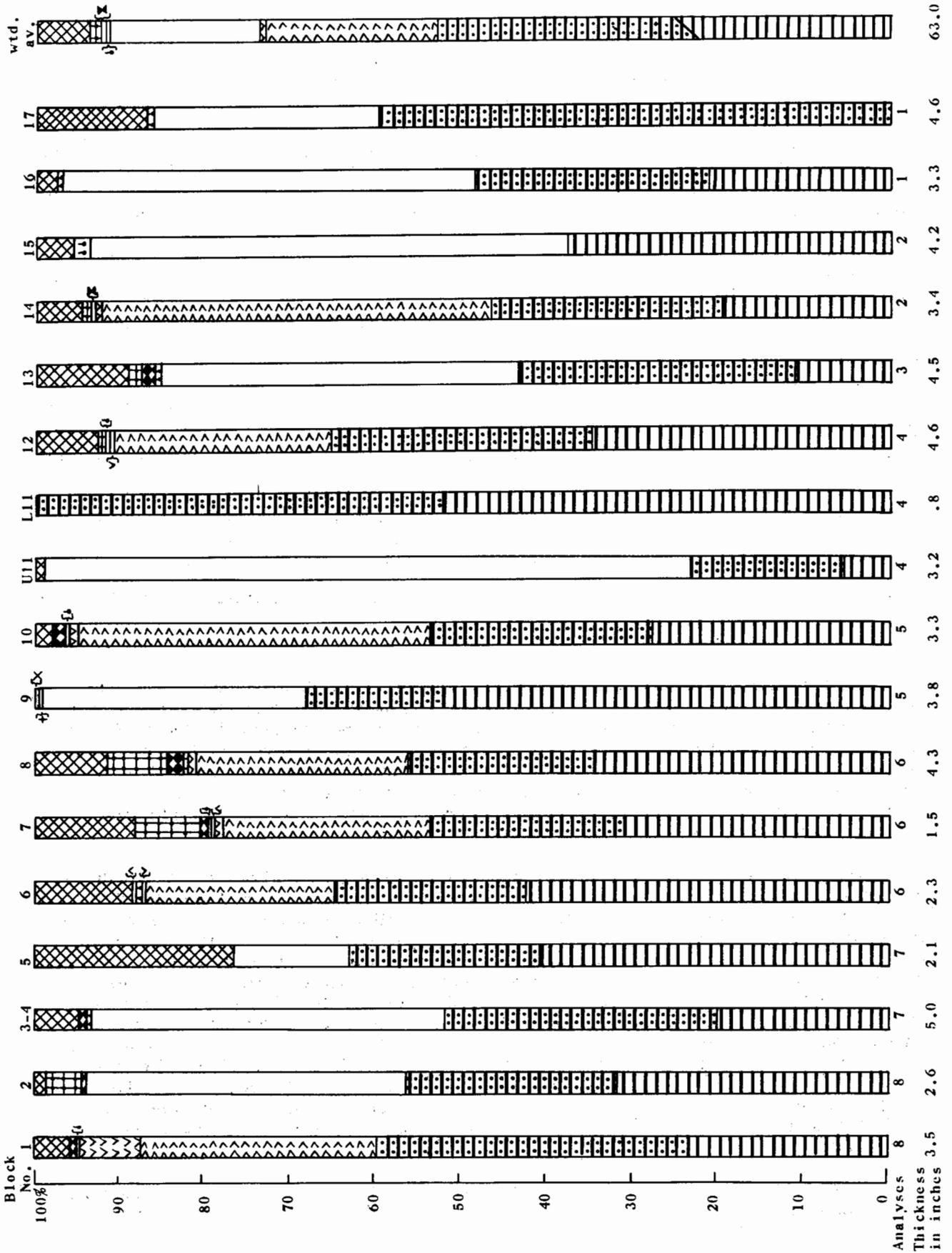


Fig. 22b. Graphic microscopic petrographic analysis of column No. 597A block by block on a mineral-matter-free weight-percent basis.

MEIGS CREEK COAL

Table 4. Petrographic Composition of Selected Blocks of Ohio Meigs Creek, No. 9, Bed Coal from Core No. 597-A.

Petrographic component	Block 2					Block 5					Block 9					
	Units		Percent			Units		Percent			Units		Percent			
	Volume	Weight	Volume	Weight	Mineral-matter-free	Volume	Weight	Volume	Weight	Mineral-matter-free	Volume	Weight	Volume	Weight	Mineral-matter-free	
Vitrain: (Sp.gr.=1.30)																
Vitrain.....	528	686	23.78	19.38	31.90	357	464	28.40	17.63	40.49	2749	3574	80.76	48.55	52.21	
Microvitrain.....	407	529	18.27	14.95	24.61	196	255	18.59	9.69	22.26	848	1102	15.66	14.97	16.10	
Total.....	935	1215	42.02	34.33	56.51	553	719	43.99	27.32	62.75	3597	4676	66.42	63.52	68.31	
Clarain: (Sp.gr.=1.30)																
Loss than 5% spores.....	254	330	11.40	9.33	15.36	23	30	1.83	1.14	2.62	471	612	8.70	8.31	8.94	
5% - 10% spores.....	14	18	0.63	0.81	0.84	-	-	-	-	-	2	3	0.15	0.14	0.15	
10% - 25% spores.....	-	-	-	-	-	-	-	-	-	-	8	10	0.15	0.14	0.15	
Megaspores.....	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
With cuticles (few or no spores)	63	82	2.85	2.32	3.82	-	-	-	-	-	1141	1483	21.07	20.15	21.67	
Mineral matter up to 10%.....	280	364	12.57	10.29	16.94	97	126	7.72	4.79	11.00	8	10	0.15	0.14	0.15	
Total.....	611	794	27.45	22.45	36.96	120	156	9.55	5.93	13.62	1630	2118	30.11	28.78	30.95	
Inerts: (Sp.gr.=1.35)																
Fusain.....	26	35	1.17	0.99	1.62	201	271	15.99	10.30	23.66	18	24	0.33	0.34	0.37	
Semifusain.....	67	90	3.01	2.54	4.18	-	-	-	-	-	15	20	0.28	0.27	0.29	
Total.....	93	125	4.18	3.53	5.80	201	271	15.99	10.30	23.66	33	44	0.61	0.61	0.66	
Micrinite.....	11	15	0.49	0.42	0.69	-	-	-	-	-	2	3	0.04	0.04	0.04	
Sclerotinite.....	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
Total.....	104	140	4.67	3.95	6.49	201	271	15.99	10.30	23.66	35	47	0.65	0.65	0.70	
Mineral matter:																
Pyrite (Sp.gr.=5.0).....	19	95	0.85	2.68	-	244	1220	19.41	46.35	-	49	250	0.90	3.40	-	
Mineral matter (not pyrite) (Sp.gr.=2.6).....	392	1019	17.59	28.80	-	33	86	2.63	3.27	-	97	282	1.79	3.42	-	
Bone (impure clarain and fusain) (Sp.gr.=1.7).....	162	275	7.27	7.77	-	106	180	8.43	6.84	-	8	14	0.15	0.19	-	
Total.....	573	1389	25.71	39.25	-	383	1486	30.47	56.46	-	154	546	2.84	7.01	-	
Total.....	2223	3538	99.85	99.98	99.96	1257	2632	100.00	100.01	100.03	5416	7357	100.02	99.96	99.96	

Although it has generally been assumed that vitrain, microvitrain, and vitrinite consist of essentially the same kind of coal material, P. A. Hacquebard has recently expressed doubt concerning the validity of this assumption, having found that the vitrinite exhibited a different rate of oxidation than the vitrain (35). The appearance of the microvitrain in the megascopic clarain is usually sufficiently different from that of the vitrinite to permit their individual identification. However the validity and value of this differentiation remains undetermined. Probably the humic degradation matter contains shreds of microvitrain too small for practical differentiation at the magnification usually employed.

Megascopically dull coal or durain comprises a considerable part of the coal in column No. 597-A. Microscopic analysis, however, resolves most of this material into "bony" coal, coaly shale, or mineral matter. In microscopic investigation "dullness" as a basis for identification of a coal component is of no significance. In polished sections certain components of the coal which contribute to dullness of luster megascopically, such as micrinite (opaque matter) and fusain, actually have a very high reflectivity and appear nearly white in polished surfaces. Clayey mineral matter and exinite have low reflectivity and appear dark viewed in reflected light. If such material as durain is to be recognized microscopically, it must be on some other basis than dullness. The U. S. Bureau of Mines has used the amount of opaque matter (21) as a basis of differentiating splint coals, which undoubtedly appear dull megascopically. Others have suggested the content of total vitrinite as a basis of differentiation. The present authors are of the opinion that the amount of total vitrinite is a suitable means of identifying microdurain or "durite" (see footnote p. 13) if this same judged satisfactory, with splint coal being a special variety of "durite".

On the assumption that microdurain contains not more than 10 percent of total vitrinite, none of this microscopic variety of coal is found in column No. 597-A. This statement also excludes the occurrence of splint coal variety of "durain".

PETROGRAPHIC CHARACTERISTICS

Table 4. Petrographic Composition of Selected blocks of Ohio Meigs Creek, No. 9, Bed Coal from Core No. 597-A. (Continued)

Block 10					Block 12					Block 13					Block 14				
Units		Percent																	
Volume	Weight	Volume	Weight	Mineral-matter-free	Volume	Weight	Volume	Weight	Mineral-matter-free	Volume	Weight	Volume	Weight	Mineral-matter-free	Volume	Weight	Volume	Weight	Mineral-matter-free
802	1043	25.60	21.69	27.73	525	683	23.83	19.65	35.08	328	426	10.63	10.19	11.17	629	818	18.84	17.26	19.61
757	984	24.16	20.47	26.17	455	592	20.65	17.03	30.41	953	1239	30.89	29.63	32.49	871	1132	26.09	23.80	27.13
1559	2027	49.76	42.16	53.90	980	1275	44.48	36.68	65.49	1281	1665	41.52	39.82	43.66	1500	1950	44.93	41.00	46.74
701	911	22.37	18.95	24.23	314	408	14.25	11.74	20.96	948	1232	30.73	29.46	32.30	1072	1394	32.12	29.30	33.40
229	298	7.31	6.20	7.93	71	92	3.22	2.65	4.73	89	116	2.88	2.77	3.04	322	419	9.65	8.81	10.04
35	46	1.12	0.96	1.23	1	1	0.05	0.03	0.05	-	-	-	-	-	34	44	1.02	.92	1.05
9	12	0.29	0.25	0.31	10	13	0.45	0.37	0.66	2	3	0.06	0.07	0.08	-	-	-	-	-
254	330	8.10	6.86	8.77	2	3	0.09	0.09	0.16	51	66	1.65	1.58	1.73	-	-	-	-	-
17	22	0.54	0.46	0.59	-	-	-	-	-	142	185	4.60	4.43	4.86	43	56	1.29	1.18	1.35
1245	1619	39.73	33.68	43.06	398	517	18.06	14.88	26.56	1232	1602	39.92	38.31	42.01	1471	1913	44.08	40.21	45.84
79	107	2.53	2.23	2.85	103	139	4.68	4.00	7.14	325	439	10.53	10.49	11.50	167	225	5.00	4.73	5.39
-	-	-	-	-	9	12	0.41	0.35	0.62	37	50	1.20	1.20	1.32	47	63	1.41	1.32	1.50
79	107	2.53	2.23	2.85	112	151	5.09	4.35	7.76	362	489	11.73	11.69	12.82	214	288	6.41	6.05	6.89
5	7	0.16	0.15	0.19	3	4	0.14	0.12	0.21	43	58	1.39	1.39	1.52	17	23	0.51	0.48	0.55
-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
84	114	2.69	2.38	3.04	115	155	8.23	4.47	7.97	405	547	13.12	13.08	14.34	231	311	6.92	6.53	7.44
174	870	5.55	18.09	-	49	245	2.22	7.05	-	10	50	0.32	1.20	-	103	515	3.09	10.83	-
63	164	2.01	3.41	-	179	465	8.11	13.38	-	56	146	1.82	3.49	-	13	34	0.39	0.71	-
8	14	0.26	0.29	-	482	819	21.88	23.56	-	101	172	3.27	4.11	-	20	34	0.60	0.71	-
245	1048	7.82	21.79	-	710	1529	32.21	43.99	-	167	368	5.41	8.80	-	136	553	4.08	12.25	-
3133	4808	100.00	100.01	100.00	2203	3476	99.98	100.02	100.02	3085	4182	99.97	100.01	100.01	3338	4757	100.01	99.99	100.02

Microscopic examination shows that some blocks of column 597-A are dull, that is contain considerable durain, because "bone coal" or mineral matter makes up one-third to one half the block. It probably would be readily possible to separate such high ash coal from the purer coal by float-and-sink methods.

It should be apparent on the basis of the preceding comments and the data presented in Table 3 and Figs. 22a and 22b that visual inspection or megascopic analysis cannot be relied upon to provide an adequate description of the Meigs Creek (No. 9) bed coal. This statement applies equally well to most if not all bituminous coals. In this case microscopic examination and reclassification results in a material reduction of the amount of clarain, mainly because of the separate differentiation of microvitrain. It also shows that the remaining portion of the clarain (microclarain) consists largely of vitrinite. Microscopic examination also tends to increase the estimate of mineral matter, "bony" coal, and fusain, these substances being shown to compose much of the megascopic durain. Such examination practically eliminates durain as a separate coal ingredient or lithotype in this column of Meigs Creek coal bed.

a. Clarain in Selected Blocks of Column No. 597-A

The data presented in Table 4 and graphically in Figs. 23a and 23b are based upon a somewhat more discriminating differentiation of the constituents composing clarain particularly for Blocks Nos. 2, 5, 9, and 13 than is shown by the more generalized analyses in Table 3 and Figs. 22a and 22b.

MEIGS CREEK COAL

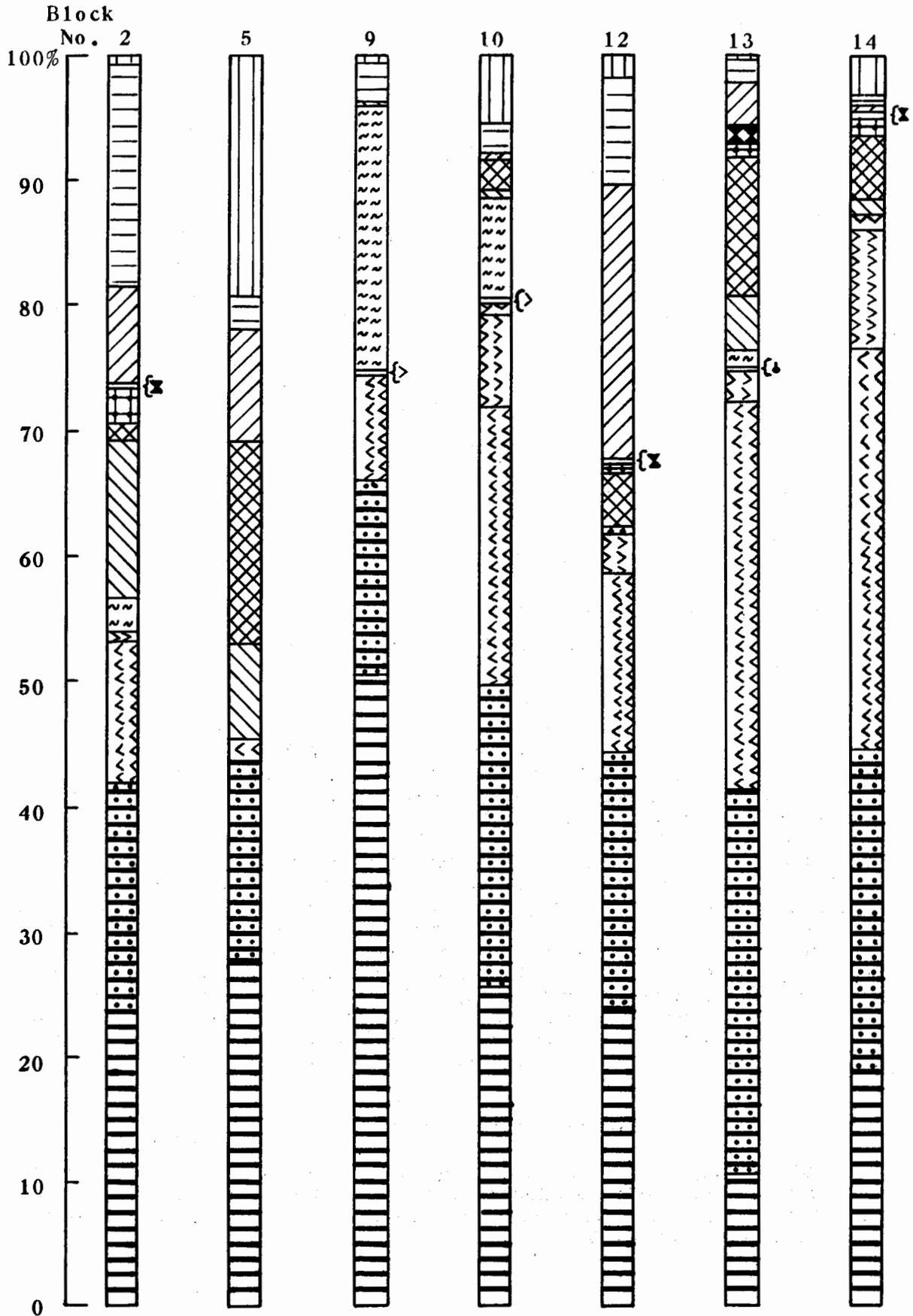


Fig. 23a. Graphic microscopic petrographic analysis of selected blocks of column No. 597A with clarain shown in greater detail than in figure 22, on a volume-percent basis.

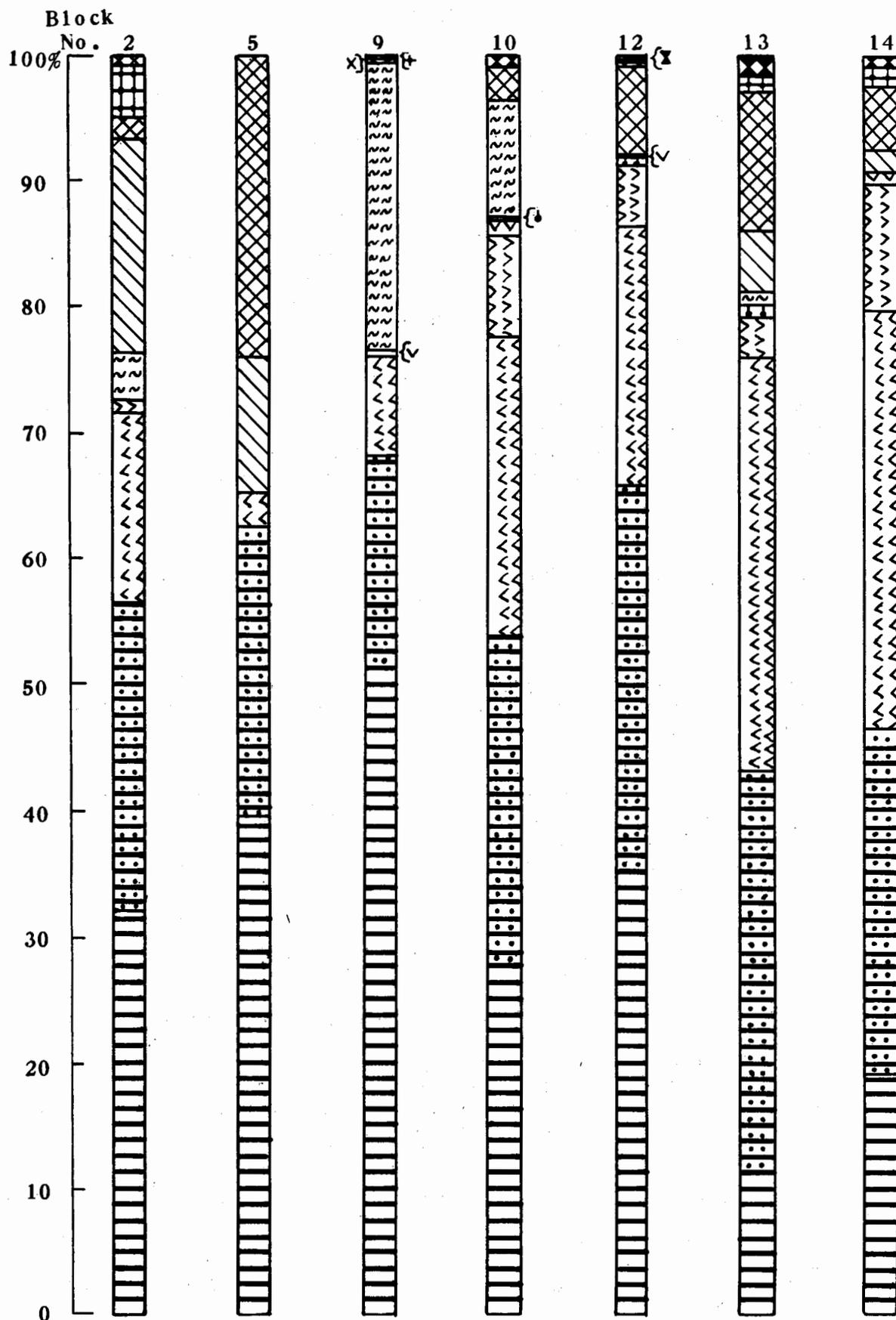


Fig. 23b. Graphic microscopic petrographic analysis of selected blocks of column No. 597A block by block with clarain shown in greater detail than in figure 22, on mineral-matter-free weight-percent basis.

MEIGS CREEK COAL

In these analyses it will be observed that cuticular clarain is differentiated from spore-exinite clarain. The cuticles appear as fine grayish lines separating microvitrain bands, rather than as particles embedded in a undifferentiated groundmass of vitrinite (see Figs. 7a and 7b). The cuticles are extremely attenuated with a width in the order to 1 to 3 microns, but may extend laterally completely across and beyond the immediate field of observation. The material enclosing the cuticles commonly appears to consist of vitritized closely packed leaves or stems or both. It might better be called cuticular microvitrain than clarain or microclarain. Most of the blocks of Column No. 597-A contain some of this material and some blocks a considerable amount: Block No. 9 contains 21 percent of cuticular clarain or microvitrain; Block No. 12, 8 percent, with lesser amounts in other blocks represented in Table 4 and Figs. 23a and 23b. It is roughly estimated that the amount of cuticular exinite in these blocks as a whole is less than 5 percent.

Both sets of microscopic petrographic analysis (Tables 3 and 4, Figs. 22 and 23) also differentiate certain bands of clarain of low mineral matter content (10 percent or less), beyond which limit the clarain (or fusain) is designated as shaly coal and calculated as mineral matter. In Block No. 2 (Fig. 23) 12 percent of the coal is impure clarain, and in Block No. 5 about 8 percent.

The seven analyses given in Table 4 (Fig. 23) indicate that the designation of clarain as having an exinite content less than 10 percent in Table 3 might better have indicated the exinite content as less than 5 percent.

The percentages on a calculated weight, mineral matter free basis (Figs. 22b and 23b) show little difference in range from values based upon volume percentage. All remaining values are proportionately higher but original differences are essentially maintained.

There is no reason why uniformity in petrographic composition from block to block should be expected. In fact fair uniformity with respect to the petrographic composition of the Meigs Creek coal, marked by the consistently high total vitrinite content, is a noteworthy characteristic of the bed as are also the relatively high cuticle and mineral matter content of some microclarain bands.

4) CHEMICAL ANALYSIS OF COAL FROM COLUMN NO. 597-A BY BLOCKS

The core representing column No. 597-A after being sawed into halves was divided between the coal petrology laboratory and the chemical laboratory of the Engineering Experiment Station of Ohio State University, Dr. Peter O. Krumin in charge. The half of the core given to the Engineering Experiment Station was divided into approximately equal length blocks and proximate items, B. t. u. values, and total sulphur and forms of sulphur (organic, sulphate, and pyritic), were determined for each bench and for a composite sample representing the full thickness of the coal bed. (Table 9, Appendix II, and Fig. 24).

The composition of the coal is shown on a dry basis with values also given for unit coal (dry, mineral-matter-free) volatile matter, fixed carbon, and heat value. The unit coal B. t. u. value of the composite sample is 14,669 units (unit coal index 147). This is rather low for coals from Noble County. The coal core had been stored for sometime before and also after it had been split and probably had suffered some oxidation. The analyses are not

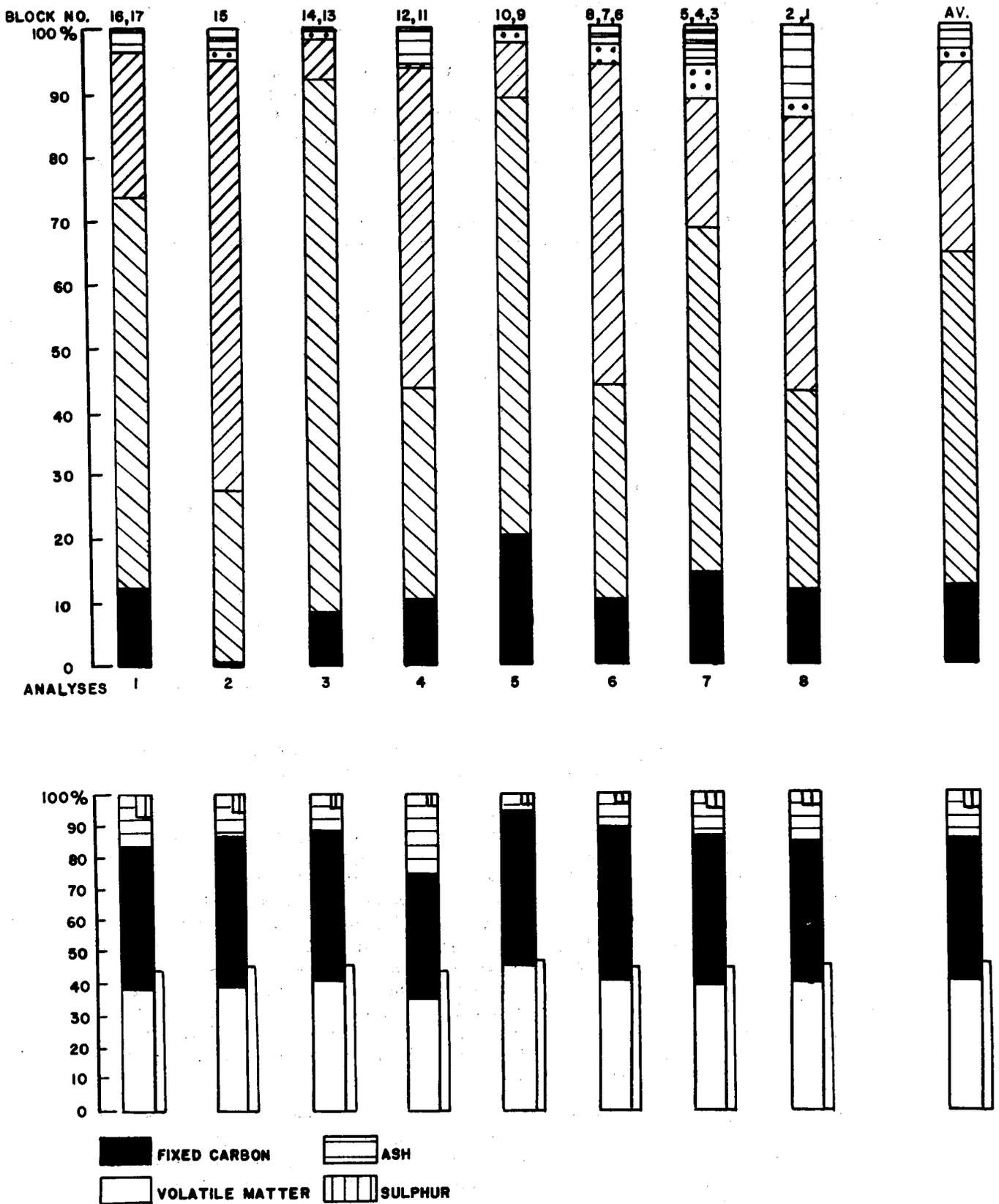


Fig. 24. Graphic representation of petrographic (above) and chemical (below) analyses for equivalent parts of column No. 597A. Proximate analyses on dry and on dry mineral-matter-free (unit coal bases).

MEIGS CREEK COAL

regarded as fully satisfactory for indicating the rank of the coal in comparison with standard face samples. The "as received" moisture values are uniformly about 2 percent compared with a usual value of about 5 percent for fresh coal from the same general locality.

In spite of the unsatisfactory character of the samples for indicating precisely the character of the coal, it was thought that a series of samples representing the supposedly full thickness of the bed but separated into blocks of fairly uniform length might provide information that indicated some correlation between chemical and petrographic compositions. The bed, however, is so generally uniform taken in benches approximately 8 inches in length that significant correlations are not apparent.

The positions and thicknesses of the blocks of the Meigs Creek (No. 9) coal bed which were analyzed and their relation to the blocks used in making the petrographic analyses are as follows:

Bench No.	From Top Ins.	To Ins.	Thickness Ins.	Block No.
8	0	5½	5½	1 & 2
7	5½	13	7½	3, 4, & 5
6	13	19.3	6.3	6, 7, & 8
5	19.3	28.2	8.9	9 & 10
4	28.2	36	7.8	11 & 12
3	36	44.8	8.8	13 & 14
2	44.8	48	3.2	15
1	48	56.8	8.8	16 & 17.

The analysis of each of the eight blocks of coal and of a composite sample representing the complete core and summary megascopic petrographic analyses of the same portions of the coal are shown graphically in Fig. 24.

There was a possibility that variations in the proximate items of the different blocks of coal might correlate with the petrographic variation from block to block. This possibility received some consideration. Correlation seemed most probable and most readily discoverable with respect to such more or less adventitious items as mineral matter, pyrite, dull coal or durain, and fusain contents. The megascopically discernible mineral matter is greatest in blocks 1 & 2 (11.89 percent), but the determined ash content in this analysis (No. 8) is less than in a number of others. The highest ash value (24.43 percent) is in analysis No. 4. In the block represented by this analysis only 4.4 percent of mineral matter was found megascopically, but the amount of durain was large amounting to 49.7 percent of the coal (blocks 11 and 12). The lower part of block No. 11 contained some very dull durain with a mineral matter content of 49.4 percent and there was 10 percent of mineral matter in the upper half of block No. 11 and 8 percent in block No. 12.

The low ash content shown in analysis No. 5 and the large amount of sulphur are more or less in agreement with the low mineral matter content of blocks No. 9 (1.79 percent) and No. 10 (2.01 percent), and with the large amount of pyrite in block No. 10 (5.53 percent). It is suspected that the large lens of pyrite in block No. 5 (19.41 percent) was removed from the coal before analysis No. 7 was made.

The volatile matter content on the dry basis is quite constant at about 40 percent in spite of the variations in mineral matter and ash content. The fixed carbon values on a unit coal (dry, mineral-matter-free) basis vary from about 53 (52.92) to 56 (56.13) percent. In the case of the two extreme values 56.13 percent for analysis No. 1 and 52.99 percent for analysis No. 5. Note that although no megascopic fusain is reported in blocks 16 and 17 the microscopic profile (Fig. 23) shows 12.78 percent of fusain in block No. 17 and 2.46 percent in block No. 16, block No. 17 being about one-third longer than block No. 16.

In the case of analysis No. 5 which contains the lowest percent of fixed carbon, it is found that the corresponding block No. 9 has a microscopic fusain content of only 0.37 percent and block No. 10, 2.85 percent, the two blocks being of about the same length.

Although the foregoing data suggest that there may be a correlation between fusain content and fixed carbon content, analyses Nos. 2, 4, and 7, show between 55 and 56 percent fixed carbon with fusain in corresponding blocks varying from 0.77 to 7.44 percent, whereas analyses Nos. 3, 6, and 8, containing less than 55 percent fixed carbon, the fusain content in the corresponding blocks varies from 5.39 to 19.55 percent. The data therefore fail to reveal any consistent correlation of the fixed carbon and fusain contents of the chemical and petrographic analysis respectively.

Attempts at correlation of volatile matter with vitrain contents, or with vitrain plus microvitrain, or with clarain contents are no more fruitful than was the attempt at finding correlations between mineral matter and ash, pyrite and sulphur, fusain and fixed carbon. This, however, does not necessarily mean that there is no correlation between petrographic and chemical compositions. It may mean that the data are too few for satisfactory analysis. Or it may be that the similarity of the chemical composition of the parts of the core suggests, as has been previously pointed out, that for benches or blocks the length of these the petrographic and chemical composition is in all cases essentially the same as the average composition of the bed. It is expected, however, that differences do exist in the chemical composition of the different ingredients and macerals or between portions of the coal in which different individual constituents may have become concentrated for one cause or another; there was, however, no opportunity to explore this possibility.

5) PETROGRAPHIC ANALYSIS OF SELECTED BLOCKS OF COLUMN NO. 603

Microscopic petrographic analyses of Meigs Creek (No. 9) coal bed as represented by column No. 603 were prepared for only a few blocks, selected mainly because of their high content of dull coal or durain, the composition of which is inadequately revealed by megascopic examination.

From the upper bench of column No. 603 only blocks No. 2 and No. 5 were selected for microscopic analysis. Block No. 2 extends from 2.5 to 6.2 inches from the top of the bed, and block No. 5 from 9.2 to 13.4 inches from the top. Block No. 5 is in two parts No. 5a and No. 5b, the upper and lower parts respectively, each about 2 inches in length.

From the lower bench of column No. 603, blocks No. 1, No. 5, No. 7, and No. 10 were selected for microscopic analysis. Block No. 1 extended from the top of the lower bench to 4.4 inches; block No. 5 from 17.6 to 19.9 inches; block No. 7 from 26.5 to 32.3 inches; and block No. 10 from 39.5 to 43.6 inches. Blocks No. 1, 7, and 10 were each in two parts, No. 1a being 2.3 inches; No. 1b, 2.1 inches; No. 7a, 2.0 inches; and No. 7b, 3.8 inches; and No. 10a 2.5 inches and No. 10b, 1.6 inches in length.

The graphical analyses (Figs. 25a and 25b) show the petrographic composition of the various blocks or block parts of column No. 603 on the volumetric percentage and mineral-matter-free weight percentage bases respectively.

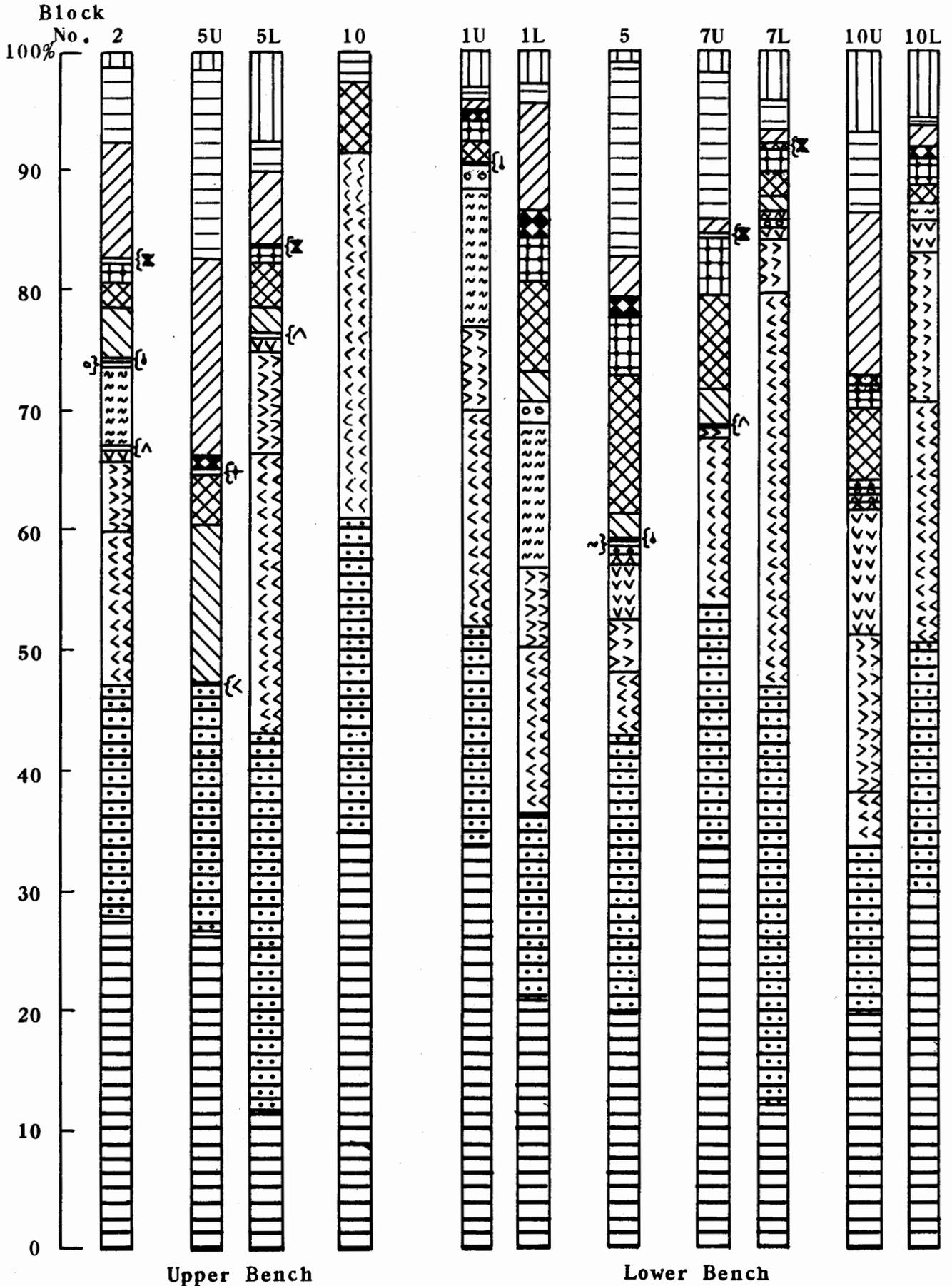


Fig. 25a. Graphic microscopic petrographic analyses of certain blocks of No. 9 coal from column No. 603 on a mineral-matter-free weight-percent basis.

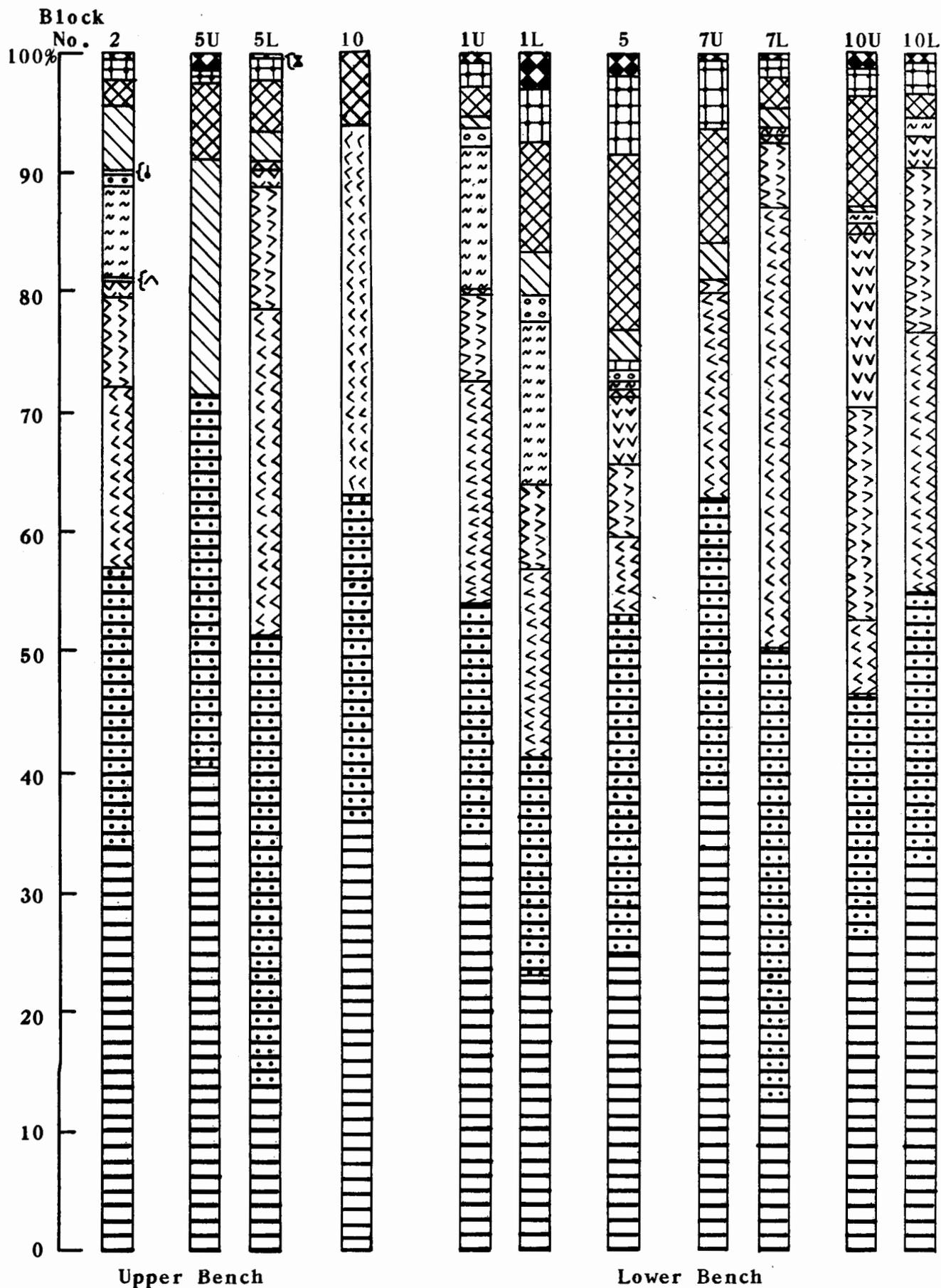


Fig. 25b. Graphic microscopic petrographic analyses of certain blocks of No. 9 coal from column No. 603 on a mineral-matter-free weight-percent basis.

MEIGS CREEK COAL

a. Vitrain and Microvitrain Contents

The vitrain content of the upper bench of column No. 603 by megascopic analysis was recorded as 10.6 percent and of the lower bench 13.7 percent. The accompanying table (Table No. 5) gives the vitrain and microvitrain contents of ten blocks or sub-blocks. The vitrain content varies from 11.8 percent to 33.9 percent or 22.1 percentage figures; microvitrain varies from 14.8 percent to 35.0 percent or 20.2 percentage figures. The total of both varies from 34.4 to 53 percent or 18.6 percentage figures. Thus it is evident that the two constituents vary in quantity without much relation one to the other. Inasmuch as the blocks selected were all relatively dull in luster it is noteworthy that the amount of vitrain exceeds the megascopic content for both upper and lower benches of the column. It is probable, therefore, that the quantity of vitrain visible microscopically exceeds the quantity megascopically apparent. The amount of vitrain and microvitrain varies considerably from block to block.

b. Clarain and Microvitrain Contents

Chemically and in behavior characteristics, vitrain and microvitrain should be grouped together, but megascopically and petrographically microvitrain is a component of clarain. They are so grouped together in Table 5, column 5. The megascopic analysis of column No. 603 showed 85 percent of clarain and claro-durain in the upper bench and 78.3 percent

Table 5. Percent of Vitrain, Microvitrain and Clarain Individually and in Combination in Selected Blocks of Ohio Meigs Creek, No. 9, Bed Coal in Column No. 603.

Bench and block number	Vitrain		Microvitrain		Clarain		Vitrain and microvitrain		Clarain and microvitrain		Vitrain, microvitrain, and clarain	
	Volume	Mineral-matter-free	Volume	Mineral-matter-free	Volume	Mineral-matter-free	Volume	Mineral-matter-free	Volume	Mineral-matter-free	Volume	Mineral-matter-free
Upper bench												
2	28.2	33.9	19.4	23.3	32.5	39.0	47.6	57.2	51.9	62.3	80.1	96.2
5a	27.1	40.8	20.6	31.0	12.9	19.5	47.7	71.8	33.5	50.5	60.6	91.3
5b	11.8	14.1	31.2	37.2	35.3	42.1	43.0	51.3	66.5	79.3	78.3	93.4
Lower Bench												
1a	33.9	35.5	17.9	18.7	39.3	41.1	51.8	54.2	57.2	59.8	91.1	95.3
1b	20.5	23.5	15.8	18.1	37.1	42.5	36.3	41.6	52.9	60.6	73.4	84.1
5	19.6	24.8	22.9	28.8	18.4	23.2	42.5	53.6	41.3	52.0	60.9	76.8
7a	33.0	39.0	20.4	24.0	18.0	21.2	53.4	63.0	38.4	45.2	71.4	84.2
7b	12.0	15.0	35.0	37.8	40.9	40.3	47.0	50.8	75.9	78.1	87.9	91.1
10a	19.6	26.6	14.8	20.2	30.2	41.0	34.4	46.8	45.0	61.2	64.6	87.8
10b	29.8	32.3	21.0	22.7	36.6	39.8	50.8	55.0	57.6	62.5	87.4	94.8

in the lower bench (54.6 percent and 44.8 percent respectively of clarain). The amount of clarain exclusive of the microvitrain varies from 12.9 to 35.3 percent in the three blocks in the upper bench; and from 18.0 to 40.9 percent in the lower bench. This is that part of the clarain that has been called the microclarain which consists mainly of vitrinite (humic degradation matter) and exinite.

c. The Bright Coal

The amount of bright coal represented by vitrain, microvitrain, and clarain (microclarain) in the selected blocks of column No. 603 is shown in Table 5, column 6. On a volume percent basis this varies from 60.6 to 80.1 percent for the upper bench and from 60.9 to 91.10 percent for the lower bench. On a weight percent mineral-matter-free basis corresponding values are 91.4 to 96.2 percent, and 76.8 and 95.3 percent. These figures based on values determined from relatively dull portions of the bed indicate the general bright luster of the coal represented by column No. 603.

d. Exinite

The brightness of the luster of the microclarain is determined very largely by the amount of exinite represented by spores, particularly microspores, and cuticle present in

Table 6. Percent Exinite and Mineral Matter Content of Microclarain in Selected Blocks from Column No. 603 of the Ohio Meigs Creek, No. 9, Bed Coal.¹

Bench and block number	Spore content range								Cuticles (10%) ²		Total		Resins	Megaspores	Mineral matter 0 - 10% (5%) ²		Total microclarain
	0 - 5% (2½%) ²		5% - 10% (7½%) ²		10% - 25% (17½%) ²		+25% (30%) ²		Microclarain	Exinite	Microclarain	Exinite			Microclarain	Mineral matter	
	Microclarain	Exinite	Microclarain	Exinite	Microclarain	Exinite	Microclarain	Exinite									
Upper bench																	
2	12.75	0.319	6.28	0.471	1.26	0.221	0.24	0.060	6.52	0.652	27.05	1.723	0.79	0.26	4.37	0.216	32.47
5a	0.17	0.004	-	-	-	-	-	-	-	-	.17	.004	-	-	12.76	0.638	12.93
5b	23.22	0.581	8.42	0.631	1.31	0.229	0.11	0.033	-	-	33.06	1.474	-	-	2.19	0.110	35.25
Lower bench																	
1a	17.91	0.448	6.97	0.522	0.64	0.112	-	-	11.44	1.140	36.96	2.222	1.19	0.05	1.09	0.055	39.29
1b	13.98	0.349	6.33	0.475	-	-	-	-	12.06	1.206	32.37	2.030	1.91	-	2.80	0.139	37.08
5	5.04	0.126	4.22	0.316	4.58	0.802	0.68	0.204	0.46	0.046	14.98	1.494	0.74	0.53	2.11	0.105	18.36
7a	14.33	0.358	0.79	0.059	-	-	0.06	0.018	-	-	15.18	0.435	-	-	2.84	0.142	18.02
7b	33.44	0.836	4.93	0.370	0.68	0.119	-	-	-	-	39.05	1.325	0.51	-	1.31	0.066	40.87
10a	4.46	0.112	13.10	0.982	10.50	1.838	0.74	0.222	0.81	0.081	29.61	3.235	0.29	0.04	0.26	0.013	30.20
10b	19.99	0.500	12.45	0.934	2.55	0.446	-	-	1.60	0.160	36.59	2.040	-	-	-	-	36.59

1. Expressed in terms of certain categories of frequency of occurrence of certain phyterals (macerals) and mineral matter.
 2. Average frequency of occurrence.

the vitrinite or groundmass of the clarain. In Table 6 the spore exinite content of the microclarain is shown in four categories: less than 5 percent, 5 to 10 percent, 10 to 25 percent, and more than 25 percent. In very few clarain bands did the spore content exceed 25 percent. The cuticle exinite was arbitrarily rated as 10 percent of the clarain when it was present.

The exinite represented by the microspores and cuticles made up from less than one-hundredth percent (.004) to about 3 percent (3.198) of any of the 10 blocks or sub-blocks of column No. 603 that were examined. In these same portions of the column the amount of resins varied from none to 1.9 percent of the individual block and the amount of megaspore exines from none to about 0.5 percent. The amount of mineral matter varied from 0.05 to 0.64 percent. Hence the total non-vitrinite portion of the microclarain did not exceed 5 percent. Even in these duller portions of the column the vitrinite composed about 95 percent of the microclarain. The figures for bright coal given in a preceding paragraph require no essential modification to make allowance for the exinite portion of the microclarain.

e. Inertinite

The inertinite portion of the coal material contained in the blocks of column No. 603 that were examined microscopically consist of fusain, semifusain, and micrinite (opaque matter). The occurrence of these substances on a volume percent and a mineral-matter-free weight percent basis is presented in Table 7.

In these blocks the inertinite content varies from 3.16 to 17.72 percent on a volume percent basis, but only three of them show more than 9 percent. Four of the blocks show less than 5 percent of inertinite. The dullness of the three blocks 1-b, 5, and 7-a may, in part at least, be owing to the presence of 10 percent or more of fusain and semifusain. The amount of micrinite present, except for block 1-b is less than 2 percent and in five blocks 1 percent or less. It is thought to be unimportant in its affect on the characteristics of the coal.



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Table 7. Percent of Occurrence of Inertinite in Six Blocks of Ohio Meigs Creek, No. 9, Bed Coal from Column No. 603.

Bench and block number	Fusain		Semifusain		Micrinite		Total	
	Volume	Mineral-matter-free	Volume	Mineral-matter-free	Volume	Mineral-matter-free	Volume	Mineral-matter-free
Upper bench								
2	1.65	2.05	1.20	1.50	0.31	0.39	3.16	3.94
5a	3.93	6.17	0.64	1.00	0.92	1.47	5.49	8.64
5b	3.50	4.31	1.53	1.91	0.27	0.35	5.30	6.57
Lower bench								
1a	1.73	1.87	1.69	1.83	0.91	1.00	4.33	4.70
1b	7.53	8.94	3.77	4.47	2.18	2.60	13.48	16.01
5	11.20	14.67	5.02	6.57	1.50	1.96	17.72	23.20
7a	7.80	9.55	4.60	5.61	0.48	0.60	12.88	15.76
7b	2.53	2.84	1.37	1.54	0.51	0.57	4.41	4.95
10a	6.63	9.34	1.10	1.57	0.96	1.34	8.69	12.25
10b	1.47	1.66	2.04	2.30	1.09	1.22	4.60	5.18

f. Mineral Matter

The accompanying table (Table 8) shows the amount and character of the mineral matter consisting of pyrite, mineral matter other than pyrite, and "bony" coal found in the selected blocks of Meigs Creek (No. 9) coal bed. In block 5a of the upper bench mineral matter makes up over one-third of the coal by volume, in block 10a of the lower bench about one-fourth, and in block 5, also in the lower bench, about one-fifth. In the rest of the blocks the mineral matter comprises from about one-sixth to one-eighth of the block.

That the dullness of the coal in block 5a of the upper bench is caused by the high content of mineral matter (38.23 percent by volume) is evident. The relatively high mineral matter content of block 5 of the lower bench is accompanied by a relatively high content of inertinite (fusain, semifusain, and micrinite).

Table 8. Percent of Occurrence of Pyrite, Mineral Matter Other than Pyrite and "Bone Coal" in Selected Blocks of Ohio Meigs Creek, No. 9, Bed Coal from Column No. 603.

Bench and block number	Pyrite		Mineral matter		"Bone coal"		Total	
	Volume	Weight	Volume	Weight	Volume	Weight	Volume	Weight
Upper bench								
2	1.18	4.02	6.20	11.02	9.45	10.98	16.83	26.02
5a	1.21	3.72	16.40	26.20	16.34	17.07	33.95	46.99
5b	7.49	22.82	2.68	4.23	6.39	6.63	16.56	33.68
Lower bench								
1a	2.73	9.63	1.05	1.93	0.82	0.99	4.60	12.55
1b	2.84	9.67	1.53	2.72	8.79	10.19	13.16	22.58
5	1.03	3.25	16.93	27.85	3.48	3.74	21.44	34.84
7a	1.75	5.70	12.52	21.14	1.39	1.53	15.66	28.37
7b	4.07	13.65	2.59	4.50	1.13	1.30	7.79	19.45
10a	6.78	20.00	6.63	10.17	13.26	13.30	26.67	43.47
10b	5.62	18.40	0.77	1.30	1.72	1.92	8.11	21.62

g. General Statement in Regard to Petrographic Character
of Coal in Column No. 603

The amount of column No. 603 examined microscopically mainly because of its dull luster, and hence largely classified as megascopic durain, consisted of 7.9 inches or about 28 percent of the upper bench and 16.6 inches or about 35 percent of the lower bench or about one-third of the entire column. Megascopic examination found 10.6 and 13.3 percent of vitrain respectively in the upper and lower benches. Microscopic examination gave values for vitrain in the 10 blocks or sub-blocks varying from 11 to 33 percent. It may be assumed, therefore, that the estimates based upon megascopic examination are much too low, probably because numerous thin bands were not included in the megascopic survey. It has been pointed out that in column No. 584, which was obtained not far from where column No. 603 was cut, there was found 17.5 percent of vitrain in the upper bench and 18.7 percent in the lower bench. It is probable that the vitrain content of column No. 603 is similar.

The coal in column No. 603 may be characterized as a bright banded coal with a high vitrain, microvitrain, and vitrinite content. Even in the durain bands the exinite content is low. Dullness of luster is caused mainly by mineral matter, fusain, and semifusain. The coal is essentially the same as that represented by column No. 597A.

6) SUMMARY OF THE RESULTS OF THE PETROGRAPHIC STUDY OF
THE MEIGS CREEK (NO. 9) COAL BED AS REPRESENTED
BY COLUMNS NOS. 597A AND 603

a. Coal in Column No. 597A

1. The vitrain content of the No. 9 coal in this column is about 23 percent on the basis of microscopic analysis, and the content of microvitrain about 24 percent, giving a total of about 47 percent. The total content of microclarain is in the order of 34 percent of which 30 percent is regarded as vitrinite. The "total vitrinite" (vitrain, microvitrain, and vitrinite) is between 75 and 80 percent. Exinite about 4%, inertinite (fusain, semifusain, and micrinite) 6%, and mineral matter 12% including 3-4% pyrite, make up the balance.

2. There are no "extra thick" (p. 24) or "very thick" band of vitrain, which generally varies between medium thick (0.10 in.) and very thin (0.05 in.).

3. Vitrain does not predominate in any of the block portions of the column. Block Nos. 3-4 (5 inches thick) contains 15 vitrain bands, block No. 8 (4.3 inches) 13 bands, blocks Nos. 1 (3.5 inches) and 8 (4.3 inches) each contain 10 bands all of which are relatively thin and therefore probably exercise little if any selective influence on coal breakage.

4. Occasionally there appears to be a selective preference of the more massive pyrite for vitrain bands. Most disseminated pyrite seems to be distributed indiscriminately with respect to constituents but with some suggestions of preference for cuticles,

5. The megascopic clarain content of column No. 597A is 82.7 percent on a volume-percent basis (49.2 percent clarain, 33.5 percent claro-durain) and 85.7 percent (51 percent clarain, 34.7 percent claro-durain) on a mineral-matter-free weight-percent basis. Microscopic examination gives corresponding values for microclarain only as 33.9 percent by volume and 38.4 percent by mineral-matter-free weight percent. By adding the values for microvitrain to those for microclarain the values for clarain become 57.7 and 56.4 percent for volume-percent and mineral-matter-free weight-percent respectively. These are considerably less than megascopic values.

6. Total mineral matter (pyrite, other mineral matter, and "bone coal") comprises 12.1 percent on a volume-percent basis and 23.2 percent on a weight-percent basis.
7. Cuticular microvitrain or microclarain is relatively common in some parts of the column.
8. Megascopic petrographic analysis, which essentially equivalent to visual inspection, is inadequate to determine the petrographic composition of the coal.

b. Coal in Column No. 603

1. The No. 9 bed coal in column No. 603 is bright banded coal with a "total vitrinite" (vitrain, microvitrain, and vitrinite) content varying between 70 and 90 percent in the blocks microscopically examined.
2. The microclarain content of the coal in the blocks examined varies between 30 and 40 percent.
3. The exinite content of the microclarain is in the order of about 4 percent.
4. Cuticles are fairly common and are associated with microvitrain and microclarain and vitrinite.
5. The dull luster of the megascopic durain bands is due to high mineral matter or high inertinite contents or to both.
6. The coal represented by column 603 is very similar in general petrographic composition to that represented by column No. 597A.

c. Comparison of Results of Polished Surface and Thin Section Analyses

On an earlier page (p. 17) a petrographic analysis of Meigs Creek (No. 9) bed coal represented by column No. 584 was given on the basis of thin section examination and expressed in standard American terms used in such technique. In these analyses of the coal from the upper and lower benches the amount of mineral-matter-free anthraxylon is given as about 50 percent and attritus about 30 percent. That is, the bright coal composes about 80 percent of the coal. Opaque matter is reported as about 10 percent of the mineral-matter-free coal and fusain makes up the balance.

The petrographic analysis of the coal from column No. 584 gives no indication of the amount of translucent humic matter or vitrinite in the translucent attritus, hence does not provide any suggestion as to the amount of vitrinite or of exinite in this material. The anthraxylon corresponds fairly well with vitrain and microvitrain and the quantity reported is not greatly different.

The greatest difference in the results of the two types of analysis is in the relatively high percent of opaque matter reported by the thin section method. This may reflect the tendency of this method to over estimate the quantity of this material in thin sections for reasons previously explained (p. 16).



PETROGRAPHIC STUDY OF BROKEN COAL FROM THE MEIGS CREEK No.9 COAL BED

A. Definition and General Explanation

By the term "broken coal" is designated any fragmentary coal such as that produced by the ordinary processes of mining and preparation or by deliberate breakage or crushing. In these studies coal fragments representing a sample of run-of-mine coal were used and also fragments produced by dropping pieces of a continuous diamond drill core on a steel plate as described in Appendix I.

When the diamond drill core is broken by dropping one can be sure that the entire thickness of the coal bed is represented in the sample. This is not so in the case of the sample of the run-of-mine coal sample. Nevertheless petrographic analyses of the various size fractions will give some idea of the extent to which there has been selective concentration of the petrographic constituents because of their variability in physical properties.

B. Sources of Samples of Broken Coal

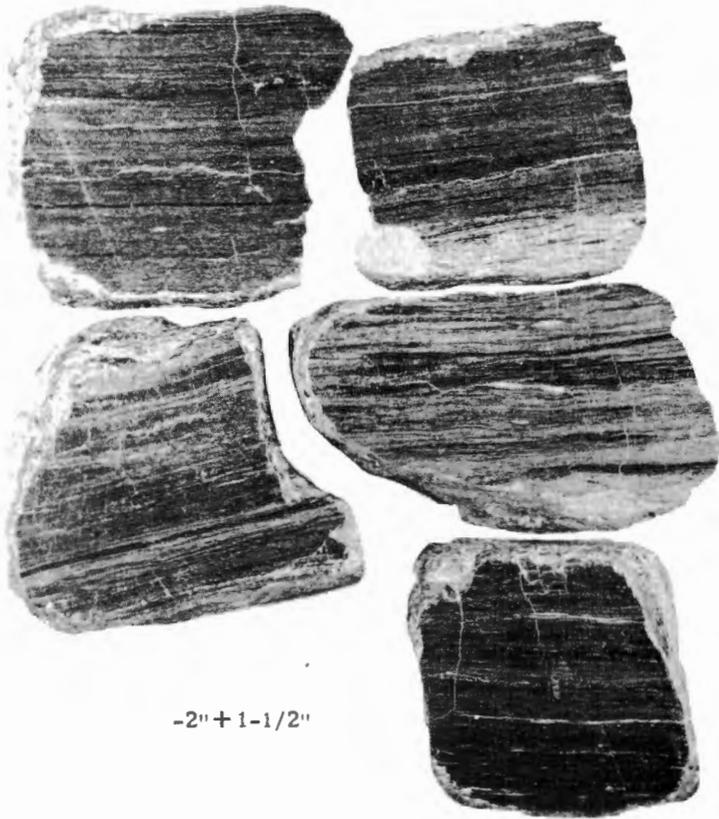
Three sets of samples of broken coal from the Meigs Creek coal bed have been investigated. Two, 598A and 601D, were obtained by dropping individual fragments of complete diamond drill cores according to procedures described in Appendix I. One, 603B, consisted of a sample of mine-run coal being in two parts, one (603 B-1) representing the lower bench of the coal bed and the other, (603 B-2) representing the upper bench.

C. Investigation of the Larger Fragments

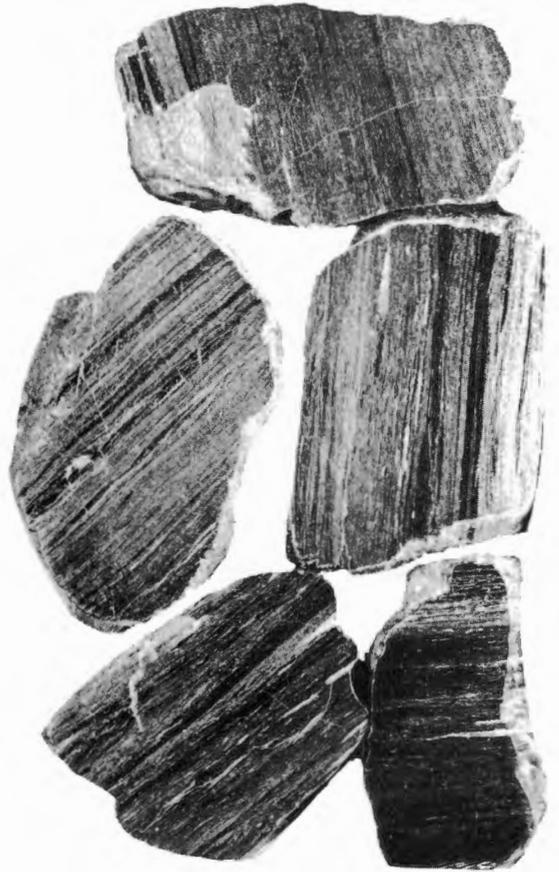
In these investigations only fragments less than 2 inches in diameter, that is such fragments as would pass a 2-inch round screen, were investigated. Fragments of 2 x 1-1/2 inch coal were not mounted in plaster but were prepared for study and studied individually. The method of selection of these fragments and others down to minimum diameter of 1/2 inch is described in Appendix I where the procedure followed in mounting the fragments is also described.

Surfaces of the 1-1/2 inch x 2 inch fragments that were ground and polished were perpendicular to the bedding of the coal, thus making it possible to prepare a micro-petrographic profile of the fragment. Such a profile may be graphically recorded in minute detail by the method used in making graphic profiles of coal beds or portions of coal beds (Fig. 26) or it may be prepared by the use of the integrating stage, in which case the relative size of the individual components cannot be indicated.

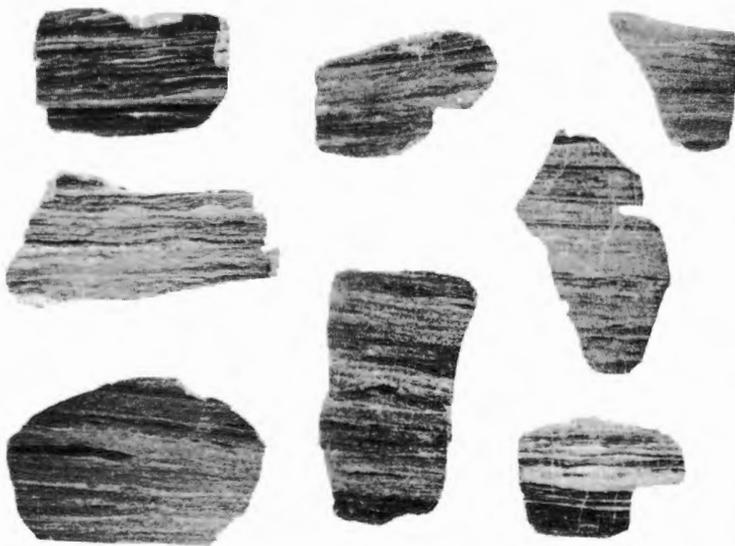
Only six spindles are available for use with the integrating stage and the items usually recorded consisted of vitrain, clarain, megaspores, fusain (usually includes all inertinite),



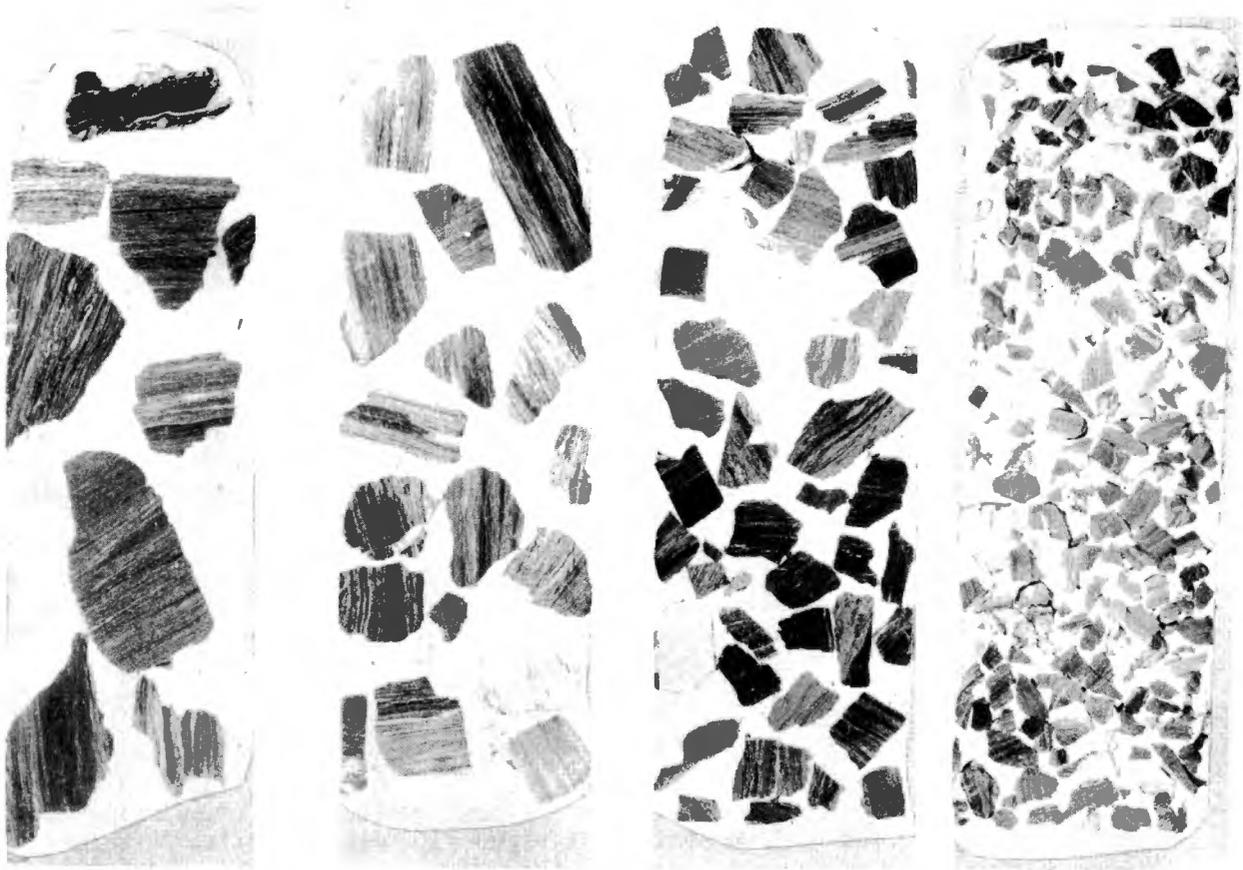
-2" + 1-1/2"



-1-1/2" + 1"



-1" + 3/4"

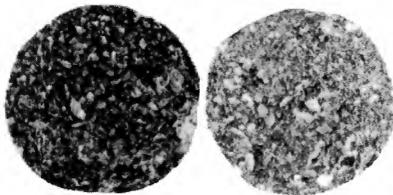


-3/4" + 1/2"

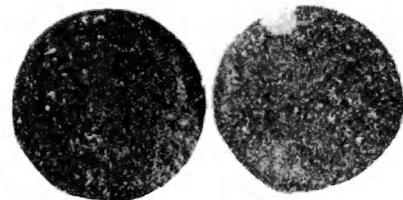
-1/2" + 3/8"

-3/8" + 1/4"

-1/4" + 1/8"



-1/8" + 28 mesh
sp. gr. 1.58
Float Sink



-28 mesh
sp. gr. 1.58
Float Sink

B

Figure 26a and 26b. Natural size photographs of various screen sizes from the run-of-mine sample 603-B-1 of the Meigs Creek (No.9) coal.

pyrite, and mineral matter. One traverse is made, across the bedding, for each fragment, and the individual results provide the totals for all fragments from which percentage values are calculated. Profiles are usually made across 20 fragments.

In detailed graphic profiles made by the use of the ocular micrometer, it was general practice to differentiate vitrain, microvitrain, clarain with less than 5 percent spore exines, clarain with between 5 and 10 percent spore exines, with between 10 and 25 percent spore exines, and with more than 25 percent spore exines. Since the number of microspores is relatively small in the Meigs Creek (No. 9) bed coal, these categories are adequate, but other categories would probably be desirable for a coal with many spore exines. In the case of Meigs Creek coal, clarain with cuticles was differentiated, and also clarain with not more than 10 percent mineral matter. If the clarain contained more mineral matter than this, it was called "bony" coal or even coaly shale. Other macerals identified consisted of megaspores, resin bodies, fusain, semifusain, micrinite, mineral matter, and pyrite, the latter being recorded separately from mineral matter. After the completion of the profile, the area occupied by each type of maceral was determined from the graph by counting the small squares and thus the percentage constitution determined.

In general, profiles of the larger fragments were prepared with the use of the eyepiece micrometer. Small fragments mounted in carnauba wax or some plastic, such as lucite were generally analyzed by using the integrating stage. Analyses were of necessity of a more generalized character.

D. Vitrain and Clarain

In the broken coal vitrain was so designated if it measured 0.5 mm. or more in width irrespective of its orientation in the case of small fragments. Microvitrain was identified as vitrain-like material of less than 0.5 mm. in width. No minimum size of microvitrain was recognized so long as it could be recognized as similar to vitrain. Hence more microvitrain could be recognized as the magnification increased. Magnification above 250-300 was infrequently employed.

The clarain identified and measured in broken coal fragments consists of the microclarain that has been described in connection with the description of the coal columns and cores. This clarain consists mainly of vitrinite (humic degradation matter) in which exinite of various kinds is embedded. In view of the importance of spore exines in producing toughness in the clarain in which it is contained (34) the amount of spore material is of importance, particularly the microspores. The microclarain is therefore classified in terms of the amount of such material present, that is the amount of exinite is determined not in terms of the coal fragment as a whole but in terms of the clarain. Thus it is possible to form some idea of the effect of variation in the character of clarain and of the coal breakage. Of course, at the start, it was impossible to know whether or not important differences existed. It was only as the investigation proceeded that it became apparent that the clarain of this coal was characterized by a low exinite content rarely exceeding 10 to 15 percent.

E. Results of Broken Coal Analysis of Meigs Creek No.9 Bed Coal

One core sample used in the study of broken coal, No. 598-C, was from a diamond drill hole located 200 feet east of the drill holes from which the core No. 598-A (Pl. I) was taken (see p. 6). The other core sample, No. 601-C was taken from a drill hole located 100 feet west from that which supplied core No. 601-D (Pl. I) (opposite p. 5) and 150 feet west of the hole that supplied the core No. 601-B used for chemical analysis. It is assumed that the coal in the cores that were dropped resembled that in holes 200 and 100 feet distant respectively.

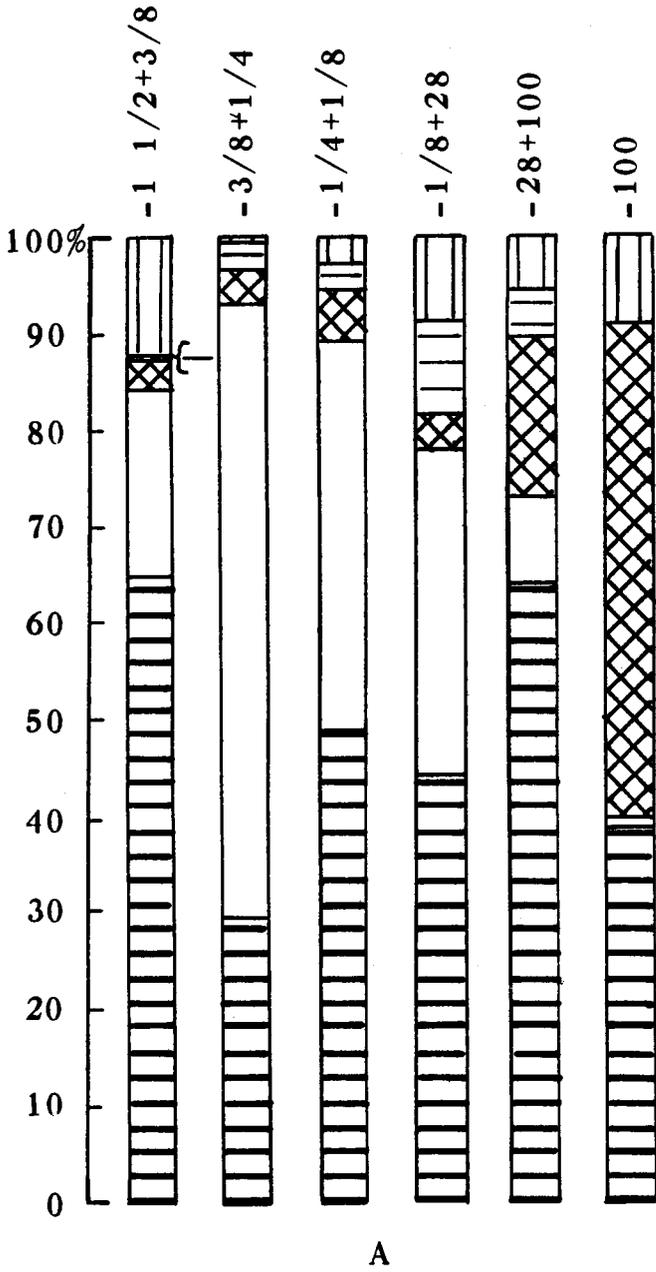


Fig. 27a. Graphic petrographic analyses of screen sizes from sample No. 601C (dropped core) on a volume-percent basis.

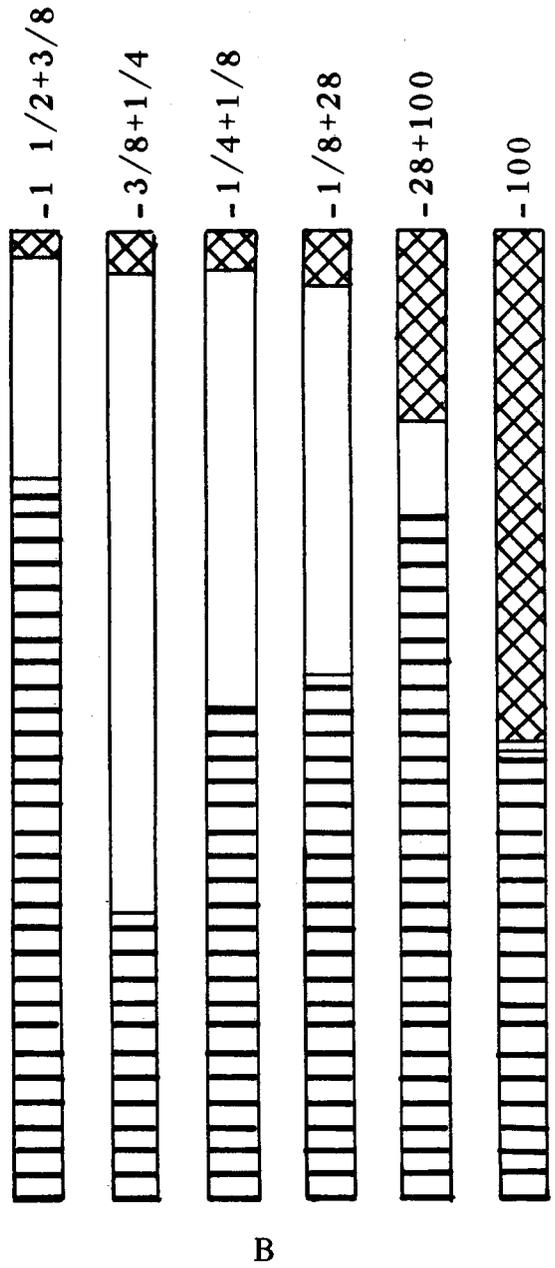


Fig. 27b. Same on mineral-matter-free weight-percent basis.

MEIGS CREEK COAL

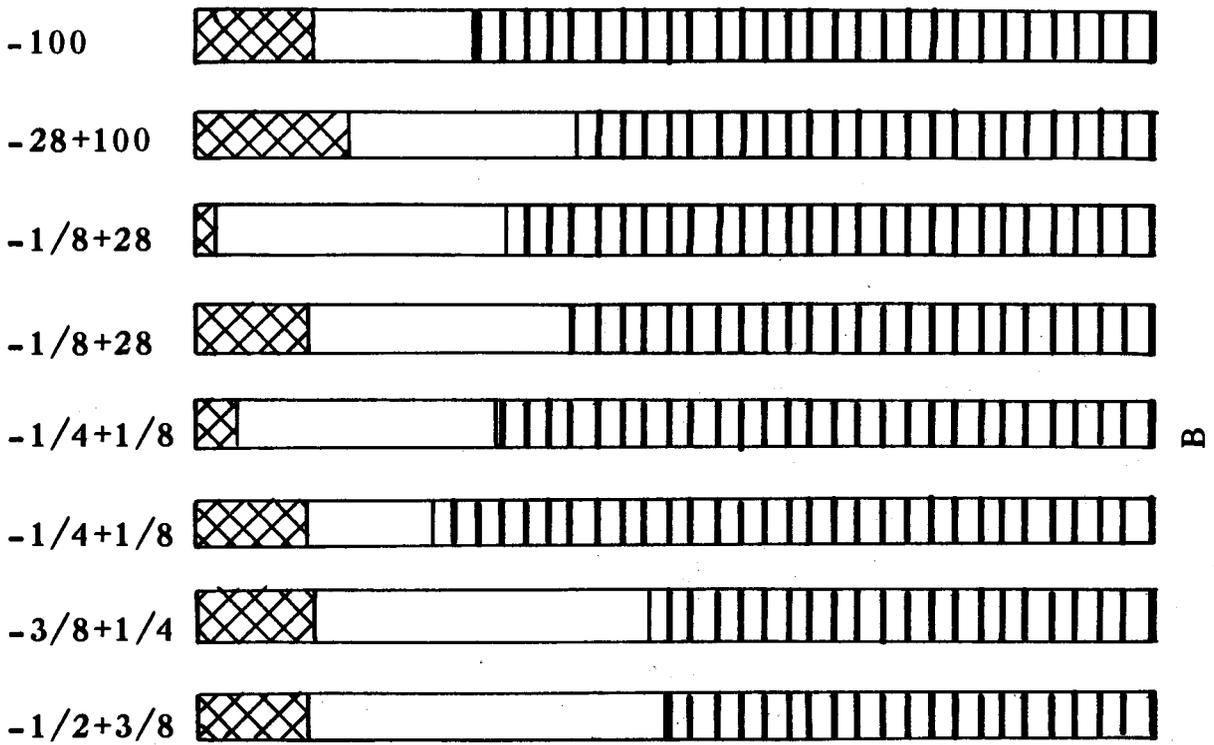


Fig. 28b. Graphic petrographic analyses of screen sizes of broken coal obtained by dropping core No. 598C, on a volume-percent basis.

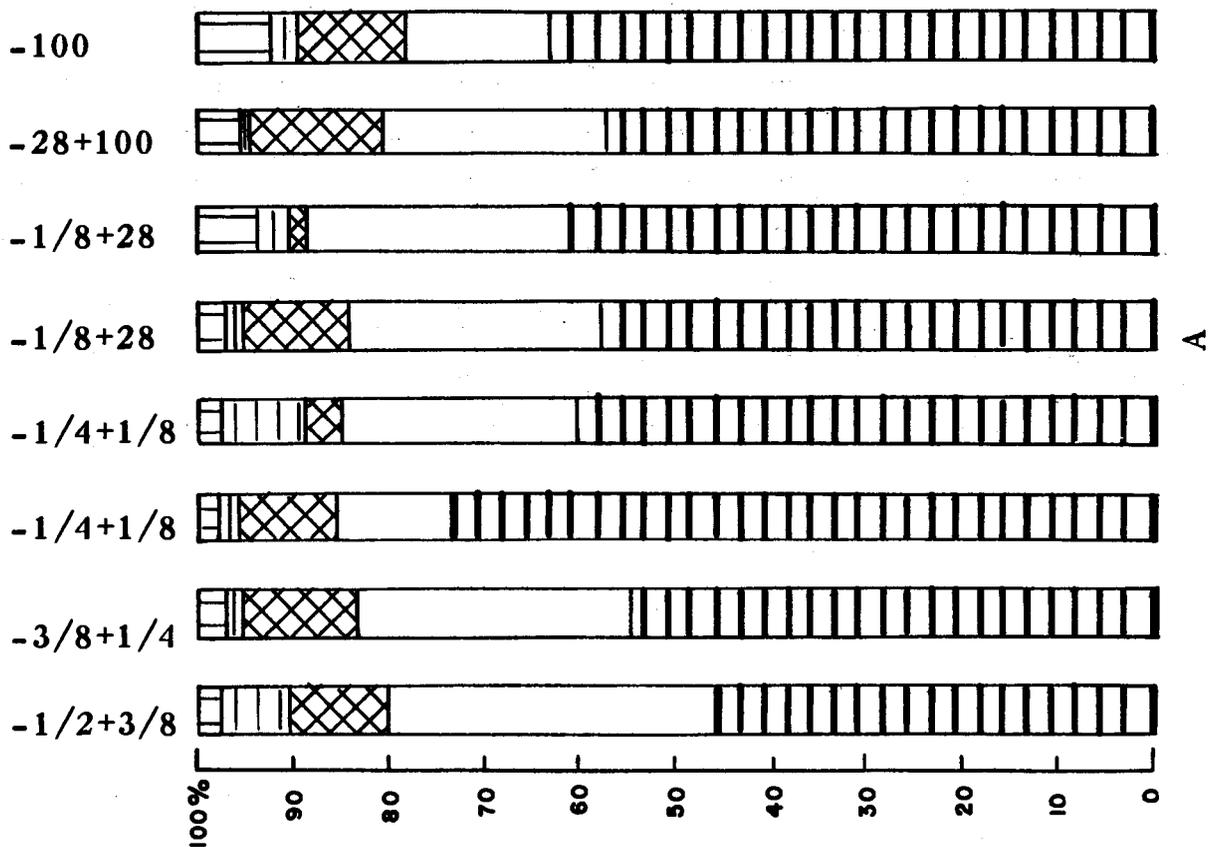


Fig. 28a. Graphic petrographic analyses of screen sizes of broken coal obtained by dropping Core No. 598C, on a volume-percent basis.

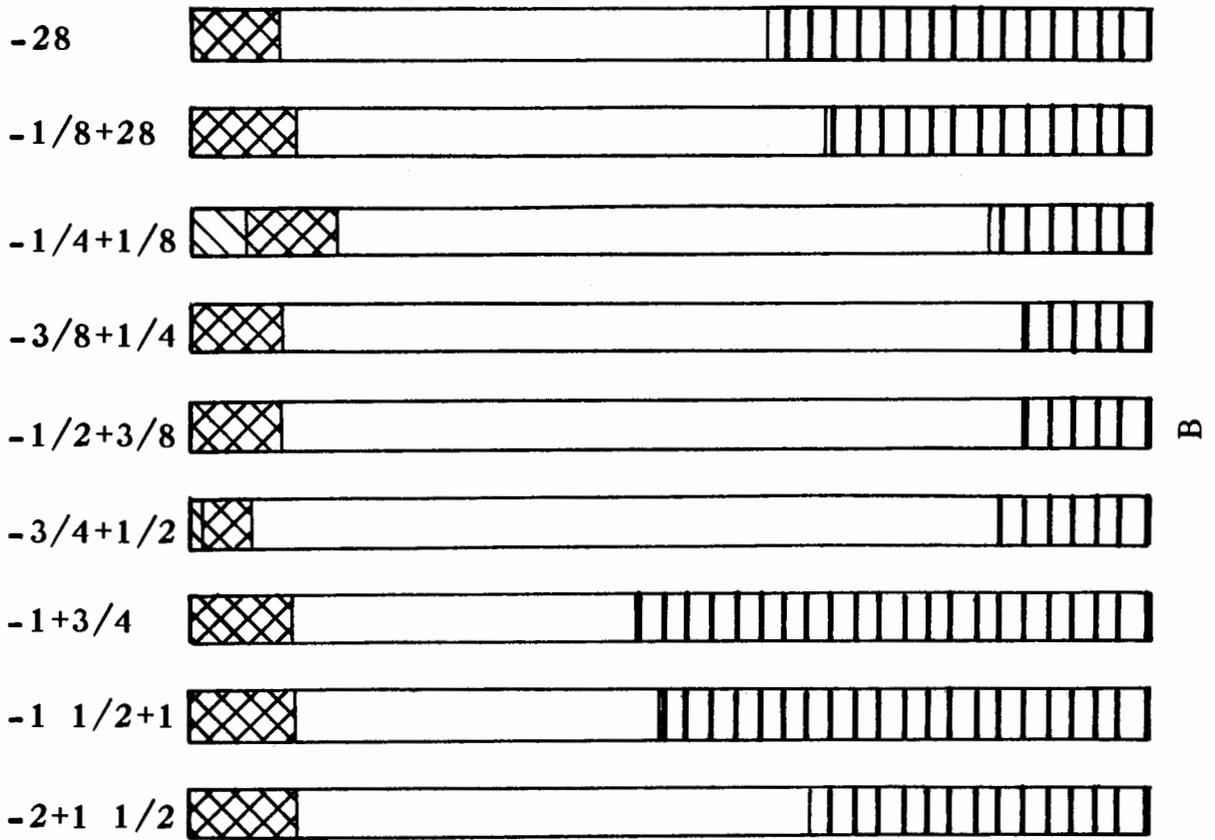


Fig. 29b. Graphic petrographic analyses of screen sizes of run-of-mine coal sample No. 603B-1 on a mineral-matter-free weight-percent basis.

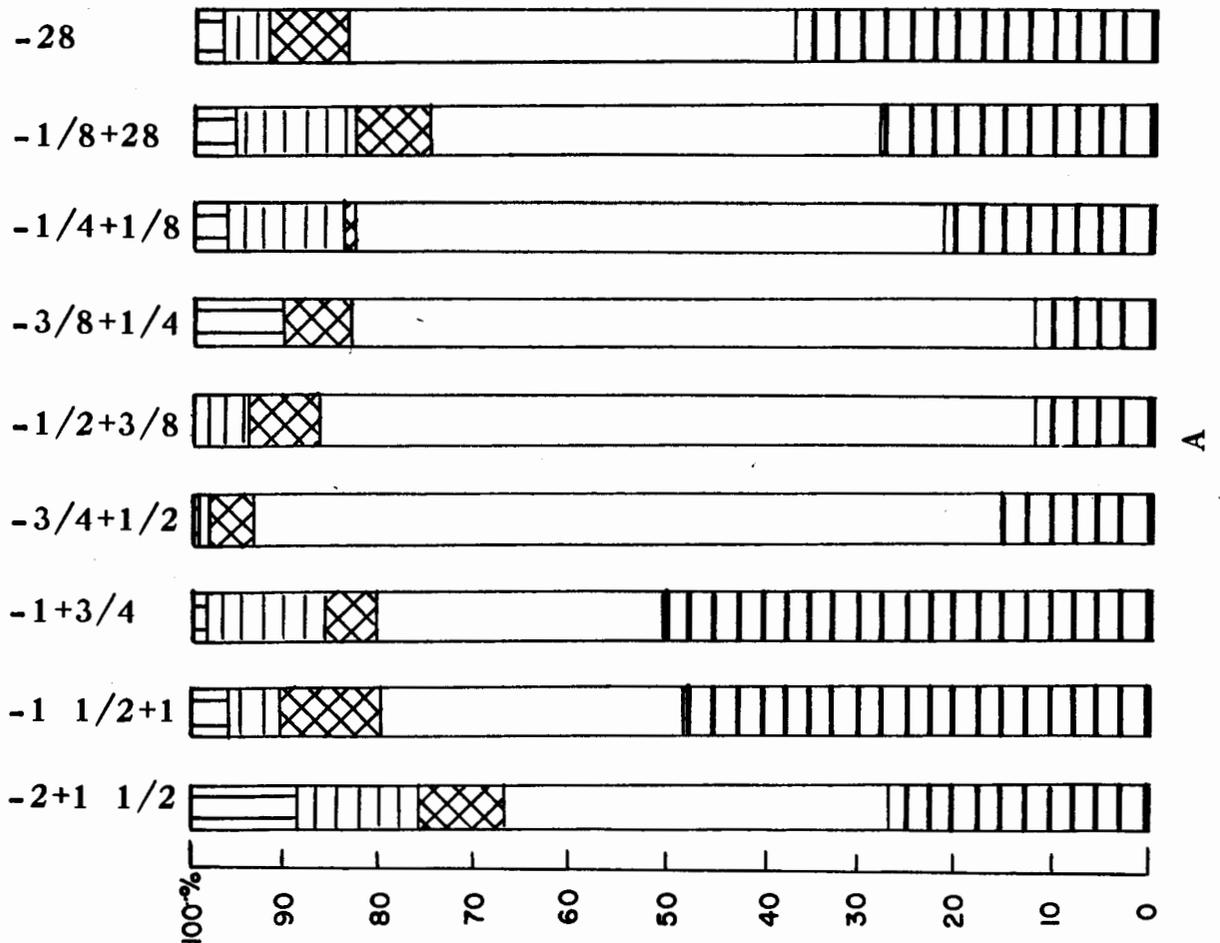


Fig. 29a. Graphic petrographic analyses of screen sizes of run-of-mine coal sample No. 603B-1 on a volume-percent basis.

MEIGS CREEK COAL

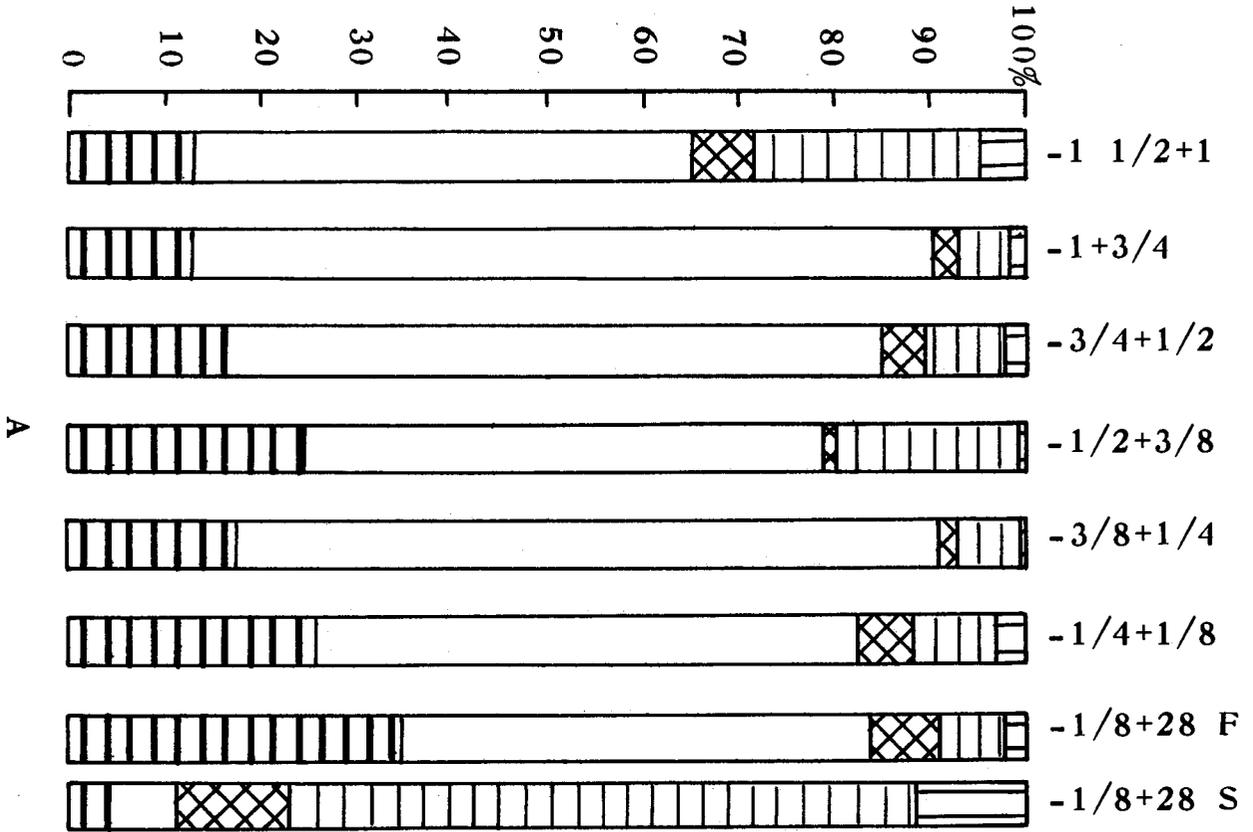


Fig. 30a. Graphic petrographic analyses of screen sizes of run-of-mine coal sample No. 603B-2 on a volume-percent basis.

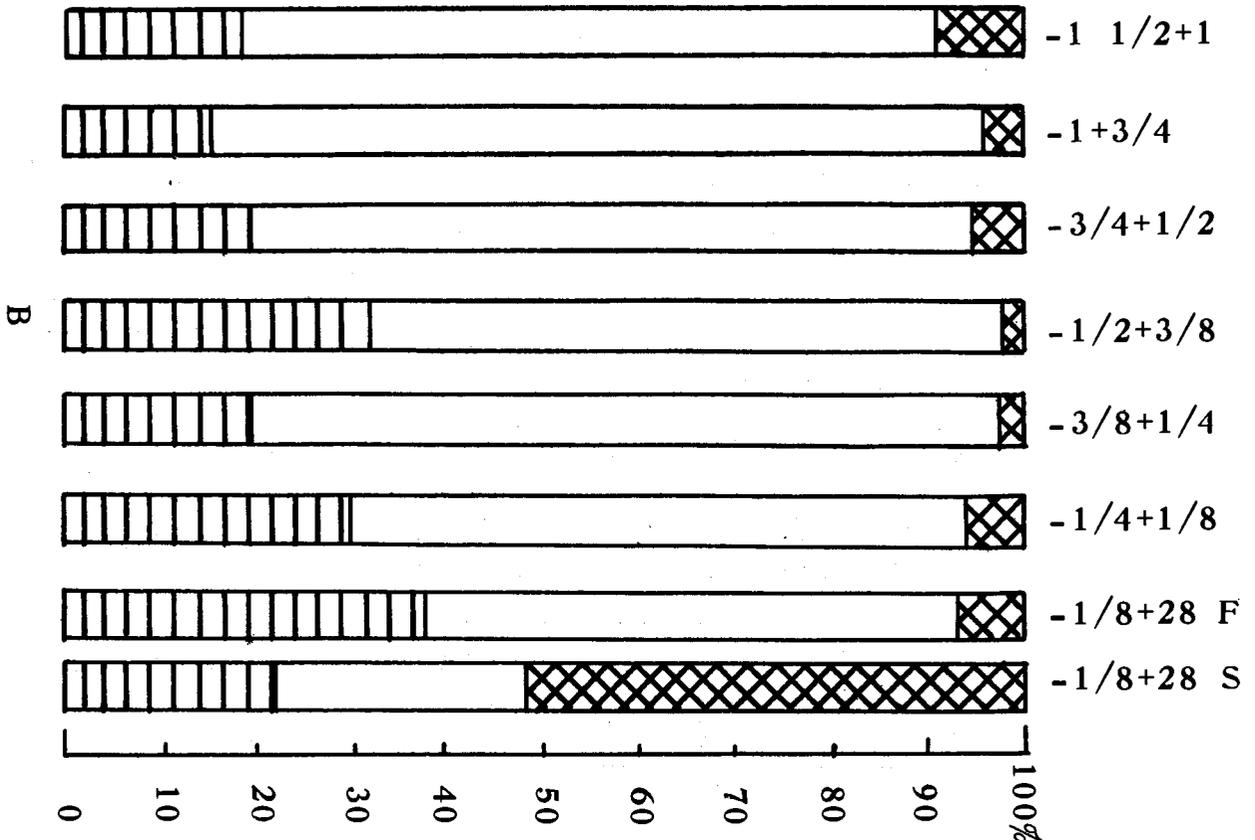


Fig. 30b. Graphic petrographic analyses of screen sizes of run-of-mine coal sample No. 603B-2 on a mineral-matter-free weight-percent basis.

The variations in the petrographic composition of the broken coal from the Meigs Creek (No. 9) coal bed from samples taken at three localities are shown on the accompanying charts (Figs. 27, 28, 29, and 30). The first two represent the petrographic composition of sizes produced by dropping the two cores noted above and the last two the composition of run-of-mine coal from the upper and lower benches of the coal at the mine of the Union Carbide and Carbon Company, Noble County, being samples No. 603B-2 and No. 603B-1 respectively (see p. 8).

There are certain characteristics of these analyses that are more or less common to all. One is the general increase in ash and sulphur contents with size decrease. This increase is irregular among the different samples but seems to be general. In run-of-mine sample No. 603 B-2 (Fig. 30a) there is a great increase in mineral matter in the very fine coal. This may be due to the inclusion in the sample of a fragment of fairly soft clay or shale that went to pieces in subsequent handling. There is no consistent increase in the fusain content. In one of the run-of-mine samples 603B-2 and one of the core samples 601C there is a large increase in fusain in the smallest size best shown in the mineral-matter-free form of analysis, but little or no evident increase in the other two samples (Nos. 598C and 603B-1).

The distribution of variations in the vitrain content shows quite striking differences between the samples of dropped cores (Nos. 601C and 598C) and the samples of run-of-mine. In the first place the amount of vitrain in the dropped core samples is much larger than the amount in the run-of-mine samples. There is also a relatively large percent of vitrain in the larger sizes of the run-of-mine samples particularly the samples No. 603B-1. These two relationships taken together suggest that a good deal of the vitrain in the run-of-mine coal had gone into the fines before the sample was collected and the sampling failed to include a suitable amount of the fines which were close to the belt. In consequence the courser sizes which contained bands of unbroken vitrain showed a relatively high percent of this material. The variation in vitrain content in dropped core sample No. 598C for some reason not apparent showed relatively little increase in vitrain content toward the smaller sizes.

F. General Comments

Of the samples of broken coal neither those obtained by dropping diamond drill cores nor those consisting of run-of-mine coal showed consistent results even within each pair. At least one of the dropped-core samples showed the expected increase in vitrain and fusain contents in small sizes. The results obtained from the run-of-mine samples suggests that sampling did not include a suitable amount of fine coal or that such coal was largely lost in handling between the mine and petrography laboratory. The run-of-mine samples are consistent in showing some increase in vitrain content with decrease in size below $3/4$ inch, and fusain shows great increase in one sample (603B-2).

The general impression gained by the study of the petrography of the coal bed and that of the broken coal is that the close similarity in the properties of vitrain and clarain because of the high microvitrain and vitrinite content of the latter does not result in the characteristic differential breakage when clarain contains a larger amount of exinite. However, these conclusions must be regarded as tentative pending the study of broken coal from the remaining three coal beds No. 8, No. 6, and No. 4-A.

G. Ash and Sulphur Determinations for Broken Coal

The only available analytical data relating to the composition of the samples of broken coal consist of conventional ash and sulphur determinations of the size fractions (Appendix II, Table 10). These values on an air-dried basis (moisture usually about 2 percent) are given in the diagrams showing the petrographic composition of the different sizes (Figs. 41, 42, 43, and 44). There is little if any appreciable relationship between the petrographic composition

and chemical values. Even in the case of sulphur there is essentially no evident relationship between sulphur and pyrite content, even though in some cases the pyrite may represent 10 percent of the coal sample. For example, the samples of run-of-mine coal from the lower bench of No. 603B-1 the visible pyrite varies from 0.5 to 9.2 percent by volume (1.8 to 28 percent by weight), whereas the chemically determined sulphur is uniformly between 6.2 and 6.4 percent. It is probable therefore that the sulphur content is determined more by the amount of organic sulphur and finely disseminated pyrite than by the amount of measureable pyrite present.

Mineral matter contents show no better correlation with determined ash values than do pyrite measurements with sulphur values. This no doubt is in some part owing to the fact that fragments consisting entirely of mineral matter were not included in the samples used in the petrographic analysis.



RECOMMENDATIONS IN REGARD TO FURTHER INVESTIGATIONS OF THE PETROGRAPHIC CONSTITUTION OF THE MEIGS CREEK No.9 BED COAL

On the basis of the results obtained from the limited studies that have been made of the petrography of Meigs Creek (No. 9) bed coal recommendations in regard to future activities are suggested along three lines. These consist (1) of further exploration of petrographic variability of the coal, (2) correlation studies based upon occurrence and distribution of fossil plant spores found in coal beds, and (3) the bearing of coal petrography upon coal preparation.

1. From a comparison of the megascopic petrography of various columns of the Meigs Creek coal from localities scattered fairly widely but very unevenly over its area of occurrence, it appears that regional variations in petrographic composition exist. Columns 603, 597A and 584 are all from localities fairly closely situated along or adjacent to the southern line of Noble County. Several cores or columns of this coal bed representing different parts of the area underlain by the No. 9 coal field are needed to discover differences that may exist and to explore the differences more thoroughly.

2. Attention has been called to the uncertainty in regard to the detailed correlation of the parts of the Meigs Creek (No. 9) coal bed when it is represented by a single bed and when the bed is split into two benches. This correlation problem needs to be solved for obvious reasons. It is quite possible it can be done by use of the fossil plant spores as index fossils. There is also a possibility that correlation can be made by data relating to the occurrence and distribution in the bed of the cuticular exinite.

3. One of the greatest handicaps in the marketing of the Meigs Creek (No. 9) bed coal resides in the high sulphur and high mineral matter or ash contents of the coal. To determine whether or not a possibility exists of using the information provided by coal petrography to any helpful extent in overcoming these handicaps requires some definite information of the general petrographic characteristics of the coal. The brief studies that have been made provide some knowledge of the petrographic characteristics of the No. 9 coal in the general vicinity of southern Noble County. These indicate certain limitations with respect to the composition of the coal that have a bearing on its probable behavior in the mining and preparation processes. It has been pointed out that the coal in the columns studied has a high "total vitrinite" content so that the difference between vitrain and clarain in physical properties is not great. Furthermore, the coal contains much disseminated pyrite and mineral matter, so that bands of coal megascopically identified as durain consist of shale, shaly coal, "bony coal", and disseminated mineral matter. Pyrite also is very intimately disseminated. The coal contains a fairly high amount of fusain but a small percent of exinite.

From washability studies recently made by Krumin (2) and from the results of commercial practice it is known that standard cleaning procedure can produce improved varieties of coal from the Meigs Creek (No. 9) coal bed. Two questions arise, however: one is whether gravity separation plus some differentiation on the basis of petrographic variability would achieve better results; and second whether the conventional cleaning process involving mainly crushing and gravity separation tend to bring about at least partial segregation of petrographic components or could be made to do so with some slight modification of the procedure.

Consideration can appropriately be given to the determination of the petrographic composition of preparation fractions produced by processes involving (a) simple size separation and (b) gravity separation. It is not until such studies are done in a thorough manner that correct judgment can be passed upon the potential value of preparation procedures based in some part upon petrographic consideration.



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**APPENDIX I****PREPARATION OF SAMPLES FOR STUDY****1) PREPARATION OF CORES FOR MOUNTING**

The coal cores were usually delivered to the laboratory wrapped in water-tight paper to insure retention of moisture and prevent the disrupting effect of alternate drying and wetting with humidity changes. If the cores were not wrapped or were not to be mounted at once the cardboard boxes containing the cores were wrapped in oiled paper and thus sealed for storage.

The first step in the preparation of a core for study was to lay it out in a V-shaped trough and note major partings and breaks in the core on a heavy paper strip with 1" and 1/10" markings extending the length of the core. This strip constituted the initial record of the core.

All broken pieces were restored to their original position, so far as possible, and cemented in place with "Duco Cement."

A line of sawing was then indicated on the core that would give as nearly as possible a complete vertical section. The core was then wrapped in adhesive paper tape in sections of from 2" to 6", using natural breaks whenever possible. These sections were numbered and the line of cutting indicated on the paper. The core sections were then split on the line with a medium grained carborundum saw. One half of the core was again split. This provided one quarter of the core for chemical analysis and a second quarter for detailed microscopic examination where small pieces were required. The remaining one-half of the core was mounted in wood putty, eventually to be prepared for megascopic examination as a basis for the megascopic bed profiles (Plate 1). In some instances one-half the core was used for chemical analyses with the remaining half serving as a basis for both megascopic and microscopic petrographic description of the coal bed.

2) PREPARATION OF CHANNEL SAMPLES FOR MOUNTING

In order to assure a complete log of the bed, careful sampling is essential. All blocks must be carefully marked by number, and with orientation indicated, to insure proper assembly in the laboratory. The following procedures were followed in the project and proved to be highly satisfactory.

After selecting the face to be sampled, a channel is cut on either side leaving a clean face 6" to 8" wide the thickness of the bed. A strip of paper (adding machine tape was used here) is laid on the face and the top, bottom, and noticeable partings marked on it. Blocks, as nearly as possible 6" square, are removed from bottom to top. As each block is removed top, bottom, and original face are marked with a wax pencil (red, yellow or white) and placed in a box of sawdust. The blocks are placed in order in the box so that the complete sample is laid out as it appeared on the face of the coal bed. Each block is also recorded on the paper strip to further assure proper reassembly in the laboratory.

MEIGS CREEK COAL

In the laboratory the larger blocks are sawed, being careful to maintain proper markings and orientation on each piece, into small blocks 2" wide by 1" thick. This cutting gives a channel the same size as the half core sample. A smaller sample 1" wide is also made, this being a more convenient size for microscopic study. The remainder of the sample is divided into a part for natural breakage studies and a part for chemical analysis.

3) MOUNTING OF CHANNEL AND CORE SAMPLES

Since bituminous coal is fragile and the polishing processes require much handling, it is necessary to protect the sample. The blocks used in this project were mounted in water putty, a compound similar to plaster of paris. This material is available as a powder and when mixed with water hardens to become a quite satisfactory mounting medium. The product may be obtained from local hardware stores or in large bulk quantities from the Donald Durham Company, Des Moines, Iowa, under the commercial name "Durham Rock-Hard Water Putty."

For mounting, the blocks are laid out on a smooth waxed base board 3' to 6' long and 4" wide. The blocks are placed with the flat, sawed face down and side boards placed along them forming a trough 2-1/2" wide and at least 1-1/2" deep with the coal in the center. The length of the sides depend on the size of the base, but units of about 3' were found to be the maximum length for ease of handling. Small blocks of wood are used to seal the ends and all pieces of this collapsible form are then taped together. This type of form is desirable to facilitate easy removal from the semi-hard strip of mounted coal. The putty is mixed to a thick but flowing consistency and poured over the coal completely covering it. While the putty is still slightly soft any identifying marks are etched in the smooth back. The side boards may be removed after about 20 minutes and the edges of the putty smoothed with a knife if desired. At this time one side of the mounted channel is marked off in inches beginning with the top of the coal sample. These marks were found helpful later in locating the blocks in the column or on the logs. These marks also serve as reference points for locating portions of the bed for further detailed study. When sufficiently hard the strip is sawed (on the natural break if possible) and broken again into shorter blocks of 2" to 6". These shorter blocks are easier to handle in polishing. The smaller blocks representing 1/4 core or the equivalent in a column sample are mounted similarly but in narrower strips.

After about 24 hours the coal may be polished. The first wetting may produce a thin soft surface on the putty but it will readily harden again upon drying. When the blocks are not to be polished at once they should be dried in an oven and stores in air-tight plastic bags to hinder oxidation.

4) BROKEN COAL SAMPLES

The broken coal samples used in this project were obtained in two ways. No. 603-B is a run-of-mine sample taken from the belt of a mechanical loader. No. 598-C, 601-C, 604, 602, and 607, were obtained by regulated dropping of the large pieces of coal in the laboratory until most of the sample passed through a 1-1/2" screen. The blocks were dropped through a tube 6' long and 10" in diameter upon a steel plate. The dropped sample was screened each time and only the larger pieces dropped again. All samples were then screened to various sizes below 2" for mounting and study.

5) MOUNTING OF BROKEN COAL SAMPLES

Three methods were used in the handling of screen sizes of broken coal. All pieces larger than 1-1/2" were polished without mounting, those fractions less than 1-1/2" but larger than 1/8" were mounted in groups of 3 or 4 in wood putty blocks 1-1/4" x 4" x 3/4", and the

smaller fractions of less than 1/8" were mounted in either 1" lucite discs or 1" Carnauba wax blocks.

The 1-1/2" to 1/8" pieces were first ground flat on one side, then placed, flat side down, on the base board and at the same time oriented so that on the finished surfaces all banding is parallel. This orientation saves much moving of the block when microscopic studies are being made. If an integrating stage is used, the putty blocks may be sawed into individual pieces of coal for ease of handling.

Most of the fine coal samples were mounted in lucite discs. The fine coal and Fisher "lucite" were mixed in equal amounts and the discs formed with a Fisher Metallographic Mounting Press. Buehler AB Transoptic Mounting Powder was also tested and the results were quite similar. The plastic is harder than the coal and upon grinding usually produces a surface in two planes. The coal being softer is ground lower, but a smooth even polish is obtained with a little effort.

"Santolite" a resin product of the Monsanto Chemical Company was tried, but the relatively low softening point of 62°C caused the deformation of the surface of some blocks. The heat from the microscope lamp would often soften the polished surface and the small polished blocks would deform if stored at room temperature for any great period of time.

A later group of blocks was made by mixing the fine coal and finely ground Carnauba wax in equal parts. To aid in the differentiation of the coal from the mounting media under the microscope, small amounts of red wax were added to the melted mixture. Both red and black wax were tried with equal success. Molds for the hot mixture were made by using four or more small steel blocks 1" x 1/2" x 2-1/2" laid out on a piece of stainless steel. Various arrangements of the blocks will give different size molds, but the 1" x 1" x 1/2" seems most suited to use on the integrating stage. A slight warming of the molds before the melted mixture is poured into it will result in a smoother block. Cold molds will cause deformation of the block by the contraction of the wax due to sudden cooling.

Grinding and polishing procedure for the broken coal is the same as for the larger blocks, but it is usually possible to begin grinding with the finer powders.

GRINDING AND POLISHING

The grinding and polishing of coal samples for reflected light studies seems to vary in each laboratory and with the type of machines available. The work was done for this project on one Eberbach Low Speed, Portable Polisher, supplemented with glass plates. The coarser grinding was done with carborundum powder on a cast iron lap or on a glass plate mounted on a rotating lap while the finer work was done on glass plates alone.

In sawing the blocks before mounting a flat surface was gained and was utilized as the surface for polishing.

1 Grinding

Silicon Carbide Grain manufactured by the Carborundum Company was used for the first three stages of grinding as follows:

1. F (240-280 grit) on iron plate.
2. FF (320-400 grit) on iron plate.
3. FFF (400-600 grit) on iron plate.

After these three grinding steps, the block may be polished with tin oxide suspended in distilled water on AB billiard cloth or AB selvyt cloth on a rotating lap. These cloths are available from Buehler Ltd., of Evanston, Illinois. This surface is quite satisfactory for megascopic examination or natural size photography.

For a much higher degree of smoothness such as needed for high power microscopic examination, it is necessary to carry the grinding further. To achieve this, the blocks are taken through the following 3 steps:

1. AB grinding compound, medium fine, (800 mesh) on a glass plate.
2. AB grinding compound, fine, (1200 mesh) on a glass plate.
3. AB grinding compound, extra fine, (3200 mesh) on a glass plate.

(The AB grinding compounds are a product of Buehler, Ltd.).

At the completion of the grinding procedure the blocks should have a smooth surface free of scratches. This may best be noted when the ground surface is dry. Drying is quickly achieved by a blast of air. If the block has a high content of finely disseminated pyrite scratch free surfaces are not easily attained.

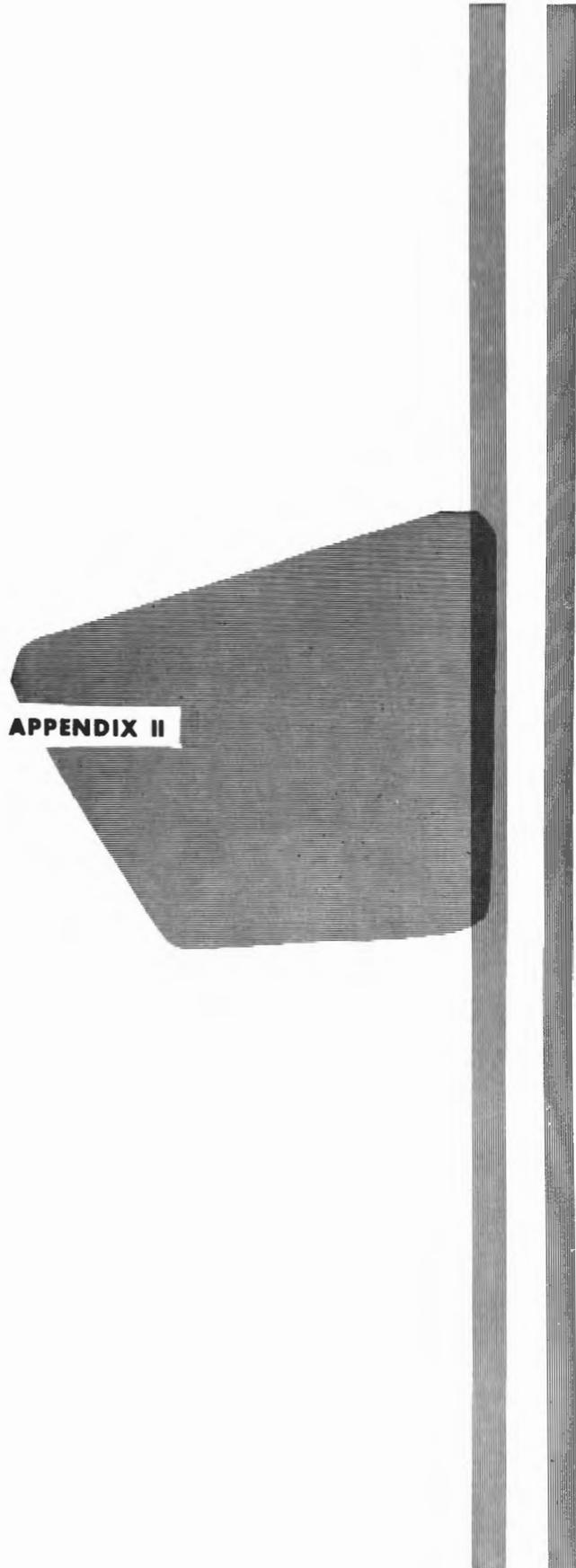
When a scratch free surface or at least an essentially scratch free surface is attained, the block is ready for the final polishing.

2 Polishing

Many combinations of grinding compounds and cloths were tried and the use of almost any combination of high grade materials will result in a usable surface. At this point the quality of the surface depends upon the technician doing the polishing, for while one person may produce a good surface with one set of materials another cannot equal that quality of surface without a great deal of effort. A combination was finally adopted which gave all who tried on this project a certain degree of success in attaining polished surfaces of desired quality.

Buehler's AB Alpha Polishing Alumina No. 2, diluted with 10 parts distilled water is applied to a wet revolving wheel covered with Buehler's AB Selvyt cloth. After a period of the alumina alone, a small flow of water is applied and polishing continued until all the polishing material is washed from the selvyt cloth. This usually leaves a clean, highly polished surface free of scratches and small pits.

Care must be exercised in the amount of pressure used to hold the surface to the wheel or an etched polish will result. It is advisable to delay the polishing, after the final grinding with 3200 mesh, until just before the block is to be logged to prevent oxidation of any fine particles of pyrite and the ruining of the flat surface. After logging, the block may be stored with the slight oil covering protecting the surface or they may be washed and dried in an oven and then sealed in air tight plastic bags for storage. But rarely can such blocks be used satisfactorily for detailed microscopic examination, after standing a few days without, re-storing the polish.



APPENDIX II

MEIGS CREEK COAL

Table 9. Chemical Analyses of Meigs Creek No. 9 Coal Samples.
(Percent by weight)

Sample		Bench number ²	Thick-ness (in.)	Condi-tion ³	Proximate analysis				Ultimate analysis				Sulphur forms				Heat value	
Number	Kind ¹				Mois-ture	Vola-tile matter	Fixed carbon	Ash	Hydro-gen	Carbon	Nitro-gen	Oxygen	Sul-phur	Sul-fate	Pyri-tic	Or-ganic	B.t.u.	Calo-ries
584	2	C (Upper)	29-1/8	1	3.4	35.3	41.3	20.00	4.8 ⁴	60.8	1.1	9.3	4.0	0.09	2.46	1.42	11,060	6,194
				2	-	36.5	42.8	20.70	4.6	62.9	1.1	6.6	4.1	0.10	2.54	1.47	11,450	6,361
				3	-	46.0	54.0	-	5.8	79.3	1.4	8.3	5.2	0.12	3.21	1.85	14,440	8,021
				4	-	44.0	56.0	-	-	-	-	-	-	-	-	-	14,916	8,287
	C (Lower)	57-3/4	1	3.2	37.6	44.7	14.5	5.0	65.8	1.1	8.8	4.8	0.10	3.15	1.59	11,990	6,661	
			2	-	38.8	46.3	14.9	4.8	67.9	1.1	6.3	5.0	0.10	3.25	1.64	12,380	6,878	
			3	-	45.6	54.4	-	5.7	79.8	1.30	7.3	5.9	0.12	3.82	1.93	14,550	8,082	
			4	-	43.9	56.1	-	-	-	-	-	-	-	-	-	14,946	8,303	
597-A	1	C	55-1/2	1	2.14	39.59	44.78	13.49	4.97	66.13	1.03	9.45	4.93	0.10	2.32	2.51	12,067	6,704
				2	-	40.46	45.76	13.78	4.84	67.58	1.05	7.71	5.04	0.10	2.37	2.57	12,331	6,850
				3	-	46.93	53.07	-	5.61	78.38	1.22	8.95	5.84	0.12	2.75	2.97	14,302	7,945
				4	-	45.35	54.65	-	-	-	-	-	-	-	-	-	3.11	14,669
	8	5	1	1.85	39.57	43.10	15.48	-	-	-	-	-	3.39	0.06	1.07	2.26	11,729	6,516
			2	-	40.32	43.91	15.77	-	-	-	-	-	3.45	0.06	1.09	2.30	11,950	6,639
			3	-	47.87	52.13	-	-	-	-	-	-	4.10	0.07	1.30	2.73	14,188	7,882
			4	-	46.48	53.52	-	-	-	-	-	-	-	-	-	2.87	14,527	8,070
	7	6-1/2	1	2.00	39.19	45.29	13.52	-	-	-	-	-	4.05	0.13	1.67	2.25	11,988	6,660
			2	-	39.99	46.21	13.80	-	-	-	-	-	4.13	0.13	1.70	2.30	12,236	6,797
			3	-	46.39	53.61	-	-	-	-	-	-	4.79	0.15	1.97	2.67	14,195	7,886
			4	-	44.96	55.04	-	-	-	-	-	-	-	-	-	2.78	14,524	8,068
	6	7	1	1.92	40.91	46.60	10.57	-	-	-	-	-	3.78	0.07	1.33	2.38	12,608	7,004
			2	-	41.71	47.51	10.78	-	-	-	-	-	3.85	0.07	1.36	2.42	12,855	7,141
			3	-	46.75	53.25	-	-	-	-	-	-	4.32	0.08	1.52	2.72	14,408	8,004
			4	-	45.58	54.42	-	-	-	-	-	-	-	-	-	2.81	14,683	8,157
	5	8-1/2	1	2.18	43.99	47.57	6.26	-	-	-	-	-	4.81	0.07	1.89	2.85	13,162	7,312
			2	-	44.97	48.63	6.40	-	-	-	-	-	4.92	0.07	1.93	2.92	13,455	7,475
			3	-	48.04	51.96	-	-	-	-	-	-	5.25	0.08	2.06	3.11	14,375	7,986
			4	-	47.01	52.99	-	-	-	-	-	-	-	-	-	3.23	14,615	8,119
	4	7-1/2	1	1.94	34.40	39.70	23.96	-	-	-	-	-	3.85	0.11	1.53	2.21	10,474	5,819
			2	-	35.08	40.49	24.43	-	-	-	-	-	3.93	0.11	1.56	2.26	10,681	5,934
			3	-	46.42	53.58	-	-	-	-	-	-	5.20	0.15	2.06	2.99	14,414	8,007
			4	-	44.16	55.84	-	-	-	-	-	-	-	-	-	3.16	14,673	8,151
	3	9	1	2.16	40.74	45.99	11.11	-	-	-	-	-	4.82	0.11	2.05	2.66	12,472	6,929
			2	-	41.64	47.00	11.36	-	-	-	-	-	4.93	0.11	2.10	2.72	12,747	7,081
			3	-	46.98	53.02	-	-	-	-	-	-	5.56	0.13	2.36	3.07	14,380	7,988
			4	-	45.59	54.41	-	-	-	-	-	-	-	-	-	3.20	14,703	8,168
2	4	1	2.12	39.11	44.67	14.10	-	-	-	-	-	6.98	0.13	4.43	2.42	11,953	6,640	
		2	-	39.96	45.64	14.40	-	-	-	-	-	7.13	0.13	4.53	2.47	12,212	6,784	
		3	-	46.68	53.32	-	-	-	-	-	-	8.33	0.15	5.29	2.89	14,267	7,926	
		4	-	44.65	55.35	-	-	-	-	-	-	-	-	-	3.07	14,724	8,180	
1	8	1	2.20	37.42	43.47	16.91	-	-	-	-	-	7.40	0.16	4.51	2.73	11,496	6,386	
		2	-	38.76	44.45	17.29	-	-	-	-	-	7.57	0.16	4.61	2.80	11,755	6,530	
		3	-	46.26	53.74	-	-	-	-	-	-	9.15	0.20	5.57	3.38	14,212	7,895	
		4	-	43.87	56.13	-	-	-	-	-	-	-	-	-	3.63	14,743	8,190	
597-B	1	C	58-1/8	1	1.92	38.25	42.43	17.40	4.74	62.09	0.96	9.90	4.91	0.16	2.42	2.33	11,373	6,318
				2	-	39.00	43.26	17.74	4.62	63.31	0.98	8.35	5.01	0.16	2.47	2.38	11,596	6,442
				3	-	47.41	52.59	-	5.61	76.96	1.19	10.15	6.09	0.20	3.00	2.89	14,096	7,831
				4	-	45.56	54.44	-	-	-	-	-	-	-	-	-	3.04	14,530
	Upper 4-1/2"	4-1/2	1	1.96	36.46	38.83	22.75	-	-	-	-	-	5.31	0.23	3.26	1.82	10,399	5,777
			2	-	37.19	39.61	23.20	-	-	-	-	-	5.42	0.23	3.33	1.86	10,607	5,892
			3	-	48.43	51.57	-	-	-	-	-	-	7.05	0.31	4.33	2.41	13,812	7,673
			4	-	46.09	53.91	-	-	-	-	-	-	-	-	-	-	14,363	7,979
	Next 6-1/4"	6-1/4	1	1.78	31.28	30.86	36.08	-	-	-	-	-	3.28	0.18	1.63	1.47	8,497	4,720
			2	-	31.85	31.42	36.73	-	-	-	-	-	3.34	0.18	1.66	1.50	8,651	4,806
			3	-	50.34	49.66	-	-	-	-	-	-	5.28	0.29	2.62	2.37	13,674	7,596
			4	-	47.14	52.86	-	-	-	-	-	-	-	-	-	2.56	14,504	8,057
597-C	1	C	58-3/4	1	2.36	38.32	43.66	15.66	4.76	63.15	0.97	10.26	5.20	0.15	2.69	2.36	11,575	6,430
				2	-	39.25	44.71	16.04	4.61	64.67	0.99	8.36	5.33	0.15	2.76	2.42	11,855	6,586
				3	-	46.74	53.26	-	5.49	77.03	1.18	9.96	6.34	0.18	3.28	2.88	14,119	7,843
				4	-	44.93	55.07	-	-	-	-	-	-	-	-	-	3.03	14,532
	4	6-3/8	1	1.80	29.08	30.23	38.89	-	-	-	-	-	2.50	0.11	1.14	1.25	8,024	4,458
			2	-	29.61	30.79	39.60	-	-	-	-	-	2.55	0.11	1.16	1.28	8,171	4,539
			3	-	49.03	50.97	-	-	-	-	-	-	4.22	0.19	1.92	2.11	13,529	7,516
			4	-	45.54	54.46	-	-	-	-	-	-	-	-	-	2.28	14,407	8,003

1. 1 - Core; 2 - Channel

2. C - Composite

3. 1 - As received; 2 - moisture-free; 3 - moisture- and ash-free; 4 - dry mineral-matter-free.

4. Does not include top 6-3/8"

Table 9. Chemical Analyses of Meigs Creek No. 9 Coal Samples. (Cont'd.)
(Percent by weight)

Sample Number	Kind	Bench number	Thick-ness (in.)	Condi-tion ³	Proximate analysis				Ultimate analysis				Sulphur forms				Heat value		
					Mois-ture	Vola-tile matter	Fixed carbon	Ash	Hydro-gen	Carbon	Nitro-gen	Oxygen	Sul-phur	Sul-fate	Pyri-tic	Or-ganic	B.t.u.	Calo-ries	
597-C (Cont'd)	1	3	29-1/4	1	2.32	39.71	44.09	13.28	-	-	-	-	5.07	0.20	2.60	2.27	11,809	6,560	
				2	-	40.68	48.14	14.21	-	-	-	5.19	0.21	2.66	2.32	12,089	6,716		
				3	-	47.39	52.61	-	-	-	-	6.05	0.24	3.10	2.71	14,092	7,828		
				4	-	45.77	54.23	-	-	-	-	-	-	-	2.84	14,462	8,034		
	2	10-1/4	1	2.11	33.79	37.06	27.04	-	-	-	-	3.16	0.10	1.01	2.05	9,889	5,494		
			2	-	34.52	37.86	27.62	-	-	-	3.23	0.10	1.03	2.10	10,102	5,612			
			3	-	47.69	52.31	-	-	-	-	4.46	0.14	1.43	2.89	13,958	7,754			
			4	-	45.38	54.65	-	-	-	-	-	-	-	3.06	14,534	8,074			
	1	19-1/4	1	2.35	38.59	45.80	13.26	-	-	-	-	5.56	0.18	2.69	2.69	11,954	6,641		
			2	-	39.52	46.90	13.58	-	-	-	5.69	0.18	2.75	2.76	12,242	6,801			
			3	-	45.73	54.27	-	-	-	-	6.59	0.21	3.19	3.19	14,165	7,869			
			4	-	43.98	56.02	-	-	-	-	-	-	-	3.35	14,546	8,081			
598-A	1	C	37-3/4	1	2.41	37.79	43.25	16.55	4.76	62.98	1.01	9.92	4.88	0.21	2.20	2.47	11,450	6,361	
				2	-	37.72	44.32	16.96	4.60	64.43	1.04	7.97	5.00	0.22	2.25	2.53	11,733	6,518	
				3	-	46.63	53.37	-	5.54	77.59	1.25	9.60	6.02	0.26	2.71	3.05	14,179	7,849	
				4	-	44.80	55.20	-	-	-	-	-	-	-	3.21	14,548	8,082		
	5	15-1/2	1	2.12	34.43	39.95	23.50	-	-	-	-	5.88	-	-	-	-	10,326	5,736	
			2	-	35.18	40.81	24.01	-	-	-	-	6.01	-	-	-	-	10,550	5,861	
			3	-	46.29	53.71	-	-	-	-	7.91	-	-	-	-	-	13,883	7,713	
			4	-	43.60	56.40	-	-	-	-	-	-	-	-	-	-	14,484	8,046	
	4	4-1/2	1	2.28	41.24	47.71	8.77	-	-	-	-	4.29	-	-	-	-	12,695	7,052	
			2	-	42.20	48.83	8.97	-	-	-	-	4.39	-	-	-	-	12,991	7,217	
			3	-	46.36	53.64	-	-	-	-	4.82	-	-	-	-	-	14,272	7,928	
			4	-	45.20	54.80	-	-	-	-	-	-	-	-	-	-	14,530	8,072	
	3	4-1/2	1	2.22	41.65	47.59	8.54	-	-	-	-	3.36	-	-	-	-	12,873	7,151	
			2	-	42.60	48.67	8.73	-	-	-	-	3.44	-	-	-	-	13,165	7,313	
			3	-	46.67	53.33	-	-	-	-	3.77	-	-	-	-	-	14,425	8,013	
			4	-	45.70	54.30	-	-	-	-	-	-	-	-	-	-	14,652	8,140	
	2	6-1/4	1	2.28	38.43	42.52	16.77	-	-	-	-	5.28	-	-	-	-	11,392	6,329	
			2	-	39.33	43.51	17.16	-	-	-	-	5.40	-	-	-	-	11,658	6,476	
			3	-	47.47	52.53	-	-	-	-	6.52	-	-	-	-	-	14,073	7,818	
			4	-	45.60	54.40	-	-	-	-	-	-	-	-	-	-	14,508	8,060	
	1	7	1	2.47	41.16	45.70	10.67	-	-	-	-	3.58	-	-	-	-	12,373	6,874	
			2	-	42.20	46.86	10.94	-	-	-	-	3.67	-	-	-	-	12,686	7,047	
			3	-	47.39	52.61	-	-	-	-	4.12	-	-	-	-	-	14,245	7,913	
			4	-	46.26	53.74	-	-	-	-	-	-	-	-	-	-	14,510	8,061	
598-B	1	C	50-3/8	1	2.64	37.62	42.50	17.24	4.69	62.55	0.93	9.61	4.98	0.18	2.27	2.53	11,299	6,277	
				2	-	38.64	43.65	17.71	4.51	64.25	0.95	7.46	5.12	0.19	2.33	2.60	11,605	6,447	
				3	-	46.98	53.08	-	5.49	78.07	1.16	9.06	6.22	0.22	2.80	3.11	14,103	7,835	
				4	-	45.06	54.94	-	-	-	-	-	-	-	3.33	14,539	8,077		
	4	16	1	2.21	35.07	40.25	22.47	-	-	-	-	5.23	-	-	-	-	10,449	5,805	
			2	-	35.86	41.16	22.98	-	-	-	-	5.35	-	-	-	-	10,685	5,936	
			3	-	46.56	53.44	-	-	-	-	6.94	-	-	-	-	-	13,873	7,707	
			4	-	44.14	55.86	-	-	-	-	-	-	-	-	-	-	14,421	8,011	
	3	11-1/2	1	2.46	39.47	44.89	13.18	-	-	-	-	3.64	-	-	-	-	12,060	6,700	
			2	-	40.47	46.02	13.51	-	-	-	-	3.73	-	-	-	-	12,364	6,869	
			3	-	46.79	53.21	-	-	-	-	4.31	-	-	-	-	-	14,296	7,942	
			4	-	45.46	54.54	-	-	-	-	-	-	-	-	-	-	14,609	8,116	
	2	12-1/4	1	2.62	39.48	44.55	13.35	-	-	-	-	4.35	-	-	-	-	11,894	6,607	
			2	-	40.54	45.75	13.71	-	-	-	-	4.47	-	-	-	-	12,214	6,785	
			3	-	46.98	53.02	-	-	-	-	5.18	-	-	-	-	-	14,154	7,863	
			4	-	45.52	54.48	-	-	-	-	-	-	-	-	-	-	14,493	8,051	
	1	10-5/8	1	2.55	37.70	41.20	18.55	-	-	-	-	8.62	-	-	-	-	11,016	6,120	
			2	-	38.69	42.27	19.04	-	-	-	-	8.85	-	-	-	-	11,304	6,280	
			3	-	47.78	52.22	-	-	-	-	10.93	-	-	-	-	-	13,962	7,756	
			4	-	45.09	54.91	-	-	-	-	-	-	-	-	-	-	14,566	8,092	
	598-C	1	C	48-1/2	1	3.14	36.76	41.84	18.26	-	-	-	-	5.56	0.22	2.89	2.45	11,023	6,124
					2	-	37.95	43.20	18.85	-	-	-	-	5.74	0.23	2.98	2.53	11,380	6,322
					3	-	46.77	53.23	-	-	-	-	7.07	0.28	3.68	3.11	14,024	7,791	
					4	-	44.65	55.35	-	-	-	-	-	-	-	3.31	14,503	8,057	
4		12-3/8	1	2.89	32.61	35.01	29.49	-	-	-	-	7.33	0.24	5.63	1.46	9,208	5,115		
			2	-	33.58	36.05	30.37	-	-	-	-	7.55	0.25	5.80	1.50	9,482	5,267		
			3	-	48.23	51.77	-	-	-	-	10.84	0.35	8.33	2.16	13,617	7,565			
			4	-	44.62	55.38	-	-	-	-	-	-	-	2.38	14,441	8,022			

1. 1 - Core; 2 - Channel
 2. C - Composite
 3. 1 - As received; 2 - moisture-free; 3 - moisture- and ash-free; 4 - dry mineral-matter-free.

MEIGS CREEK COAL

Table 9. Chemical Analyses of Meigs Creek No. 9 Coal Samples. (Cont'd.)
(Percent by weight)

Sample Number	Kind	Bench number	Thick-ness (in.)	Condi-tion ³	Proximate analysis				Ultimate analysis					Sulphur forms			Heat value		
					Mols-ture	Vola-tile matter	Fixed carbon	Ash	Hydro-gen	Carbon	Nitro-gen	Oxygen	Sul-phur	Sul-fate	Pyric-tic	Or-ganic	B.t.u.	Calo-ries	
598-C (Cont'd)	1	3	11-7/8	1	3.53	39.88	45.76	10.83	-	-	-	-	4.22	0.10	1.50	2.62	12,199	6,777	
				2	-	41.34	47.43	11.23	-	-	-	-	4.37	0.10	1.55	2.72	12,645	7,025	
				3	-	46.57	53.43	-	-	-	-	-	4.93	0.12	1.75	3.06	14,245	7,913	
				4	-	45.27	54.73	-	-	-	-	-	-	-	-	3.18	14,539	8,077	
	2	13-1/8	1	3.19	36.67	42.42	17.72	-	-	-	-	5.56	0.20	2.84	2.52	11,045	6,136		
			2	-	37.88	43.82	18.30	-	-	-	-	5.74	0.21	2.93	2.60	11,409	6,338		
			3	-	46.36	53.64	-	-	-	-	-	7.03	0.25	3.59	3.19	13,965	7,758		
			4	-	44.27	55.73	-	-	-	-	-	-	-	-	3.38	14,429	8,016		
	1	11-1/8	1	3.33	37.13	44.16	15.38	-	-	-	-	5.94	0.30	2.76	2.88	11,361	6,311		
			2	-	38.41	45.68	15.91	-	-	-	-	6.14	0.31	2.86	2.97	11,752	6,529		
			3	-	45.68	54.32	-	-	-	-	-	7.31	0.37	3.40	3.54	13,976	7,764		
			4	-	43.65	56.35	-	-	-	-	-	-	-	-	3.75	14,407	8,003		
600	2	C	42-1/2	1	3.14	35.99	44.11	16.76	4.80	64.17	1.01	10.05	3.21	0.12	1.63	1.46	11,547	6,415	
				2	-	37.16	45.54	17.30	4.60	66.25	1.04	7.49	3.32	0.12	1.69	1.51	11,921	6,622	
				3	-	44.93	55.07	-	5.56	80.11	1.26	9.06	4.01	0.15	2.03	1.83	14,414	8,007	
				4	-	43.34	56.66	-	-	-	-	-	-	-	-	1.90	14,788	8,215	
601-B	1	C	39-7/8	1	2.24	40.44	45.32	12.00	5.13	67.76	1.05	9.67	4.39	0.10	2.17	2.12	12,407	6,890	
				2	-	41.37	46.36	12.27	4.99	69.31	1.07	7.86	4.49	0.10	2.22	2.17	12,686	7,047	
				3	-	47.15	52.85	-	5.69	79.01	1.23	8.95	5.12	0.12	2.53	2.47	14,461	8,033	
				4	-	45.79	54.21	-	-	-	-	-	-	-	-	2.57	14,786	8,214	
	4	12-3/4	1	2.35	40.90	50.06	6.69	-	-	-	-	-	2.52	-	-	-	13,288	7,382	
			2	-	41.88	51.27	6.85	-	-	-	-	-	-	2.58	-	-	-	13,608	7,560
			3	-	44.96	55.04	-	-	-	-	-	-	-	2.77	-	-	-	14,609	8,116
			4	-	44.20	55.80	-	-	-	-	-	-	-	-	-	-	-	14,782	8,212
	3	8-7/8	1	2.16	36.25	39.68	21.91	-	-	-	-	-	3.83	-	-	-	10,892	6,051	
			2	-	37.05	40.56	22.39	-	-	-	-	-	-	3.91	-	-	-	11,132	6,184
			3	-	47.74	52.26	-	-	-	-	-	-	-	5.04	-	-	-	14,345	7,969
			4	-	45.74	54.26	-	-	-	-	-	-	-	-	-	-	-	14,846	8,247
	2	8-5/8	1	1.92	42.47	44.98	10.63	-	-	-	-	-	5.79	-	-	-	12,668	7,037	
			2	-	43.30	45.86	10.84	-	-	-	-	-	-	5.90	-	-	-	12,916	7,175
			3	-	48.56	51.44	-	-	-	-	-	-	-	6.62	-	-	-	14,486	8,047
			4	-	47.12	52.88	-	-	-	-	-	-	-	-	-	-	-	14,840	8,244
1	9-5/8	1	1.96	41.60	44.53	11.91	-	-	-	-	-	5.32	-	-	-	12,449	6,916		
		2	-	42.43	45.42	12.15	-	-	-	-	-	-	5.43	-	-	-	12,698	7,054	
		3	-	48.30	51.70	-	-	-	-	-	-	-	6.18	-	-	-	14,454	8,030	
		4	-	46.83	53.17	-	-	-	-	-	-	-	-	-	-	-	14,813	8,229	
601-C	1	C	42-3/8	1	2.24	38.51	44.71	14.54	4.91	65.46	0.94	9.56	4.59	0.17	2.64	1.78	11,923	6,624	
				2	-	39.39	45.74	14.87	4.77	66.96	0.96	7.74	4.70	0.18	2.70	1.82	12,196	6,775	
				3	-	46.27	53.73	-	5.60	78.66	1.13	9.09	5.52	0.21	3.17	2.14	14,327	7,959	
				4	-	44.65	55.35	-	-	-	-	-	-	-	-	-	2.24	14,702	8,167
	4	9-1/4	1	2.48	35.97	46.95	14.60	-	-	-	-	-	3.74	0.19	1.98	1.57	11,825	6,569	
			2	-	36.88	48.15	14.97	-	-	-	-	-	-	3.84	0.20	2.03	1.61	12,126	6,736
			3	-	43.38	56.62	-	-	-	-	-	-	-	4.51	0.23	2.39	1.89	14,261	7,922
			4	-	41.79	58.21	-	-	-	-	-	-	-	-	-	-	-	14,603	8,112
	3	11-1/4	1	2.34	39.02	50.71	7.93	-	-	-	-	-	3.77	0.13	1.75	1.89	13,046	7,247	
			2	-	39.95	51.93	8.12	-	-	-	-	-	-	3.86	0.13	1.79	1.94	13,361	7,422
			3	-	43.49	56.51	-	-	-	-	-	-	-	4.20	0.14	1.95	2.11	14,539	8,077
			4	-	42.38	57.62	-	-	-	-	-	-	-	-	-	-	2.17	14,778	8,210
	2	12	1	2.31	36.62	41.79	19.28	-	-	-	-	-	4.62	0.17	2.69	1.76	11,238	6,243	
			2	-	37.49	42.77	19.74	-	-	-	-	-	-	4.73	0.18	2.75	1.80	11,504	6,391
			3	-	46.70	53.30	-	-	-	-	-	-	-	5.89	0.22	3.43	2.24	14,332	7,962
			4	-	44.71	55.29	-	-	-	-	-	-	-	-	-	-	2.37	14,754	8,196
1	9-7/8	1	2.18	41.95	42.57	13.30	-	-	-	-	-	5.63	0.13	3.16	2.34	12,209	6,782		
		2	-	42.88	43.52	13.60	-	-	-	-	-	-	5.76	0.14	3.23	2.39	12,481	6,934	
		3	-	49.63	50.37	-	-	-	-	-	-	-	6.66	0.15	3.74	2.77	14,445	8,025	
		4	-	48.08	51.92	-	-	-	-	-	-	-	-	-	-	2.91	14,843	8,246	
601-D	1	C	45-1/4	1	2.10	39.46	44.02	14.42	4.97	65.70	0.94	9.12	4.85	0.13	2.66	2.06	11,986	6,659	
				2	-	40.31	44.96	14.73	4.84	67.11	0.96	7.41	4.95	0.13	2.72	2.10	12,243	6,801	
				3	-	47.27	52.73	-	5.67	78.70	1.13	8.69	5.81	0.15	3.19	2.47	14,358	7,976	
				4	-	45.65	54.35	-	-	-	-	-	-	-	-	-	2.59	14,742	8,190
	4	14-1/8	1	2.44	40.05	45.68	11.83	-	-	-	-	-	2.95	-	-	-	12,545	6,969	
			2	-	41.05	46.82	12.13	-	-	-	-	-	-	3.02	-	-	-	12,859	7,143
			3	-	46.72	53.28	-	-	-	-	-	-	-	3.44	-	-	-	14,633	8,129
			4	-	45.60	54.40	-	-	-	-	-	-	-	-	-	-	-	14,908	8,282

1. 1 - Core; 2 - Channel

2. C - Composite

3. 1 - As received; 2 - moisture-free; 3 - moisture- and ash-free; 4 - dry mineral-matter-free.

APPENDIX

Table 9. Chemical Analyses of Meigs Creek No. 9 Coal Samples. (Cont'd.)
(Percent of weight)

Sample		Bench number ²	Thick-ness (in.)	Condi-tion ³	Proximate analysis				Ultimate analysis					Sulphur forms			Heat value	
Number	Kind				Mois-ture	Vola-tile matter	Fixed carbon	Ash	Hydro-gen	Carbon	Nitro-gen	Oxygen	Sul-phur	Sul-fate	Pyri-tic	Or-ganic	B.t.u.	Calo-ries
601-D (Cont'd)	1	3	10-1/2	1	2.12	37.73	42.40	17.75	-	-	-	-	4.89	-	-	-	11,536	6,409
				2	-	38.55	43.32	18.13	-	-	-	-	5.00	-	-	-	11,786	6,547
				3	-	47.09	52.91	-	-	-	-	-	6.10	-	-	-	14,397	7,998
				4	-	45.19	54.81	-	-	-	-	-	-	-	-	-	14,853	8,251
	2	11	1	1	2.14	39.96	44.27	13.63	-	-	-	-	5.65	-	-	-	12,021	6,678
				2	-	40.83	45.24	13.93	-	-	-	-	5.77	-	-	-	12,284	6,824
				3	-	47.44	52.56	-	-	-	-	-	6.71	-	-	-	14,272	7,928
				4	-	45.60	54.40	-	-	-	-	-	-	-	-	-	14,668	8,148
	1	9-5/8	1	1	2.18	41.38	44.35	12.09	-	-	-	-	5.60	-	-	-	12,350	6,861
				2	-	42.30	45.34	12.36	-	-	-	-	5.72	-	-	-	12,625	7,014
				3	-	48.27	51.73	-	-	-	-	-	6.53	-	-	-	14,406	8,003
				4	-	46.73	53.27	-	-	-	-	-	-	-	-	-	14,774	8,207
603-A	2	C (Upper)	30-1/2	1	3.30	37.36	40.52	18.82	4.88	61.44	1.08	9.88	3.90	0.02	2.17	1.71	11,247	6,248
				2	-	38.64	41.90	19.46	4.67	63.53	1.12	7.18	4.04	0.02	2.24	1.78	11,631	6,461
				3	-	47.97	52.03	-	5.79	78.89	1.39	8.92	5.01	0.03	2.78	2.20	14,442	8,023
				4	-	46.20	53.80	-	-	-	-	-	-	-	-	2.31	15,102	8,390
	C (Lower)	46	1	1	2.93	32.51	42.99	15.57	4.90	63.19	0.99	9.24	6.11	0.03	4.07	2.01	11,689	6,494
				2	-	39.67	44.28	16.05	4.71	65.10	1.02	6.83	6.29	0.03	4.19	2.07	12,042	6,690
				3	-	47.26	52.74	-	5.61	77.54	1.22	8.14	7.49	0.04	4.99	2.46	14,343	7,968
				4	-	45.29	54.71	-	-	-	-	-	-	-	-	2.61	14,804	8,224
603-B	2	C (Upper)	27-1/2	1	2.85	34.86	37.98	24.31	4.57	57.00	1.00	9.31	3.81	0.12	2.18	1.51	10,478	5,821
				2	-	35.88	39.10	25.02	4.38	58.68	1.03	6.97	3.92	0.12	2.25	1.55	10,786	5,992
				3	-	47.85	52.15	-	5.84	78.25	1.38	9.30	5.23	0.16	3.00	2.07	14,385	7,991
				4	-	45.62	54.38	-	-	-	-	-	-	-	-	2.19	14,953	8,307
	C (Lower)	47-3/4	1	1	2.76	36.63	41.67	18.94	4.65	60.14	0.93	9.04	6.30	0.28	3.80	2.22	11,155	6,197
				2	-	37.67	42.86	19.47	4.47	61.85	0.96	6.77	6.48	0.29	3.91	2.28	11,472	6,373
				3	-	46.78	53.22	-	5.55	76.81	1.19	8.41	8.04	0.35	4.85	2.84	14,246	7,914
				4	-	44.46	55.54	-	-	-	-	-	-	-	-	3.03	14,785	8,213

1. 1 - Core; 2 - Channel
 2. C - Composite
 3. 1 - As received; 2 - moisture-free; 3 - moisture- and ash-free; 4 - dry mineral-matter-free.

MEIGS CREEK COAL

Table 10. Ash and Sulphur Content of Screen Sizes of Meigs Creek, No. 9 Bed Coal.¹

Sample number	Screen size (in.)	Moisture-free percent	
		Ash	Sulphur
598-C	Composite	19.27	5.74
	-1 1/2 to +3/8	19.03	5.72
	-3/8 to +1/4	19.76	6.19
	-1/4 to +1/8	18.57	6.50
	-1/8 to +28 mesh	20.57	6.80
	-28 mesh to +100 mesh	21.76	5.46
	-100 mesh to 0	23.96	6.61
600	Composite	16.77	3.32
	-2 to +1 1/2	14.73	3.45
	-1 1/2 to +1	15.45	3.55
	-1 to +3/4	16.16	4.24
	-3/4 to +1/2	17.30	3.75
	-1/2 to +3/8	18.63	4.14
	-3/8 to +1/4	19.80	4.00
	-1/4 to +1/8	22.49	3.94
	-1/8 to +28 mesh	24.69	3.78
	-28 mesh to 0	25.74	3.59
601-C	Composite	14.87	4.70
	-1 1/2 to +3/8	15.04	4.46
	-3/8 to +1/4	11.81	4.51
	-1/4 to +1/8	14.62	5.21
	-1/8 to +28 mesh	14.39	5.08
	-28 mesh to +100 mesh	16.42	4.87
	-100 mesh to 0	16.36	4.37
603-B ² Upper	Composite	19.46	4.04
	-3/8 to +1/4	21.43	3.85
	-1/4 to +1/8	19.77	4.42
	-1/8 to +28 mesh	18.30	4.10
	-28 mesh to 0	19.95	4.27

1. Made in the laboratory of the Ohio State University Engineering Experiment Station, Dr. Peter O. Krumin in charge, 1953-1955, values being shown only of those coals of which petrographic analyses have been made.
2. Entire sample crushed to -3/8".

Table 10. Ash and Sulphur Content of Screen Sizes of Meigs Creek, No. 9 Bed Coal. (Cont'd)

Sample number	Screen size (in.)	Moisture-free percent		
		Ash	Sulphur	
603-B ¹ Lower	Composite	16.04	6.29	
	-3/8 to +1/4	17.25	7.37	
	-1/4 to +1/8	15.84	6.32	
	-1/8 to +28 mesh	15.82	6.02	
	-28 mesh to 0	17.01	6.00	
603-B Upper	Composite	25.02	3.92	
	-6 to +2	23.60	3.92	
	-2 to +1 1/2	25.81	3.43	
	-1 1/2 to +1	27.45	4.25	
	-1 to +3/4	25.33	4.44	
	-3/4 to +1/2	23.89	4.01	
	-1/2 to +3/8	24.24	3.82	
	-3/8 to +1/4	24.84	3.70	
	-1/4 to +1/8	28.85	3.78	
	-1/8 to +28 mesh	29.13	3.72	
	-28 mesh to 0	34.14	3.65	
	603-B Lower	Composite	19.47	6.49
		-6 to +2	14.76	5.97
-2 to +1 1/2		16.30	6.73	
-1 1/2 to +1		19.31	6.32	
-1 to +3/4		18.92	6.44	
-3/4 to +1/2		21.46	6.55	
-1/2 to +3/8		20.02	6.33	
-3/8 to +1/4		20.13	6.34	
-1/4 to +1/8		20.88	6.37	
-1/8 to +28 mesh		24.08	6.45	
-28 mesh to 0		29.66	6.38	

1. Entire sample crushed to -3/8".