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UNIVERSITY OF VIRGINIA

ALBERT WILLIAM GILES, PH. D.
ACTING DIRECTOR

Bulletin No. XXV

The Valley Coal Fields of Virginia

BY

MARIUS R. CAMPBELL and OTHERS

PREPARED IN CO-OPERATION WITH THE
UNITED STATES GEOLOGICAL SURVEY

WITH A CHAPTER ON

The Forests of the Valley Coal Fields of Virginia

BY

FRED C. PEDERSON

PREPARED IN CO-OPERATION WITH THE
OFFICE OF STATE FORESTER

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VIRGINIA GEOLOGICAL SURVEY,

UNIVERSITY OF VIRGINIA,

CHARLOTTESVILLE, JANUARY 30, 1925.

Governor E. Lee Trinkle, Chairman, and Members of the State Geological Commission:

Gentlemen:—I have the honor to transmit to you, herewith, and to recommend for publication as Bulletin No. XXV of the Virginia Geological Survey Series of Reports, a manuscript and illustrations of a report on "The Valley Coal Fields of Virginia," by Marius R. Campbell and others, with a chapter on "The Forests of the Valley Coal Fields of Virginia," by Fred C. Pederson.

This report has been prepared by the Virginia Geological Survey in coöperation with the United States Geological Survey and the office of State Forester. The field work on which the report is based had its inception during the administration of the late Doctor Thomas L. Watson as State Geologist, and it was completed and the results prepared for publication before his death. This report is the eighth one of a series of detailed reports by the Virginia Geological Survey on the coal resources of southwest Virginia, under the coöperative agreement of the State and Federal Surveys. The report is accompanied by a geologic map of the area covered.

Respectfully submitted,

ALBERT WILLIAM GILES,
Acting Director.

THE VALLEY COAL FIELDS OF VIRGINIA

BY MARIUS R. CAMPBELL AND OTHERS.

INTRODUCTION

GENERAL STATEMENT.

Throughout that part of the Appalachian Valley province, extending from northern Pennsylvania to near the south line of Virginia, there is a more or less continuous outcrop of coal-bearing rocks which are very much older than the rocks of the well-known bituminous coal fields lying to the northwest. The coal beds in this belt are greatly disturbed, being folded and faulted in much the same manner as are the beds in the anthracite fields of Pennsylvania, and the coal itself is so metamorphosed that it has passed the rank of bituminous coal and is intermediate in character between bituminous coal and anthracite. As these coal beds crop out in or near the Valley of Virginia, the areas in which they occur will here be called the "Valley coal fields."

The coal beds of the Valley fields have been known for at least 100 years, but so many unsuccessful attempts have been made to mine them and place the coal on the market that the public has become skeptical about the value of the coal and the possibility of any one being able to mine and market it in a satisfactory manner. The result of such a reputation has been disastrous to the development of the fields, with the result that at the present time there are in operation only three or four small shipping mines and a half-dozen or so wagon mines catering alone to the local trade. Capitalists have been loath to invest in an enterprise in which there have been so many failures, and the local people have not had the means to finance a mine that extended much below drainage level, consequently most of the operations have been confined to small drift or slope mines which served the needs of the neighborhood for a year or two and then were allowed to cave and become unworkable.

For a long time both the State and the Federal Geological Surveys have been of the opinion that the past failures in these fields have been due not so much to bad mining conditions and poor quality of coal as they have to a combination of circumstances that has placed the coal of the Valley fields at a great disadvantage in the available markets. Thus with the best Pocahontas and New River coals selling for less than one dollar per ton at the mines, as they did for many years prior to 1917, it was practically impossible to market the Valley coals for power purposes, and similarly with Pennsylvania anthracite, at not to exceed $2.50 per ton at the mine; it was difficult, if not impossible for the Valley coals to hold their own in the domestic coal market.

The World War, with the resulting high price of "smokeless" coal and of anthracite, completely changed these conditions and has seemingly made it possible for operators in the Valley fields with moderate capital to compete in both the steam and domestic markets with the output of the giant organizations in the other regions. Since the war, conditions have not materially improved, as far as price and available tonnage of coal are concerned, so that general conditions in the coal trade continue to be favorable to the introduction of a fuel that is primarily a domestic coal but that in a small way would also be a competitor of the steam coals of the country. Whether or not these conditions will continue in the future can be told only by actual trial; at the present time there seems to be little hope that fuel from a new source could successfully compete with the high-rank steaming coals of the bituminous fields, but there does seem to be an excellent opportunity for such competition with anthracite. Owing to the high cost of labor in the anthracite fields, the high royalties that have to be paid for productive territory, and the high cost of deep mining there seems to be little prospect that the selling price of anthracite will be materially lowered from its present standard and consequently the time is opportune for the introduction of any fuel that would be accepted as a satisfactory substitute.

The present report, prepared by geologists of the United States Geological Survey in coöperation with the Geological Survey of Virginia, is brought forward with the idea that the coal of the Valley fields offers one of the best substitutes for anthracite that has yet been proposed and that the present is the psychologic moment for it to secure its proper place in the domestic trade of the country.

If this view of the situation is correct, the Valley fields present a great opportunity for the operator who has sufficient means to erect and equip a plant with modern machinery for the mining of coal, the handling of it in a large way, and for its preparation for the market, provided he will be content to charge a moderate price, at least until his market is established.

The writer fully believes that a market built up in this manner and with this coal can be maintained almost indefinitely, or possibly until the coal of these fields approaches exhaustion.

LOCATION OF THE COAL FIELDS.

The Valley coal fields, as shown in Fig. 1, are located in the counties of Augusta, Bland, Botetourt, Montgomery, Pulaski, Roanoke, Smyth, and Wythe. They may be roughly subdivided, according to their relative importance, into five groups as follows: (1) The fields of Montgomery and Pulaski counties, Virginia; (2) the fields of Wythe County, Virginia; (3) the fields of Morgan and Berkeley counties, West Virginia; (4) the fields of Bland and Smyth counties, Virginia; (5) the fields of Roanoke and Botetourt counties; (6) the fields of Augusta and Rockingham counties; and (7) the scattering fields of little or no economic importance.

(1) The coal fields of Montgomery and Pulaski counties, Virginia, have the greatest linear extent of outcrop of workable coal beds and the greatest development of mines of any of the fields in the Valley region and they are also the most accessible to railroads. In these fields there are two or three mines that have been in operation most of the time since 1902, and the Merrimac mine (Pl. XV A) in Montgomery County has the unique distinction of having furnished coal for the Confederate frigate *Merrimac* in its momentous engagement with the *Monitor* in Hampton Roads on March 9, 1862. These fields are so situated that they are crossed by the main line of the Virginian Railway, and by the main line and the Bristol branch of the Norfolk and Western Railway as well as by a short branch of the latter system which runs from Christiansburg to Blacksburg.

(2) The coal fields of Wythe County are second in importance to those of Montgomery and Pulaski counties. They are two in number, the larger extending nearly across the northern part of the county in an east-west direction, and the smaller consisting of a detached basin or trough in the rocks in the vicinity of Max Meadows. This trough contains coal that compares favorably in quality and quantity with the coal in the adjoining part of Pulaski County, and it is being developed by a fairly large mine that in the near future probably will become a shipping mine with railroad connections. Most of this field is within easy reach of the railroad at Gunton Park or at the town of Max Meadows. Little is known regarding the field in the northern part of the county, but it appears to

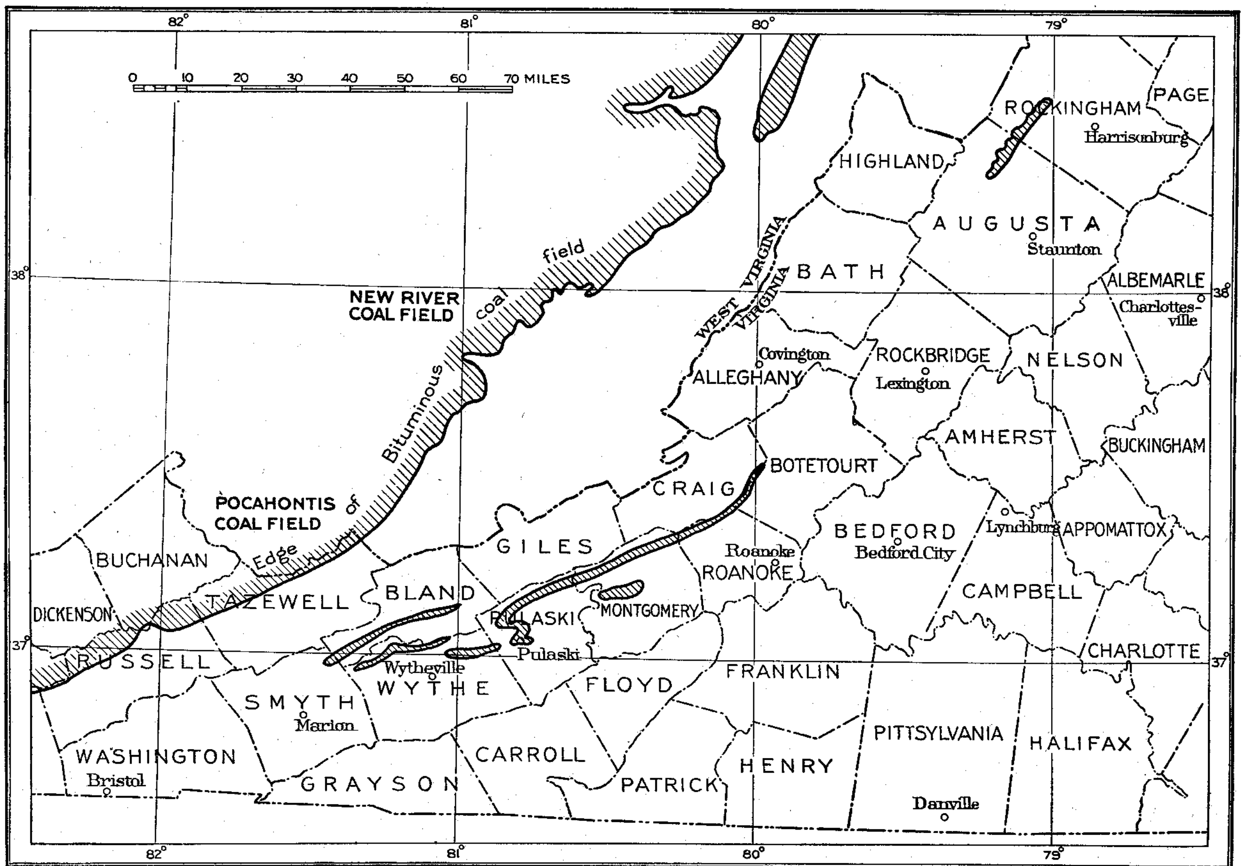


Fig. 1.—Key map, showing location of the Valley coal fields and their relations to the bituminous coal field to the northwest.

contain considerable coal of a lower rank,[1] however, than the coal in the Max Meadows trough. It is not so favorably situated regarding routes of transportation as the other field and would require branch railroad lines from 6 to 10 miles in length to give an adequate outlet for the coal.

(3) The coal field next on the list is that usually called the Meadow Branch field of Morgan and Berkeley counties, West Virginia. As this field lies outside of Virginia it will not be considered further, but a brief description by the writer can be found in a paper entitled: *The Meadow Branch Coal Field of West Virginia,* U. S. Geol. Survey, Bull. 225, pp. 330-344, 1904.

(4) The next group of fields worthy of a separate description are those of Bland and Smyth counties, Virginia. These fields consist of a narrow belt of coal-bearing rocks which extends for a distance of more than 30 miles, but judging from the evidence at hand, the coal beds are generally thin and irregular, the coal is high in ash and on the whole not particularly promising. No commercial development in these counties has been attempted and on account of the lack of railroad connections and the high percentage of ash carried by the coal it does not seem probable that it will be used for several generations, if indeed it ever can be mined and cleaned in a profitable way.

(5) The northeastward extension of the Brushy Mountain field of Montgomery County is considered as a separate field for convenience of description and will be called here the coal field of Roanoke and Botetourt counties. This field is not active at the present time, but in the past has attracted considerable attention because of its nearness to James River and the possibility of transporting its coal to Richmond by this water route.

(6) An area of coal-bearing rocks in Augusta and Rockingham counties has in the past received considerable attention in a public discussion as to its prospective value. At that time the field was extensively prospected and the Dora mine was widely known from its prominence in the discussion. The field is of doubtful value, but probably has enough coal to be classed as a coal field.

(7) Besides the principal fields and groups of coal fields listed above, there are scattering occurrences of coal beds of this same general geologic age in various parts of the Appalachian Valley province of Virginia, but,

[1] For definition of this term see p. 98.

judging by the evidence now at hand, it does not seem probable that these coal beds will ever be used for fuel purposes.

FIELD WORK.

The field work upon which this report is based has been done largely by members of the United States Geological Survey working in coöperation with the Geological Survey of Virginia. The field examination was begun in 1912 by Ralph W. Howell, and much of the success of the final work is to be attributed to his painstaking efforts to gather all of the facts regarding the actual and reported occurrence and character of coal. Before Howell could complete the work he was called off for geologic work in other parts of the country and on other problems, and finally he was ambushed and foully murdered while engaged in private geologic work in Baluchistan, Asia.

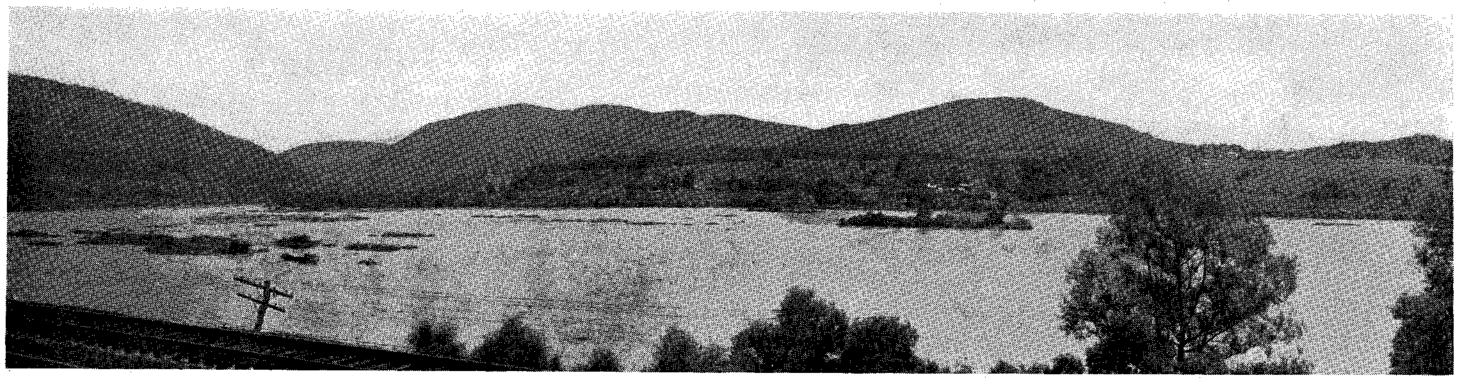
Upon the death of Howell the preparation of the report on the Valley fields fell to the writer, and desultory work has been carried on for a number of years, the delay being caused largely by the lack of an adequate base map upon which to portray the outcrops of the coal beds.

In 1923 it was finally decided that the present base maps could not be used and that a new base would have to be prepared from planetable surveys in the field. Before this plan was put into effect it was found that the Army Air Service was willing to make a survey of the region by the photographic method and as this promised to save time and to supply infinitely more details, an agreement was entered into for the survey of the outcrop of coal-bearing rocks from the Catawba Sanatorium in Roanoke County southwestward to the western borders of Wythe County. One flight was made in June which gave photographs covering the Brushy Mountain field from Catawba Sanatorium to the Empire mine in Pulaski County and also a belt of country from Wytheville eastward across New River. Clouds prevented the taking of photographs of the field farther west. Weather conditions in the latter part of the summer were very bad and although other flights were attempted no results were obtained.

With the approach of winter, the idea of completing the taking of airplane photographs was given up and then the only recourse was to prepare the best base possible with the odds and ends of airplane photographs, foot traverses, and inadequate topographic maps. In order to combine this heterogeneous mass of material the topographic base maps were photographed up to a scale of 1½ inches to the mile, and on this base all of

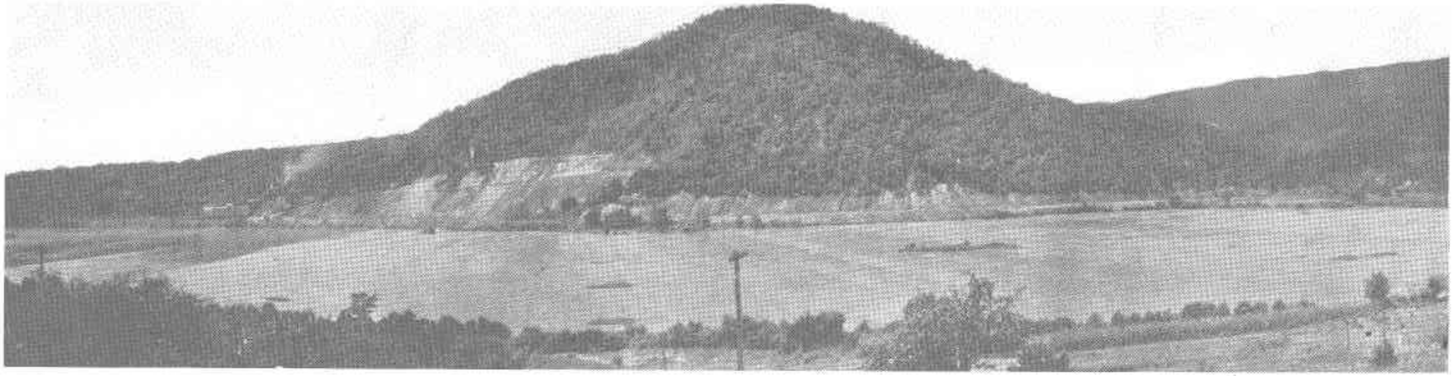
(A) Parrott coal mine on New River and the end of Little Walker Mountain.

Photograph by Marius R. Campbell.



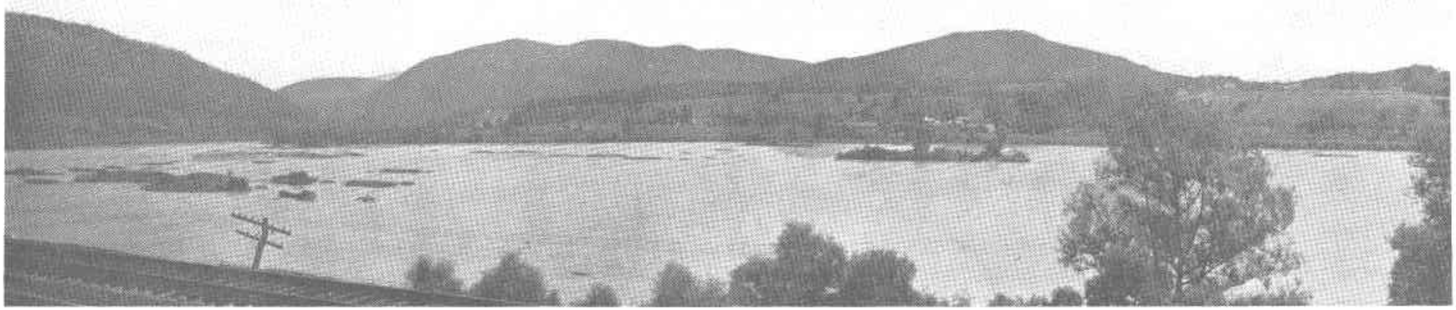
(B) End of Brushy Mountain and gap New River has cut through Walker Mountain.

Photograph by Marius R. Campbell.



(A) Parrott coal mine on New River and the end of Little Walker Mountain.

Photograph by Marius R. Campbell.



(B) End of Brushy Mountain and gap New River has cut through Walker Mountain.

Photograph by Marius R. Campbell.

the data were plotted, on the assumption that prominent places such as Blacksburg, Christiansburg, Radford, Dublin, Pulaski, Max Meadows, and Wytheville are correctly located.

As the new data are not sufficient to cover the entire surface, the map has not the same degree of detail and exactness in one part that it has in another. In what roughly may be considered as the coal field, the roads, streams, and prominent ridges are correctly located, but in the broad areas of limestone only a few of the roads were traversed and few data were obtained on other features. Because of this heterogeneous character, the map is not very satisfactory, but it is the best that could be made under the circumstances. An attempt is made to indicate by different kinds of lines the different character of the data, showing some as quite accurate, and some of varying degrees of accuracy, merging in certain places outside of the coal fields with that which is quite inaccurate.

In the field work carried on in 1923, the writer was assisted by Kent K. Kimball and Curt H. Gudheim. Kimball devoted his time and attention to the mapping of the Price Mountain coal field and to him is due much of the credit of working out the geologic structure of this interesting field. Gudheim was associated with Kimball in his work and later was of great assistance to the writer in the geologic mapping of the coal beds and associated rocks of Montgomery, Pulaski, and Roanoke counties and in sampling the coal beds for analysis. To both these men the writer is greatly indebted for faithful and efficient service in the field work.

As explained in detail later, a report on the Valley coal fields must of necessity deal with the geologic structure as well as with the coal beds, for the structure has much to do with the workable extent of the beds and with the manner in which mines should be developed. This phase of the subject has been made a joint study by Professor Roy J. Holden of the Virginia Polytechnic Institute at Blacksburg and the writer. This study was not conducted jointly in the field, but each author has made special studies of certain parts of the fields and the chapter dealing with geologic structure is a combination of the observations and conclusions of the two authors. Where they differ in their interpretations of the facts, the opinion of each is stated so that due credit may be given each for his contribution as well as fix his responsibility for the statements he has made.

As the report embraces material collected by a number of men, it is not thought possible to credit each one on the title page, but their names are given under the various headings of the text so as to give them full credit for the work done and make them responsible for the statements contained in their parts of the report. Parts unsigned are understood to have been prepared by Marius R. Campbell who alone is responsible for the matter contained therein.

ACKNOWLEDGMENTS.

During the progress of the work in the field, the authors have been greatly aided by a number of citizens who, realizing the importance of the commercial development of these coal fields, have cheerfully furnished information regarding coal prospects and in certain cases have at considerable expense unwatered some of these prospects so that the coal bed could be measured and samples of the coal secured for analysis. The mine operators and owners, without exception, have cordially coöperated with the geologists, for they realized fully that the time has come to deal fairly and openly with the public and that the value of a geological report is greatly enhanced by an impartial statement of facts without exaggeration or concealment of any kind; also most of the operators have encountered difficulties of a geological nature and they are eager for any assistance that can be given in the solution of these problems.

For the information thus contributed by those interested in the fields, the authors wish to express their gratitude and to assure the persons furnishing it that it has been very helpful in drawing conclusions regarding the commercial value of the coal and the extent of the coal beds. The authors do not pretend to be able to answer in the report all of the questions that may arise concerning the geology of these fields, particularly concerning the extent of the coal beds beneath the surface, but they have in the course of their examinations of the fields, acquired considerable data bearing on this and other troublesome questions and the geologic evidence as well as the meaning of this evidence is contained in the present report.

GEOLOGIC FORMATIONS

GENERAL STATEMENT.

In most coal fields one needs to be acquainted with only one or two geologic formations in order to do systematic prospecting or to carry on mining operations, but in the Valley coal fields of Virginia the conditions are different from those which prevail in most other coal fields, and to prospect intelligently and even to plan a mine successfully, one should be acquainted not only with the geologic formations that carry coal, but he should have a working knowledge of such other formations as in any respect resemble the coal-bearing formation or are liable to come in contact with it.

For those who carry on exploration in advance of mine development the need of a knowledge of the formations resembling the coal-bearing formation is particularly great, for the prospector may waste much time, energy, and money, if he does not understand that certain formations, although containing thin seams of coal or material which, in a weathered condition, resemble coal, still do not carry beds of coal of commercial value.

The need of a general knowledge of the character of the associated geologic formations is equally urgent, for it is only by being able to differentiate the formations that one may be sure of the geologic structure in which he is prospecting or in which his mine is being developed. The geologic distribution of the formations on the surface coupled with their attitude,—that is, the way they lie or stand—is the only clue, aside from the information to be derived from deep drilling, that one can obtain regarding the underground extension and the depth of the coal beds.

As this wide knowledge of the geologic formations cropping out in the Valley coal fields seems essential to the practical man, a general geologic column or sequence of formations is presented on Pl. I, with information regarding the relation of the formations to the coal beds, so that every person, though unfamiliar with the science of geology, may learn something of their characteristics and be able to identfy them in the field.

The rocks of the Valley coal fields are of three distinct kinds: limestone, shale, and sandstone. It must not be inferred, however, from this simple statement, that it is an easy task to separate the rocks into these groups, because the limestone is rarely pure, generally grading into shale or sandstone, and the same intergradation takes place between the other kinds of rock. Because of this merging of characteristics and also because of the fact that the weathered outcrop of a rock generally appears very different from the same rock that has not been subjected to weathering processes, it is sometimes difficult to determine whether it should be classed as an earthy limestone, a shale, or a calcareous sandstone.

CHARACTER OF ROCKS EXPRESSED IN SURFACE FEATURES.

General effect of different rocks.

The easiest way to become familiar with the rocks of a region is to study carefully the surface features, such as hills, valleys, plateaus, and mountains that have been carved from them, for each kind of rock or formation produces features characteristic of that particular formation. Thus, as limestone is more or less readily soluble and where relatively pure weathers down much more rapidly than other rocks, it generally forms broad valleys or plains, such as those which make up the surface of the Valley of Virginia. In the humid climate of the eastern part of the United States, limestone rarely if ever forms mountains or even hills of any considerable height unless it contains a great abundance of chert or sandstone. Shale is variable in composition and texture, but in general it is more easily affected by weathering than sandstone and hence in many places it also may be found in the bottoms of valleys, but where it is sandy it may be quite resistant to the processes of erosion and form low hills and ridges. Sandstone is the most resistant rock in the Valley coal fields and consequently it forms in many places the crests and upper slopes of the more pronounced ridges and mountains. There are, however, differences in the resistant properties of sandstone for in many of the beds the grains of sand are very loosely cemented and such rock soon falls to pieces or disintegrates under the influence of the weather. If, however, a porous sandstone has been long saturated with silica-bearing waters the interstices between the grains may have become entirely filled with hard vitreous quartz, and in that condition the rock becomes a quartzite and is more resistant than granite.

The prominent surface features that characterize the Appalachian Valley are its ridges and valleys. The valleys are considerably greater in width and in longitudinal extent than the ridges and the ridges themselves differ in height, but, on examination, it will be found that every ridge has been preserved as a ridge, in the general process of lowering the surface of the land by erosion, because it is composed of some bed of sandstone or quartzite, and that the higher ridges are almost universally due to thicker or more resistant beds of sandstone or quartzite than those making the lower ridges. The valleys on the other hand, are almost without exception, excavated in limestone or shale, both of which are soft and easily removed by erosion.

The relation of the surface features to the underlying formations is well-brought-out in the cross-sections at the bottom of the map, Pl. 1. As these sections represent the geology along lines approximately at right angles to the trend of the main ridges and valleys, they show that each ridge is formed by the outcrop of a hard bed of rock and each valley, by one that is easy to dissolve or to wear mechanically by the streams. Pl. I also gives a column representing the various formations, as they are piled one upon another in their normal succession from the lowest and oldest up to the highest and youngest; and the resistant or mountain-making formations are shown as projecting to the left in much the same way as they project above the general surface of the region. This column has been extended upward to include the formations that carry coal in the great bituminous fields to the northwest, so that the reader may have a clear idea of the relative positions in the geologic column of the coal-bearing formations and groups of formations.

Ridge-making formations.

In the geologic column there are three groups of sandstone that are more resistant than the others and these make mountainous ridges of the first order of magnitude. The lowest and oldest of these beds are the Cambrian quartzites, the uppermost bed of which, the Erwin quartzite, is shown at the base of the column. These beds make the mountains on the southeastern side of the Valley, such as Lick Mountain (Pl. XXI B) south of Wytheville, Mays Mountain south of Max Meadows, the ridges south of New River, from the mouth of Cripple Creek to the mouth of Little River, and Pilot Mountain south of Christiansburg. The next mountain-making formation is the Clinch and associated sandstones, mainly of Silurian age. These sandstones form the crest of Draper Mountain (Pl. XIX), Cove Mountain, Paris, and Catawba mountains, Walker Mountain, Gap Mountain, Buckeye Mountain, Spruce Run Mountain, Sinking Creek Mountain, and all of the high ridges to the northwest of those listed above, to and including East River Mountain on the extreme northwest side of the Applachian Valley province. The third formation of prominence is the Lee formation at the base of the great mass of coal-bearing rocks of the bituminous fields to the northwest. This formation, where it is upturned on the southeast side of the coal field, forms a mountain as high and rugged as any of the mountains composed of the Clinch sandstone, but it does not extend southeastward beyond the margin of the coal field and hence is not known anywhere in or adjacent to the Valley coal fields.

A ridge-maker of the second order of magnitude is composed of the flaggy sandstones at and near the top of the Devonian and the bed of conglomerate (Ingles conglomerate member) and its containing sandstone at the base of the Carboniferous system. These beds make the ridges that generally bound the Valley coal fields on the northwest. In Montgomery

County this ridge is known as Brushy Mountain; in Pulaski County, as Little Walker Mountain (Pl. II A), Tract Mountain and Caseknife Ridge; in Wythe County, as Little Walker, or Brushy Mountain; and in Bland County, as Brushy Mountain.

In addition to the ridges or mountains mentioned above, there are several ridge-makers of the third order of magnitude. The most important of these ridges in the Valley proper is made by the Tellico sandstone which lies between the Athens and the Sevier shales. The outcrop of this sandstone is usually on the northwest slope of the Clinch sandstone mountains, and so is not conspicuous, but where the sandstone stands alone it makes a ridge of some importance. The most prominent ridge composed of this sandstone is Pine Ridge which begins at Wytheville and runs westward on the north side of the State Road,—or Valley Pike as it is more commonly called—for a distance of about 9 miles. Another ridge of this sandstone which is even more striking than Pine Ridge is a range of sharp conical hills on the northwest side of Paris Mountain and the eastward extension of the same ridge on the north face of Catawba Mountain in Roanoke County, and the third ridge of importance composed of the Tellico sandstone is an interrupted ridge lying in the south side of Draper Valley, mainly in Pulaski County.

Other ridges of this order of magnitude are formed by cherty or sandy layers in the Shenandoah limestone. The low ridges formed by these beds are not generally cleared and farmed because the great number of chert or sandstone fragments on the surface makes the soil poor and tillage difficult if not impossible. As a consequence these ridges are generally covered with trees and are thus conspicuous objects in the landscape.

Valley-making formations.

The best known of the valley-making formations is the great Shenandoah limestone which forms the floors of most of the valleys of Virginia from the northern to the southern boundaries of the State. Its greatest exposure (see Pls. V and XXI) in this district is in the Valley of Virginia, which extends from the mountains and hills marking the northwestern margin of the Blue Ridge province on the southeast to Brushy Mountain on the northwest; it also shows on the northwest side of Walker Mountain, in Crockett Cove on the northwest side of Cove Mountain, and on the same side of most other ridges composed of the Clinch sandstone.

The shale which overlies the Shenandoah limestone is probably more easily soluble than the limestone and as a consequence it is quickly eroded into even deeper valleys than those formed in the limestone. A good example of the deepening of the shale valley below that of the limestone occurs in Montgomery County where the North Fork of Roanoke River has eroded a very deep valley in the dark Athens shale which directly overlies the Shenandoah limestone, and the Sevier shale lying a little higher in the section would likewise be deeply eroded were it not for the protection afforded by the Clinch and overlying sandstones. These hard beds form the crests of ridges and the Sevier shale outcrops high up on their northwest slopes. The reason why both of these shale formations are naturally valley-makers is because they are strongly calcareous and the calcareous matter dissolves very readily causing the shale to break down and be carried away by the rain and the rills which gash the side of the mountain. Both formations make good farming land for the same reason that they are good valley-makers, and consequently their outcrops are generally cleared and farmed even where they are high on the steep slope of a Clinch sandstone ridge. The shale formations also show in outcrop in Draper Valley on the south slope of Draper Mountain, in Crockett Cove on the northwestern slope of Cove Mountain, and in Millers Cove in Roanoke County.

Another valley-making shale of considerable importance is the soft shale near the base of the Devonion system, which being black resembles in color the Athens shale just described. The Devonian shale is not, however, calcareous and therefore does not produce a rich and fertile soil such as characterizes the outcrop of the Athens shale. The Devonian black shale is noted for the poor quality of its soil and the valleys carved in it are almost universally known throughout the middle and southern Appalachians as "poor valleys." As this shale lies just above the great group of mountain-making beds,—the Clinch and associated sandstones—and as these beds dip generally toward the southeast, the poor valleys occur at the southeastern base of the higher ridges or mountains, such as Walker, Gap, Sinking Creek, Cove, Catawba, and Paris mountains.

The Maccrady shale, which is a red shale lying just above the coal-bearing formation of the Valley coal fields, is essentially a valley-making formation, as it is soft and easily eroded, but its outcrop is usually too narrow to permit of the development of extensive valleys and, as it is generally in contact with the Shenandoah limestone on the south, the valleys formed in the shale are merged with the much broader valleys formed in the limestone. Near the edge of the bituminous coal field, far to the northwest, the Maccrady shale is normally overlain by the Carboniferous limestone and here again a valley which is due to the erosion of the shale is merged with and is indistinguishable from the valley formed by the erosion of the Carboniferous limestone. On account of this association of easily eroded beds the Maccrady shale does not stand out as an individual valley-maker, especially when compared with the ones previously described. In the northern part of the Appalachian Valley province the Carboniferous limestone makes extensive tracts of rolling valley country which, in area, are comparable to the valley floor made by the Shenandoah limestone, but as this part of the province is not considered here in detail, these valleys will not be described.

DESCRIPTION OF FORMATIONS.

General statement.

The geologic column given in Pl. I represents in a general way only the formations showing in outcrop in Montgomery, Pulaski, Wythe, and Bland counties, but even in this restricted area there is considerable variation in thickness of the formations and in places entire formations may be absent or new ones may come in. In general most of the formations grow thinner toward the northwest, for the materials of which they are composed were derived from the wearing down of a land area to the southeast, in the region of the Blue Ridge or the Piedmont plateau, and the coarse fragments of these materials were dropped near shore while the finer materials were swept northwestward farther and farther out into the sea. Because of this thinning of the sediment away from the point of supply on the shore of the Devonian sea, this system also decreases markedly in a southwesterly as well as in a northwesterly direction from a thickness of over 5,000 feet on New River to only a few inches in the vicinity of Birmingham, Alabama. On account of these irregularities the reader should not be surprised to find that some formations are thicker or thinner than they are represented on Pl. I, or that some disappear and others take their places or appear in other portions of the column. For the benefit of those readers who desire to become better acquainted with the geologic formations of the region specified above, a brief description of the formations or groups of formations, as seems best suited to the purpose of this paper, will be given. These descriptions will begin with the lowest and oldest rocks and proceed to the youngest and highest formations in regular order.

The oldest rocks here considered are some quartzites of Cambrian age that form the mountains (except Draper Mountain) which lie south of the Norfolk and Western Railway. These formations have no special significance with regard to the coal, but they serve as a convenient and well-marked starting point in the consideration of the overlying formations that are intimately associated in their outcrop with the coal beds. The uppermost bed of this group is the Erwin quartzite which is taken as the base of the column in Pl. I.

Shenandoah limestone.

Above the Erwin quartzite there is a great mass of limestone and shale, having a thickness of 6,000 or 7,000 feet, which for convenience has been called the Shenandoah limestone, because it forms the floor of the well-known Shenandoah Valley in the northern part of the State. Although this mass will be generally referred to as though it were a single limestone formation, it is known to consist of many recognizable units which differ considerably in their physical character and appearance, and which on detailed geologic mapping would be separated and shown individually on the map. For the purposes of this paper, however, the limestone will be treated as a unit, as in most cases it is difficult to determine what part of the mass is exposed at any particular place.

The first of these recognizable units overlying the Erwin quartzites is a mass of dark limestone or dolomite [1] 800 to 1,000 feet thick which is generally known as the Shady limestone. This formation is of great importance in many places in the Valley of Virginia for it carries iron and manganese which, when the limestone decomposes, as it does very readily, segregate in the residual clay, forming deposits of ore.

Above the Shady limestone there is a formation about 1,000 feet thick, composed of rusty brown or purplish shale or limestone interbedded with thin bands of purple shale, which has been called the Watauga shale. The largest area of outcrop of the Watauga shale in the part of Pulaski County covered by this report is around the east end of Draper Mountain. From this point it extends eastward down Peak Creek to its mouth and westward along New River to the western edge of the county. In Wythe County, a belt of Watauga shale which is cut off by the Pulaski fault on

[1] Dolomite is distinguished from a limestone by the fact that it is a double carbonate of calcium (lime) and magnesium (Ca, Mg) CO_3, whereas a limestone, when pure, consists entirely of calcium of carbonate, $CaCO_2$.

the south side of Draper Mountain extends nearly due west along the State Road to within about 6 miles of Wytheville. Here the outcrop swings to the south in a course nearly parallel with the Norfolk and Western Railway, past Wytheville, Crocketts, Rural Retreat, and Groseclose, as shown in Pl. I. West of Groseclose in Smyth County it extends indefinitely westward, but generally south of the railroad.

The Watauga shale changes greatly in character in a northwesterly direction and in Pulaski County just south of the outcrop of the coal-bearing formation there are only a few narrow bands of purplish shale interbedded with limestone, which is supposed to represent the Watauga shale. Good exposures of this shale are not easily found, the most common showing being a band of red soil in freshly plowed fields. In tracing these bands care must be taken to distinguish them from the red shale of the Maccrady formation which is of Carboniferous age and is separated from the Cambrian shale by a profound fault. The purplish and red shale occurring in Montgomery County between Blacksburg and New River and north of the Price Forks road are doubtless also the representative of the Watauga shale. An effort was made to map these bands of purplish shale west of Blacksburg, but finally the project was abandoned because no band is continuous for more than a few hundred yards and, without better exposures on the upland, it was all but impossible to determine whether an exposure noted in one place should be connected with another showing at some distance or whether it should be regarded as separate and distinct. As explained on page 149, the disconnected condition of these shale bands in this area can be explained only on the supposition that the limestone has been broken into fragments and these fragments mixed, so that now they are without apparent order or arrangement.

Above the Watauga shale lies a mass of limestone about 800 feet in thickness which has been called the Honaker limestone. This limestone is generally dark in color, though in places it contains layers of blue, or dove-colored limestone.

In the southern part of Virginia the Honaker limestone is overlain by a distinct band of greenish and yellowish calcareous shale which has been called the Nolichucky shale. Though this bed is not well-developed in the area here being considered, it seems probable that certain thin bands of yellowish shale near the base of the Knox dolomite are its representatives. The Nolichucky, in its type locality, has a thickness of 300 feet, but in this region it is very much thinner and apparently is broken by bands of limestone.

The great body of limestone overlying the Nolichucky shale is generally known in the South as the Knox dolomite, although not all of the layers are composed of that material. It is a heterogeneous mass of dolomite, pure bluish or dove-colored limestone, whitish dolomite, chert or flint-bearing limestone, and in places decidedly sandy limestone. The chert and sandstone fragments show prominently when the limestone decomposes and are excellent horizon-markers as they weather very slowly and consequently tend to accumulate on the surface. The Knox dolomite is about 3,600 feet thick, the lower part belonging to the Cambrian system and the upper part to the Ordovician system.

A layer of sandy limestone occurring from 1,500 to 2,000 feet below the top of the Knox dolomite was found to be fairly constant in the region east of Blacksburg and as it was desirable to determine the structure of the limestone mass in this region in order to have some idea of its depth the band of sandy limestone was traced in the field and it appears on the geologic map, Pl. I. In this work it was assumed that there is but one of these layers of sandstone and consequently where it is repeated the repetition is due to faulting as shown on the map.

A careful study of the fossils that may be found in certain parts of this great mass of limestone combined with an equally close study of the physical characteristics of the limestone itself would doubtless enable one to map and identify many other divisions and thus bring out the structural relations of the component parts of the mass, as well as to determine the age of the limestone exposed at any given locality. But the writer had no time to devote to such a detailed study and that is the reason why, on the map, all of the formations composing the Shenandoah limestone are grouped into a single unit.

In practical work there is a certain phase of this limestone that may cause the layman or even the geologist considerable trouble, both in tracing formations and in determining the geologic structure. This is the brecciated condition of the limestone which at many places completely obliterates the original bedding planes, so that a determination of strike or dip is impossible. This brecciated condition of the limestone was noted by the writer [1] in his reconnaissance of this region in 1893 and the following description of the breccia was given:

> "In the vicinity of Radford this formation carries heavy beds of limestone conglomerate; these beds or rather masses appear to be free

[1] Paleozoic overlaps in Montgomery and Pulaski counties, Virginia. Bull Geol. Soc. Am., vol. V., 1894.

from bedding planes, and in only one place could their attitude relative to the regularly bedded limestone be determined. On the bank of the [New] river, two miles below Radford, where the railroad has made a sidehill cut, the face of the cliff is well exposed and shows the contact of the conglomerate and limestone. The limestones are somewhat folded, and were evidently eroded previous to the deposition of the conglomerate, for the surface upon which the conglomerate was laid down is smooth and regular and cut across the edges of the folded strata below. The conglomerate is composed of yellowish white chalk-like matrix, in which are embedded pebbles of a character similar to the matrix. The pebbles are of various sizes, from grains as large as the head of a pin to masses from six to nine inches in diameter, and more or less rounded. In a few cases the smaller grains are of foreign material, but the whole is so deeply decayed that it is difficult to determine the genesis of the rock. In places it seems to be a subaerial deposit, while in others it appears like a true water-deposited conglomerate. Its meaning is obscure, but the writer is of the opinion that it indicates the existence of overlaps in early Paleozoic time probably during the deposition of the Shenandoah limestone itself; that the limestone was folded and elevated above sea level and formed cliffs along which the masses and half-rounded fragments washed from the bank were recemented and formed these curious deposits of conglomerate."

It seems now that the application of the term conglomerate was a mistake, as the cemented material is almost entirely angular or subangular, and hence that the more appropriate term is to call it a breccia.

The limestone breccia is now known to be much more widely distributed than it was supposed to be by the writer in 1893. In recent work in this region he has found it in great abundance along New River from the vicinity of Radford down to the crossing of the Pulaski fault below Belspring, and on many of the small streams flowing into New River.

Regarding its mode of formation, the writer is much less inclined to attribute it to the geologic past than he was 30 years ago. A more extended experience in widely separated fields has led him to believe that it is possible to account for this breccia by the processes that are going on all the time in a humid region. Thus the writer has seen similar breccias being deposited under the following conditions: (1) deposition on the surface by springs, (2) deposition in the channels of streams flowing on the surface, and (3) deposition in caverns and underground channels. In this particular region the writer has seen only one of these processes going on at the present time and that is No. 2,—deposition by streams flowing on the surface. This is a common phenomenon in this region, as breccias of this character may be found as they are forming to-day in many streams, but the writer has no doubt that the other two processes are now or have been in operation too as they are some of the most common operations in nature. Pl. VIII A shows a cliff of the limestone breccia on the Norfolk and Western Railway just below Peppers Ferry on New River which has many of the characteristics of a spring deposit. As shown by the photograph, the cliff resembles the "Liberty Cup" that is such a common feature of hot springs depositing calcareous tufa in Yellowstone Park and other localities in the West.

Although the writer made no attempt to determine accurately the geographic distribution of the limestone breccia, the data at hand seem to show that, if not limited to the basin of New River, it certainly is more common there than in other parts of the district. This apparent limitation not only to the drainage basin of New River but largely to the vicinity of the river itself may have a physiographic significance, as the breccia seems to have been largely formed at the time when New River began to cut into the Blacksburg peneplain (for description see pp. 132-134) that marks the upland level about 400 feet above the river. It seems probable that in a basin which was reduced to a very perfect peneplain, the streams, both those flowing in caverns and narrow underground channels, would be more heavily charged with carbonate of lime than streams in a more rugged region, that flow swiftly into the trunk streams. Much of the water in such a basin would flow toward the trunk stream in underground channels and would enter the main stream as springs, either at water level or higher up on the river banks. As the river deepened its channel the spring would tend to discharge at lower and lower levels, but with the final result that the breccia would be deposited from top to bottom of the cliffs, as it appears to-day in places on New River.

Overlying the Knox dolomite there is generally a band of blue, fossiliferous limestone that has been called Chickamauga limestone. In the Valley coal fields the limestone above the Knox dolomite in the region southeast of Brushy Mountain is very different from that which overlies the Knox northwest of Walker Mountain. For that reason no single section represents the natural conditions in all parts of the area here being considered. As, however, the composition of the limestone overlying the Knox is not a vital question in the consideration of the coal, the writer will content himself with the statement that in general there are blue limestone beds above the Knox and in this region it is perhaps fair to assign them a thickness of about 200 feet. This may include more than the true Chickamauga, but as no attempt was made to subdivide the rocks, they will be lumped together under that name.

Sevier and associated shales and sandstones.

Above the Shenandoah limestone is a great mass of generally shaly rock, which in the counties of Montgomery, Pulaski, and Wythe attains a thickness ranging from 1,400 to 2,400 feet. This mass is made up of the Athens (black) shale at the base, the Tellico (red and gray) sandstone, and the Sevier shale. The top and bottom members are calcareous and hence are generally cleared and farmed, but the middle member is sandy and not adapted to cultivation. The Tellico sandstone is responsible for Pine Ridge which extends westward from the reservoir at the town of Wytheville for about 9 miles, lying entirely north of the State Road or Valley Pike as it is frequently called. It is also prominent on the northwest slope of Paris Mountain in Montgomery County and Catawba Mountain in Roanoke County, where it forms a row of sharp, conical, forest-covered knobs. In Wythe County the sandstone is generally greenish in color, but in Montgomery and Roanoke counties it is bright red, resembling the typical Tellico of East Tennessee. In Paris and Catawba mountains the sandstone is several hundred feet thick at the west end, but it thins rapidly eastward and probably disappears as a distinctly sandy phase a short distance east of the Catawba Sanatorium.

The Athens shale and the Tellico sandstone are phases of deposition limited to the southern and eastern parts of the Appalachian Valley province and consequently they do not show northwest of Walker Mountain in Bland County. In that county the shale is entirely calcareous, but at the base it is of a distinctly red color.

Clinch and associated sandstones.

The next division above the shale group just mentioned is a very resistant mass composed largely of sandstones, some of which are massive and unusually resistant to erosion. This group is, as noted before, the principal mountain-forming group of beds in the geologic column. Its aggregate thickness varies considerably, but probably averages about 650 feet. It generally contains in ascending order the Juniata and Clinch sandstones, the Clinton formation which here is particularly sandy and massive, and the Helderberg limestone of Devonian age. The sandstones, with the exception of the Juniata, are distinctly white or gray, and they are in-

Block of semianthracite coal from Montgomery County, Va.

Block of semianthracite coal from Montgomery County, Va.

terbedded with softer sandstone and shale of a red color. The Helderberg limestone is too readily soluble to show at the surface, but the chert or flint that it contains strews the lower southern slopes of the larger ridges. This limestone carries considerable iron and on dissolution it is in places replaced by beds of brown iron ore. Deposits of ore, having such an origin are, according to report, abundant on the south slope of Walker Mountain and also on the south slope of Cove Mountain.

The best exposure of the Clinch and associated formations, exclusive of the Helderberg limestone, that occurs in these fields is in the gap cut by New River through Walker Mountain. Here in grading for the Virginian Railway almost every foot of this group of formations is exposed.

Devonian shale and sandstone.

Overlying the Helderberg limestone which is included as the uppermost formation in the Clinch group of sandstones, as described in the preceding paragraph, is the great mass of Devonian shale and sandstone which, on New River has a thickness of about 5,000 feet. At the base for a distance of 600 or 800 feet the material is fine-grained black shale which merges upward into more and more sandy material, until the upper part, for a distance of fully 3,000 feet consists of thin-bedded reddish sandstones or flags, with occasional beds of rather coarse white sandstone. The black shale is very soft and is rapidly eroded, forming valleys, whereas the sandstones of the upper part are quite resistant and form ridges of the second order of importance. The base of the black shale is clearly marked as the shale is sharply differentiated from the limestone that underlies it. The top of the system has no clear line of separation between the flaggy sandstones of the Devonian and the sandstones of the Carboniferous. Generally throughout the counties here considered there is a white quartz conglomerate at about the division line between the two systems, and as this rock is quite distinctive in character and different from that which lies below, it has been taken as the basal bed of the Carboniferous.

The shale and sandstone of the Devonian system are recognized by geologists as having been derived from a land area lying to the northeast of the present Appalachian Highlands and as the material composing this system was washed into the sea on the west, it was swept by currents in all directions, but with rapidly diminishing thickness in a direction opposite to that from which it came. As a consequence of this mode of deposition the Devonian formations decrease in thickness rapidly in a westerly and a southerly direction. Because of this rapid decrease the measurement of 5,000 feet made at the gap New River has cut through Walker Mountain will not hold in either a southerly or westerly direction. It is probable that in Smyth County the Devonian sandstone and shale are not more than 4,000 feet thick and it is possible that they measure even less than that number of feet.

Carboniferous system.

GENERAL CHARACTER.

This review of the formations in the Valley coal fields has now reached the Carboniferous system which is of paramount interest, as it contains the coal beds for which these fields are noted. As a matter of convenience geologists have divided the Carboniferous system into three parts or series, calling the lower series the Mississippian; the middle, the Pennsylvanian; and the upper the Permian. The coal beds of the great bituminous fields of the Appalachian region belong in the Pennsylvanian and Permian series, but the coal of the Valley fields belongs in the Mississippian series. Up to the close of the Devonian period practically all of the formations in the Appalachian region had been laid down in a sea, which in general extended only a short distance to the southeast of the region here being considered, but which stretched to the northwest far beyond the limits of what is now generally known as the Appalachian Highlands. The eastern shore of this sea shifted its position considerably from time to time, but in a general way it may be said that throughout Paleozoic time the sea was bounded on the southeast by a continental area which furnished by its erosion material for most of the formations laid down in the sea to the west. At certain times the land was so low that the streams carried to the sea only a small volume of the finest material and consequently the formations then deposited are composed largely of limestone or shale of the finest texture. At other times the land on the southeast stood at a higher level, the streams were rapid and turbulent, and the amount and coarseness of the material delivered to the sea was very great. The beds resulting from the deposition of such material are sandstones of varying degree of coarseness or conglomerates, depending on the height of the adjacent land and the distance from the shore at which the material was deposited.

PRICE FORMATION.

Part above Ingles conglomerate.—The marine conditions which prevailed during the Devonian period came to an end by an uplift of this part of the crust of the earth which raised the sea bottom above water level and it became dry land. This land was probably the western margin of a continental area which lay to the east of this region and possibly included a large part of what is now the Atlantic ocean. The uplift of the land caused the streams to flow more swiftly and the first materials to be brought down from the high land in the interior of this continental area were sand and white quartz pebbles. These were spread out over the land surface by the streams of water and since have been consolidated into a sandstone carrying white quartz pebbles, or a conglomerate as the geologist calls it. The succeeding deposits on this land area consisted of sand which has since been consolidated into sandstone, of mud which has produced shale, and the vegetal remains in the swamps on the low land, that now has produced coal (Pl. XVIII). As the land was apparently very flat the streams became ponded with the material which they transported and great swamps were produced in which land plants flourished in great abundance and with great luxuriance. These plants, consisting mostly of ferns, were buried in the mud and water and after long ages became coal. At first the swamps were transient, existing for only a short time and the coal beds resulting from the vegetation are very thin, but after about 1,000 feet of material had been deposited on the land, conditions were such that the swamps remained for a long period of time and a great quantity of vegetal matter accumulated making a very thick coal bed. The number and thickness of the coal beds will be more fully described in another place.

After about 700 feet more of sand, mud, and coal had been deposited on the land, the character of the material changed somewhat and red sand and red mud were washed down and spread out in successive layers. At first the red material only came at long intervals and the consequence is that red sandstone and red shale are in thin layers, but as time went on these incursions of red material became more and more numerous, until finally the entire load carried by the streams was of this character. As the red sandstone and shale is distinctly different from the gray sandstone and dark shale of the coal-bearing rocks, they are generally regarded as a separate and distinct formation, but since the change from one to the other is gradual it is difficult to say where the line separating them should be drawn. It has generally been the custom of the writer to disregard the thin bands of red in the upper part of the Price formation, and to draw the upper line of the formation at the place where the material becomes prevailingly red.

Coal beds occur at many horizons in the Price formation, but the most important beds are found near its middle. Several measurements in this region show that the most important coal beds are about 1,000 feet above the base of the formation, marked by the contact of the conglomerate member and the underlying Devonian sandstone, and about 700 feet below the base of the red shale overlying the Price formation

The regularity and linear extent of the coal beds in the counties here being considered is one of the most surprising features, but doubtless if these beds could be traced into adjacent areas, they would be found to be quite different from what they are in the type locality. The Merrimac ("Big Bed") appears to be known throughout Montgomery and Pulaski counties (Pl. XVIII) and it is quite possible that, if adequate prospecting had been done, it could be traced some distance into Wythe County. Such an extensive bed means of course that at the time of its formation, there must have been a continuous swamp of a corresponding size. Such a large swamp would imply a flat country and the presence here and there in the formation of marine fossil shells also implies that the land was near sea level and that occasional subsidences of the land allowed the sea to encroach upon what before was dry land.

The Price formation changes in a southwesterly direction almost as rapidly as the Devonian changes. In its type locality in Montgomery County, it is 1,700 or 1,800 feet thick, but in the Lick Creek field in western Bland and eastern Smyth County, it is reduced to a thickness of about 600 feet and the more important coal beds, instead of coming near the middle of the formation, as they do in Price Mountain, occur practically at the top, within a few feet of the red Maccrady shale.

The Price formation was first systematically studied by the Rogers brothers,—Henry D. Rogers in Pennslyvania and William B. Rogers in Virginia. In their report of progress for the year 1836 (published in 1838), both used a series of numbers to designate the formations of the Paleozoic era, beginning with Number I for the oldest. According to this scheme, the Price formation, as it is now known, was No. X, and in most of the early reports on the geology of these states, this formation is referred to as No. X. Such a system of terminology is not satisfactory, for sooner or later the formations will be subdivided and possibly new formations discovered which will not fit into the accepted scheme. This method of numbering the formations was dropped within 20 years, for in 1858 when the final report of the First Geological Survey of Pennsylvania was published a fanciful scheme was used by Henry D. Rogers in which the Price formation or its equivalent appears under the title of Vespertine. Unfortunately this scheme had defects as objectionable as the scheme of numbering formations and eventually it had to give place to a more elastic system. The last report in which it was used was the final report on the geology of Virginia by William B. Rogers, which however was not published until 1884. Apparently the editor of this posthumous report, Major Jed Hotchkiss, inserted in the table of formations, the name Montgomery grits as being equivalent to what was called in the body of the report, the Vespertine or No. X formation. As no description of the formation was given, it left the matter in an uncertain condition as to what group of rocks Major Hotchkiss intended to apply the term Montgomery grits.

In 1893 the writer made a reconnaissance survey of the Dublin quadrangle, lying partly in the counties of Montgomery and Pulaski. No report of this work was published, because of the inadequacy of the base map, but the same formations, though possibly in less satisfactory development, were described in the Pocahontas folio (Geologic Atlas of the United States, folio 26, 1896). In this report the writer considered the advisability of using the term "Montgomery grits" or "Montgomery formation," but because of the lack of definition in Rogers' report of 1884 and the absence of a definite type locality, the name was not accepted and a new one, the "Price sandstone," was proposed for the coal-bearing formation of the Valley fields. This name, derived from Price Mountain in Montgomery County, which in a way may be considered the type locality of the formation, has now come into general use, and this name with the lithologic part changed from "sandstone" to "formation" will be employed here to designate the coal-bearing formation which rests upon the Devonian sandstones and in turn is overlain by a red shale that has come to be known as the Maccrady shale.

The rocks composing the Price formation, like most rocks that have been formed on the land, consist of sandstone and shale with occasional beds of coal, but few of the beds are continuous for any great distance, showing that the material composing them was brought to its position by streams flowing on the land and that while sand was being laid down in one place mud was being deposited in another. As a consequence no one bed in the formation can be depended upon in tracing and identifying the coal out-crops, for each bed is a local development of coarse or fine material dumped out locally by running water. The only exception to the statement made above is a bed of conglomerate that marks the base of the formation. As this is an important horizon marker it will be treated as a special member of the formation.

Ingles conglomerate member.—The most distinctive bed in the Price formation is a white quartz conglomerate (Pl. 4) at the base of the formation. This bed, in places, consists entirely of white or gray sandstone, but generally white quartz pebbles occur in the sandstone, either scattered through it in thin and irregular layers or deposited in a thick bed which consists of well-rounded quartz pebbles, ranging up to 1½ inches in diameter, cemented by gray or white quartzose sand.

The great value of this bed of conglomerate as an horizon marker would seem to indicate that it should be treated as an independent formation and its outcrop shown on the geologic map. The writer appreciates full well the importance of the bed to any one who contemplates the tracing and mapping of geologic formations in this region, and he made a determined effort to represent the bed on the map accompanying this report, but finally after much effort had been spent on the work the project was abandoned as hardly worth the extra effort and time requisite for its accomplishment. The abandoment of the mapping was due to (1) the general thinness of the bed, (2) the irregularity of its distribution and its apparent absence in places, (3) the difficulty of finding it in place even after many blocks of the conglomerate had been found on the surface, (4) the inaccessibility of most of the outcrops which are high on the slope or at the crest of brush-covered ridges, and (5) the fact that the base of the conglomerate is already shown by the line separating the Devonian system from the Price formation of the Carboniferous.

One of the best and most easily accessible exposures of this bed of conglomerate is on a small ridge, known as Ingles Mountain, back of Radford and just south of the old State road. It here caps an arch of Devonian sandstone and shale, but erosion has cut away the crown of the arch leaving the conglomerate on the two limbs of the fold as shown in Fig. 7. On the south limb it is well shown consisting of a white conglomerate at least 20 feet thick. Because of the excellent exposure of the conglomerate on Ingles Mountain it is proposed to regard this as the type locality and to call the bed the Ingles conglomerate member of the Price formation. This is done for the reason that on account of the importance of this bed in correlation and in geologic mapping it will be necessary to refer to it frequently and this can be done much more easily by giving it a name.

The Ingles conglomerate is quite prominent on Brushy Mountain from Millers Cove on the east to New River on the west. It generally crops out at the crest or high up on the southern slope of the ridge. In places it is impossible to find an outcropping ledge of the conglomerate, but its presence is indicated by blocks of sandstone containing white quartz pebbles, that are more or less abundant on the surface. In other places the Ingles conglomerate is thick and massive and it forms very conspicuous ledges on the sides or at the crest of the ridge. Where it is thick and of uniform texture, it has been extensively used for millstones and many old pits in which the rock has been quarried for this purpose can be seen on Brushy Mountain. With the advent of roller mills for the grinding of grain the demand for millstones has decreased, until the industry of quarrying and shipping them is almost a thing of the past. There is still, however, a small demand which is met by local farmers, working at odd times in quarrying the rock and in dressing it for the market. One of the most extensive quarries in the Ingles conglomerate lies on the south slope of Brushy Mountain just north of Poverty Gap. Pl. IV represents the rock in this quarry and some of the millstones as they showed in 1914.

The Ingles conglomerate is well shown in Poverty Gap and near the station of McCoy on the Virginian Railroad nearly opposite the Parrott coal mine. It is particularly prominent west of New River in Little Walker Mountain from the river to the end of the syncline north of the head of Crockett Cove. In this stretch of the mountain the conglomerate may be seen and studied at the following easily accessible places: (1) on the Norfolk and Western Railway, about 1,200 feet below the Parrott coal mine; near the summit of Little Walker Mountain where it is crossed by (2) the road leading from Dublin to Pearisburg; (3) the road leading north from near the head of Back Creek; (4) the road leading from Pulaski to Mechanicsburg; (5) the logging tramroad above the old Altoona coal mine (loc. 47); and (6) the road leading from the head of Crockett Cove northeastward into the valley of Little Walker Creek.

The Ingles conglomerate is also present in the ridge locally known as Brushy Mountain, extending westward from the east end of Tract Mountain on the north side of the Norfolk and Western Railway, as far as Cove Creek, but in this ridge the conglomeratic character of the rock is less constant than it is in Little Walker Mountain, and in places the pebbles appear to be lacking. The conglomerate is also present on the headwaters of Beaverdam Creek, northeast of Max Meadows, and from this place it extends eastward in Caseknife Ridge to the Pulaski fault just south of the town of Pulaski. In this part of the field, however, the conglomerate is not conspicuous and in many places it may be absent.

In the Reed Creek field the conglomerate in places is well developed, but in others it is rather inconspicuous or is wanting. In Bland County similar conditions prevail, but the conglomerate was observed in places from the extreme eastern end of the field as far west as the mouth of Lick Creek in the eastern edge of Smyth County.

East of Montgomery County the conglomerate was observed in Brushy Mountain to its extreme eastern end in Millers Cove and also in North Mountain as far as Stone Coal Gap in Botetourt County. In this region it is not very conspicuous but in all cases where it was sought fragments could be found.

MACCRADY SHALE.

Overlying the Price formation is a mass of red shale which is an excellent key rock for the identification of adjacent formations. This shale has been recognized by most geologists who have examined the region, but none, except the more recent workers, have thought it of sufficient importance to deserve a special name. The writer called it in the Pocahontas folio the Pulaski shale, because of its excellent exposure in the town of Pulaski, but as the name Pulaski had previously been given to another geologic formation, it is not regarded as appropriate for the designation of the shale herein described. Recently the name Maccrady has been proposed for this shale by G. W. Stose,[1] who in his examination of the Saltville district, found that the outcrop of the shale passes through the village of Maccrady in the vicinity of Saltville. The shale here is well exposed, but its thickness is very much less than the thickness assigned to it in the Pulaski field. As the name Pulaski is not acceptable, the name Maccrady is here used in its stead.

The Maccrady shale has been recognized by all geologists as resting on the Price formation, but its upper limit is not so well established. In the fields here treated there is no Carboniferous formation overlying the Maccrady, but in the Saltville district it is clearly overlain by calcareous

[1] Stose, George W., Salt and gypsum deposits of southwestern Virginia: U. S. Geol. Survey Bull. 530, pp. 233-235, 1913; and Bulletin VIII, Virginia Geological Survey, 1913, pp. 51-73.

shale and earthy limestone which belong to a higher formation. The thickness of the Maccrady shale varies greatly in different parts of this region. At the type locality Stose determined its thickness to range from 330 to 435 feet, whereas on New River its thickness can not be less than 800 feet, and it may be considerably more, because it is everywhere bounded on the upper side by the Pulaski fault and its full thickness may not be present in any of the measured sections.

Several geologists have maintained that the Maccrady shale is not inherently red, but that it turns red on weathering. This opinion seems to be based on the supposition that the present red color is due to the oxidation of carbonate of iron and that the original color of the shale was bluish and not red as it appears now. It is quite possible that some of the red color of the shale is due to the oxidation of iron carbonate, but recent drill cores have shown that the shale holds its red color to a depth of at least 1,000 feet and consequently we must conclude that the clayey and sandy material when it was deposited was of a deep red color.

FORMATIONS ABOVE THE MACCRADY SHALE.

The singular coincidence that everywhere throughout the counties of Montgomery, Pulaski, Wythe, and Bland the fault which bounds the shingle-block[1] including the Maccrady shale, always cuts that shale, rarely passing below it and never revealing another formation lying above it, is most interesting and suggestive. It seems hardly possible that faults of the magnitude of those involved in these structures would always occur at the same horizon unless there were some good reason for their doing so. In this case there seems to be no explanation why an overlying formation should not at some place be exposed by the fault, if such a formation existed at the time the faulting took place, and the very fact that such a formation is not exposed is rather strong evidence that it was not present at that time. In other words it means probably that deposition ended here with the laying down of the Maccrady shale and that the great limestone and shale formations of the Mississippian as well as the coal-bearing formations of the Pennsylvanian and Permian were never deposited in this region. Of course, the evidence so far presented is entirely negative in character and can not of itself be considered as conclusive, but it is to say the least strongly suggestive. This question will be more fully considered under the heading Geologic Structure.

[1] For the definition of this term see pp. 33-34.

The formations of the Carboniferous system lying above the Maccrady shale have no direct bearing upon the geology of the Valley coal fields and hence they will not be described here, but their general character and thickness are indicated in the geologic columns shown on Plate 1. Descriptions of most of these formations may be found in the publications of the Virginia Geological Survey.[1]

GEOLOGIC STRUCTURE

BY MARIUS R. CAMPBELL AND ROY J. HOLDEN.[2]

GENERAL STATEMENT.

A thorough knowledge of the geologic structure of a coal field is fully as important as a knowledge of its stratigraphy, its geographic relations, or its transportation facilities, especially where the coal beds dip steeply as they do in the Valley coal fields of Virginia.

As these fields lie in or are adjacent to the Great Valley, it may be said, even without examination, that their structure is complicated, but careful mapping of the outcrops of the formations and a detailed study of their attitude and relations have shown that the structure in the fields of Montgomery, Pulaski, and Wythe counties is unusually complicated and that this complicated structure is so intimately associated with the outcrops of the coal beds and with their possible underground extension that successful mining operations can not be carried on without the operator knowing something of the structural problems with which he may have to deal. On account, therefore, of the close relation which geologic structure has to mining operations, the writers feel that they are justified in considering quite carefully the geologic structure as it appears to-day, as well as the probable methods by which such structures have been developed in the

[1] The coal resources and general geology of the Pound quadrangle in Virginia, Bull. IX, 1914.

The coal resources of the Clintwood and Bucu quadrangles, Va., Bull. XII, 1916.

The geology and coal resources of Buchanan County, Va., Bull. XVIII, 1918.

The geology and coal resources of the coal-bearing portion of Tazewell County, Va., Bull XIX, 1919.

The geology and coal resources of Dickenson County, Va., Bull XXI, 1921.

The geology and coal resources of Russell County, Va., Bull. XXII, 1922.

Geology and mineral resources of Wise County and the coal-bearing portion of Scott County, Va., Bull XXIV, 1923.

[2] As much of the field work of the two authors of this part of the report has been done independently, it is necessary in many cases to designate the one responsible for any observation or for a conclusion stated in the text. In all such cases, Mr. Campbell will be referred to as the senior author and Professor Holden as the junior author.

past, so that, as facts are brought to light in future operations by deep mining or deep drilling, the operators may have some substantial basis for interpreting underground conditions.

The dominant geologic structures in the Valley coal fields of Virginia, as well as that of the southwestern part of the Appalachian Highlands, are (1) large, more or less open, folds (Pl. VI) in the rock formations constituting the crust of the earth, as shown in cross-section in Fig. 2M, and (2) blocks of the formation composing the earth's crust that have been broken apart and shoved up one block upon another, as shown in Fig. 2N.

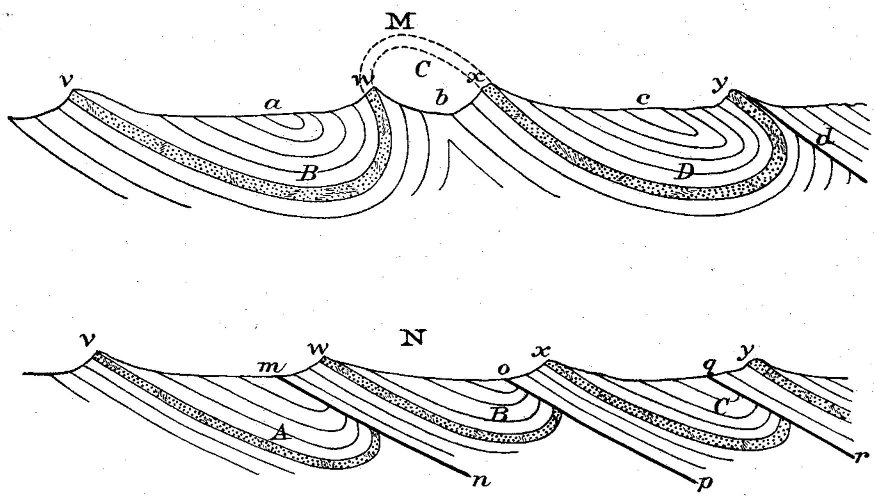


Fig. 2.—Cross-sections illustrating open folds and shingle-blocks.

Before entering upon a discussion of the origin of the folds it is desirable that the reader understand thoroughly the meaning of the terms "anticline" and "syncline" and also understand how to recognize such structures in the field, because book geology and field geology are very different things and unless one is able to read nature's book of rocks he can make little practical headway in reading the printed page.

The term "anticline" is derived from a Greek word meaning to slope from or in other words to dip away from, and the term "syncline" has a similar derivation and means to slope to or towards. An anticline then in cross-section is an arch with sides or limbs dipping away from a median line known as the axis, and a syncline is a trough with sides or limbs dipping toward the axis. Fig. 3 represents sections across M, an anticline and N, a syncline. It is very easy to distinguish the two forms on paper, but in the field the case is different and sometimes it is difficult to tell one from the other. In Fig. 3M the beds of rocks *a b c* are bent into the form of an arch or anticline. In such a case it will be noticed that the beds *a b c* appear on the two sides of the arch in reverse order and that the youngest or highest bed is farthest from the axis of the fold, and as one approaches the axis one comes upon older and older beds and when he finds that he has reached the oldest bed of rock involved in the fold, then he may feel assured that he is on the axis of the fold. Similarly, in crossing a syncline the beds appear in reverse order, but the youngest bed is in the middle or on the axis and the older beds occur in regular succession outward from the axis in both directions.

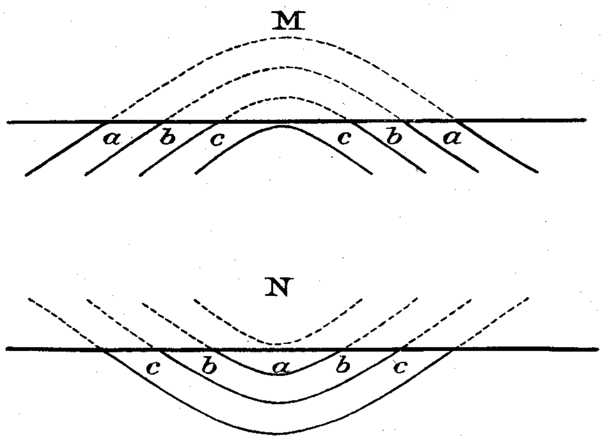


Fig. 3.—Cross-sections showing the difference between anticlines and synclines.

This may seem very simple, but when a group of beds are closely folded, as in Fig. 4, and the beds on both limbs of the fold dip in the same direction, then the problem becomes complex and one must study the beds and their succession very carefully in order to determine the character of the folds. From the exposures at the surface (O P) it is impossible to unravel such a structure until one determines the succession of the strata. Thus if the natural descending order of the strata is a b c d, then it is easy, if these beds can be everywhere recognized, to interpret the first structure on the left as an anticline with the axis at *a* and the second as a syncline with the axis at *d*, and so on. If the bed *b* is a coal bed then the identification is rendered easier, but in such a case one must remember that the first exposure from the left is right side up, but the next one is overturned and so on throughout the succession of folds (Pl. VI).

In the Appalachian region open folds comprise two classes: (1) those that are bent down, or synclines, and (2) those that are bent up into anticlines. The synclines may be long and narrow, like a trough, or they may be broad and round, like a basin; the anticlines may also be long and narrow, like an arch, or they may be broad and round, like a dome. In the Appalachian region the folds, of both the synclinal and the anticlinal varieties, are generally very long and narrow, but in places a fold may be broad in proportion to its length, and in such cases it forms a dome, if the fold is an anticline, or a basin, if it is a syncline.

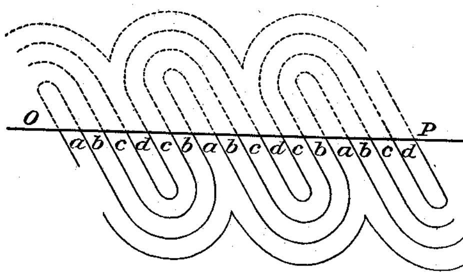


Fig. 4.—Cross-section of closed folds. The letters show how formations are repeated in such folds.

In the simplest form of a rock fold the beds dip toward the axis if the fold is a syncline (see fig. 3), and away from the axis if it is an anticline, and the dips are approximately the same in both limbs of the fold. From this simple type the fold may pass by insensible gradations into an unsymmetrical fold in which the dips on one limb are steeper than they are on the other and finally into a fold one limb of which is overturned so that the beds of rock in one limb are turned upside down. In an extreme case the fold may be overturned to such an extent that the rocks in both limbs not only dip in the same direction, but the angle of dip is approximately the same, as shown in Fig. 4.

If the fold is composed of beds of brittle rocks or the beds are not confined closely by a great mass of overlying rock, the overturned limb of a fold may break and a fault or break result. As the folds in the Appalachian region are generally long and narrow, so the faults resulting from the breaking of the overturned limb are generally long, extending in many cases more than 100 miles. Where several faulted folds are crushed together they take the form of blocks, as shown in Fig. 2N. These blocks are generally long and narrow, and when they are eroded their edges may form the entire surface of the country. Owing to the resemblance which these overlapping blocks bear to shingles on a roof, they will be referred to hereafter as "shingle-blocks." The shingle-blocks as well as the open folds may differ considerably in their appearance, depending upon the dip of the beds composing them. Thus some, made up of beds that dip very gently toward the southeast, have a great width, whereas others, made up of steeply dipping beds or of beds that locally stand on edge, are correspondingly narrow, but no matter whether they are wide or narrow all have been formed in the same general manner which will be described on another page. Similarly the open folds may vary considerably in the dips of their constituent beds and in the amount the southeast limb of the syncline is overturned toward the northwest and the amount the northwest limb of the anticline is overturned in the same direction, but the essential characteristics of the folds are still retained.

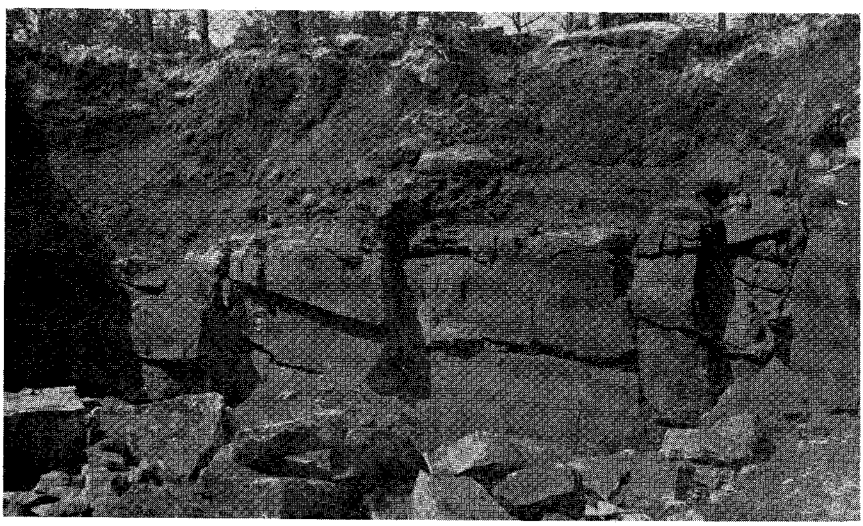
OPEN-FOLD STRUCTURES.

The open-fold type of structure is well illustrated by the Catawba syncline which lies mainly in Roanoke County, but extends to the westward into Montgomery County and terminates northeast of Christiansburg. The hard rocks involved in this trough-shaped fold show at the surface in the ridge called in the west Paris Mountain and in the east Catawba Mountain. Northeast of Christiansburg this ridge shows a decided curve to the south as it swings about the canoe-shaped end of the syncline, but the canoe-shaped end is not perfect as the south side of the syncline has been crushed and faulted so that the hard rock rim is generally absent. The east end of this trough is almost due north of Roanoke and as it is off the territory here being considered it will not be described. The rocks involved in this great trough range from near the base of the Shenandoah limestone to the Price formation of the Carboniferous system, but, judging from the reports of those who have examined the latter formation, its coal beds are very thin and the coal is of very poor quality.

This fold is of the type shown at c in Fig. 2M, except that in the Catawba syncline the overturned limb of the fold (*y* in fig. 2M) has been cut so closely by the fault that only here and there do traces remain of the hard rocks composing the ridge which marks the outcrop of this rimrock.

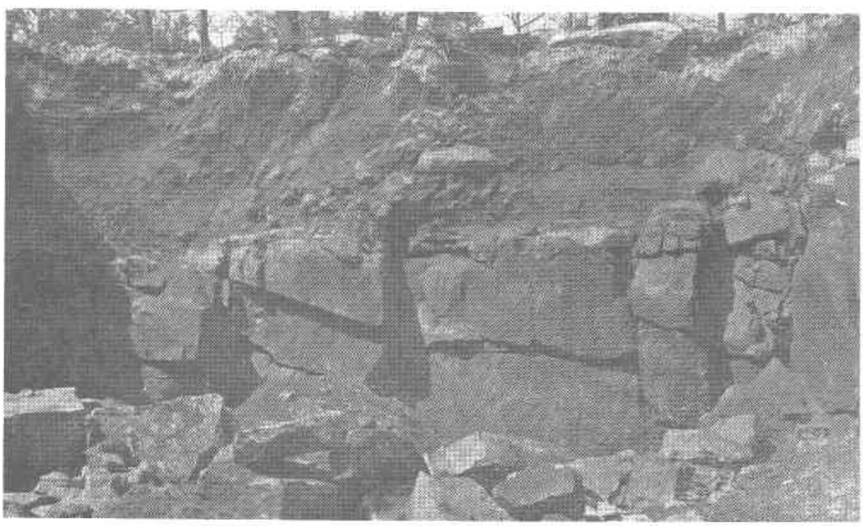
On New River south of Brushy Mountain there are a number of open anticlines and synclines, the most prominent of which is the Price Mountain anticline. This fold makes a low wooded ridge southwest of Blacks-

(A) Millstones manufactured from Ingles conglomerate. Photograph by Ralph W. Howell.



(B) Quarry in Ingles conglomerate on Brushy Mountain. Photograph by Ralph W. Howell.

(A) Millstones manufactured from Ingles conglomerate. Photograph by Ralph W. Howell.



(B) Quarry in Ingles conglomerate on Brushy Mountain. Photograph by Ralph W. Howell.

burg (see Pl. V B), called Price Mountain, and as this is the most prominent feature in the landscape its name has been given to the anticline which produced it. This anticline takes the form of an ellipsoidal dome with a length of 7 miles and a width of 2¼ miles. The lowest rock exposed on the axis of the anticline is the Ingles conglomerate, which has not yet been cut through by the streams that drain the upper part of the ridge. Around this central core of the anticline the formations higher in the series crop out in concentric zones: first, the remaining portion of the Price formation, including the Merrimac coal bed; and second, a band of red Maccrady shale which extends around the dome, except at the extreme west end.

Heretofore, those who have examined the Price Mountain coal field have regarded the structure as very simple, consisting merely of an elongate dome with the formations cropping out in concentric zones around its central area. This view has been held despite the well-known fact that for a number of years coal beds have been prospected at its eastern end. In the present examination of this part of the field, the writers found not only that the coal beds of the Price formation are exposed, but that the Ingles conglomerate, containing an abundance of distinctive pebbles shows in outcrop as a thin bed from the vicinity of the shaft near the middle of the Virginian Railway tunnel northward to the extreme eastern point of the anticline. At first some doubt was felt about this being the same as the Ingles conglomerate member of the Price formation, but this doubt was removed by the finding of marine fossils lying just to the southeast of the outcrop of the conglomerate. These fossils were pronounced by George H. Girty to be species of Devonian age. The presence of basal Carboniferous and upper Devonian rocks on the margin of this dome shows clearly that its structure is not so simple as has been supposed, and that a subsidary fold or a fault must be invoked to account for their presence. The geologic structure of this fold will be considered more in detail on pages 141-145.

South of Price Mountain there are two other open anticlines in Devonian and Carboniferous rocks, separated by synclines in the Shenandoah limestone. The first anticline south of Price Mountain is not marked by any surface ridge from which it may be named, but, as its axis passes nearly through the town of East Radford, it will be named here the East Radford anticline. As shown on Pl. I, this anticline, which is undoubtedly faulted at its western end, is about 3½ miles long by ¾ of a mile broad, crossing New River midway between Peppers Ferry and the mouth of Crab Creek. The other anticline, lying south of Radford forms at its west end two low ridges known as Ingles Mountain and at its east end a ridge known as Berringer Mountain. These are low ridges, but because of their location in the midst of the Great Valley, are conspicuous topographic features. This fold will be called the Berringer Mountain anticline for the ridge at its eastern end.

The anticlines mentioned above are separated from the Price Mountain fold by a deep syncline in the Shenandoah limestone, which, because its axis is supposed to pass through that village, will be called the Vickers syncline. This fold has not been recognized east of Vickers, but in the other direction it has been traced with certainty beyond Belspring in Pulaski County. This fold is of considerable magnitude for a measurement along the railroad of the limestone bed by bed as it disappears below the level of the grade (Pl. XI A) shows that fully 1,800 feet of rock is involved in the fold.

The open syncline between the East Radford and Berringer anticlines is well marked on the Norfolk and Western Railway and in the valley of Plum Creek. The actual measurement of the rocks in the railroad cuts along New River shows that only about 600 feet of limestone is involved in this trough. As the only town in this basin is the village of Walton on Crab Creek, that name will here be applied to the syncline.

Lying between the Price anticline and Brushy Mountain, a part of the Walker shingle-block, is a rather broad shallow syncline in the limestone, which will be referred to as the Toms Creek syncline. This fold is well developed east of the river, but probably comes to a point a few miles west of the Parrott coal mine (loc. 35, Pl. I) in Pulaski County.

Folds of this type, both anticlines and synclines, are present in the hilly area west of Pulaski and north of this town and Max Meadows. The first fold to be encountered in passing northward from New River near the mouth of Reed Creek is the Draper anticline which, in its eroded form is responsible for Draper Mountain and Draper Valley. The structure of the mountain and valley is shown in cross-sections F-F′, G-G′, and H-H′ on Pl. I. The hard bed of Clinch and associated sandstones which forms the mountain is shown as a colored band below the surface and its position before erosion occurred, by the broken lines above the surface. From this section it will be seen that the anticline is overturned toward the northwest and that the southeastern limb, as represented by the hard beds, formerly lay entirely above the present surface, so the valley has no bounding rim on the southeast side.

North of the Draper anticline lies the syncline which carries the Max Meadows coal field. The syncline, however, is much larger than the coal field, extending as it does from Draper Mountain on the south to the summit of Cove Mountain on the north and to the summit of Tract Mountain north of Pulaski. The youngest rocks involved in this trough are those comprising the Maccrady shale that occupies the middle of the trough from Gunton Park westward to Miller Creek which the trough crosses 2 miles north of Max Meadows. The rocks south of the axis of the trough are much disturbed and generally are either upturned so as to stand on edge or are overturned so as to dip steeply to the south. The rocks forming the north limb of the trough or syncline dip generally south toward the axis about 20°. This trough in a general way is outlined by the ridges made by the Clinch and associated sandstones in Cove Mountain on the north and Draper Mountain on the south. The structure of the Max Meadows syncline and the Draper anticline is shown in sections G-G′, H-H′, and I-I′ on Pl. I.

North of the Max Meadows syncline there is an anticline and a syncline before the observer reaches Little Walker Mountain. The anticline lies directly north of the Max Meadows syncline, in fact these two folds have one of their limbs in common. This relationship is well shown in the sections referred to above. At Pulaski, as shown in section G-G′, the fold is a simple unbroken anticline, but farther west it expands, is faulted, and becomes a shingle-block, as shown in sections H-H′ and I-I′.

The Crockett anticline, lying north of Cove Mountain, is faulted onto the Empire syncline (named for the mining town of Empire at the foot of Little Walker Mountain in the Little Walker Mountain coal field), as is well shown in sections G-G′ and H-H′. This fold rises westward and dies out as a definite synclinal trough in the Carboniferous rocks (see section J-J′) near the head of Crockett Cove, or rather it decreases in size to a mere wrinkle and this wrinkle merges into the sloping structure of the shingle-block of Walker Mountain. The two limbs of this trough north of Pulaski are well marked in section G-G′ by the ridges of Tract Mountain and Little Walker Mountain, both composed of the same Devono-Carboniferous rocks. The north limb of the syncline is better marked by the great ridge of Walker Mountain which characterizes the shingle-block into which the Empire syncline merges both to the east and the west.

This great group of open anticlines and synclines includes another member on the north which, though not directly connected with the coal fields, has doubtless affected them indirectly to some extent. This member is an anticlinal wrinkle on the southeast side of the Walker Mountain shingle-block and is indicated on the geologic map, Pl. I, by the duplication of the outcrop of the Clinch and associated sandstones and limestones in the valley lying between Walker and Little Walker mountains. This anticline is marked on the surface by a low ridge which appears to be a spur branching off from the southeastern slope of Walker Mountain. It is limited on the north by a valley drained by Spur Branch, and because of this fact it will here be called the Spur anticline. This anticline separates from the main Walker Mountain at a point about 4 miles east of the crossing of the direct Wytheville-Bland road and from this point it projects distinctly into the valley of Little Walker Creek. It plunges northeastward and is soon lost near the county line because the hard Clinch and associated sandstones that make the ridge farther to the west soon pass below water level and the overlying black Devonian shale is too soft to stand above the general level, no matter what its structure may be.

The development of this minor fold nearly opposite the decided bend in Little Walker Mountain west of loc. 47 which is in itself an anticlinal structure suggests at once that there may possibly be some connection between these wrinkles, but careful study of the field notes does not show any structural features connecting them. It is possible, however, that the mere dying down of the Spur anticline made it necessary for a wrinkle to appear in the overlying rocks in order to adjust themselves to the changed condition.

There is only one other pronounced open fold in the territory here being described and that is the Pine Mountain syncline west of Wytheville. The axis of this trough is marked by Pine Mountain, a low ridge, which extends from the city reservoir at Wytheville westward on the north side of the Wytheville-Marion road for a distance of about 9 miles or to a point nearly due north of Rural Retreat. The trough is very narrow, being marked mainly by bands of outcrop of the Tellico sandstone, and the Athens shale in a wide expanse of the Shenandoah limestone.

SHINGLE-BLOCK STRUCTURE.

The most important shingle-block in the territory here described is that which is dominated by Walker Mountain, but with Brushy or Little Walker Mountain as a subordinate feature in the landscape. This block develops from an anticlinal fold in the Sinking Creek valley in Craig County, nearly due north of the eastern extremity of the map shown as

Pl. I. From this point the block stretches southwestward in unbroken continuity for a distance of 80 or 90 miles to the western edge of Smyth County, where it is gradually concealed by the encroachment of the fault which farther east limits the block on the southeast side.

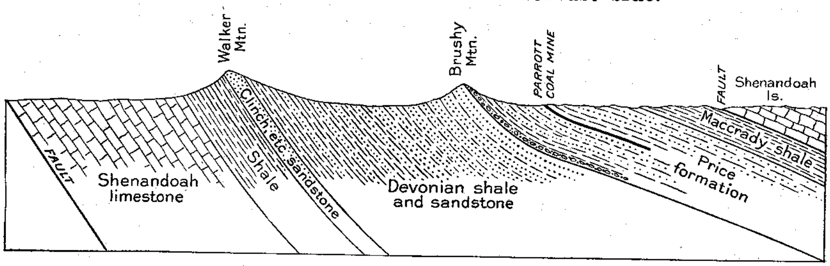


Fig. 5.—Cross-section of Walker Mountain shingle-block, as it shows on New River.

The best place to gain a clear conception of the magnitude and general structure of this great shingle-block is along New River from Goodwins Ferry to Belspring. The section here exposed is represented with true dips in Fig. 5 and it includes the section through the two mountains, Walker and Brushy, as well as rocks on the two sides of these backbone ridges. The lower limit of the block is determined by a fault which crosses the river at Goodwins Ferry and marks the northwestern limit of this outcrop of Shenandoah limestone. From this fault to Brushy Mountain the dip of the rocks is very constant, being in the neighborhood of 55 degrees to the southeast. South of Brushy Mountain the dips grow less and less until the rocks in places are nearly flat. The block is terminated on the upper side by the red shale of the Maccrady formation which is well exposed in the vicinity of the postoffice of Parrott. At the point where the Norfolk and Western Railway crosses Back Creek the shingle-block is cut off or concealed by a fault which separates the Maccrady shale on the north from another mass of the Shenandoah limestone on the south. The entire thickness of this great block of formations is about 9,000 feet.

It may even be questioned whether, in the vicinity of New River, this block of strata should be considered as a shingle-block or as an open fold of the synclinal type, for it is possible that beneath the limestone on its southeast side the syncline is complete. East of New River it seems probable that as far as Blacksburg this is the case and that the southeast limb of the Toms Creek syncline is the same as the north limb of the Price Mountain anticline. The solution of this question is possible only after sufficient deep drilling has been done between Brushy Mountain on the north and Price Mountain on the south to establish the continuity of the coal-bearing rocks between them. This has not been done and the only statement that can be made at the present time is that, from a geological point of view, it is highly probable that such a connection exists and the cross-sections on Pl. I have been drawn to represent that probability.

West of New River there are some surface indications of a similar structure, but the evidence is not such as constitutes proof of the existence of a syncline in this locality; it seems, however, to point in that direction. The evidence bearing on this question is to be found on New River and along the outcrop of the Price formation and the Maccrady shale from New River to the Dublin-Pearisburg road. At New River the sudden flattening of the dips in the coal-bearing formation as shown in the surface exposures and in the Parrott coal mine (see fig. 22), is the chief indication, but near the mouth of Back Creek there is an increase in the dip of the Maccrady red shale, the meaning of which is uncertain but it indicates either a slight depression in the bottom of a broad flat syncline or the upturned edge of a synclinal fold.

West of the Parrott mine the coal bed on the outcrop holds a fairly constant dip of from 40° to 55° to the south and, as shown in the Belle Hampton mine (now abandoned), this dip holds for a distance of at least 400 feet down the coal bed below the surface. Notwithstanding this steep dip at the outcrop that part of the Price formation lying above the coal bed and having a thickness of not more than 700 feet occupies a great width of outcrop, measuring in places nearly a mile. This great width can be accounted for on the supposition that at the depth of a few hundred feet the coal bed lies flat or that the formation is badly crumpled and perhaps faulted in this region. The dips observed along the old railroad to the Belle Hampton mine are in few places less than 35° and the rocks dip both to the south and to the north indicating that the formation is greatly crumpled. This of itself shows that structural conditions must be different from what they are on New River, for, as shown in the Parrott mine (fig. 22), the coal bed is relatively undisturbed and any crushing or folding that may have occurred in the river section, must be farther south than the lower end of the Parrott slope and probably even south of the edge of the limestone.

In order to find a solution for the seemingly exceptional structural conditions in this part of the field a careful survey was made of the outcrop of the Maccrady formation between New River and the Dublin-

Pearisburg road. In this examination it was found that the red shale of the Maccrady, which is so prominent on New River and there is in direct contact with the Shenandoah limestone, does not hold this relationship far to the west. At a distance of 2 miles up Back Creek the red shale belt gradually veers off to the north and the shale in contact with the limestone is of a yellow color and very similar to that which occurs in the upper part of the Price formation. As shown on the geologic map, Pl. I, this belt of red shale continues westward to beyond the Dublin-Pearisburg road and, as the fault swings closer to Little Walker Mountain, is again brought in contact with the Shenandoah limestone. In passing westward it was observed that the shale on the southern side of this belt dips more steeply and is more distorted by the small folds than it is on the northern side and also that the yellow shale south of the belt of red is similarly distorted in its bedding. The belt of red shale grows narrower and narrower toward the west, but so far as known the narrowness of the outcrop is not the result of greater dips in the shale.

Manifestly there are two possible interpretations that may be made of the facts cited above as follows: (1) The yellow shale in contact with the limestone on Back Creek may be an upper part of the Maccrady shale that is not red and the steeper dips on the south may mean only that the general dip of this limb of the syncline is not regular but is as represented in section A, Fig. 6; (2) that the yellow shale next the limestone is Price and that it is brought up with southeast dips on the overturned limb of a syncline, the axis of which is near the middle of the belt of red shale.

As the shale south of the belt of red shale is concealed beneath the limestone at both ends it is impossible to prove which of these explanations is the correct one without drilling.

The only deep drill hole that has been put down in this territory is one located at the point (loc. 38) where the red shale veers off to the north, 2 miles up Back Creek from the railroad, and drilled by the owner of the Belle Hampton mine. The results of this drilling have never been made public, but the writers were assured by several persons that the hole was drilled to a depth of approximately 1,400 feet, but rumors disagree as to whether the coal was penetrated at a depth of 900 feet or at the bottom of the hole. Owing to this uncertainty the well supplies little evidence regarding the structure in this region.

As doubtless the hole was drilled to get information regarding the Merrimac coal bed, it is hardly conceivable that drilling operation would have been continued for any great distance after the coal bed had been penetrated. For this reason the writers are inclined to think that the Merrimac coal bed is more likely to be 1,400 feet below the surface than 900 feet. If this assumption is correct then it would seem that the structure represented in section B, Fig. 6, is essentially correct, but if the coal was struck at 900 feet then section A would more nearly represent the facts.

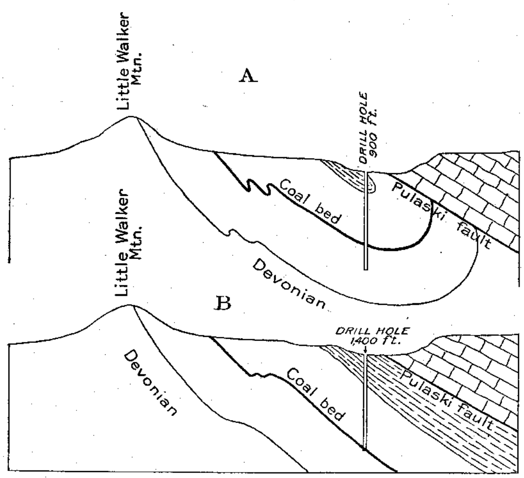


Fig. 6.—Cross-section showing two interpretations of the structure in the Little Walker Mountain coal field, 2 miles west of New River. Section A represents the structure if the coal bed was struck at a depth of 900 feet in well at loc. 38, and section B if it was struck at depth of 1,400 feet.

Doubtless there are many shingle-blocks in the great mass of Shenandoah limestone in the southern part of the territory here described, but in this limestone mass the details are difficult to determine and no effort was made to work out the structure.

FAULTS.

Over-thrust faults.

The third structural feature of importance in these fields is the great faults or breaks in the rocks which separate the shingle-blocks just described. They also in places separate the shingle-blocks from the open folds and more rarely separate one open fold from another fold of the same character. The cause of these breaks and the manner in which they occurred will be described on another page.

As the shingle-blocks are by definition bounded on both sides by faults it is obvious that the Walker block must have a fault on its northern as well as on its southern side. The fault on its northern side lies in the valley just north of Walker Mountain and although not shown on Pl. I crosses the entire mapped territory. As the youngest formation on the north side of this fault is in places the Maccrady shale and the oldest on the south side, the middle part of the Shenandoah limestone, it is obvious that the stratigraphic displacement on the plane of this fault is not less than 9,000 feet. As this fault passes through the town of Bland it is here called the Bland fault.

The Walker shingle-block is generally bounded on the south side by a great fault which has a stratigraphic displacement about as great as that of the Bland fault just described. This fault is known to extend westward in a nearly direct line from the eastern border of the territory here described, to the base of Tract Mountain a few miles west of Empire. Here it turns back abruptly at a sharp angle and trends eastward down Tract Fork of Peak Creek where, as shown in Pl. XIII A, it has been exposed in an old quarry. From the quarry it continues eastward to the Back Creek road where it turns abruptly southward to the town of Pulaski. Here it again makes an abrupt angle and pursues an easterly course to the end of Draper Mountain. Because it passes through the town of Pulaski, it is here denominated the Pulaski fault.

From the eastern edge of the territory represented on the map, Pl. I, to the east end of Draper Mountain the Shenandoah limestone on one side of the Pulaski fault is in contact with sandstone or shale on the other side, but throughout its course on the southeast side of Draper Mountain, Shenandoah limestone lies on both sides of the fault trace and at some places it is difficult to separate the one from the other.

At the west end of Draper Mountain the fault lies just south of the ridge and presses close to the foot of Hamilton Knob (see Pl. XIX B). It continues westward at the foot of a low ridge to the eastern edge of the town of Max Meadows. Here it turns in a wonderful manner abruptly to the northeast around the end of the ridge previously mentioned and follows eastward along the south bank to the head of Beaverdam Creek just south of Gunton Park or as it was formerly called, Clark Summit. It continues in the same course to a point about half a mile beyond the summit where it turns back abruptly and follows a westward course practically parallel with, but about a mile north of its previous course. In its westward course the fault is very irregular and consequently the width of the belt of limestone varies considerably. It crosses Miller Creek nearly a mile north of the railroad and thence pursues a general westerly course to the south side of Queens Knob north of Wytheville, shown in Pl. XXI A, and thence in a general way parallel with and at the south foot of Little Walker or Brushy Mountain across Wythe County and indefinitely to the southwest into Tennessee.

In addition to the two faults just described, there are several others which are not connected with the larger faults at the surface but may or may not be connected underground. One of these faults that seems obviously not to be connected with the Pulaski fault, though it appears to unite with it, is a fault in Wythe County on the north side of Cove Mountain, which will here be referred to as the Cove fault. This fault develops in the Crockett anticline in Tract Mountain and thence trends southwestward along the north side of Tract Mountain and the south side of Little Walker Mountain and either unites with the Pulaski fault a short distance east of the Stony Fork of Reed Creek or passes under that fault. The relationship of these faults will be further considered on another page. The Cove fault separates the Shenandoah limestone on the south from Devonian and Carboniferous formations on the north.

Another fault that very much resembles the Cove fault, just described, occurs in Roanoke County only a short distance northeast of the Montgomery County line. This fault apparently branches off from the Pulaski fault just within Montgomery County. In reality the fault is on the northwest limb of an anticline that plunges sharply toward the northeast and the limestone and calcareous Sevier shale on the end of this anticline have been eroded in a great recess in the north wall of the Valley, known as Millers Cove. On account of the prominence of this cove, the fault cutting through it on the northwest side is here called the Millers fault.

Although the field evidence is not entirely conclusive regarding the relation of the Millers fault to the Pulaski fault, the writers believe that the Pulaski fault cuts across it and the Shenandoah limestone lying to the southeast of the Pulaski fault merely overrides the belt of limestone which marks the point of the anticline in Millers Cove. This supposition is strengthened by the finding of evidence of the presence of a fault in the great mass of limestone lying between Dry Creek and the Blacksburg-Newport road. In this area Brushy Mountain bends distinctly to the north and, as the supposed fault bends to the south, there is a large area of Chickamauga limestone which is very cavernous and consequently has mainly underground drainage. This limestone is evidently separated from the limestone on the south by a fault and hence it seems probable that the Chickamauga limestone does not belong with the great mass of the limestone in this belt, but is probably a remnant of the faulted anticline of Millers Cove which was caught and pushed forward by the Pulaski fault and so is not now directly connected with the mass to which it formerly belonged. The northeastward extension of the Millers fault will be more fully considered under the description of the coal fields of Roanoke and Botetourt counties.

The most remarkable faults in this region are three in the vicinity of New River, which are rudely elliptical in outline and surrounded areas of Carboniferous and Devonian rocks, separating them from the Shenandoah limestone which crops out on all sides of the central mass of younger rocks. Such occurrences, where the erosion of the older, overlying rocks has exposed the younger or underlying rocks, have generally been called fensters from the German word "fenster," meaning a window. This term is very appropriate, for in a geological sense, one looks at the younger rocks through an opening or "window" in the overlying, older rocks. As no English term for such a feature is available the German term will be used.

The best known fenster in the New River region is that of Price Mountain, a low ridge about 5 miles long, lying about midway between Christiansburg and Blacksburg and west of the main road leading from one of these towns to the other. The ridge trends east-west and its highest point is scarcely more than 400 feet above the level of the valleys on either side. The structure of the ridge has already been described as that of an elongate dome with the rocks dipping in general away from the central part. Not only do the Carboniferous rocks comprising the mountain dip in this manner, but the Shenandoah limestone surrounding it dips correspondingly away from the more central part of the dome.

The most important structural feature observed in this fenster and the one which makes it possible to correlate the fault surrounding it with some other fault of the region, is the almost perfect parallelism between the beds of limestone and the beds of the coal-bearing rocks upon which they rest, even in places where the latter are overturned, as shown in cross-section A-A′. This fault has no apparent surface connection with any of the great faults of the region, but its magnitude, as indicated by the displacement of the rocks now in contact, ranks it as a part of one of the major faults and hence it is supposed that there must be a connection, but if so, the connection is beneath the surface. This phase of the question is more fully considered on pages 84-86.

The next fenster, lying about 3 miles southwest of Price Mountain, is crossed by New River between Peppers Ferry and Walton. This fenster is about 3 miles long and its western extremity which is narrow and sharply pointed is at the ferry across New River, in East Radford. The rocks composing this fenster have been somewhat of a puzzle to the various geologists who have examined them. Thus the senior author,[1] who made a reconnaissance examination of this region in 1893, mapped the shale in this fenster as of Cambrian age and correlated it with the shale showing in the vicinity of Graysonton in the southern part of Montgomery County. This correlation was made on the grounds of physical similarity and structural relations, as the shale of the fenster was observed on New River to lie beneath the Shenandoah limestone on both margins of its exposure. Not only was the shale seen to underlie the limestone but the limestone has approximately the same dip as the underlying shale (see Pl. IX B), and to all intents and purposes the relation between these two formations seemed to be conformable. Many years later this fenster was studied by Heath M. Robinson while he was a student at the Virginia Polytechnic Institute at Blacksburg, and though his conclusions were not published, it is understood that he determined the shale to be of Carboniferous age and consequently equivalent to some part of the Price formation. In coming to this conclusioin, Robinson was doubtless largely influenced by the fact that prospecting for coal had been done in the river bluff opposite East Radford and, according to report, some coal had been found.

Recently the senior author has again studied this fenster, and in the light of the knowledge gained by previous examinations and the results of his own study he has come to the definite conclusion that the shale of this fenster is of Devonian age. His conclusion is based on the following evidence: (1) Very little coal was found in the old prospect opposite East Radford. The writer searched in vain to find coal fragments on the old dump, but without avail; but it is evident that the prospect was sunk in black shale that looked very much as weathered coal will look when it has been exposed for a long time. The writer will not seriously question the finding of some coal in this old prospect, for it is a well-known fact that in places in this region the Devonian black shale does carry small seams of coal and it is altogether probable that such seams were encountered here. The character of the material as well as the evident thinness of the coal points rather strongly to the Devonian rather than the

[1] Paleozoic overlaps in Montgomery and Pulaski counties, Virginia: Bull. Geol. Soc. Am., vol. 5, pp. 171-190, 1894.

Carboniferous age of the beds.[1] (2) Typical Devonian black shale is exposed on the northern margin of this fenster in the bed of a small stream entering New River from the west a few hundred yards above Peppers Ferry. (3) The most conclusive evidence regarding the age of the shale was obtained, however, at the east end of the fenster, for in tracing the contact of the shale and the limestone around this broad outcrop it was found that a bed of conglomerate occurs in contact with the limestone around the east end and for a considerable distance on either side of the fenster. From the general distribution of the outcrop of this conglomerate, as well as its exposures in ravines, it was clearly determined that the conglomerate overlies the shale, and as there is no indication of the shale having been overturned, it seems safe to assume that the conglomerate is in normal relation to the shale and hence is younger than the shale. This conclusion is strengthened by the fact that the only known bed of conglomerate that is definitely associated with the Devonian formations is the Ingles conglomerate at the base of the Price formation, hence the conclusion seems inevitable that the conglomerate at the east end of the East Radford fenster is the basal member of the Carboniferous system and that it lies conformably above shale and sandstone of Devonian age. The fenster is therefore, at least partly anticlinal in structure with the Shenandoah limestone also partaking of the same structure as though the two were folded after they assumed their present positions. Pl. IX B clearly shows the relation of the Devonian shale to the overlying Shenandoah limestone. The man is standing at the fault and the shale and limestone both dip to the left (north) about 20°. At the west end the structure of the fenster, however, is not so simple as it ends in a sharp point and hence it is either a very closely folded anticline or a faulted mass of shale.

The third fenster in this immediate vicinity is a long narrow area of Devonian and Carboniferous rocks which forms Ingles and Berringer mountains, low ridges, but rather prominent objects in the limestone region. The length of this fenster is about 8 miles and the width about 1 mile. Ingles Mountain forms the west end of the fenster, extending from a point about due south of East Radford to Ingles Ferry on New River on the south side of the old State road; Berringer Mountain lies

[1] According to recent newspaper accounts, a bed of coal several feet thick has recently been struck at a shallow depth in a well drilled on Radford Run. The writers are skeptical about this being true coal, but think that it is more likely to have been the black coaly shale of the Devonian which in many surface prospects has been mistaken for a solid bed of clear coal.

at the other end of the fenster and is a broad swell on the north side of the old State road; the area between these two ridges at the extreme ends of the fenster is low with rather sharp knobs here and there on its margins, rising above the general level.

The reason for the existence of these two mountains is that, although the mass of the fenster is composed of rather easily eroded Devonian shale, the two ends are capped by flaggy sandstone and a bed of conglomerate, which is evidently the basal bed or Ingles conglomerate of the Carboniferous.

The structure is markedly anticlinal in character, particularly on the road leading from Radford to the mouth of Little River, at the west end of the fenster. This road crosses the point of the anticline where it plunges under New River and the conglomerate shows the form of a perfect arch as it crosses the highway and the railroad which runs directly below the highway. East of Ingles Ferry the arch increases in magnitude and has been breached on its crest by small streams leaving two prominent ridges, known as Ingles Mountain, that are composed of the conglomerate on the flanks of the fold. On the south side, this bed dips about 20° to the south and it forms the south side and crest of the more prominent of the two ridges. The north ridge is less continuous and regular than the south ridge, as it is made by the steeply dipping or overturned limb of the anticline. The structure of the two ridges is well-shown on a neighborhood road which crosses at the east end of the northernmost ridge, as shown roughly in section D-D′, Pl. I, and Fig. 7.

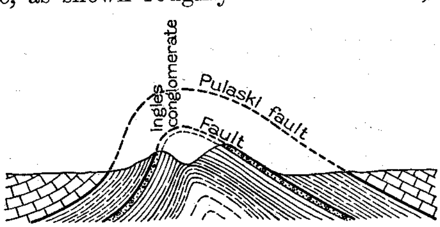


Fig. 7.—Cross-section of Ingles Mountain showing anticlinal structure.

In descending from the southern ridge to the old State road over this neighborhood road, one crosses in descending order the Ingles conglomerate, on the crest of the ridge, then the upper sandstones and more sandy shales of the Devonian, and lastly in the valley between the ridges the black shale marking the bottom part of this system. The rocks on the northern limb are crossed in reverse order, but they are badly crushed and not so easily identified as are those on the south limb.

(A) Blacksburg peneplain west of Blacksburg.

Photograph by Marius R. Campbell.

(B) Blacksburg peneplain from Berringer Mountain.

Photograph by Marius R. Campbell.

(A) Blacksburg peneplain west of Blacksburg.

Photograph by Marius R. Campbell.

(B) Blacksburg peneplain from Berringer Mountain.

Photograph by Marius R. Campbell.

Both ridges of conglomerate come to an end west of Radford Run, by the encroachment of the fault which separates the Devonion and Carboniferous rocks of this fenster from the overlying Shenandoah limestone or Sevier shale.

In Radford Run and across the divide to Plum Creek the black shale of the Devonian crops out all along the State road and the presence of this shale is responsible for the deep mud holes and the deep ruts that generally mark this stretch of the highway which is now largely abandoned by through automobile traffic. This traffic follows from the divide between the creek valleys mentioned above directly to East Radford a road which was under construction when the field was last visited, and consequently is not accurately plotted on the map.

The attitude of the Shenandoah limestone on the north side of the fenster is well-shown on Plum Creek. Formerly a road followed down this creek from the main Valley pike, but it is now closed; the contact can still be seen, however, by the traveler leaving his conveyance where the pike crosses Plum Creek and proceeding down that creek about a quarter of a mile. Here the limestone can be clearly seen overlying the Devonian shale and dipping to the north down the creek at an angle of about 20°. As far as the authors are aware, this is the only place where the relations of the rocks on the north side of this fenster are clearly shown.

A little farther east the north limb of the fenster is crossed by roads leading both from Vickers and Walton on the Norfolk and Western Railway. In approaching the fenster from either of these places one passes from the limestone soil which characterizes the outcrop of the Shenandoah to the sandy shale of the upper Devonian without seeing the actual contact, but the general position of this contact may be fixed by the presence of considerable iron ore and by the line of sharp conical knobs which appear both to the right and the left. These knobs are composed of and held up above the surrounding region by fragments of the Ingles conglomerate which have been preserved on the fault plane or of the lowest layers of the Shenandoah limestone which here and there have been silicified and hardened by silica-bearing waters that have circulated along the plane of the fault.

From near the fault the road leads due south to the Valley pike and in following this road one descends in the Devonian system from thin-bedded brown sandstone at the top, through sandy shale to the black shale which lies at the bottom of the sandy and shaly formation. Just before reaching the Valley pike the road passes over a ledge of siliceous limestone which without doubt is the Helderberg limestone and marks the axis of the anticline. South of this axis the broad valley of Plum Creek is cut in the same black shale that was just crossed north of the outcrop of the Helderberg limestone.

From the point where the road just mentioned joins the Valley pike, one can go northeast up another branch of Plum Creek, crossing the axis of Helderberg limestone and then by climbing the wooded knob to the east pass successively up through the Devonian rocks from the black shale in the valley to more and more sandy material until he reaches the summit which is composed of a nearly flat-lying bed of Ingles conglomerate, as shown in Fig. 8.

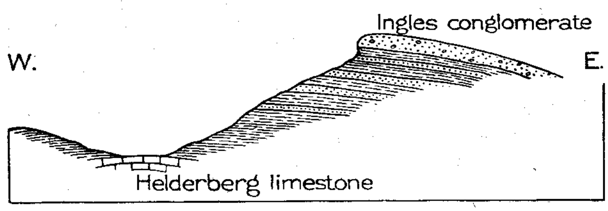


Fig. 8.—Longitudinal section of Berringer Mountain from the Helberberg limestone at the base to the Ingles Conglomerate at the top.

The evidence obtained in the localities just described shows clearly that the Berringer fenster is anticlinal in character and that at least in one place on the north side the Shenandoah limestone rests on the Devonian rocks with conformable dips of about 20°.

The structure of the Berringer fenster is quite simple, but the structure of the surrounding mass of older rock is much more complicated. In general the structure outside of the fault seems to be mainly anticlinal, but the overlying material at the west end instead of being the Shenandoah limestone, as is commonly the case, is Sevier shale, and the same shale rests against and persumably upon the Ingles conglomerate on the south side of the east end. This outcrop of calcareous shale or thin-bedded limestone can be followed eastward to the railroad where it is well exposed, as shown in Pl. IX A, in a side-hill cut. The shale is not conformable with the adjacent masses of the Shenandoah limestone and hence they must be separated by a fault or by faults. Indeed, the structure of the surrounding limestone and shale mass is apparently so complicated that, with the present knowledge of the sequence and distribution of the individual members of the limestone, it is practically impossible to formulate a theory that will account for the observed facts.

In a general way the authors believe that originally the body of limestone was thrust over the Berringer fenster in much the same manner that it was thrust over the Price Mountain fenster, but that subsequent to the main overthrust, another fault, possibly the one that bounds the Catawba syncline on the south, occurred and another mass of limestone was thrust upon the first overthrust mass on the south side of Berringer and Ingles mountains. Subsequent erosion has removed the limestone from the top of the Berringer anticline, exposing the fenster, but it has not yet reached the various layers on the south side of the uplift.

At the west end of the fenster the relations of the Sevier shale are not so apparent, but even here it seems certain that it is separated from the overlying limestone by a fault or faults. The shale crosses New River and is exposed at the base of the river bluff south of Ingles Ferry, but does not come to the surface west of this place.

The most nearly incomprehensible fault of this region is one that bounds on both sides a narrow band not over 400 feet wide of the lower part of the Shenandoah limestone which is embedded unconformably in the Devonian and Carboniferous rocks just north of Draper Mountain and which presumably extends more or less continuously from one end of the mountain to the other and is seemingly united with the great mass of the same kind of limestone at either end.

So far as is known the first publication calling attention to this limestone outcrop in the Devonian shale is that of McCreath and d'Invilliers.[1] These geologists found a mass of limestone in the Devonian shale on the north side of Hamilton Knob, part of which had been replaced by iron ore. They examined it in connection with their study of the mineral resources of this region and their opinion was that the limestone is of Carboniferous age, but they gave no evidence upon which that conclusion was based nor any explanation of the anomalous relations which this mass of limestone bears to the adjacent upper Devonian shale.

The senior author of this paper, in his examination of this region in 1893, found limestone at three places on this line of outcrop north of Draper Mountain: (1) at the north foot of Hamilton Knob, presumably the same as that described by McCreath and d'Invilliers; (2) on Beaverdam Creek near where that stream is crossed by the wagon road leading from Gunton Park to the Locust Hill Iron mine, and (3) an exposure on the old road, now abandoned, leading from Gunton Park, or Clark Summit, as it was then known, to Pulaski.

[1] The New River-Cripple Creek mineral region of Virginia, p. 141.

The limestone at locality No. 2 is well exposed in the cleared fields of a farm lying on the north slope of the divide between the drainage basin of Beaverdam Creek and the creek flowing in general to the south by way of the Locust Hill Iron ore mine. The road at locality No. 3 is no longer open to travel, as the stream flowing in this valley has been impounded to supply water for the town of Pulaski, but the limestone may still be seen along the old road now overgrown with underbrush from the reservoir eastward across the summit separating this stream from the small branch that flows through the town, nearly to the road leading southward from Pulaski to Draper Valley. East of this road the limestone was not seen, but its position is indicated by an old iron-ore pit at loc. 54 and by red calcareous soil as far as the main Pulaski fault about one-quarter of a mile south of Peak Creek.

The most striking feature of this band of outcrop is its utter disregard of formation boundaries or strike lines. Thus beginning at the east end, the limestone holds a nearly straight course in the middle of the Devonian sandstones and shales to within about 2 miles of Gunton Park where the strike of the Devonian rocks changes more to the south and the belt of limestone cuts across the upper part of the system until, near the crossing of the county line, it is in contact with the Ingles conglomerate. From this point the limestone bends distinctly toward the south, crossing at nearly right angles the entire Devonian system of rocks from the sandstones at the top to the black shale at the base near the Locust Hill iron ore mine.

The senior author, at the time of his examination in 1893, was familiar with the statement of McCreath and d'Invilliers regarding the Carboniferous age of the limestone in the ore pit north of Hamilton Knob and he studied the rock carefully to find some fossils by which it could be definitely correlated with well-known limestones in other areas, but no fossils were found and on the basis of its physical appearance he called it Shenandoah.[1] The mere matter of calling it Shenandoah, however, did not make the solution of the problem of its origin any less difficult and the senior author felt that the only explanation possible was to suppose that the Devonian shale was here laid down unconformably on a very rugged surface of the Shenandoah limestone and that subsequent erosion has exposed the underlying rock in this narrow zone.

The junior author, in his studies of the iron ore deposits of the State of Virginia, has long been familiar with the presence of this narrow band

[1] Op. cit., p. 187.

of limestone north of Draper Mountain whose outcrop is generally marked by the deposits of iron ore and manganese. He has seen the limestone at many places, the chert resulting from its decomposition at others, and iron ore, which is a replacement product, at still other places. He noted its peculiar relation to the Devonian shale and regarded it, though he has not so stated in print, as being of Devonian age and conformable to the adjacent Devonian shale and sandstone.

In the course of the present examination, the limestone was found at a number of localities in this belt, old ore pits at many other localities, and decomposition products such as chert fragments and limestone soil at many other places so that in a general way the authors regard the limestone as practically continuous, though it is possible that in places the belt thins down to a feather edge and possibly disappears completely. The bed of limestone appears to dip steeply or to stand on edge and to be inclosed generally by Devonian shale having a similar attitude or, as on Beaverdam Creek, in contact with the bed of conglomerate marking the base of the Price formation. As the limestone where it appears at the surface has all of the physical characteristics of the lower part of the Shenandoah limestone, there seems to be no reasonable question regarding its age.

The geologic structure of this bed of limestone is, however, not so easily settled, and in fact, to the writers it seems to be one of the most obscure questions with which they have had to deal in this region of complicated structure. It is clearly bounded on both sides by a fault or faults and it certainly has no direct structural relation to the adjacent shale. It must, therefore, be regarded as something in the nature of an overthrust mass, but the probable mode of its formation will not be considered here, but will be taken up in connection with the mode of formation of the great Pulaski and other faults of this region.

Normal faults.

Most geologists are of the opinion that practically all of the faults of the Appalachian region are of the overthrust variety, but during the progress of the present work a great many so-called normal faults were observed, particularly in the Devonian shale in the various fensters on or near New River.

The term "normal fault" is applied by geologists to a kind of fault that is produced by tension or a stretching of that part of the earth's crust in which the fault occurs. If the tension or pulling stress is exerted until the rocks can stand no more, rupture occurs and the rocks break and are displaced in such a manner that the faulted mass occupied more space than the original block before tension was applied.

The rocks in or near the bottom of the Catawba syncline are cut in a number of places by normal faults. They generally occur where a small wrinkle interrupts the generally regular dip toward the axis of the syncline. There are probably many of these faults in the Catawba basin, but the only ones observed were those which cut and offset the boundary between the Shenandoah limestone and the Athens shale. Two of these are shown on Pl. I, the most prominent being the one at the mouth of Mill Creek which is shown in Pl. XVI A. The band of blue limestone shown in the view suddenly comes to an end and its continuation is about a quarter of a mile to the west or in the direction in which the picture was taken. The limestone on the right is forced up or the shale on the left forced down along the fault plane.

The Devonian or Carboniferous shale composing most of the fensters here described are cut in many places by small normal faults. Ordinarily such faults are not recognized because the displacement is small and the rocks are of such a character that it is difficult, if not impossible, to identify on the surface a given bed for any distance, and so an offset can not be detected. In the comparatively fresh cuts made by the railroads, both by the Virginian in the shale of the Price formation at the west end of the Price Mountain fenster and the Norfolk and Western in the Devonian shale in the Radford fenster on New River, normal faults were observed at many places. The best example was seen in a railroad cut about a quarter of a mile above Peppers Ferry. A sketch of the rocks in this cut, made by K. K. Kimball, is shown in Fig. 9. Similar faults, though

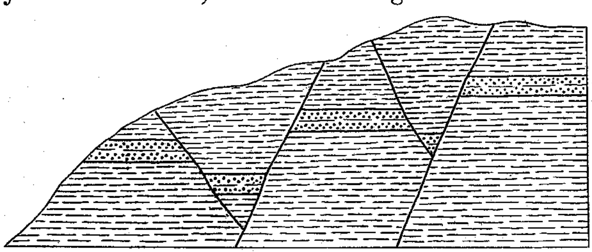


Fig. 9—Normal faults in railroad cut near Peppers Ferry.

not so perfectly developed, may be seen on the Virginian Railway north of the place where it crosses Stroubles Creek at the west end of Price Mountain.

One of the most important normal faults in the Price Mountain coal field is that which offsets the outcrop of the Merrimac coal bed between the present workings of the Merrimac mine, loc. 28, and the abandoned workings of the old Lykens Hill mine, loc. 27, as shown in Fig. 21. This fault trends in the general direction of the major structures of the region, crossing the outcrop of the coal bed at a very small angle and duplicating the outcrop for a distance of about 1,500 feet.

Normal faults are also of common occurrence in the coal mines of this region. Generally the amount of movement on the fault plane has been so slight that the coal bed is displaced only a few inches or a few feet and in such cases they are rarely recognized as faults, but in places faults of a much greater magnitude have been encountered. The largest one seen by the writers occurs in the Slusser mine as described in detail on pages 159-160. Here, as shown by Fig. 19, the offset of the coal bed is about 15 feet and it is perfectly clear that it was caused by tension or a pulling apart of the rocks at some time in the past. Fig. 20 shows a "jump" or incipient normal fault in the "College" mine at loc. 19.

Fault-line phenomena.

In many parts of the region examined in the progress of this work evidence was found which tended to show that the great fault planes, especially that of the Pualski fault, have afforded avenues for the circulation of water and the deposition of mineral matter, wherever the conditions were favorable for such deposition, that was carried in solution. In most places the water carried silica in solution and consequently the rocks along the contact are in such places silicified, but in other places the water carried iron in solution and the result has been the deposition of brown ore in sufficient abundance to be of commercial importance.

The phenomena referred to above have no bearing upon the development of faults or other structures in the rocks, but the presence of iron ore or silicified rocks may be used as excellent guides to the location of a fault and for that reason they are considered here. Another reason for their consideration is that even such dissimilar rocks as sandstone and limestone when subjected to the action of silica-bearing water are changed into quartzites which are so similar that it is with the greatest difficulty that they can be differentiated.

Thus on the Berringer fenster there are a number of sharp serrate knobs on the fault line on the north side of the fenster that stand up distinctly above the general level of the county. They are manifestly composed of rock that is harder than the average sandstone of the upper Devonian, but when one climbs these knobs he may have great difficulty in deciding whether the quartzite he finds is merely a local silicified phase of the overthrust limestone or a fragment of a white quartzose sandstone at the base of the Carboniferous. The writers have not had time to study these rocks as carefully as is desirable, but they must admit their inability to settle this question from a cursory examination in the field. The ledge of limestone shown in Pl. IX B resting upon the Devonian shale is silicified to such an extent that it is harder than the adjacent beds of limestone, so it stands out prominently in the railroad cut.

The deposition of iron ore and manganese on the fault plane is much less common than the deposition of silica and probably it depends largely upon a local supply of these materials in nearby rocks which may be leached out by the water and carried to the surface and oxidized and deposited in the clay that remains when the lime is dissolved. Iron ore is found at both ends and on the north side of Draper Mountain and is present in smaller amount on the slopes of Ingles and Berringer mountains. The Locust Hill mine (see Pl. XIX B) at the foot of Hamilton Knob southeast of Max Meadows is an open cut from which a large amount of iron ore has been taken during the past 25 years. Other ore bodies have been worked out and the pits abandoned, so that old ore pits are good guides to the presence below of a more or less important mass of limestone and to a fault in its vicinity.

With this brief résumé of the structure of the Valley coal fields as far as that structure has been determined, it will now be possible to devote some time and space to the questions of how these varied structures were produced, what were the conditions attending their production, and when the event or events took place.

ORIGIN OF GEOLOGIC STRUCTURES.

History of the development of ideas.

The development of ideas regarding the origin of the geologic structure of the Appalachian region is most interesting, as it shows how prone humanity is to stick to the old and how loath it is to accept anything new. One need not wonder at the hesitation of the laymen in accepting the teachings of modern science when we remember that it took geologists 30 or more years to formulate a reasonable hypothesis regarding the mode of formation of the folds and faults of the Appalachian region. In order to make the case clear, the writers will devote a small space to a historical statement regarding the development of ideas on this subject.

Prior to the inauguration of geological work by the State of Massachusetts in 1830, there had been little or no systematic study of the attitude or structure of the rocks in the Appalachian region. The Massachusetts survey was under the direction of Professor Edward Hitchcock of Amherst College. In his report of 1833 Hitchcock did little more than his predecessors, for he merely noted that in western Massachusetts the rocks generally dip to the east. His explanation was that the rocks constitute a series of unconformable deposits all dipping in the same direction, but at different angles.

The next important contribution to the knowledge of the structure of the Appalachian region was made by Henry D. Rogers in a report entitled, "Description of the Geology of the State of New Jersey," a final report of the State Geologist, published in the spring of 1840. In this report Rogers first called attention to the unsymmetrical shape of the anticlines in northern New Jersey as well as in the general Appalachian valley as far south as Tennessee, as follows (p. 42):

> "This departure from a central position in the synclinal axis of the valley is a very usual feature in the axes of the Appalachian chain. It results as a necessary consequence from the northwestern dips belonging to the anticlinal axes lying next to the southeast, or that of the Schooley Mountain chain, being steeper than the southeastern dips from the axis of elevation northwest of it. This want of symmetry in the dip of the strata would not claim a special mention in this place but for the truly remarkable circumstance that throughout nearly the whole length of the Appalachian chain, embracing many hundred anticlinal axes, the same rule prevails with scarcely an exception, the northwestern dips being steeper than the opposite southeastern ones."

This recognition by Henry D. Rogers of the general unsymmetrical character of Appalachian folds was really the first ray of light that was shed on the structure of this region. It, however, was not followed by Hitchcock who, in his "Elementary Geology," published the same year, offered a new explanation of the prevailing southeastward dips of the Appalachian region which the Rogers brothers (Henry D. and William B.) claim was based on a verbal communication made by them to Professor Hitchcock a few months before the book was published. In this publication Hitchcock attributes the prevailing southeast dips to an actual inversion of all the strata involved.

In 1841 the Rogers brothers, in an oral communication made to the American Philosophical Society, stated that in their opinion the southeast dips so common in the Appalachian region are not due to general inversion of the strata but to closely compressed folds in which the strata on the two limbs are essentially parallel, and hence dip in the same direction and at approximately the same angle of inclination. This statement, supplementing the one made the year previous by Henry D. Rogers gave the key by which Appalachian geologic structure could be interpreted and it was adopted by Hitchcock who, in the second edition of his textbook, published in August, 1841, was the first to advocate in print the idea that closed folds with limbs parallel and dipping in the same direction, are due to two forces compressing a mass of rocks from opposite directions. This is the first statement that in any way approaches the present conception of the manner in which the general southeastward dips of the Appalachian region were produced. But even after enunciating it Hitchcock could not carry it out to its logical conclusion, for in order to account for several parallel folds he had to invoke some other condition that would lead to the repetition of the phenomena. This he did by assuming that the process was facilitated by the elevation of parts of the rocky crust by the wave-like action of molten matter beneath.

The Rogers brothers stated their final conclusions on this subject in a paper entitled, "The Physical Structure of the Appalachian Chain.."[1] In this paper they make the following statement (pp. 483-494):

> "The above-described phenomena of the dips in the Appalachian range may, we think, be really accounted for by the peculiar character of the flexures of the strata. These flexures, unlike the symmetrical curvature usually assigned to anticlinal and synclinal axes, present, in almost every instance, a steeper or more rapid arching on the northwest than southeast side of every convex bend; and, as a direct consequence, a steeper incurvation on the southeast than the northwest side of every concave turn; . . . On the southeastern side of the chain, where the curvature is most sudden and the flexures most closely crowded, they present a succession of alternately convex and concave folds, in each of which the lines of greatest dip on the opposite sides of the axes approach to parallelism, and have a nearly uniform inclination of from forty-five to sixty degrees toward the southeast."

[1] Trans. Assoc. Am. Geol. and Nat., 1840-1842.

The statement just quoted gives a fairly clear picture of Appalachian folds, as they are known to-day, and it is interesting to note that in the same paper, these pioneers in Appalachian geology give an equally clear picture of the great longitudinal faults, which, as far as the writers are aware, is the first recognition of the presence of faults in this region. Their statement is as follows (p. 494):

> "A feature of frequent occurrence in certain portions of the Appalachian belt is the passage of an inverted or folded flexure into a fault. These dislocations, preserving the general direction of the anticlinal axes, out of which they grow, are usually prolonged to a great distance, having in some instances—for example, in southwestern Virginia—a length of about 100 miles. These lines of fault occur in all cases along the northwestern side of the anticlinal, or the southeastern side of the synclinal axis, and never in the opposite situation."

The authors of these quotations do not say distinctly that these great longitudinal faults are different from normal faults which even before this time had been clearly recognized in Europe and which had generally been referred to as the only kind of fault in the earth's crust. Although the Rogers brothers did not specifically state that these faults are in the nature of overthrusts, they nevertheless so describe them that it is perfectly clear that they fully understood their character. Their description of the great fault herein called the Pulaski fault shows that they understood its character. This description is as follows (pp. 496-497):

> "But a few miles further toward the southwest, the whole of this enormous mountain mass [North Mountain] sinks from view, excepting an isolated knob here or there, of the harder rocks, which for a short distance serve to mark the irregular progress of the fault. At length, the dislocation attains what may be called its maximum intensity; the slate, and not infrequently, the limestone of the valley, resting in an inverted attitude, with a gentle southward dip, directly upon the southeasterly dipping grits and shales of the formation next beneath the Carboniferous limestone here constituting the southeastern slope of the Brushy Mountain. The seam of semi-bituminous coal [Merrimac coal bed], generally embraced between these strata is, in virtue of the dislocation, made to assume the anomalous condition of passing under the valley limestone at a distance of only a few hundred feet, dipping in the same direction with that rock."

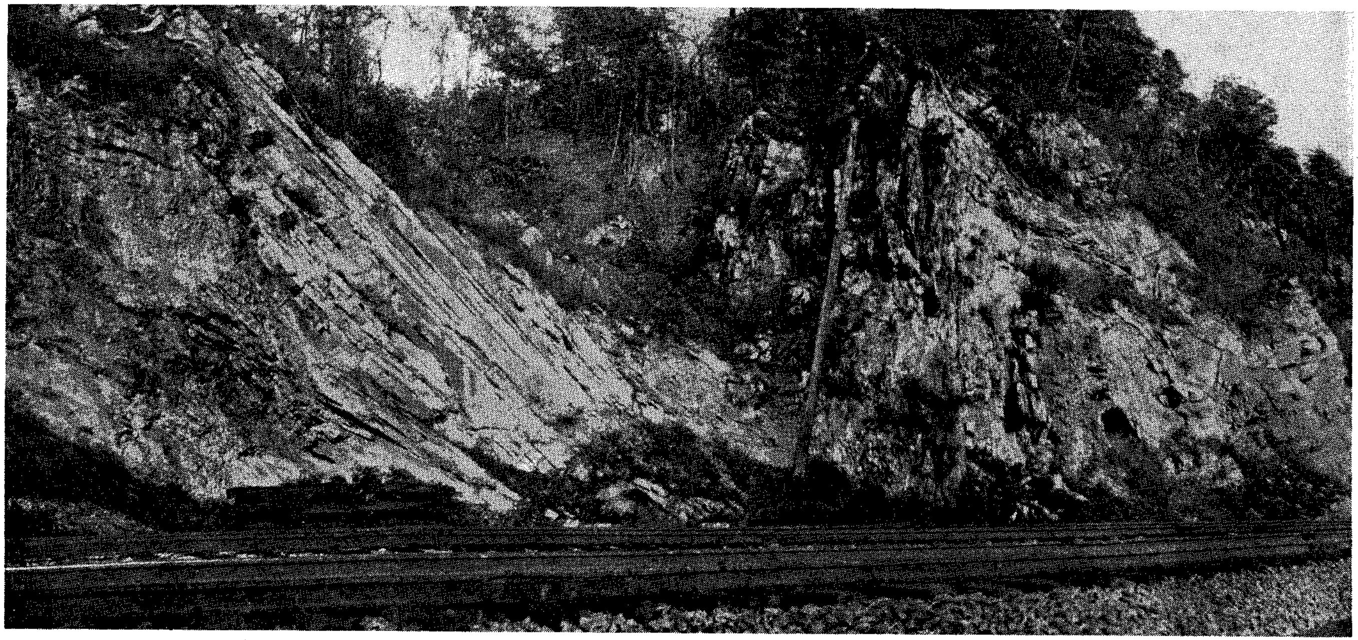
Here it is clearly stated that the coal bed on the south side of Brushy Mountain passes beneath the limestone to the southeast, though it is clear that this limestone normally belongs many thousands of feet below the coal bed. In this quotation they make the statement that the limestone is inverted or overturned. There is no basis for such a statement, for almost invariably the lowest or oldest part of the limestone is to be found at or near its northwestern edge.

Although great credit must be given to the Rogers brothers for their powers of observation and their keenness in interpreting what they saw, still they failed completely to grasp the mechanics of the problem in hand. That failure may not be surprising when we consider that the problems presented to them for solution were new to science and also that the magnitude of the forces involved and the results accomplished seem to be beyond the comprehension of man. Nevertheless, the principles of mechanics do not recognize any mass of material too large or any force too great for them to apply.

The summing up of their conclusions as to the manner in which the folds and faults, that they had so wonderfully described, were produced is most interesting. It is as follows (p. 508):

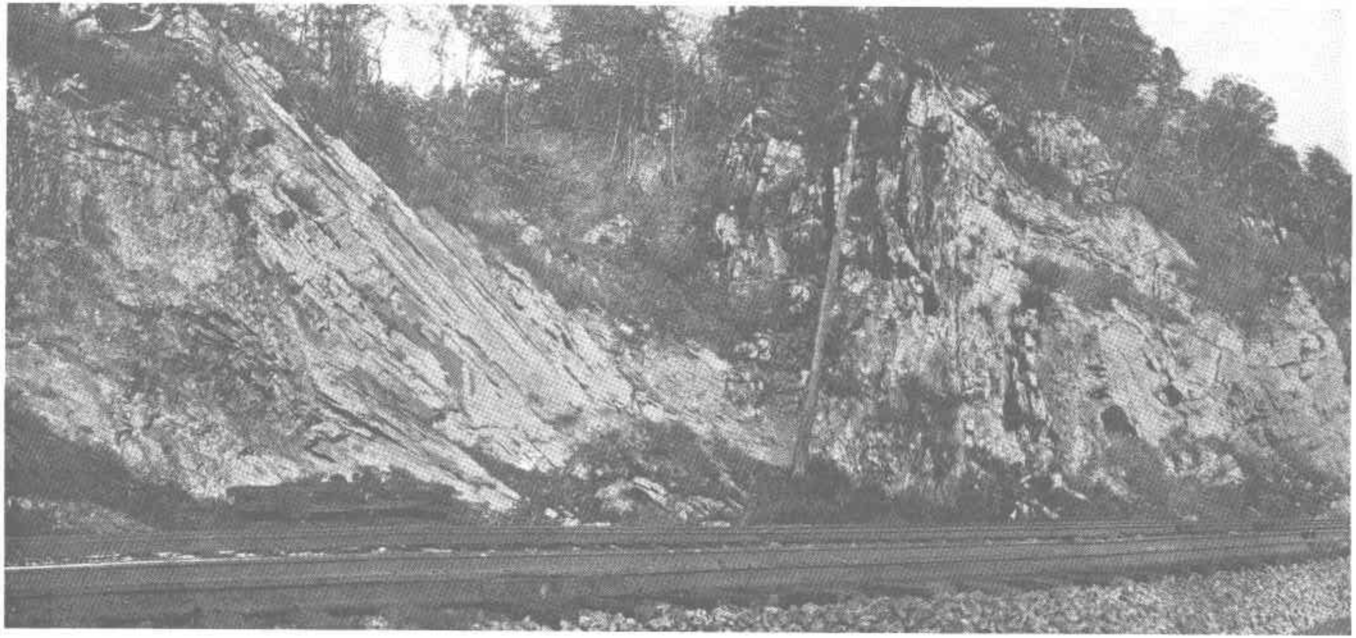
> "That the wave-like flexures of our Appalachian strata are the result of an actual onward, billowy movement, proceeding from beneath, and not of a folding due simply to some great horizontal or lateral compression, will appear from the following considerations. In the first place, it is absolutely impossible to conceive that any force, of an intensity however vast, exerted in the direction of a tangent to the earth's surface, could by itself shove a thick and imperfectly flexible crust into a system of close alternate folds. Beyond the imperceptible bulging of the whole tract laterally from the line of application of the force, no flexure could arise other, perhaps, than some diminutive, but irregular plications, caused by inequalities in the strata or crust, and these, it is needless to remark, would be destitute of any law of parallelism and gradation, such as that which strikingly characterizes the Appalachian and other regions. No system of narrow waves of the strata, however flat, could originate from the most enormous lateral pressure, if unaccompanied by some vertical oscillation, producing parallel lines of every flexure. Precisely such an alternate movement would ensue, if a succession of actual waves on the surface of the subterranean fluid rock rolled in a given direction beneath the bending crust."

Thus we see that the great stumbling block in the pathway of all of the early geologists was to account for the succession of parallel folds that had been produced in the Appalachian region. As stated by the Rogers brothers, it seemed inconceivable that such folds could have been



Folded Shenandoah limestone on New River below Peppers Ferry.

Photograph by Marius R. Campbell.



Folded Shenandoah limestone on New River below Peppers Ferry.

Photograph by Marius R. Campbell.

produced by tangential pressure and that it was necessary to appeal to waves on a molten mass below the rocks that were folded.

With the publication in 1858 of H. D. Rogers' final report embracing the results of the First Geological Survey of Pennsylvania, what may be regarded as the first stage in the investigation of the geology of the Appalachian region came to a close, but with hardly more than a beginning made on the problem of the mechanics of Appalachian structure. It is true that Hitchcock's field was limited and it is not surprising that he failed to solve the problem, but the territory studied by the Rogers brothers was almost unlimited and certainly embraced all of the structures that are now considered typical, from the faulted shingle-blocks of the southern part of Virginia to the open and largely unfaulted folds of Pennsylvania.

The correct explanation of the method of formation of overturned rock folds and the development of overthrust faults from the breaking of these folds under strong tangential pressure, was made by James M. Safford, State Geologist of Tennessee. In his report on the "Geology of Tennessee," published in 1869, he offers the following explanation of the peculiar geologic structure of East Tennessee (p. 167):

> "The formations of East Tennessee were originally horizontal. If now we suppose a vast force to be applied along the southeastern edge of these horizontal formations, and to act in a northwesterly direction, the strata, if not able to resist, would yield and rise up, like thick cloth, in great wrinkles or folds, or else, lacking the proper degree of flexibility, would break along lines of least resistance, in long parallel bands or ribbons which would be crowded together, the edges of one overlapping the adjacent edge of the other."

This was a great advance over anything that had preceded it and gave geologists a rational explanation of the phenomena before them.

The next great forward step in the interpretation of Appalachian geologic structure was the recognition that in many places the development of faults was much more complicated than Safford had supposed and the result was very different from "the edge of one [band or ribbon] overlapping the adjacent edge of the other." It remained for C. W. Hayes,[1] of the United States Geological Survey, to show that the movement on some fault planes had been much greater than was formerly supposed and that the formations in contact with the overthrust mass

[1] The overthrust faults of the Southern Appalachian, Bull. Geol. Soc. Am., vol. 2, pp. 141-154, 1891.

would depend largely upon whether or not there had been preliminary folding and erosion before the faulting occurred. Hayes' opening sentence is as follows:

> "Through the work of the Rogers brothers in Pennsylvania and Virginia and of Safford in Tennessee, the characteristic forms of Appalachian structure have long been familiar to geologists. The unsymmetrical fold has been recognized as the normal structural form through Pennsylvania, Maryland, and a portion of Virginia. In East Tennessee the reversed fault,[1] transverse to the steep limb of the anticline, becomes common. Recent study in the Southern Appalachians has shown a modification of these well recognized types, namely, broad overthrust faults which, as developed in northwestern Georgia are comparable in magnitude with those of the Scottish Highlands and the Rocky Mountains, as described by Geikie and McConnell."

The appearance of Hayes' paper opened a new era in the study of structural geology in the Appalachians and showed clearly that broad overthrust faults might logically be expected wherever the rocks have been severely compressed and the conditions such that rock folds were produced. Hayes also showed in this paper that frequently compression subsequent to the great overthrust will fold both the overriding and the overriden rocks into an apparently conformable sequence which is very difficult to interpret in a correct manner. Geologists working in the Appalachian regions since 1891 have found that most of the faults are of the overthrust variety and that here and there conditions have been favorable for the development of overthrusts up to 8 or 10 miles in extent and possibly much more, if the exact location of the original break could be determined.

The last important contribution to the theoretical study of Appalachian structure was the formulation in 1893 by Bailey Willis[2] of the principle of competent and incompetent strata and structures as follows (p. 250):

> "If we describe the sufficiently firm stratum by the word competent, we may formulate the law of anticlinal development, as deduced from these experiments, as follows: In strata under load an anticline arises along a line of initial dip, when a thrust, sufficiently powerful to raise

[1] The term "reversed" fault was used by Hayes to apply to a fault in which the "hade" or dip of the fault plane is not toward the downthrown side as it is in a normal fault. A reversed fault is an overthrust fault.

[2] The mechanics of Appalachian structure. Thirteenth annual report of the United States Geological Survey, pp. 211-281, 1893.

the load, is transmitted by a competent stratum. The resulting anticline supports the load as an arch, and being adequate to that duty it may be called a competent structure. From the conditions of the case it follows that none other than a competent structure can develop by bending. If the thrust be not powerful enough to raise the load there will be no uplift; or if the layers be so plastic that they yield to the thrust by swelling, then the principal result of deformation is change of form other than by simple flexure, and it assumes some phase of flowing. This is incompetent structure."

Application of the principles to local structures.

GENERAL STATEMENT.

From the historical account just given it is apparent that most of the broad features characteristic of the Valley coal fields have been worked out and now it remains to be seen whether or not the seemingly abnormal features of this local district can be explained in a manner which shall make them accord with the principles just enumerated. Before that is undertaken, however, it seems desirable to review briefly the previous structural work that has been done and the statements that have been made regarding the geologic structure of the Valley coal fields of Montgomery, Pulaski, and Wythe counties.

STRUCTURAL WORK PRIOR TO THE PRESENT EXAMINATION.

The first geological report dealing with the coal or the structure of the coal fields of this region was that of William B. Rogers, published in 1838 or 1839. As State Geologist he was expected to cover all the territory embraced in what is now Virginia and West Virginia, and necessarily with such a large region to examine, his work partook largely of the nature of a rapid reconnaissance. He, however, mentions the various fields described later in this report, but he confined his attention largely to the coal itself and so has left little information on the geologic structure of this most interesting region. His main contribution was the correct determination of the relation of the Shenandoah limestone to the coal bed on the south slope of Brushy and Little Walker mountains. In his report for 1838 and also in the joint paper of the Rogers brothers, already referred to on page 58, he states clearly that the coal bed dips beneath the limestone which he regarded as having been faulted over the coal (see statement on page 59). This was a very important generalization, but it seems to have been ignored or forgotten by most of those who have been interested in this coal field. Rogers mentions the Price Mountain field, but he makes no attempt to interpret its structure.

The next report with which the writers are familiar is that by J. P. Lesley,[1] published in 1862. He described the coal fields of Montgomery County, giving one page of cross-sections covering most of the important geologic structures of the region. Some parts of his interpretations are very good indeed, but he had no conception of overthrust faults, and so all of the faults of the region are represented as being nearly vertical and as cutting the coal beds and other rocks obliquely as they descend below the surface. The Price Mountain coal field is shown as a wedge-shaped block of Carboniferous sandstone and shale, of anticlinal structure, lying between larger masses of the Shenandoah limestone.

The next report of this region, that is available, is that of Professor William M. Fontaine,[2] published in 1877. This paper deals with all of the areas of Mississippian coal-bearing rocks in the two states of Virginia and West Virginia. On account of the large size of the field covered, little detailed information is given on the structure. The following quotations from Professor Fontaine's paper, however, show that he had essentially the same ideas regarding the structure of the Montgomery County fields as that expressed by Lesley in 1862, despite the fact that in the interim between the appearance of Lesley's and Fontaine's papers Safford had clearly stated what is now universally regarded as the true theory of the mode of development of Appalachian structures. Fontaine's statements are as follows:

> "The structure of this field which bears the name of Price Mountain, is one of the most curious products of the force which has produced the numerous faults in this region. It is a belt, with an anticlinal structure, about 7 miles long, and 2½ miles wide, running nearly east and west." (p. 117).

> "In this portion [the highest part of Price Mountain] the coals are worked. Here we find the red marlites [Maccrady shale] forming the outer band on each side of the ridge, and cut off abruptly north and south by the Lower Silurian limestone, which also sweeps around the eastern end. . . . The field seems to be a prism of Vespertine strata, engulfed by a double fault in the limestone. . . ." (p. 118).

[1] Coal formations of southern Virginia: Proc. Am Phil. Soc., vol 9, pp. 30-38, 1862.

[2] Notes on the Vespertine strata of Virginia and West Virginia: Am. Jour. Sci., 3d ser., vol. 13, pp. 37-48 and 115-123, 1877.

The next contribution to the subject was made by the senior author [1] in 1894 when he published some of the results of a reconnaissance examination of the Dublin quadrangle in 1893. The full results of this work were, on account of the inadequacy of the base map, never published. Although at that time the author had comparatively little experience in geologic mapping and the interpretation of complicated structures, he had had the advantage of two years association with C. W. Hayes and had assisted in working out some of the details of the broad overthrust faults which Hayes had so graphically portrayed in his paper of 1891, already referred to.

In his work along New River the senior author was greatly impressed with the apparently anomalous relations of the various formations which lie between the ridges of Cambrian quartzite on the southeast and Brushy Mountain, composed of coal-bearing rocks of Mississippian age, on the northwest,—relations which involve the exposure of young Paleozoic formations in isolated masses, completely surrounded by the Shenandoah limestone. The contact and attitude of this limestone on the southeast side of a mass of younger rocks he readily understood, as that is the constant relation and attitude of formations along an overthrust fault of the Appalachian type. At that time faults of this type had just been recognized as the dominant ones in Appalachian structure and the senior author was thoroughly familiar with some of their vagaries, but he was not aware that similar relations on the northwest side of a mass of younger rocks could also be explained by the same type of fault. Its possibility, however, was considered, but the author could not bring himself to accept such an apparently far-fetched explanation, any more than he could accept the theory of block faulting to account for this apparently anomalous relation, hence he was forced to the conclusion that the anticlines of Mississippian or Devonian rocks merely rested on the surface of the Shenandoah limestones in unconformable contact, due to their deposition on the limestone after it had been raised and denuded by erosion, and this view was published in the paper cited above.

It seldoms happens that after a lapse of 30 years a geologist has an opportunity to correct the errors of his youth, but such is the present case and the senior author takes this opportunity to publicly acknowlthe error of his previous explanation and, to correct, as far as possible, the false impression conveyed by it.

[1] Paleozoic overlaps in Montgomery and Pulaski counties, Virginia, Bull. Geol. Soc. Am., vol. 5, pp. 171-190, 1894.

No other description of the geologic structure of this region has been published, but several geologists have been familiar with the facts for a long time and have recognized that the correct explanation has not yet been offered. The junior author for a number of years had been carrying on desultory studies of the structure and stratigraphy of the Price Mountain coal field in connection with his studies as Professor of Geology at the Virginia Polytechnic Institute at Blacksburg, and he had become convinced that the fault which surrounds Price Mountain and which separates the coal-bearing rocks from the conformably overlying Shenandoah limestone is the same as the fault showing similar geologic relations at the south foot of Brushy Mountain, some 4 miles to the north, and that the structure of Price Mountain is that of a fenster, as stated on a previous page. Also Mr. Heath M. Robinson, one of the junior author's students, had found and described a similar fenster just above Peppers Ferry on New River, but Robinson's description and conclusions have not been published.

The object of the present chapter is to bring together all of the known related facts that have a bearing on the structure of these fields; to consider the facts carefully in order to determine the manner in which the faulting took place; to discuss briefly the mechanics involved in the movement; and lastly to point out some of the possible consequences of such a fault on the position of coal beds, on their geographic distribution, and the manner in which they can best be exploited, and also, in a brief way, on the influence such faults have had on the deposition of ore in workable deposits.

THEORETICAL CONSIDERATIONS.

One object of this paper is to show that the Pulaski fault throughout the course mentioned on pages 43-44 and 76-77 is a single broad overthrust; that the minimum amount of movement on the plane of this fault, as measured from the position of the fault south of Draper Mountain to the foot of Little Walker Mountain is 9 miles; and that three fensters, Price Mountain, East Radford, and Berringer Mountain, previously described, are merely parts of the formations underlying this fault plane that have been exposed by holes cut by erosion in the overthrust limestone mass.

In order to prove the points specified above it will be necessary first to consider, as briefly as possible, the mode of formation of overthrust faults and then see if the development of a fault of this character could under certain conditions have led to the production of such features as the fensters.

All geologists are agreed that Appalachian structure is the result of compressive forces acting horizontally toward one another from opposite sides of a given region or that the force has acted from one side only and movement toward the other side has been resisted by a great mass of horizontal rocks that have served as a buttress. It is at once manifest that the resultant structure will depend largely upon the composition of the material and upon the way such material behaves under strong compressive stresses.

We shall assume, therefore, that the blocks A and B, Fig. 10, represent two conditions of the earth's crust: A, where it is composed of heterogeneous rocks, or rocks so deformed and intimately folded that under pressure they behave practically the same as homogeneous rocks (see Pl. XI B); and B, where the rocks are flat-lying and very resistant to compressive stresses acting in a horizontal direction. If these blocks are held firmly in position by boxes having rigid bases, side walls, and ends on the left, and pressure is applied at *a* and *b* on the right, the blocks, because of the rigid walls of the boxes, can not find relief by movement either downward or to the left; consequently, the only direction in which relief can be obtained is upward. On account of this direction of relief the forces represented by the arrows may be considered as made up of a horizontal component *c e* and *f h* and a vertical component *e d* and *h g*. The result of the resolution of the forces into these two components is a tendency to move along the diagonals *c d* and *f g*. The results of such a change in the direction of the thrusts will depend largely upon the character and arrangement of the materials composing blocks A and B. In block A, composed of homogeneous or intimately folded non-resistant rocks, the tendency of a strong force applied at the point *a* will be to shear the block along the line *c d*, but in block B, composed of very resistant rocks in a horizontal position, the force *f g* would rarely, if ever, result in shearing, because it is applied to the rocks in almost the

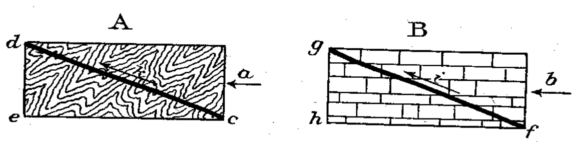


Fig. 10.—Diagram showing effect of stresses on (A) incompetent and (B) competent strata.

direction of their greatest strength, and consequently, if the pressure is intense enough, they will be deformed in some other way rather than be sheared at a low angle to their bedding planes.

If horizontal stresses develop in the crust of the earth similar results may be expected. If the rocks are practically homogeneous a horizontal thrust may result in slicing directly through the rock mass and in the thrusting of the block thus cut off far out of its normal position, but if the rocks are flat-lying, homogeneous, and fairly resistant, then slicing will not take place and the results of the thrust will be manifest in other forms of distortion or displacement.

Overthrust faults produced directly without the intervention of rock folds have been described in the Scottish Highlands and it is probable that some of the faults of the Blue Ridge and the Piedmont provinces of the United States may have been formed in a similar manner. This method of the production of overthrust faults does not, however, seem to apply to the Valley coal fields of Virginia because: (1) the rocks involved in the faulting are not homogeneous, and (2) there are abundant evidences of the formation of folds in conjunction with or but little preceding the formation of the overthrust faults. Because of the apparent inapplicability of this method of fault production, it seems desirable to test other methods to see if they have not a more direct bearing on the case in hand.

If the block to be experimented with is composed of horizontal layers of hard and soft materials as shown in A, Fig. 11, then the effect of compression will be to cause the layers to bow upward as shown in block B. In this upward bowing, however, the thrust will not be transmitted to the same extent by all layers composing the block, for some layers, being hard and resistant, are capable of transmitting the thrust and of supporting themselves as well as a load of superincumbent strata, whereas other beds are incapable of transmitting a thrust, but are deformed by it and the materials composing such beds flow under pressure into every available space. The rocks represented in the block in Fig. 11 simulate the strata involved in the folds of the Valley coal fields, for the formations

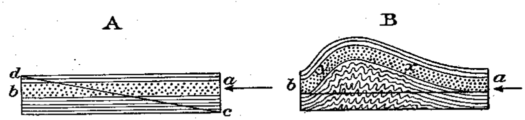


Fig. 11.—Diagram showing the development of an anticline in a compentent stratum under intense horizontal pressure.

are heterogeneous in character, some soft and yielding and some hard and resistant. The harder and thicker formations are generally competent to transmit a thrust without bending and therefore are generally called "competent formations" or "competent strata" and the soft members, "incompetent strata."

If a horizontal thrust is applied to the block A at the point *a* the horizontal force will be deflected as shown in Fig. 11 to the line *c d* and this upward thrust will tend to lift the competent stratum *a b* into an arch, the incompetent strata below flowing into the space produced by the upward bowing of the competent stratum. As a consequence of the upward deflection of the horizontal thrust, the arch formed of the competent stratum *a b* is generally developed as an unsymmetrical fold with the longer limb on the side from which the force acts. As the limb *x* is nearly in the line of the deflected force it is manifest that further application of the force at the point *a* in block B will result in the movement of the nearly straight limb *x* in the direction of the bedding accentuating the lack of symmetry of the fold and causing the limb *y* to be rotated more and more to the left. At some point in this rotation the thrust will act at right angles to the limb *y* and at that point the rocks will probably break and a fault will be the result. If the thrust continues the limb *x* will override the limb *y* and an overthrust fault is produced.

As the conditions assumed in this theoretical case are fairly comparable with the conditions found in the Valley coal fields, it seems reasonable to suppose that similar results were produced when the rocks of this region were folded as they must have been in the geologic past.

Let us assume, therefore, that section A in Fig. 12 represents the rocks as they were originally laid down in the Valley coal fields. As they were in general deposited in the sea it is safe to conclude that they were approximately horizontal, and so they are represented in section A. We will then suppose that these rocks are subject to a strong thrust from the right (southeast) at *b* and that this thrust affects the various layers of rock differently, depending upon their competency to transmit the thrust. The layer *a b* may be assumed to represent the Shenandoah limestone, the most nearly competent formation that is involved in the folds of this region. The thrust (represented by the arrow) directed against the Shenandoah limestone (layer *a b*) will cause this competent stratum to rise in an arch and the magnitude of this arch will depend upon the competency of the stratum.

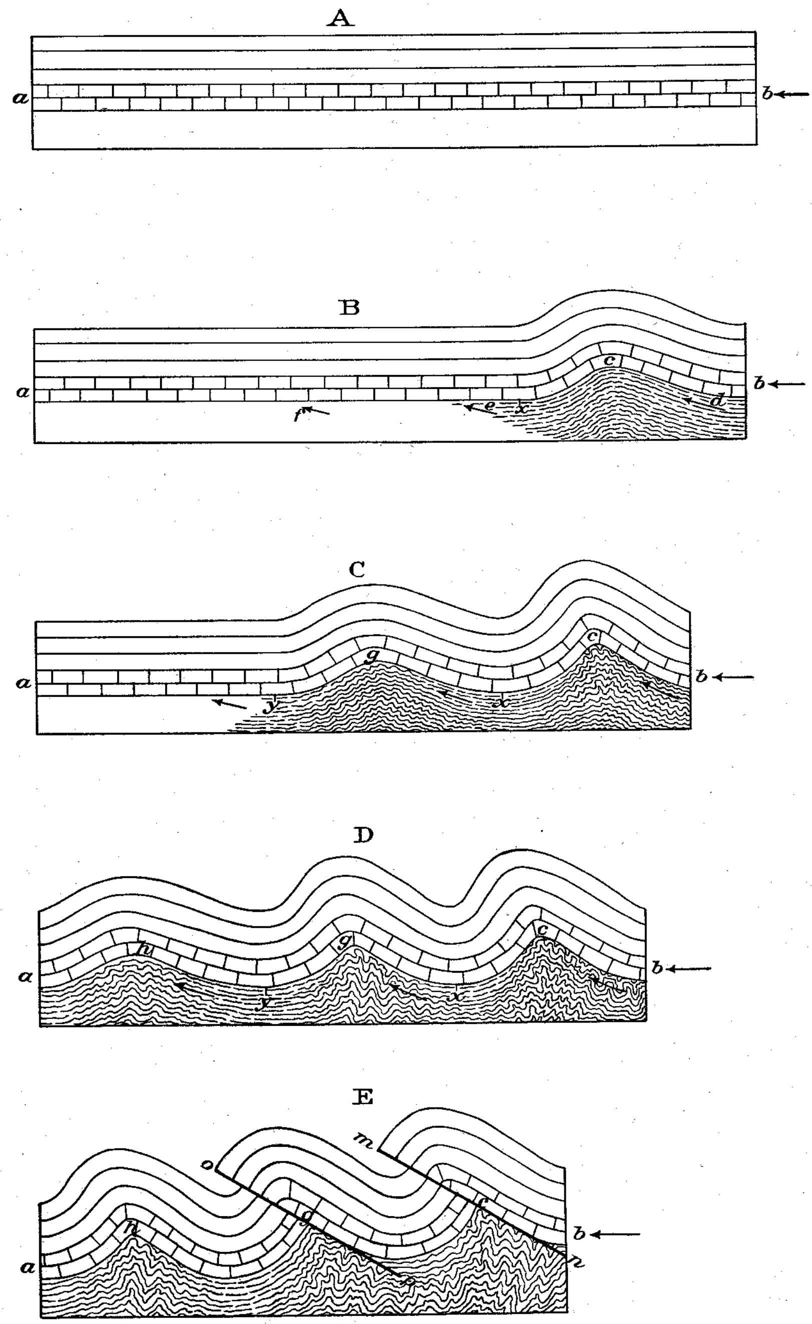


Fig. 12.—Block diagrams showing the progressive development of folds and shingle-blocks in competent and incompetent strata.

Some may question the statement made above that compressive stresses will always tend to cause competent strata to bulge upward and form an arch. Some geologists have argued that the phenomenon of overthrust faults in the Appalachian region could as readily be explained by underthrusting from the northwest as by overthrusting from the southeast. Underthrusting would involve down-folding as the initial movement and this the authors are unwilling to admit ever occurs, except possibly on a very small scale where a void is produced by the rising of some competent stratum. When strong tangential pressure is applied to rocks, the tendency is for them to move along the line of least resistance, which certainly is not downward, for in that direction the rocks are under much stronger gravitational pressure than are those nearer to or at the surface. Underthrusting, as the authors understand that term, could not possibly happen, because it would mean movement not in the direction of least resistance, but in the direction of greater difficulties and this will not happen, for the laws of mechanics are inexorable. The only place where such a movement might take place is in the readjustment of a non-competent stratum under an arch formed by a competent stratum. In such a place the rocks would be to a large extent relieved from pressure and they would be free to move in whatever direction involved the least resistance, but such movements would be small and of little consequence beside the great movements of arching and overthrusting.

We shall then proceed upon the proposition that the competent strata will always move upward under strong tangential pressure. If the competent stratum *a b* is very resistant then the arch will be wide and it will rise to a similar height, but if the layer is not so resistant, the arch will be narrower and the height will be less. We shall assume, therefore, that the thrust is able to raise the layer *a b* in an arch whose original width is *x b* (Sect. B). As the arch *x c b* rises, its weight will more and more rest upon the points *x* and *b* and consequently these points will not rise no matter how great the pressure may be.

Most of the force exerted at *b* is consumed in raising the arch *x c b*, but some of it is transmitted to the resistant layer to the left of the point *x*. Not only is the thrust transmitted through the competent layer *a b* to the left of the point *x*, but it is also transmitted through the incompetent layer below *a b*, for notwithstanding the fact that this layer when free to move is totally incompetent to transmit the thrust, when confined, as it is under the stratum *a b* it acts as a rigid body and transmits some of the thrust to the left of the point *x*. As all of these forces are deflected upward there is a constant pressure upward on the layer *a b* throughout the entire block but at the point *x* this is more than counteracted by the weight of the strata bearing on this point. As the arch *x c b* grows in height, the block is shortened and more and more of the force transmitted through the incompetent rocks below the layer *a b* and so there is constantly a growing tendency to form another arch to the left of the one originally produced.

This point has been neglected by those who have attempted to explain the mechanics of Appalachian structure. They have found it easy to account for the formation of one fold, but they have offered no rational explanation of how other and parallel folds were produced. In the laboratory experiments which have been carried on from time to time to duplicate Appalachian structure, efforts have been made to produce more than one fold, but in all cases known to the writers the effort has been unsuccessful. Increased pressure has piled up the initial fold to a great height, but it has not led to the formation of even a second fold, not to mention the many parallel folds that characterize certain parts of the Appalachian region. The reason for this failure, as seen by the writers, is that all models rest upon a rigid base which is not in any way connected with the model and does not transmit any of the thrust. In nature there is no such rigid base; the competent rocks involved in the folding rest upon a great mass of incompetent rocks which nevertheless do transmit much of the thrust, because they are confined and are compelled to transmit that portion of the thrust which is not consumed in their intimate deformation and recrystallization. No theory concerning the formation of Appalachian structure is correct unless it will account for the formation of more than one longitudinal fold, either contemporaneously or in a later epoch of folding. The writers have considered the possibility of the formation of succeeding folds at a later date than the initial fold, but they must confess that they are unable to account for their formation in that manner. They have assumed, therefore, that the parallel folds at least of a single group were produced practically at the same time.

In resuming the consideration of the stresses that act in block B, Fig. 12, it will be seen from the diagram that most of the force is exerted in the formation of the initial fold *c*, as represented by the arrow *d*, but that there are other stresses which are transmitted to the left through the incompetent material underlying the competent layer *a b* and that these stresses act in an upward direction but distinctly inclined toward the left. These are represented by the arrows *e* and *f*. As a large part of the weight of the rising fold *x c b* is borne by the competent layer at the point *x*, the friction of the competent layer upon the underlying incompetent material tends to transmit the thrust *e* from the incompetent to the competent layer and consequently this force acts at the point *x* in much the same fashion that the original thrust acted at the point *b*, with the result that there is a tendency to the left of the point *x* to form another fold which, as it is supported by the same competent stratum, *a b* will be of the same proportions as the fold *c*. The result of this tendency to lift the competent stratum to the left of the point *x* is, on the further application of the force, the production of the fold *g* which in form will be similar to the fold *c*, except that it will probably be lower in altitude.

As a consequence of the greater and greater development of the folds *c* and *g*, more and more of the weight of the fold comes upon the points *x* and *y* and as a result more and more of the original thrust is transmitted to the unfolded portion of the competent stratum and this results in the formation of a new fold *h* (Sect. C) to the left. If the folds *c* and *g* are developed to such an extent that they break and produce an overthrust fault, it might be supposed that the mere matter of breaking would relieve the pressure to such an extent that little, if any of the thrust would be transmitted to the unfolded rocks on the left, such is not necessarily the case, for with the increased thickening of the material above the competent stratum comes a great increase in the friction on the rocks beneath and this increase in friction is a very material help in transmitting the thrust into the unfolded rocks; also, as the faulting does not relieve the incompetent mass below the stratum *a b* the stress which at the surface results in great overthrust faults will, at a depth, be transmitted beyond the fold *g* and will be largely instrumental in producing the fold *h*. It seems quite probable, however, that in certain cases where the strata involved include a bed of great competency, the entire thrust may be taken up in the development of a single fold and the overturned fault which is the result of its breaking.

In section D the thrust has proceeded to such an extent that three folds, *e*, *g*, and *h* have been produced, all of the same general pattern, but the one at the right which received the most direct thrust is the largest and the others decrease in magnitude gradually to the left. Each fold is unsymmetrical in cross section and should the pressure be continued in the same direction would be liable to break on the steeper side where the thrust operates at right angles to the bedding of the strata. In section E breaks *mn* and *op* are represented as having occurred in the two folds *c* and *g*, but the fold *h* has not yet reached the breaking point. In the folds *c* and *g*, the rocks have not only broken but the right-hand limb of the fold *c* has been thrust over and upon the right-hand limb of the fold *g* and this in turn has been thrust upon the fold *h*. In the process of breaking and overriding the left limb of each fold has practically disappeared, having been stretched, crushed, and sheared off so that the remaining portion is scarcely recognizable. In places in the Appalachians the senior author has observed broken and disordered blocks of formations on an overthrust fault plane and he is thoroughly satisfied that these blocks are fragments of the overturned and crushed limb of the underlying syncline. Usually, however, the limb is so badly crushed as to be unrecognizable. In this form the folds lose their character as folds and become merely a series of blocks with curved ends which are so disposed that the one on the right or on the southeast in the field is thrust upon the next one to the northwest, and in this form they are what on a previous page were denominated "shingle-blocks." The typical form of such blocks is shown in Fig. 2.

Manifestly the case shown in Fig. 12 is the simplest that can be imagined, but in nature it is unlikely that such simple cases have occurred in many places or in many epochs of the past. It is probably impossible for any geologist to grasp all of the variable factors that may enter into such a problem and materially affect the geologic structure produced, but it is comparatively easy to visualize a few of the conditions that apparently have had an effect on past crustal movements.

The condition that has probably had the greatest effect, because it is more likely to have been present in all cases of folding of the rock formations, is that of variability in composition of the individual members and the consequent variability in the competency of those formations in transmitting a thrust. It is seemingly impossible to evaluate this condition and make due allowance for its effect, unless the change in the character of a given formation is so great as to change completely the competency of the mass of sedimentary rocks involved in the movement.

Another condition that appears to have been present in several parts of the Appalachian region during the time when folding was in progress, is the presence in certain areas of masses of rock that seem to have been stationary and immovable,—buttresses against which the rock folds have been crushed and obliterated as completely as waves of the ocean crash

Block of semianthracite with mineral charcoal on bedding plane.

Block of semianthracite with mineral charcoal on bedding plane.

against a rocky shore and are destroyed by the impact. Why these masses of rocks should have been thus immovable is one of the problems that at the present time is seemingly unsolvable.

Other complications, though the authors find difficulty in evaluating them, doubtless occur when periods of great stress are separated by long periods of quiescence. Recent studies in regions frequently subjected to earthquakes have shown that in such regions the crust of the earth is under stress all the time. These stresses generally accumulate in zones of weakness until they reach the elastic limit of the rocks and then a break and a slip occur. The movement tends to relieve the pressure for a time, but eventually it accumulates again until it finds relief by another break in the same or a different place.

During the period of folding in the Appalachians it is probable that the deformation which we see to-day was accomplished in much the same manner, by a series of impulses rather than by one great movement. If this theory is correct, then it is safe to assume that shingle-blocks such as are represented in section E, Fig. 12 or Fig. 2, may have after a long period been subjected to a second compression, and in this second period they may have behaved very differently from what they did in the epoch of original compression and deformation. If such an epoch of movement occurs after a broad overthrust has occurred, the plane of the fault will doubtless be folded, the magnitude of the folds depending upon the intensity of the pressure applied in the second epoch, and the resulting structures will be similar to the fensters described on New River. At present this can be presented merely as a suggestion, but if the suggestion is true, and the authors are fully convinced that all of the folding and faulting of the rocks of the Appalachian region did not take place in one epoch, but has been repeated, possibly many times, may be responsible for many of the hitherto unexplained complications in the geologic structure.

In certain cases, it seems probable that the thrust from the southeast in a certain given epoch has, on account of some condition not now understood, resulted in the production of one gigantic anticline, strongly resembling some that Bailey Willis[1] produced experimentally in 1893. When such a fold broke, the resulting fault was extensive, for in reality all of the pressure which, in other localities was distributed in the production of several folds and their resulting overthrusts faults, was concentrated in

[1] Op. cit.

one fold and one fault of extraordinary great magnitude. Such, the authors believe to have been the origin of broad overthrust faults, such as were described by Hayes[1] and also such as the Pulaski fault herein described. The production of normal faults, or faults due alone to tension, in a region that in general has been subjected only to compressive stresses, is one of the seeming anomalies of this region. The formation of normal faults under such conditions is not remarkable, however, when one considers the stresses that are produced by the thrusting of a great mass of rock thousands of feet thick over other rocks of different composition and competency. As the overthrust mass is more or less competent it probably does not rest upon all parts of the overridden mass and consequently those parts are subject to very severe torsional stresses resulting from the drag of the overthrust mass. In this manner were probably produced most if not all of the normal faults described in this paper.

Another source of complications in broad overthrust faults is the possibility, if not probability, that the faulting did not occur while the formations were still on the bottom of the sea, nor immediately after they were upraised into dry land, but that it occurred very much later, after erosion had had an opportunity to remove the rocks irregularly after they had been converted into dry land, or possibly after they had been seriously disturbed in a previous epoch of deformation. Geologists are much divided in their opinions on the question of possible erosion before faulting, some holding that all the deformation in the Appalachian region occurred in one great convulsion, while others are of the opinion that the Appalachian "revolution" was a long-drawn-out affair and that it probably consisted of a number of epochs of folding and faulting, separated by long epochs of erosion.

PULASKI FAULT.

Extent of the fault.—The full extent of the Pulaski fault has not been determined. It has been traced continuously from Pulaski southwestward to the vicinity of Timberridge, a small village 6 miles southwest of Greenville, Tennessee (see fig. 13), where it apparently dies out in an anticline of Knox dolomite which plunges in a southwesterly direction under a similar structure in the Athens shale. In the opposite direction the fault has been traced from Pulaski to a point about 5 miles northwest of Fincastle, Virginia. It extends still farther toward the northeast, but the evidence available at the present time indicates that its termination

[1] Op. cit.

will be found near James River in the vicinity of Eagle Rock. Fig. 13 shows the extent of the Pulaski fault, as it is known at the present time.

The southwestern termination appears to be well established, but the northeastern extremity has not been positively determined and it is possible that the fault may continue beyond the limit shown in Fig. 13.

The Pulaski fault, as outlined in Fig. 13, is about 200 miles in length. As far as length is concerned it can not be regarded as one of the great faults of the Appalachian region, but, as determined by the amount of known and measurable overthrust, it is one of the largest that has been described. There is a general impression among geologists that broad overthrust movement is directly connected with great longitudinal extent, but such is not necessarily the case; in fact the general rule seems to be that the stresses which accumulated in the region to the southeast of the Appalachian Valley were relieved in one place by great movement on a certain fault and in another place by equally great movement on another fault or a distribution of the movement among several faults, no one of which is great enough to be out of the ordinary class. The relation of one of these broad overthrusts to another and their general distribution throughout a large region is shown diagrammatically in Fig. 14, the net result being that the northwestward movement in different parts of the region has been practically the same though distributed throughout a number of faults of varying amount of overthrust. From the statements just made and from the diagram (fig. 14), it must not be inferred that faults are equally abundant in all parts of the Appalachian region, for it is a well-known fact that such is not the case. In the southern part faults are the rule and open folds are the exception, but in the central and northern part of the province, open folds are the rule and faults are the exception. But no matter whether faults are few in number or relatively rare the northwestward movement is fairly evenly distributed among them.

In a general way the faults of the Appalachian Valley province are rudely parallel, but the Pulaski fault proves to be a decided exception, for in places it departs widely from the general trend of the geologic structures characteristic of that part of the province. Fig. 13 shows the Pulaski fault with relation to certain other faults which are associated with it or which come close to or in contact with it in some part of its course. The course of the Pulaski fault, from its southwestern extremity to the vicinity of Abingdon, Virginia, conforms strictly to the general structural features of that region, though it shows no harmony nor relation to the Bland fault which near the State line veers off to the west in its

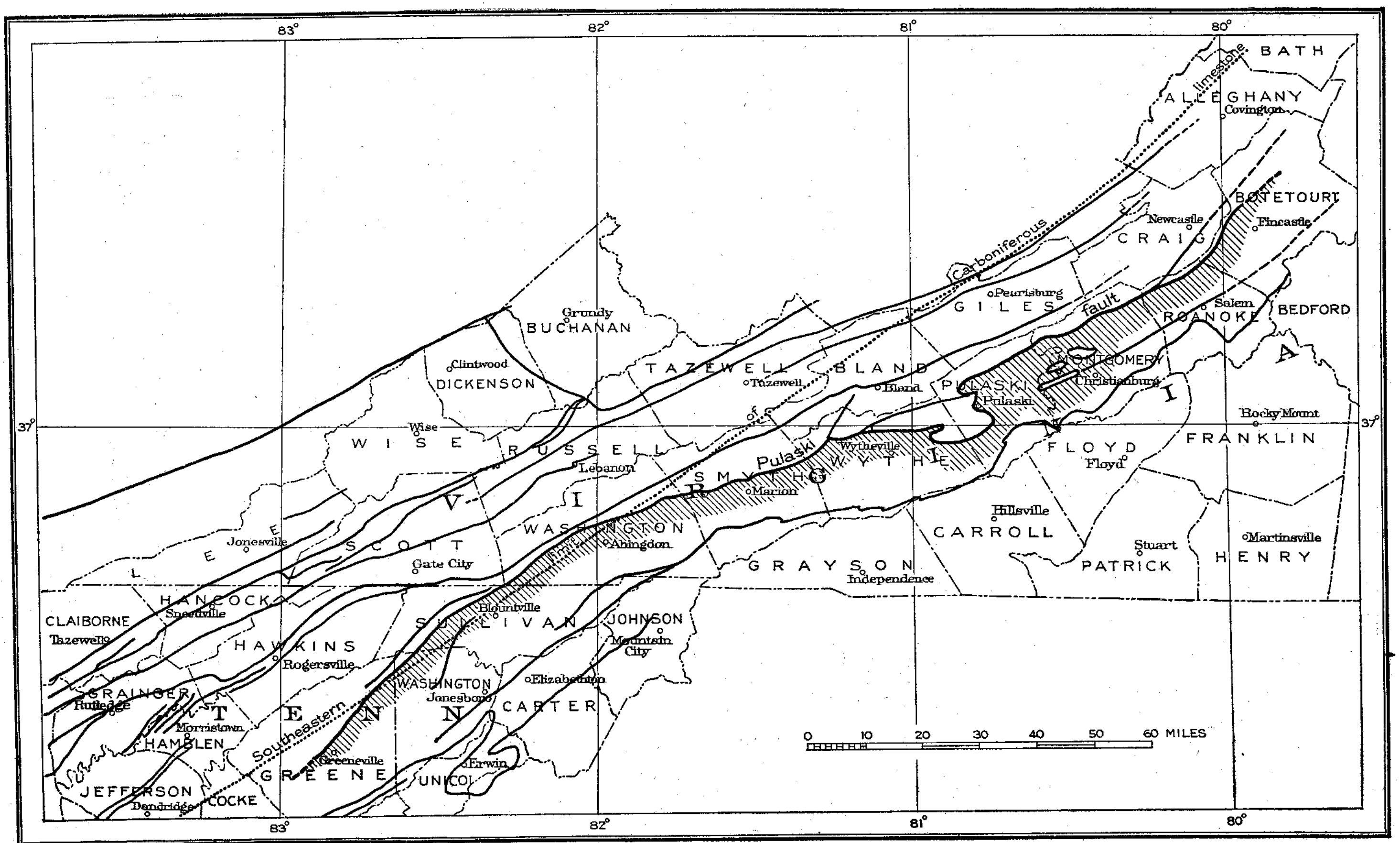


Fig. 13.—Map showing the known extent of the Pulaski fault and also other faults of southwest Virginia and northeast Tennessee.

course into Tennessee. The cause of this great divergence of the two faults is that in Tennessee they lie on opposite sides of a great syncline which apparently was thrust bodily to the northwest and the original relationship of the two faults on opposite sides of the trough is preserved despite the deformation that has taken place in the surrounding rocks.[1]

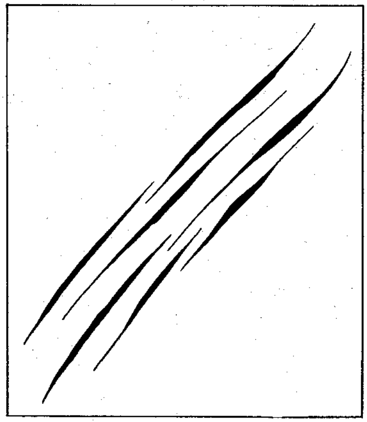


Fig. 14.—En echelon arrangement of the overthrust faults.

Northwest of Abingdon the Pulaski fault trends to the right, away from the Bland fault and in doing so it crosses at a low angle all of the formations making up the Walker Mountain shingle-block. Because of this transgression of the overthrust mass, Walker Mountain makes its first appearance as a low ridge (Chestnut Ridge) nearly due west to Glade Spring. From this small beginning, the mountain increases in magnitude eastward until, on the boundary between Washington and Smyth counties it attains the prominence that it holds generally in the Valley coal fields. Just north of Chilhowie, Brushy Mountain makes its appearance in a similar manner to the south of Walker Mountain.

From this place eastward to the eastern boundary of Montgomery County the course of the Pulaski fault is most irregular, crossing a number of anticlines and synclines, as has been described on previous pages of this report. At the boundary of Montgomery County noted above the Pulaski fault occupies its normal position at the southern foot of Brushy Mountain, but east of the crossing of this line the Pulaski fault bends slightly to the south away from Brushy Mountain which here

[1] Detailed maps of these structures may be found in the Bristol (No. 59), Estillville (No. 12), Greenville (No. 118), and the Morristown (No. 17) folios of the United States Geological Survey.

turns slightly in the opposite direction. At the point where these two structural lines diverge a subordinate fault appears seemingly from beneath the overthrust limestone mass. This fault passes through Millers Cove and because of this fact it is here named the Millers fault. It extends down the valley of Craig Creek and bounds on the northwest a syncline, which because of its broken condition suggests that the entire syncline lying between Millers fault on the north and the Pulaski fault on the south—here called the Craig Creek syncline—has been shoved towards the northwest against the Sinking Creek anticline.

The Pulaski fault, as shown in Fig. 29, extends eastward from the junction of Millers fault, cutting close to the south base of Cove Mountain and badly crushing the Clinch sandstone on the south limb of this syncline between Cove Mountain and McAfee Gap. From McAfee Gap to Stone Coal Gap the southeast limb of the syncline is concealed and the Shenandoah limestone rests upon the Price formation in the middle of the syncline. Northeast of Stone Coal Gap the Clinch sandstone in the upturned limb of the syncline is preserved in Caldwell Mountain, and consequently the Pulaski fault lies somewhere south of this ridge. At North Fork gap, 5 miles northwest of Fincastle, the fault leaves the foot of the mountain and turns slightly to the east where it is lost in the flat floor of the broad valley. It has not been traced farther to the northeast. but it may be expected to terminate in a great overturned anticline on James River. This structure is an irregular anticline of large dimensions overturned to the northwest and pitching to the northeast. On the far side of the river it is about 6 miles wide. Mays Mountain is an erosion remnant of its southeast limb and Rat Hole Mountain, of its northwest limb. In the latter mountain the Clinch and associated sandstones, overturned to the northwest, are duplicated by faulting which occurred before the formation of the great anticline. Ten miles to the northeast there is relatively little folding and faulting. James River in the vicinity of Eagle Rock is, therefore, the dividing line between a region of little overthrusting on the northeast and a region of much overthrusting on the southwest. In view of these conditions the Pulaski fault may be expected to terminate in this region.

Structural relations in the local fields.—By the enumeration of faults along the contact of the Shenandoah limestone and the overriden mass of younger formations and the lack of enumeration of similar faults within the mass of the limestone, the writers do not for a moment wish to be understood as maintaining that the overthrust mass of the Shenandoah limestone, throughout the Valley coal fields here considered, is a unit without a break of any kind. For a mass of rock, such as this must originally have been, thrust many miles out of its normal position, must necessarily have suffered much and it would not be surprising to find it cut by numerous thrust and normal faults by which it adjusted itself to the different conditions that it encountered in different stages of its journey. In addition to the vicissitudes of such a broad thrust, there is ample evidence, as will be shown later, that since the overthrust mass reached its present position, it has again been subjected to compression which wrinkled it and in places may have faulted it in a small way.

In spite, however, of the possible occurrence of faults in the overthrust limestone, the writers believe that they are fully justified in considering the limestone surrounding the projecting point of the upland between Pulaski and Wytheville as a unit and that it reached its present position by the same overthrust movement that affected the rocks from Greensville, Tennessee, to James River, Virginia. Two possible explanations may be offered for the conditions in and surrounding the area referred to above: (1) that the overthrust mass of limestone originally covered the entire area and that because of later uplift, corrugations by folding, and then erosion, the overthrust mass has been largely removed; or (2) that Draper, Cove, and Tract mountain anticlines were formed prior to the overthrust and the limestone never extended much farther over them than it does to-day.

Both explanations suggested in the preceding paragraph present problems that are difficult, if not impossible, to solve at the present time, so it may be that the true explanation should combine the two, applying one explanation to certain parts of the area and the other explanation to other parts of the area. For instance, the Cove anticline and the Crockett fault seemingly must have been developed prior to the overthrust of the Pulaski fault, for it is impossible to conceive of such a fold and fault as having originated and developed under thousands of feet of rock, as they must have done if the Shenandoah limestone was originally thrust as far to the northwest as Little Walker Mountain. Another point in favor of the second explanation is that the Max Meadows syncline, which is bounded on the north by the Crockett anticline and on the south partly by the Draper anticline, has its south limb, as marked by the Clinch sandstone, completely obliterated by the Pulaski fault from Queens

Knob on the west to Max Meadows on the east, and that this same rim is badly overturned and shattered from Max Meadows to the hook in the west end of Draper Mountain north of Graham Forge. As this sandstone rim is either overturned or crushed out of existence by the Pulaski fault, the syncline must have been developed in about its present form before faulting took place. It is evident, therefore, that the Shenandoah limestone overrode this syncline to a certain extent, for it crushed and obliterated its south limb, and left such a mass of limestone across the axis of the syncline that, even to-day, after having been exposed to erosion for untold millions of years, there is, as shown on Pl. 1, a tongue of limestone lying unconformably across the axis of the basin from Max Meadows to Gunton Park, a distance of 5 miles.

One can not but wonder how thick some of these overthrust masses of limestone really are. This can be told only by drilling, and unfortunately very little drilling has been done in this region. It seems quite probable that the tongue of limestone extending from Max Meadows to Gunton Park is not very thick, because it has all the appearance of being only a small remnant of a much larger mass. Several years ago the village of Max Meadows endeavored to obtain a water-supply by drilling wells on Miller Creek. Five or six wells were drilled within the corporation limits, testing the territory from the mouth of the creek northward to the edge of the limestone. In each well, according to report, the base of the limestone was reached at a depth of about 30 feet and sandstone and shale were encountered which are supposed to belong to the formation below the fault. If this report is correct the overthrust mass of limestone is surprisingly thin and in the normal course of events may be cut through by Miller Creek in the course of a few thousand years. On the other hand, it is possible that the sandstone and shale which were found to underlie the limestone in each well are really members of the limestone mass and do not belong to the underlying Devonian system. Unfortunately, the material brought up by the drill was not examined by a competent geologist and as a consequence the records of the wells can be taken only as probably correct, but lacking complete verification.

From the structural relations on the south side of the basin the conclusion is obvious that the Max Meadows syncline and the Crockett anticline were formed prior to the Pulaski overthrust fault, but it is possible that when the Pulaski fault occurred the submerged folds may not have attained the magnitude that they have to-day and that a subsequent thrust increased their proportions.

East of the Locust Hill iron mine the problem of accounting for the different masses of overthrust limestone is much more complicated as the evidence of the overridden folds is much less conclusive than it is farther west, and the presence of large bodies of Shenandoah limestone behind, or on the northwest side of, ridges ranging from 700 to 1,400 feet high seems to call for extensive movement subsequent to the great fault, as it is inconceivable that a mass of rocks several thousand feet in thickness could have been thrust up over ridges and deposited in valleys behind them.

If we assume, as it seems reasonable to do, that the limestone was thrust in a direction at right angles to the general trend of the geologic structure of the region, then the movement must have been approximately along a line that trends N. 22° W. On this assumption the limestone on Beaverdam Creek, northeast of Max Meadows must have come over Hamilton Knob, that stands nearly 1,000 feet above Beaverdam Creek, and the limestone at Pulaski must have come over Peak Creek Knob, nearly 1,400 feet higher than the surface of the limestone is to-day within the corporation limits. An even more striking case is that of the limestone in Tract Fork valley, below the old Altoona coal mine. If this limestone reached its present position by being thrust in a direct line, it must have passed over Peak Creek Knob at a height of 1,200 feet, and over Tract Mountain at a height of 600 feet above the floor upon which the limestone rests to-day in the Tract Fork valley.

The question might arise as to whether or not the writers are justified in assuming that the overthrust mass moved in straight lines at right angles to the general structural lines of the region. This objection has been carefully considered with the result that any other supposition seems untenable. If the overthrust mass behaved as a viscous fluid, then it might be reasonable to assume that under its own pressure the mass would tend to flow laterally and fill spaces that otherwise would be voids, but in the very act of overthrusting, the material was relieved from every confining condition, except the pressure of gravitation and the urge from the rear and it is inconceivable that a combination of these two forces alone would be sufficient to cause the rock mass to behave as it would were it deeply buried beneath the surface of the earth in the "zone of flowage." It is also equally difficult to imagine a mass of rocks thousands of feet in thickness rising 1,000 feet over a narrow serrate ridge and then descending a like distance into a valley.

The conditions and movements which resulted in the engulfing of the thin band of Shenandoah limestone in the Devonian sandstones and shales just north of Draper Mountain are difficult to conceive and the writers are free to confess that any explanation they may put forward is offered only as a suggestion, but with the hope that some other geologist may be able to suggest something very much better. The only explanation that the writers can offer is that after the great overthrust and before the rocks between Pulaski and Max Meadows had been folded as extensively as they are to-day, a narrow tongue of this limestone, in many respects probably resembling the limestone tongue extending from Max Meadows to Gunton Park, lay in a slight valley along the present course of the outcrop. If then we suppose that another epoch of folding ensued, it is conceivable that this tongue of limestone might have been so crushed by the shales and sandstones on its two sides that it was tilted on edge and really engulfed by the Devonian rocks,—in other words the softer rocks of the Devonian simply flowed about and almost concealed the resistant limestone mass.

After weighing all of the available evidence the writers have come to a tentative conclusion that, although the structures in the highlands between Pulaski and Wytheville were inaugurated before the faulting occurred, they were not developed, at least in their more eastern portions, to the extent that they are to-day, and that movement since that epoch of faulting has accentuated the structures begun in the previous epoch. The Draper Mountain anticline appears to have been largely, if not wholly, formed after the overthrust occurred. This hypothesis may seem to be somewhat strained in its application to the facts here presented, but it is a noticeable fact that on the Wytheville side of the highland the structure of the limestone does not show any agreement with the underlying structures, whereas on the Pulaski side this general agreement is one of the most striking features. The agreement in dips in the reentrant angles on the east side is the strongest reason for assuming subsequent movement here.

If it is granted that the writers are correct in their idea that the overthrust mass of limestone once covered a large part of the highland west of Pulaski, then it is easy to see the similarity of the conditions that then existed in that region and the present conditions of the fensters on and near New River. It is easily conceivable that at some epoch in the dim and distant past Draper Mountain was surrounded by the overthrust mass of limestone and was a true fenster. At that time it might have been difficult to prove that the fault which must have surrounded the mountain and was responsible for the fenster was one and the same as the Pulaski fault, as it was then shown at the foot of Little Walker Mountain, but to a geologist the condition would have been essentially the same as those which prevail in the Price Mountain coal field at the present time. In other words, the faults surrounding the fensters on New River, while disconnected now, undoubtedly will not remain so indefinitely in the future, for as erosion progresses and the surface of the country is lowered, all of these faults will doubtless be connected and at such a time they will also without much doubt be found to be connected with the Pulaski fault along the southeast foot of Brushy Mountain.

With this interpretation in mind, the origin of the Price Mountain fenster is relatively plain. Originally the surface rock in this field was the Maccrady shale and this was overridden by the Shenandoah limestone at the time of the Pulaski thrust. In a subsequent epoch of movement an elongate dome was produced in the basement rocks and as the dome rose it carried with it the Shenandoah limestone and any other rocks that may have formed a part of the overthrust mass. The upward bulge in the basement rocks,—Price formation and Maccrady shale— produced a similar bulge in the overthrust mass and consequently there are accordant dips in both the basement rocks and in the overthrust limestone. After the deformation took place the region has been subjected, for almost untold ages, to erosion which has succeeded in removing the overthrust limestone from the dome, but still leaving it as an encircling rim to the fenster. Erosion has also removed the Maccrady shale from the higher parts of the dome and cut down nearly to the base of the Price formation, exposing the Merrimac coal bed as a dark band encircling the dome. The fault surrounding the Price Mountain coal field should therefore be called the Pulaski fault, because, without doubt, if it could be followed to the north beneath the surface, the observer would find that it makes direct connection with the Pulaski fault at the southeast foot of Brushy Mountain.

A similar line of argument may be followed in the case of the East Radford fenster, except that here the basement rocks are largely Devonian with only the Ingles conglomerate above them to represent the Carboniferous system. Another difference is in the more faulted character of the west end of the East Radford fenster as compared with the Price Mountain fenster, but the presence of this fault in no way militates against the theory that it has had a history similar to that of the Price

Mountain fenster just described. The similarity at the east end of the East Radford fenster is particularly striking as the structure of the Devono-Carboniferous rocks are broadly anticlinal with the limestone apparently resting on the Ingles conglomerate all around the periphery of the east end of the dome. It is true that the limestone is not exposed here but its presence, as indicated by chert, is beyond question and it seems safe to conclude that the dips, if they could be measured, would be found to be in general accordant. The side-hill cuts of the Norfolk and Western Railway on the east side of New River show an excellent cross-section of this fenster. Here the limestone on both sides of the anticline clearly dips away from the axis of the fold and is underlain by Devonian shale which has a very similar dip. The exposure on the north side of the dome is shown on Pl. IX B.

The syncline lying between the East Radford fenster on the south and the Price Mountain fenster on the north is very deep and the fault plane, as indicated by the thickness of dipping beds of limestone on New River, is 1,800 to 2,000 feet below the general upland surface. It is probable that farther east in the vicinity of Vickers it is not so deep, but this conclusion is not based on definite evidence, but a general impression that, owing to the close proximity of the fensters in this region it would hardly be possible for the fault plane to be so badly deformed.

The authors are firmly of the opinion that the main fault surrounding the East Radford fenster is the same as the fault surrounding the Price Mountain fenster, and that it should be called the Pulaski fault.

The internal structure of the Berringer Mountain fenster is as simple as that of the Price Mountain fenster, but the surrounding geologic conditions are so complicated that it is difficult, if not impossible without detailed work in the limestone area, to unravel its geologic history. The structure of the Devonian and Carboniferous rocks forming the core of the fenster is that of a very elongate dome with the Ingles conglomerate probably originally capping the entire mass.

Mode of formation of the fault.—With an adequate picture of the Pulaski fault before the reader, it is now pertinent to consider the mode of origin of this fault: is it an ordinary overthrust fault that has developed from an overturned fold or has it been developed by the slicing of homogeneous rocks? Many geologists regard broad overthrusts of this character as exceptional and as not having the same mode of origin as ordinary faults of only moderate horizontal movement, but the writers can not subscribe to this idea for they see no difference between great and small overthrusts except that of magnitude. As shown in Fig. 10, it is possible for slicing overthrust faults to develop where homogeneous rocks or rocks so intimately folded and crushed as to behave like homogeneous rocks are subject to intense horizontal thrusts, but the rocks involved in the Pulaski fault, at least, as far as their character can be determined from surface observations, are not of this type, but are very distinctly made up of strong and weak strata which upon being subjected to pressure would develop folds and these folds under a continuation of the same pressure would break and a part of the fold be thrust over the other part and possibly over other folds produced by the same internal stresses.

A study of the southwest termination of the Pulaski fault as portrayed in the Greenville folio makes it clear that this fault develops in an anticline of Knox dolomite and anyone familiar with the geology of the Appalachians will at once recognize that the Knox dolomite is probably the most nearly competent of any of the beds or formations present in the Paleozoic column.

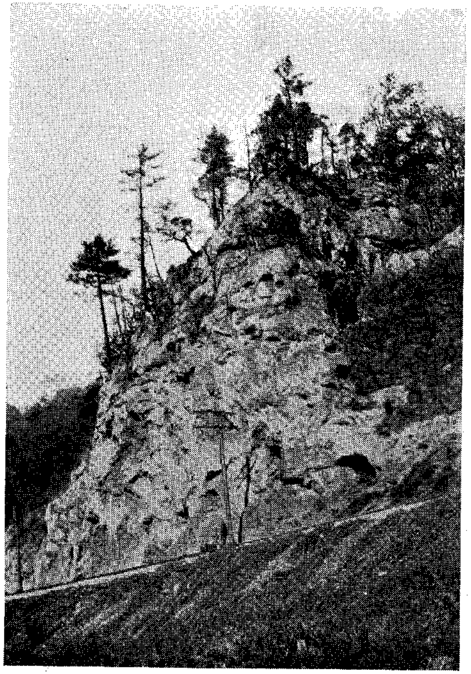
Another point in favor of the fold hypothesis is the succession of strata or formations in the overthrust mass. Thus movement in block B, Fig. 10, along the line *fg* would result in the younger rocks being thrust farther than the older rocks at the base of the block, or in other words, that the material at or near the farthest limit of the overthrust mass would be younger than the rocks in contact with the fault plane to the right, and the bedding would not be parallel to the plane of the fault. In a fault developed from an overturned fold (N, fig. 2), there is, after erosion has removed the fold at the extreme edge of the overthrust mass, a general agreement in the dip of the overthrust beds and that of the fault plane and the oldest rocks are found along the trace of the fault. The evidence in the field shows that as a rule the oldest rocks mark the farthest extent of the overthrust and that younger rocks are exposed toward the southeast, hence the conclusion is obvious that the Pulaski fault was developed from a fold and is not a slice fault.

In view of all of these facts the writers are fully convinced that the Pulaski fault is essentially the same as the other overthrust faults of the region, differing only in the extent of the movement that has taken place on its fault plane. As measured in the vicinity of Pulaski the horizontal displacement of this fault is not less than 9 miles, and it may be much more. As the overthrust limestone covers Walker Mountain in the vicinity of Abingdon, it is conceivable that originally it was thrust over this mountain or rather over the outcrop of the Clinch sandstone that at present marks the crest of this mountain on New River, and if such were the case 2 miles should be added to the figure given above. Again all measurements must of necessity start from the present trace of the fault on the southeast, but no one knows how far to the southeast of this the fault originated. It may have been only a short distance or it may have been many miles. Consequently 9 miles is the minimum measure, with the maximum, indeterminate.

It is interesting to note that if it had not been for the circuitous course of the fault from the Stony Fork of Reed Creek by Queens Knob, Max Meadows, Draper Mountain and Pulaski and for the fensters on and near New River no one would have suspected that the movement on the plane of this fault had been very great. If at some time in the past the overthrust mass of limestone completely covered the rough, hilly country between Pulaski, Max Meadows and Little Walker Mountain and if at the same time it concealed the younger rocks in the fensters on New River, then one is forced to the conclusion that the true character of an overthrust fault is not always shown. Deeper erosion than is shown to-day might reveal similar features on other faults that now look like simple breaks with an overthrust of little, if any, more than one mile.

Rocks in contact with the overthrust mass.—The rocks in contact with the overthrust mass of Shenandoah limestone are different in different parts of the course of the fault. Thus from its southwestward termination near Greenville, Tennessee, to the vicinity of Abingdon, Virginia, the Shenandoah rests upon rocks of Ordovician or Cambrian age, but northeast of Abingdon, the southward swing of the fault reveals in ascending order the Clinch and associated sandstones of Silurian age, which composed Walker Mountain, then the entire Devonian system and near Marion the Price formation of Mississippian (Carboniferous) age. From the crossing of Reed Creek to a point nearly due north of Blacksburg the Maccrady shale is generally in contact with the Shenandoah, but east of the last mentioned point the fault cuts back into the Price formation and the Maccrady shale is seen no more on the trace of the fault.

When one studies the geologic map (Pl. I) and sees that such a soft and incompetent stratum as the Maccrady shale is in contact with the superincumbent mass of Shenandoah limestone from Reed Creek to Blacksburg (as shown in Pl. XIII A), he can not but wonder if this fact

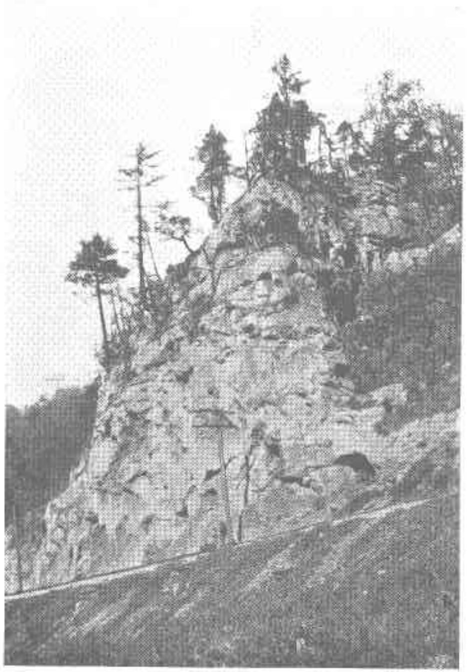


(A) Cliff of calcareous tufa at Peppers Ferry.

Photograph by Marius R. Campbell.

(B) New River south of Newbern.

Photograph by Marius R. Campbell.



(A) Cliff of calcareous tufa at Peppers Ferry.

Photograph by Marius R. Campbell.

(B) New River south of Newbern.

Photograph by Marius R. Campbell.

is not indicative that at the time of faulting the Maccrady shale was the youngest formation in this part of the Appalachian region and that neither the Carboniferous limestone nor the coal-bearing rocks of Pennsylvanian age were ever laid down here.

Many geologists will doubtless question such an interpretation, but the writers fully believe that this interpretation is the most reasonable one that can be put upon the facts set forth in this report, although from the very nature of the case it is impossible to get conclusive evidence that the formations above the Maccrady shale were not originally here.

The southeastern limit of the Carboniferous limestone, as it is known to-day, is marked by a nearly straight line (see fig. 13) extending from near Allegheny Station on the Chesapeake and Ohio Railroad, through Peterstown, West Virginia, near New River and then through Saltville in western Smyth County, Virginia. At this line, especially in the vicinity of Saltville, the limestone is very earthy, being more nearly a calcareous shale than a true limestone. As the continental area in early Carboniferous time lay to the east, it is but reasonable to suppose that near shore the calcareous matter would be more or less intimately mixed with earthy matter washed in from the land and this earthy material would upon consolidation appear as calcareous shale. In the Clinch Mountain basin northwest of Bristol, Virginia-Tennessee, the lower part of the Carboniferous limestone is relatively pure, but towards the top it is very earthy, showing that either the sea grew more and more shallow during the deposition of the calcareous material or that as time went on erosion was more rapid on the adjacent land and more and more earthy material was washed into the sea.

It seems inconceivable to the writers that the Carboniferous limestone or even calcareous shale was deposited far to the southeast of the line described in the last paragraph, for if it had been deposited it should have been preserved in some of the deeper synclines of the region. It seems reasonable to assume that a soft and easily eroded formation, such as the Maccrady shale, might not be preserved, especially if it were not overlain and protected by a more resistant formation, but it does not seem reasonable to suppose that a competent stratum, such as the Carboniferous limestone or calcareous shale, would be entirely removed in a like situation.

On account of the various facts cited above the writers believe that they are fully justified in assuming, at least as a working hypothesis, that the Carboniferous limestones as well as all more recent formations were not deposited in Montgomery, Pulaski, Wythe, and Bland counties.

GEOLOGIC DATE OF THE PULASKI FAULTING.

General statement.—For nearly a century the world has been taught that the geologic structures of the Appalachian Highlands are the result of a gigantic "revolution"—the crumpling on a large scale of the rocks of the entire province from middle Alabama to Newfoundland into great folds, which if not eroded would have been of mountainous proportions. All of this is supposed to have been accomplished just after the last and youngest of the coal-bearing formations of the bituminous fields had been laid down, and thus to mark the closing stages of the Paleozoic era. As the study of the Pulaski fault seems to indicate that there was more than one epoch of thrust and movement, it seems desirable to consider the bearing that such conclusions may have on the general question of the succession of movements and period of time in which they were operative in the Appalachian "revolution."

The discussion which follows is based on the statement that the thrust with which we are dealing and which is responsible for the production of the various kinds of structures found in this province came from the southeast. Whether this thrust was the result of contraction in the crust of the earth or of isostatic adjustment, the writers are not prepared to say. The present treatise is merely an attempt to explain how and when the great overthrust was produced and in doing that it will not be necessary to consider ultimate causes.

Long ago geologists were disposed to regard such events as the so-called Appalachian "revolution" as cataclysmic in character and that the result we see to-day was produced by one gigantic upheaval, but such ideas are now regarded as obsolete, and the belief now prevails that the stresses within the earth's crust gradually accumulate until they are sufficient to overcome the resistance of the rocks and then the rocks move. They continue their movement until the stresses are relieved and then there is a period of quiescence until the stresses again gather power to move the rock mass which hitherto had held them in check. The periods of quiescence doubtless varied greatly in length, some of them being of only a few years duration and others probably extending over centuries. The writers are satisfied that the Appalachian "revolution" was of this spasmodic character, and that some of the folds and faults are very much older than others of a similar form and character.

One of the most difficult problems in Appalachian structure, as before mentioned, is to account for the presence of shingle-block after shingle-block, or of open fold after open fold, across the entire width of the Appalachian Valley province and also a narrow band of outlying folds on the eastern edge of the Allegheny Plateaus. As the stresses that produced them evidently came from the southeast, the folds or shingle-blocks must have been produced in one of two ways: either by (1) successive folds beginning on the southeast side of the belt and extending gradually northwestward as fold after fold was produced, or (2) by the formation of fold after fold beginning on the northwest side of the belt and gradually extending to the southeast as the various folds were completed. Either horn of this dilemma will involve difficulties; hence it is necessary to investigate each in order to determine which would involve the least difficulty and at the same time provide a reasonable hypothesis for its solution.

A broad study of Appalachian structure shows at once that the rocks on the northwest side of the province are much less affected by stresses than are the rocks on the southeast side. This difference is notable in not only the large structures into which the formations have been thrown, but in a marked degree by the difference in the metamorphism of the rocks, or the alteration of their intimate structures by compression and heat. This lack of metamorphism on the northwest and the great display of it on the southeast side of the province is a strong argument against the formation of the folds from the northwest to the southeast sides in regular succession, for if that had been the method of their formation, each fold or group of folds would have been formed independently and completed before another epoch of folding would have been initiated on its southeastern side. If the folds were formed in this manner each fold or group of folds would have suffered the same degree of metamorphism as the next fold or group of folds on either the northwest or the southeast. In other words, the phenomenon of metamorphism, as we see it to-day in the Appalachian Valley province, would have been impossible if the folding had begun on the northwestern side of the province and extended southeastward.

Again, if the folding began on the northwest side, there is seemingly no reason why the folds should vary in intensity or magnitude, except the variations in sedimentation which affect rock folds wherever they may have been formed. However, a field examination of the two sides of the province shows that the folds on the northwest side do not end suddenly with folds of the greatest magnitude, but the folds die out gradually, especially in northern Pennsylvania, in a series of oscillations which decrease in magnitude very regularly in a northwestward direction. On the opposite or southeast side the most intense folding as well as metamorphism of the rocks mark the first fold to be seen on entering the province. As this evidence is entirely against the origin of movement being on the northwest, that hypothesis will be regarded as entirely disproved, but if the folding began on the southeast, how were succeeding parallel folds produced? This question can not be answered very positively, but the authors will at least venture to suggest how, in their opinion, it may have come about.

Sequence of movements.—It has been generally assumed that folding began on the southeast side of the Appalachian Valley at an early date in the Pennsylvanian epoch and that as stresses accumulated the folds were developed farther and farther west, until the last epoch of folding in which the anticlines and synclines in the great coal region to the northwest were produced, may have been in the closing stages of the Permian epoch. Such an hypothesis at once raises the question as to whether rocks that had once been folded and faulted are competent to transmit a thrust to undisturbed rocks farther to the northwest, without themselves being subjected to a second period of deformation which would greatly accentuate or largely obliterate the structures already produced.

The explanation of such a seemingly anomalous condition as the transmission of stresses through a mass of rock already deformed and apparently weakened by stresses of a similar character, is apparently simple, depending upon the difficulty of moving a load that has come to rest and the pull of gravity in the piled up mass of rock in the zone of deformation resulting from the first thrust.

Thus it is reasonable to suppose that the first epoch of deformation resulted in the piling up in a relatively narrow zone along the southeastern side of the Appalachian region of rocks probably thousands of feet in thickness, or until the weight of the rock counterbalanced the effect of the thrust. When that condition was reached the overthrust masses came to a standstill and remained until the stresses in the earth's crust accumulated sufficiently to enable them to again disturb the crustal formations. The stresses were then exerted not on a mass in motion, but one that had for some time been at rest and the inertia of the mass to be moved, together with the great friction on its rocky bed was so great that it was probably easier to lift a new portion of the earth's crust than again to set in motion the mass that previously had moved so readily. Owing to the conditions just outlined, the incompetent rocks below the original overthrust, now because of their confinement under a great stationary load, behaved as a rigid body transmitting the stresses to a relatively undisturbed portion of the crust to the northwest of that previously folded and new folds would be initiated. This procedure repeated several times would account for the formation of the folds and faults across the entire Appalachian Valley province.

In the progressive deformation of the rocks of the province, just described, large open structures having great resistance, especially synclines, may have been produced. The formation of such synclines may be due to their being synclines of deposition with a much greater thickness of rocks than the adjacent folds, or it may be the result of the natural resistance to upward stresses being increased by the slight bending that the rocks have undergone. As the rocks in the syncline are bowed down and as the direction of the stresses is in general upward and toward the northwest, the pressure on the syncline is exerted against the fold in the line of its greatest power to resist and consequently the synclines were probably thrust bodily forward instead of being deformed. In the section across the Valley in the vicinity of Wytheville or Pulaski, it seems probable that the first impulse folded the rocks as far as Bland; that a second impulse at a later date produced the open anticlines and synclines that characterize the region between Bland and lower Wolf Creek or between Lick Creek and Tazewell; and a third impulse produced the more intense deformation between Tazewell and Pocahontas.

The foregoing discussion applies only to those faults and folds lying northwest of the Pulaski fault, for there is rather strong evidence to show that this fault was produced at a later date than the faults and folds toward the northwest. The evidence of a later date for the formation of the Pulaski fault consists in the crossing of this fault by pronounced structures, both folds and faults, that must have been produced in an epoch of folding prior to that which resulted in the Pulaski fault. The transgression of structures is apparently limited to that part of the fault lying between Abingdon on the southwest and James River on the northeast. The structures overridden are (1) most of the Walker Mountain shingle-block, (2) the Crockett anticline, (3) the Draper anticline and the associated Max Meadows syncline, and the crushed anticline and syncline represented by Cove Mountain, Brushy Mountain, and Caldwell

Mountain east of Millers Cove. It is not conceivable that such structures involving anticlines, synclines, and overthrust faults could have been developed under the overthrust mass of Shenandoah limestone as must have been the case if they were developed contemporaneously with the faulting or if they were developed in a later epoch of deformation. The writers have concluded, therefore, that these facts fully warrant the conclusion that the Pulaski fault was produced after the folds and faults to the northwest had been formed.

Folds and faults are not restricted to the northwestern part of the Appalachian Valley province, so it will be necessary, in this connection, to consider some to the southeast of the Pulaski fault. In general there is a fault or faults along the line that is usually regarded as separating the Blue Ridge province from that of the Appalachian Valley. In Virginia these have not been mapped in detail, but in Tennessee most of the territory covered by these faults has been mapped by Arthur Keith.[1] In the vicinity of Roanoke the crystalline rocks of the Blue Ridge have been thrust over and rest upon the Watauga shale and the horizontal movement on this fault plane is supposed to have been considerable. As shown in Fig. 13, this fault is supposed to extend southwestward from the vicinity of Salem to the crossing of New River at Ivanhoe, but in this stretch there is little data regarding the extent of the overthrust, and in some places there may have been no movement at all at this horizon. Near the south line of the State, however, it comes in again in force and across Tennessee it is most eccentric, in places showing an overthrust of 8 or 10 miles and the fault plane as well as the overthrust mass has been wrinkled by movement subsequent to the main fault.

The overthrust movement on this line of faults appears to supplement that of the Pulaski fault, for opposite the places where the movement in the Pulaski fault was greatest, the other faults are least or wanting altogether and the movement in the southeastern faults are greatest in Tennessee where the Pulaski fault dies out.

The mountain faults resemble the Pulaski fault in that they cross the general structures of the region at all angles and because of that fact they are regarded as having been produced after the main epochs of disturbance that produced the folds and faults of the Appalachian Valley.

[1] For detailed description of these interesting faults see the following U. S. Geological Survey Folios: Cranberry (No. 90), Roane Mountain (No. 151), Greenville (No. 118), London (No. 25), and Knoxville (No. 16).

As in Tennessee just south of the limits of the map shown in Fig. 13 the mountain fault crosses the minor anticlines and synclines that are the southwestward continuation of the Pulaski fault, and it is supposed to have been produced by a movement subsequent to that which produced the Pulaski fault.

According to Mr. Keith there is no evidence that this fault developed from an overturned fold and as its place of inception seems to have been in crystalline rocks, it is logical that the stresses which in the sedimentary rocks of the Appalachian Valley would have produced overturned folds and then faults here have resulted in a slice directly through the homogeneous mass. The field evidence regarding the age of this fault is rather meager as most of the formations with which the overthrust mass comes in contact belong in the lower part of the Paleozoic column, but near the place where the fault crosses Little Tennessee River the overthrust mass doubtless, before erosion had reduced the surface to the present low level, rested on the Carboniforous limestone. This merely fixes the date as post-Mississippian.

After the great overthrust of the Pulaski and the mountain fault there was another epoch of deformation on the southeastern side of the Appalachian Valley, but the stresses seem to have lost much of their force, having power enough to produce only minor wrinkles in the planes of the broad overthrust faults and in the rocks associated with them. In the Valley coal field this deformation produced or accentuated the anticline wrinkles of the three fensters,—Price Mountain, East Radford, and Berringer Mountain,—perhaps some of the minor folds north of Draper Mountain, and the cross wrinkle northwest of Wytheville which causes the breaks in Brushy and Big Walker mountains. On the mountain faults it probably produced similar features, and they are more pronounced than the features already mentioned in the Valley coal fields.

From the preceding discussion it is apparent that there is some basis for the statement that probably the deformation of the rocks of the Appalachian Highlands did not take place in one spasm or at one epoch, but that it extended through a long period of time. As outlined above, the first movement was apparently that which folded the rocks adjacent to and on the southeastern side of the Appalachian Valley and then the folding continued at intervals until it reached the northwestern side and the low folds of the coal region were produced. The first of these movements appear to have originated in a region of sedimentary rocks similar to the Appalachian Valley of to-day, but of course it lay many miles to the southeast of the present valley. After the movement had extended to the present northwestern limit of rock folds, stresses accumulated in the rocks to the southeast of the Valley and the great overthrust faults were produced. The first of these great faults, in the region here being considered, is the Pulaski fault and this was followed by the mountain faults which are as prominent on the edge of the mountains of Tennessee as the Pulaski fault is in Virginia. The last and apparently the expiring stage of the Appalachian "revolution" was marked by another epoch of movement which by comparison with those that preceded it appears like the expiring gasp of some giant force, as indeed it seems to have been.

In the region here being considered there is absolutely no data available regarding the exact part of the Carboniferous era in which these movements occurred. We know only that as they involve the Mississippian limestone they must have occurred after that formation was deposited. Fortunately, however, in other parts of the Appalachian Highland, especially in Pennsylvania, there is much more direct evidence on this subject. If the writers are correct in their interpretation of events in Virginia the folding or Appalachian "revolution" began with the deformation of the rocks immediately to the northwest of the Shenandoah Valley. In eastern Pennsylvania the rocks directly north of the extension of this valley contain coal beds which constitute the Southern Anthracite coal field and as these coal beds have on paleobotanic evidence been proved to be of the same geologic age as the coal beds of the bituminous fields, they must mark the beginning of Pennsylvanian time and it is known that they extend upward in the system nearly to the upper limit of this series. If, therefore, these rocks were the first to be folded, the folding could not have been begun before the beginning of Permian time.

It seems probable, therefore, that the Appalachian revolution may have begun in early Permian time and continued at intervals throughout that epoch and ended with its closing and the termination of the Paleozoic era.

THE COAL

GENERAL STATEMENT.

The coal of the Valley fields of Virginia, a sample of which is shown in Pl. 3, has generally been regarded as anthracite or a species of anthracite but in order to differentiate it in the trade from the true high-rank anthracite of Pennsylvania has been called "Virginia anthracite." When, however, it is compared with true anthracite it is at once apparent that it is not so hard and an anaylsis shows that it has more volatile matter and less fixed carbon than anthracite should have. If it be compared with the semibituminous Pocahontas coal of Tazewell County, Virginia, or of Mercer and McDowell counties, West Virginia, it will be found to differ from that coal in both its physical appearance and its chemical composition; to be less friable and to contain a lower percentage of volatile matter and a higher percentage of fixed carbon. It is evident, therefore, that it is really intermediate in character between the Pocahontas or semibituminous coal below and the Pennsylvania anthracite above.

Before entering into the question of the proper classification of this coal, it may be well to consider something of the origin of coal in general and of the conditions that have been instrumental in producing the different kinds of coal with which the coal-using public in the eastern part of the United States is more or less familiar.

ORIGIN OF COAL.

It is now generally agreed that coal is the material resulting from the accumulation of vegetal matter in an age long past and for that reason is sometimes referred to poetically as "stored sunshine." While geologists are agreed upon this general fact, they differ in their opinions regarding the mode of accumulation of the vegetal matter into the coal beds that we see to-day. Some, particularly the European geologists, maintain that coal beds are formed of trees and other vegetal material that have been floated in water and carried by the currents to a place where they have found lodgement and where they have gradually accumulated until they formed great masses, something like the raft of logs and growing plants which has accumulated on Red River in Louisiana. Others maintain that the coal-making plants grew in great swamps, much like the

Dismal Swamp of this State and North Carolina, and that in the course of many thousands of years the woody material which, being under water and thus largely preserved from decay, was in the course of time converted into peat; the peat into lignite; the lignite into bituminous coal, and so on until in some cases it reached the anthracite stage, the highest one in this series of fuel transformation. The latter theory is the one generally held by geologists in the United States.

METAMORPHISM OF THE COAL.

The change in the form and composition of the vegetal material has been brought about by low-temperature distillation of the material by the heat of the earth. This process, operating through the long ages that have elapsed since the living plants were entombed, has driven off more and more of the volatile matter, leaving a higher and higher percentage of fixed carbon with every change. The heat that has made such a slow distillation possible has been in small part that which is normal to the interior of the earth, in part that due to the proximity of volcanic dikes and sills, but more largely to heat produced by pressure which, from time to time, has been exerted in the rocky crust and has resulted in the great folds and faults that are common in the Valley fields and other parts of the Appalachian region.

Prof. Henry D. Rogers,[1] State Geologist of Pennsylvania, as early as 1858, showed clearly that the carbon content of the coals of that state increases steadily and more or less regularly from the lowest rank[2] of bituminous coal in the extreme western part to the highest rank anthracite in the eastern part. This difference was attributed by him to the metamorphism or change of the coal due to heat generated during the periods of rock-folding and also to the increasing effect of volcanic activity as manifest in the increased number of dikes in the eastern part of the State.

Geologists are still in agreement with Professor Rogers in regarding this change in the composition of the coal as being due to stresses in the rocks that at a later date found expression in great folds, faults, and

[1] The geology of Pennsylvania, vol. 2, pp. 991-997, Philadelphia, 1858.

[2] The United States Geological Survey has adopted the term "rank" to express the various stages in the progressive change of coals from lignite to anthracite. The term "grade" has similarly been adopted to express the purity or impurity of a coal. Thus a high-rank coal simply means one which has parted with most of its volatile constituents, whereas a high-grade coal is one that is relatively free from impurities.

tilted beds, but they incline to attribute more of the heat generated in the Appalachian region to pressure and less to volcanic activity than was assumed by Professor Rogers. They also find that the Virginia coal fields offer equally good opportunities for a study of the effects of such stresses and movements as does the Pennsylvanian field, except that in Virginia there are no coals that were in a position to be subjected to the most severe stresses and consequently were converted into high-rank anthracite. In a general way the coals of Virginia show the same differences in composition and appearance as one crosses the State from west to east as do those of Pennsylvania, and those in the Valley fields here described are the ones which have been most affected and have reached the highest rank in the scale of coal transformation that are to be found in the State.

From the statements in the preceding paragraph, it must not be inferred that the change or metamorphism of the coals is regular or constant, for, from the nature of the rocky crust of the earth, it could hardly be expected that the stresses everywhere increased regularly toward the southeast. It has long been recognized that these stresses were exerted from that direction and if the crust of the earth had been composed of homogeneous materials and confined so that the rocks could not have broken, then the effects of the pressure should have been increasingly apparent toward the southeast and the rate of increase should have followed a fairly definite law. But as neither of these conditions have prevailed, the metamorphism of the rocks, including the coal beds, has been very irregular, as some parts have been more resistant than others and consequently these parts have had to withstand the brunt of the thrust and they have suffered corresponding internal changes. Others were soft or composed of thin layers of somewhat different materials which yielded readily to pressure and such rocks were thrown into folds or wrinkled up into a complex mass of contorted strata without having suffered metamorphism to any considerable extent. Again when a large fold has been developed to the breaking point, as illustrated in Fig. 12, the breaking or faulting of the rocks has served as an avenue of escape and thus the pressure has been relieved wherever faulting has taken place. The effect of a fault in relieving pressure within the rocks is well illustrated in the Pocahontas coal field in Tazewell County, Virginia, and in Mercer and McDowell counties, West Virginia. Here a great fault on the southeastern margin of the field has so relieved the pressure that the coal of highest rank does not occur on the southeast margin of the field, as is generally the case, but is found in the vicinity of Welch in McDowell

County, some 14 or 15 miles back from the margin. According to Government analyses, the fixed carbon in the pure coal at Pocahontas, Virginia, on the southeastern margin of the coal field, is about 75 per cent, whereas at Vivian in McDowell County, West Virginia, it is 82 per cent. As these figures are both obtained from analyses of Pocahontas No. 3 bed they are strictly comparable.

Again, it seems probable that many of the broad synclines, especially in an overthrust mass, such as that which characterizes the Pulaski fault, may have been thrust bodily over the underlying rocks without in great degree affecting the coal beds, if any such beds were contained in them. In other words, the synclines seem to have been "floated" into their present positions without involving the exertion of great pressure on the constituent beds.

That the fairly regular rate of increase in metamorphism in the main bituminous coal field of West Virginia is not continued in the rocks of the Appalachian Valley province is shown by a comparison of the fixed carbon content of the coals. Thus the fixed carbon in the pure coal at Logan, West Virginia, is about 63 per cent; at Vivian, McDowell County, about 82 per cent; and in the vicinity of Pulaski and Price Mountain in the Valley fields, about 88 per cent. In the 40 miles from Logan to Vivian the increase is 19 per cent, whereas in the same distance from Vivian to Pulaski it is only 6 per cent. In view of the conditions briefly outlined above, it would not be surprising to find the coals of the Valley fields varying in rank considerably and irregularly across the strike and even in a longitudinal direction from southwest to northeast.

As the coal of the Valley fields differs from the bituminous or the semibituminous coals of the large field to the west and also from the anthracite of Pennsylvania, it is important to determine its real relation to these coals. In any discussion of the rank of a coal it is necessary to consider (1) the form and meaning of coal analyses in general and (2) how the data furnished by these analyses can best be used to determine the rank of a coal, or, in other words, its true position in the general scheme which represents the progressive changes in a coal from its lignitic to its anthracitic stage.

COAL ANALYSES.

In this country two forms of analysis are in common use; a simple one which is known as a proximate analysis, because it determines only certain constituents of the coal, such as moisture, volatile matter, fixed carbon and ash, and another, an ultimate analysis, so-named because it determines the ultimate elements which make up the coal substance. Both analyses are useful and important, but the proximate analysis, because of its simplicity and cheapness, is the one most commonly made and it is upon the data furnished by this form of analysis that most attempts at classification are based. The table on pages 108-115 shows the difference between these forms and what each form includes.

In many ways the ultimate analysis is much more accurate and satisfactory than the proximate analysis, but the objection to the ultimate analysis is its great cost and the fact that it does not afford the information regarding the materials that give to a coal its distinctive characteristics and determines its best use. Thus one does not care particularly about the percentage of hydrogen, carbon, nitrogen, and oxygen, but he does want information about the hydro-carbons and other compounds that make up the coal. In this respect the proximate analysis is somewhat better, but even in this form the so-called volatile matter includes many compounds and the amount and character of the matter that may be volatized depend entirely upon the manner in which the analysis is made.

All Government analytical work on coal is done by the Bureau of Mines and in a recent bulletin[1] the following statements regarding the constituents of coal and analytical methods are made:

> "The proximate analysis of coal originated in response to industrial demand for laboratory tests of the relative amounts of certain compounds, either present in the coal or derived from it, that affect its use as a fuel. These compounds are grouped by the proximate analysis as follows: (1) water or moisture; (2) mineral impurities that remain in a somewhat altered condition, as ash when the coal is burned; and (3) organic or combustible matter, which is approximately represented by the volatile matter and fixed carbon.
>
> "The moisture in coal consists of (a) extraneous moisture, which comes from external sources, and (b) inherent moisture, which is one of the products of the original vegetable matter from which coal is derived.
>
> "The volatile matter and fixed carbon represent approximately the relative proportions of gaseous and solid combustible matter that are obtained from coal by heating it in a closed vessel. The volatile matter consists chiefly of the combustible gases, hydrogen, carbon monoxide, and methane and other hydrocarbons, and some noncombustible gases, as carbon dioxide and water vapor. . . .

[1] Fieldner, Arno C., Selvig, Walter A., and Paul, J. W., Analyses of mine and car samples of coal collected in the fiscal years 1916 to 1919. Bureau of Mines Bull. 193, p. 10, 1922.

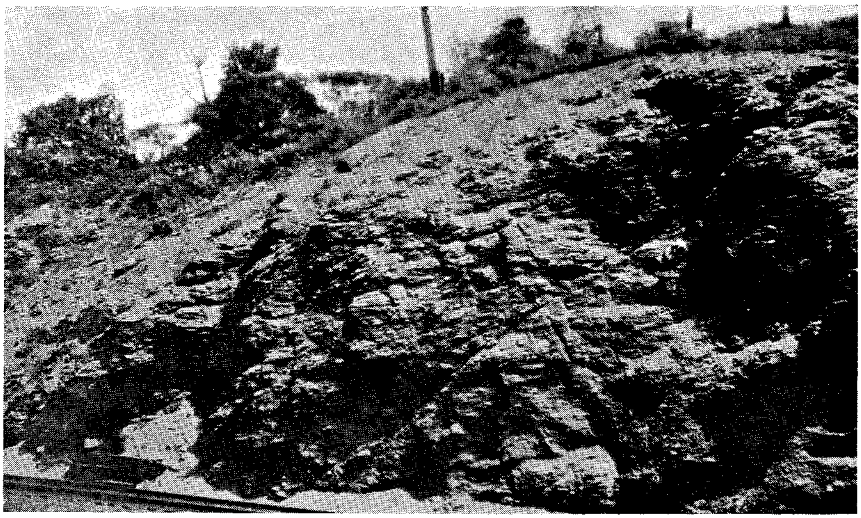
"The residue of coke left in the crucible after the ash has been deducted is reported as 'fixed carbon'. The fixed carbon does not represent the total carbon in the coal, for a considerable part of the carbon is expelled as volatile matter, being in combination with hydrogen and hydrocarbon or with oxygen as carbon monoxide and carbon dioxide. Furthermore, fixed carbon is not pure carbon. The carbonized residue contains, in addition to the ash-forming constituents, several tenths per cent of hydrogen and oxygen, from 0.4 to 1.0 per cent nitrogen, and approximately half the sulphur that was in the coal. The terms 'volatile matter' or 'volatile combustible matter' and 'fixed carbon' do not represent definite compounds that exist in the coal before heating. The method of determination is arbitrary, and the results are comparable only when the temperature and the rate of heating are the same."

Consideration of the statements just quoted from reports by the chemists of the Bureau of Mines makes it very obvious that the proximate analysis of coal is merely a convenient makeshift and does not give much information regarding the real composition of the coal. It is also clear that the method of making the proximate analysis is mainly a "rule of thumb," controlled entirely by arbitrary rules. This condition of affairs was early recognized and a committee of the American Chemical Society [1] was appointed to study the subject and make recommendations regarding the standardization of the methods of making a proximate analysis of coal. This committee made a preliminary report in 1898 and a final report in 1899. The committee recognized the arbitrary character of such an analysis and submitted rules by which the work in the laboratory was supposed to be controlled and standardized.

The report of the committee was accepted by all of the leading coal chemists in the country, but despite its supposed control over laboratory practice great discrepancies were observed and the work of no two laboratories agreed. This question was brought to a focus soon after the organization of the Bureau of Mines by the discovery that the work of three of its laboratories, situated in different parts of the country, showed such discordant results as to cast doubt on the value of any proximate analysis.

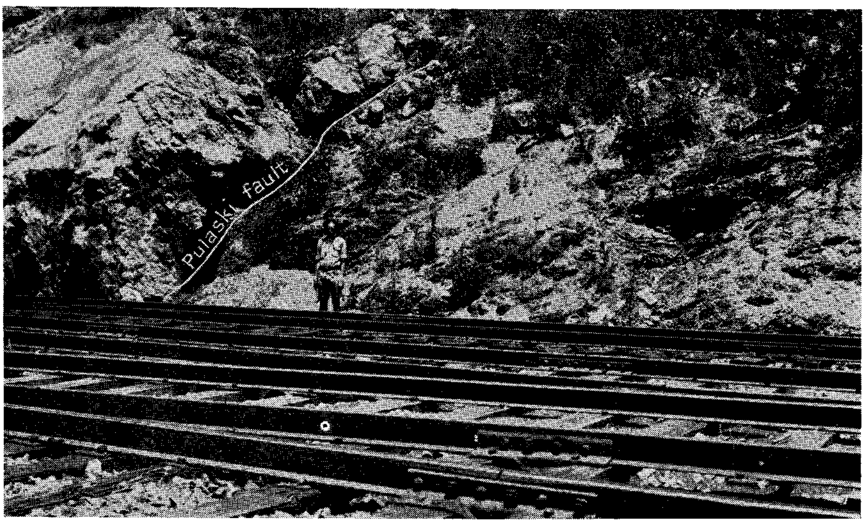
Careful checking up of analyses from the different laboratories led to the discovery that most of the discordance in results was due to the fuel used in the analytical work. To obviate this an electric furnace was installed in the Pittsburgh laboratory of the Bureau on February 26, 1913, and all analyses made since that date and bearing laboratory

[1] See Jour. Am. Chem. Soc., vol. 20, p. 281 and vol. 21, p. 1116, 1899.



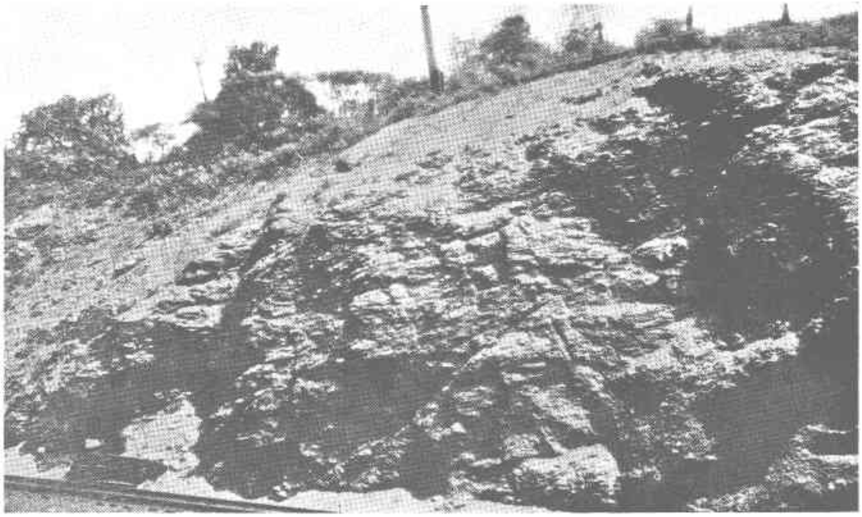
(A) Shaly fossiliferous limestone east of Vickers.

Photograph by Marius R. Campbell.



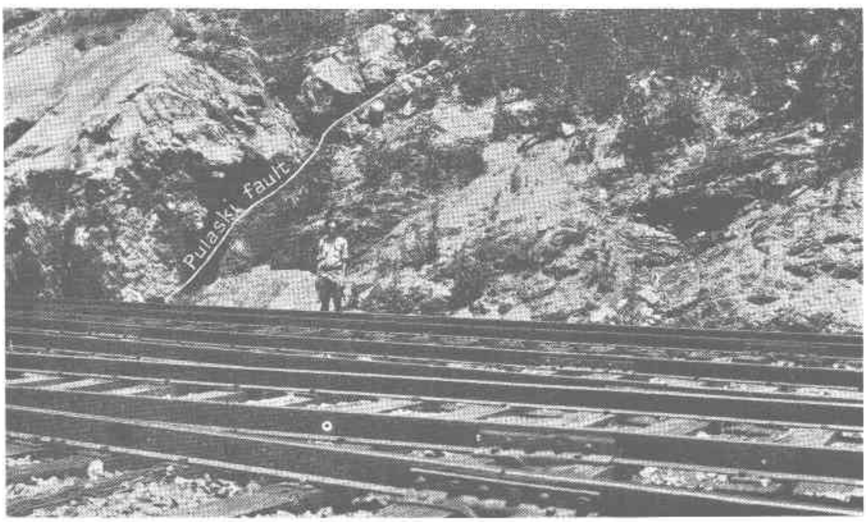
(B) Pulaski fault near Peppers Ferry.

Photograph by Marius R. Campbell.



(A) Shaly fossiliferous limestone east of Vickers.

Photograph by Marius R. Campbell.



(B) Pulaski fault near Peppers Ferry.

Photograph by Marius R. Campbell.

numbers in excess of about 16,500 have been found to agree very closely and, therefore this method of work is now considered to be the only method that will give accordant results. In the following discussion regarding the classification of coal only those analyses made in the electric furnace will be considered and the percentages of volatile matter thus determined will be found in many cases to differ 4 or 5 per cent from the volatile matter of the same coals, determined by the use of the Bunsen burner. In general the volatile matter, determined in the electric furnace, is greater than that obtained by heating over a Bunsen burner and consequently the fuel ratio (the fixed carbon divided by the volatile matter) as determined from analyses made in the new way is much lower than it is when determined from analyses made in the old way. As the ranks of all eastern or high-rank coals are expressed in terms of the fuel ratio, all of the criteria for establishing the boundaries of the various ranks will necessarily have to be changed.

As the determination of the most logical classification of the Valley coals depends upon their chemical composition, considerable time and energy were expended by the writer in securing representative samples of coal for analysis. Few persons, except those who have made a study of the subject of coal, realize how difficult it is to secure such samples. Most persons regard coal as a simple substance and think all that is required in sampling is to get one or more lumps of coal, generally the brightest to be found, and send them to the laboratory tied up in a canvas bag or wrapped in paper.

Samples secured in this manner are absolutely worthless, if not entirely misleading, as furnishing a basis for comparison with coals of other fields or for classification purposes. They are defective in two respects, namely (1) that being picked lumps, they do not represent the coal bed or bench from which they were taken, and (2) that not being kept in air-tight receptacles, they have given off or taken on moisture in transit to the laboratory and not only has the moisture been affected, but oxidation has doubtless taken place and the value of the sample has been thereby materially reduced.

The geologist taking a sample of coal for analysis is instructed to procure unweathered material if possible. He is supposed to face up the bed in the mine or prospect until fresh coal is available, and then to obtain the sample by making a uniform cut across the bed from roof to floor, excluding such material as is generally discarded by the miners or removed by the pickers. He is expected to cut sufficient coal to give at least 6 pounds to the foot of coal bed sampled. The sample thus obtained is hastily pulverized in the mine until it will pass through a ½-inch-mesh screen and then is quartered down to about 4 pounds in weight. This sample is placed in a galvanized iron can, which is sealed with a rubber gasket and adhesive tape and mailed to the laboratory for analysis. The geologist proceeds on the principle that a coal mine should be sampled as carefully as a gold mine and that the sample should be even more carefully handled after it has been taken. The object of sealing is mainly to prevent change in the moisture content, so that the coal may reach the laboratory in practically the same condition as it leaves the mine. Coal is a very unstable substance, and great care must be exercised to prevent the taking on or giving off of moisture and the oxidation of the coal in the course of preparation of the sample and in its transit to the laboratory. It is also important that the sample should consist of neither the best nor the poorest coal, but that it should be representative of the output of the mine, if one is in operation, or, if the field is undeveloped, it should represent as nearly as possible the merchantable coal that may be procured at some time in the future when mining is carried on.

Although the aim of the geologist in sampling by the method specified above is to obtain coal that is representative of the output of the mine, experience has shown that this aim is seldom or never accomplished. Almost invariably the sample obtained in the mine contains a lower percentage of impurities than the coal which reaches the consumer. This difference is due largely to carelessness in mining and handling and probably could be mostly eliminated were conditions of mining more nearly ideal. By comparing a large number of samples taken in mines with samples from the same mines taken at the points of consumption, it has been found that there is a fairly constant but small difference in the percentages of moisture, ash, and sulphur, and that almost invariably the amounts of these substances in the mine samples are less than they are in the coal that reaches the market. The writer has summed up the difference in the composition of mine and car samples in the work of the United States Geological Survey and of the Bureau of Mines in 1904 and 1905 [1] as follows: "If, therefore, the amount of ash in any given mine sample be multiplied by this coefficient (1.3), the result will be approximately the amount of ash that may be expected

[1] The value of coal-mine sampling, Economic Geology, vol. 2, pp. 48-57, 1907.

in the commercial output of the mine." Thus if a mine sample shows 18.5 per cent of ash, the coal from the same mine as it goes to market is liable to contain 18.5 x 1.3 = 24 per cent of ash unless the coal is picked and washed as it comes from the mine.

Many years of experience have taught the author that comparatively few persons dealing in coal, aside from trained engineers or chemists, know the meanings of analyses and how they should be used. Most persons, especially those working with high-rank coals, such as characterize the Valley fields, know that in some way a low volatile or high fixed carbon content coal is desirable and the reverse, that a high volatile or low fixed carbon content coal is undesirable, but frequently such persons can not correctly compare two analyses and say which is the higher-rank coal. If, for instance, three analyses were presented to the average layman would he know how to compare them? Let us take for trial the three analyses given below:

	Normal form of analysis.				Moisture and ash-free form.	
Designation of sample.	Moisture.	Volatile matter.	Fixed carbon.	Ash.	Volatile matter.	Fixed carbon.
A	2.0	13.0	78.0	7.0	14.3	85.7
B	2.0	10.0	60.0	28.0	14.3	85.7
C	8.0	9.2	54.8	28.0	14.3	85.7

Most persons, not familiar with coal analyses, would at once say that C is the best sample because it has the lowest volatile matter. Some, however, might think that A is the best sample because it has the highest fixed carbon. Persons who would thus pronounce upon these analyses might not believe the author when he says that, as far as volatile matter and fixed carbon are concerned, the three samples, A, B, and C, are identical, differing only in the percentage of moisture and ash they contain. This is made perfectly plain in the two columns at the right. These figures are obtained by recalculating the analyses of A, B, and C on a new base, theoretically excluding the moisture and ash, and, as shown, the three analyses are identical in this form.

If now he begins to analyze the figures given in the normal analysis he will see at once that sample C really has the lowest percentage of volatile matter, but it has a proportionately low percentage of fixed carbon and that sample A, having a high percentage of volatile matter has likewise a high percentage of fixed carbon.

In order to afford such data as will enable anyone to make direct comparison of one coal with another the analyses on pages 108-115 are given in three forms: A, B, and C. Analysis A represents the sample as it comes from the mine. As coal may take on or give off moisture in transit from the mine to the consumer, depending upon the state of the weather, the analysis of the sample as it comes from the mine is not necessarily the same as that of coal delivered into the consumer's bin, but in a coal of as high rank as are those here considered, the difference is generally slight and consequently form A of the analysis is the one that should be used by the operator and the consumer, but, as shown on page 153, this form should not be used when direct comparisons are made of volatile matter and fixed carbon, because there are too many variable factors in such an analysis and a variation of one element must necessarily cause a corresponding variation in another element, but in the opposite direction. In comparing heating values this form alone should be used.

Analysis B is the same as analysis A, except that the moisture has been theoretically eliminated by recalculation. This form is used exclusively by mechanical engineers who are engaged in testing apparatus rather than fuels and in making such tests they find it necessary to theoretically reduce their fuel to a stable condition by eliminating all moisture. As no coal reaches the consumer in a perfectly dry condition, form B is not suitable for general use and should be restricted solely to the use of mechanical engineers. Analysis C is another special form in which both moisture and ash are theoretically eliminated. As moisture and ash are impurities, form C represents approximately the pure coal substance and is used in certain cases when one wishes to compare the real coal substance of one coal with that of another, but it should never be used by the ordinary producer or consumer of coal because it represents a substance, that from its very nature, can never be mined, shipped, or consumed.

Many persons are confused by the giving of three forms and they think that the user is free to select the one best suited to his needs. Thus if he is wishing to put his coal on the market as an anthracite or a "smokeless" coal, he should select the form of analysis showing the lowest percentage of volatile matter. Such, however, is not the meaning and use of the three forms given. It is true they are merely three forms of the same analysis, but they are published separately as a matter of convenience for those who wish to use them in a legitimate manner.

The analyses reported from the laboratory have been somewhat generalized, in the table on pages 108-115, as it is commonly recognized that the figures representing the different percentages are not generally correct to the second decimal place or to the ultimate unit. Because of this uncertainty the percentage of the constituents of both proximate and ultimate analyses is given to one decimal place only, and as the determination of the heating value of a coal in the calorimeter can not be made with accuracy to individual units, the results are generalized in the table to the nearest tens, for this is sufficiently accurate for all commercial uses.

Analyses of coal of the Valley fields of Virginia.

(All analyses made by the Bureau of Mines or the U. S. Geological Survey.)

Name of mine or operator and location of sample analyzed.	Collector.	Name of coal bed.	Number.	Location number on Plate I.	Form of analysis.	Proximate analysis. Moisture.	Proximate analysis. Volatile matter.	Proximate analysis. Fixed carbon.	Proximate analysis. Ash.	Ultimate analysis. Sulphur.	Ultimate analysis. Hydrogen.	Ultimate analysis. Carbon.	Ultimate analysis. Nitrogen.	Ultimate analysis. Oxygen.	British thermal units.	Fuel ratio FC/VM
COAL FIELDS OF MONTGOMERY COUNTY:																
Local mine of Slusser and Doss. Sample from main entry, 100 feet from mine mouth. September 7, 1923.	[1] C	Merrimac......	94184	9	A	4.8	10.0	69.7	15.5	.5	......	......	......	......	12,240	6.97
					B	......	10.6	73.2	16.2	.5	......	......	......	......	12,850	
					C	......	12.6	87.4	......	.6	......	......	......	......	15,350	
Mine of M. C. Slusser Coal Co. Sample 25 feet N. of slope and 900 feet from mine mouth. April 30, 1914.	H	.... do	19358	15	A	1.9	12.3	66.8	19.0	.7	3.5	72.3	.9	3.6	12,160	5.41
					B	......	12.6	68.1	19.3	.7	3.4	73.7	.9	2.0	12,390	
					C	......	15.6	84.4	......	.8	4.2	91.4	1.1	2.5	15,360	
Mine of M. C. Slusser Coal Co. Sample 25 feet NE. of slope and 1,050 feet from mine mouth. May 14, 1915.	W & H	.... do	22629	15	A	1.6	12.3	68.1	18.0	.5	......	......	......	......	12,340	5.53
					B	......	12.5	69.2	18.3	.5	......	......	......	......	12,540	
					C	......	15.3	84.7	......	.6	......	......	......	......	15,340	
Do..	W & H	.... do	22630	15	A	1.9	13.5	69.8	14.8	.6	......	......	......	......	12,710	5.16
					B	......	13.8	71.1	15.1	.6	......	......	......	......	12,960	
					C	......	16.3	83.7	......	.8	......	......	......	......	15,260	
Do..	W & H	.... do	22631	15	A	1.8	11.8	53.5	32.9	.3	......	......	......	......	9,780	4.54
					B	......	12.0	54.5	33.5	.3	......	......	......	......	9,960	
					C	......	18.1	81.9	......	.5	......	......	......	......	14,970	
Mine of M. C. Slusser Coal Co. Sample 100 feet NE. of slope and 225 feet from mine mouth. May 23, 1918.	C & H	.... do	30689	14	A	2.1	13.9	68.7	15.3	.5	......	......	......	......	12,610	4.94
					B	......	14.2	70.2	15.6	.6	......	......	......	......	12,890	
					C	......	16.8	83.2	......	.7	......	......	......	......	15,280	
Mine of M. C. Slusser Coal Co. Sample 200 feet SW. of slope and 225 feet from mine mouth. May 23, 1918.	C & H	.... do	30690	14	A	1.7	14.2	69.4	14.7	.5	......	......	......	......	12,850	4.90
					B	......	14.4	70.6	15.0	.5	......	......	......	......	13,070	
					C	......	16.9	83.1	......	.6	......	......	......	......	15,380	
Mine of M. C. Slusser Coal Co. Composite of samples 30689 and 30690.	C & H	.... do	30691	14	A	1.9	14.1	68.9	15.1	.5	3.6	75.3	.9	4.6	12,740	4.90
					B	......	14.3	70.2	15.5	.5	3.4	76.8	.9	2.9	12,990	
					C	......	16.9	83.1	......	.6	4.1	90.8	1.1	3.4	15,360	
Mine of M. C. Slusser Coal Co. Sample 650 feet E. of slope and 350 feet from mine mouth. June 14, 1924.	C & T	.... do	A2349	14	A	3.0	12.2	70.1	14.7	.5	......	......	......	......	12,680	5.75
					B	......	12.6	72.3	15.1	.6	......	......	......	......	13,070	
					C	......	14.8	85.2	......	.7	......	......	......	......	15,400	
Mine of M. C. Slusser Coal Co. Sample 800 feet east of slope and 350 feet from mine mouth. June 14, 1924.	C & T	.... do	A2350	14	A	5.0	12.0	66.4	16.6	.5	......	......	......	......	12,150	5.53
					B	......	12.7	69.8	17.5	.6	......	......	......	......	12,790	
					C	......	15.3	84.7	......	.7	......	......	......	......	15,500	
Mine of M. C. Slusser Coal Co. Composite of samples A-2349 and A-2350.	C & T	.... do	A2351	14	A	4.1	12.5	67.8	15.6	.5	3.9	73.4	.9	5.7	12,420	5.45
					B	......	13.0	70.7	16.3	.5	3.6	76.6	.9	2.1	12,950	
					C	......	15.5	84.5	......	.6	4.3	91.4	1.1	2.6	15,460	

Analyses of coal of the Valley fields of Virginia—Contd.

Name of mine or operator and location of sample analyzed.	Collector.	Name of coal bed.	Number.	Location number on Plate I.	Form of analysis.	Proximate analysis. Moisture.	Volatile matter.	Fixed carbon.	Ash.	Ultimate analysis. Sulphur.	Hydrogen.	Carbon.	Nitrogen.	Oxygen.	British thermal units.	Fuel ratio FC/VM
Mine of Diamond Coal Co. Sample from west entry, 75 feet from slope. August 6, 1923.	C	Merrimac......	93530	16	A	2.3	12.7	58.7	26.3	.5	......	......	......	......	10,770	
					B	......	13.0	60.1	26.9	.5	......	......	......	......	11,020	4.62
					C	......	17.8	82.2	......	.6	......	......	......	......	15,080	
Mine of Diamond Coal Co. Sample from east entry, 10 feet from slope. August 6, 1923.	C	.... do	93531	16	A	2.7	12.9	68.2	16.2	.5	......	......	......	......	12,460	
					B	......	13.3	70.0	16.7	.5	......	......	......	......	12,800	5.25
					C	......	16.0	84.0	......	.6	......	......	......	......	15,360	
Mine of Diamond Coal Co. Composite of samples 93530 and 93531.	C	.... do	93532	16	A	2.5	12.8	63.5	21.2	.5	3.5	68.6	.8	5.4	11,620	
					B	......	13.1	65.1	21.8	.5	3.3	70.3	.9	3.2	11,910	4.98
					C	......	16.7	83.3	......	.6	4.2	89.9	1.1	4.2	15,230	
Mine of Plunkett and Wall. Sample 100 feet NE. of slope and 300 feet from mine mouth. April 28, 1914.	H	.... do	19357	18	A	2.5	12.4	67.5	17.6	.5	3.6	72.8	.9	4.6	12,360	
					B	......	12.7	69.2	18.1	.5	3.4	74.7	.9	2.4	12,680	5.45
					C	......	15.5	84.5	......	.6	4.2	91.2	1.1	2.9	15,480	
Mine of Seymour Price and Co. Sample 150 feet NE. of slope and 350 feet from mine mouth. April 29, 1914.	H	.... do	19360	20	A	4.7	11.5	65.4	18.4	.5	3.7	70.2	.9	6.3	11,820	
					B	......	12.0	68.6	19.4	.6	3.3	73.6	.9	2.2	12,410	5.69
					C	......	14.9	85.1	......	.7	4.1	91.3	1.1	2.8	15,380	
Mine of Virginia Polytechnic Institute. Sample 950 feet NE. of slope and 350 feet from outcrop. August 6, 1923.	C	.... do	93536	20	A	2.4	11.8	70.5	15.3	.5	......	......	......	......	12,760	
					B	......	12.1	72.3	15.6	.5	......	......	......	......	13,070	5.94
					C	......	14.4	85.6	......	.6	......	......	......	......	15,500	
Mine of Virginia Polytechnic Institute. Sample 1,050 feet NE. of slope and 350 feet from outcrop. August 6, 1923.	C	.... do	93537	20	A	2.7	12.4	68.8	16.1	.5	......	......	......	......	12,470	
					B	......	12.7	70.7	16.6	.5	......	......	......	......	12,820	5.54
					C	......	15.3	84.7	......	.6	......	......	......	......	15,380	
Mine of Virginia Polytechnic Institute. Composite of samples 93536 and 93537.	C	.... do	93538	20	A	2.5	11.9	69.8	15.8	.5	3.8	73.8	1.0	5.1	12,630	
					B	......	12.2	71.6	16.2	.5	3.6	75.7	1.0	3.0	12,960	5.90
					C	......	14.5	85.5	......	.6	4.4	90.4	1.2	3.4	15,460	
Mine of Virginia Polytechnic Institute. Picked sample of splint coal from railroad car.	C	.... do	95621	20	A	.7	12.9	65.2	21.2	.5	3.4	70.8	.9	3.2	11,970	
					B	......	13.0	65.6	21.4	.5	3.3	71.3	.9	2.6	12,050	5.05
					C	......	16.5	83.5	......	.6	4.2	90.7	1.1	3.4	15,330	
Mine of Linkous and Kipp. Sample from foot of slope. August 7, 1923.	C	.... do	93533	21	A	2.9	11.7	69.7	15.7	.5	......	......	......	......	12,570	
					B	......	12.0	71.8	16.2	.6	......	......	......	......	12,950	5.94
					C	......	14.4	85.6	......	.7	......	......	......	......	15,450	
Mine of Linkous and Kipp. Sample from face of east entry, 75 feet from the slope. August 7, 1923.	C	.... do	93534	21	A	2.7	11.9	67.3	18.1	.5	......	......	......	......	12,230	
					B	......	12.3	69.1	18.6	.6	......	......	......	......	12,570	5.62
					C	......	15.1	84.9	......	.7	......	......	......	......	15,440	

Analyses of coal of the Valley fields of Virginia—Contd.

Name of mine or operator and location of sample analyzed.	Collector.	Name of coal bed.	Number.	Location number on Plate I.	Form of analysis.	Proximate analysis. Moisture.	Proximate analysis. Volatile matter.	Proximate analysis. Fixed carbon.	Proximate analysis. Ash.	Ultimate analysis. Sulphur.	Ultimate analysis. Hydrogen.	Ultimate analysis. Carbon.	Ultimate analysis. Nitrogen.	Ultimate analysis. Oxygen.	British thermal units.	Fuel ratio FC/VM
Mine of Linkous and Kipp. Composite of samples 93533 and 93534.	C	Merrimac......	93535	21	A	2.7	11.9	68.4	17.0	.5	3.8	72.6	.9	5.2	12,390	5.73
					B	......	12.2	70.3	17.5	.5	3.6	74.6	1.0	2.8	12,730	
					C	......	14.8	85.2	......	.6	4.3	90.3	1.2	3.6	15,430	
Poverty mine of Virginia Anthracite Coal Co. Sample from point 1,750 feet SW. of mine mouth. October 31, 1906.	W	.... do	4092	22	A	3.5	11.1	67.8	17.6	.8	......	......	......	......	....	......
					B	......	11.4	70.8	18.3	.9	......	......	......	......	....	
					C	......	14.0	86.0	......	1.1	......	......	......	......	....	
Poverty mine of Virginia Anthracite Coal Co. Sample from point 1,765 feet from mine mouth. October 31, 1906.	W	.... do	4093	22	A	3.0	10.9	64.2	21.9	.7	......	......	......	......	11,670	5.86[2]
					B	......	11.3	66.1	22.6	.7	......	......	......	......	12,030	
					C	......	14.6	85.4	......	.9	......	......	......	......	15,540	
Local mine of J. H. Keister. Sample from main entry, 125 feet from mine mouth. August 7, 1923.	C	Langhorne ...	93539	23	A	2.9	12.3	72.0	12.8	.3	......	......	......	......	12,890	5.85
					B	......	12.7	74.1	13.2	.3	......	......	......	......	13,270	
					C	......	14.6	85.4	......	.4	......	......	......	......	15,290	
Mine of Big Vein Anthracite Collieries Corp. Sample from main entry, 700 feet from mine mouth. October 20, 1923.	C	Merrimac......	95615	25	A	2.0	12.7	65.0	20.3	.8	......	......	......	......	11,900	5.09
					B	......	13.0	66.2	20.8	.8	......	......	......	......	12,140	
					C	......	16.4	83.6	......	1.0	......	......	......	......	15,320	
Kinzar mine of Eureka Coal Co. Sample from point 50 feet NE. of slope and 80 feet from mine mouth. September 6, 1923.	C	.... do	94185	33	A	3.8	9.2	69.7	17.3	.7	......	......	......	......	11,990	7.58
					B	......	9.6	72.4	18.0	.7	......	......	......	......	12,460	
					C	......	11.7	88.3	......	.9	......	......	......	......	15,190	
Mine of Lykens Hill Coal Co. Sample 200 feet E. of slope and 360 feet from mine mouth. May 7, 1914.	H	.... do	19408	27	A	1.7	9.4	66.6	22.3	.7	3.2	69.3	.8	3.7	11,570	7.12
					B	......	9.5	67.8	22.7	.7	3.1	70.4	.8	2.3	11,770	
					C	......	12.3	87.7	......	.9	3.9	91.1	1.1	3.0	15,220	
Mine of Merrimac Anthracite Coal Corp. Sample from fourth level, 2,150 feet west of slope. May 23, 1918.	C & H	.... do	30692	28	A	3.6	9.5	67.6	19.3	.5	......	......	......	......	11,850	7.09
					B	......	9.9	70.0	20.1	.5	......	......	......	......	12,290	
					C	......	12.4	87.6	......	.6	......	......	......	......	15,380	
Mine of Merrimac Anthracite Coal Corp. Sample from face of 7th east entry, 850 feet from slope. September 6, 1923.	C	.... do	94180	28	A	1.4	9.0	72.6	17.0	.5	......	......	......	......	12,510	8.07
					B	......	9.1	73.7	17.2	.5	......	......	......	......	12,690	
					C	......	11.0	89.0	......	.6	......	......	......	......	15,320	
Mine of Merrimac Anthracite Coal Corp. Sample from 7th west entry, 900 feet from slope. September 6, 1923.	C	.... do	94181	28	A	2.7	9.7	70.5	17.1	.5	......	......	......	......	12,110	7.24
					B	......	10.0	72.4	17.6	.5	......	......	......	......	12,450	
					C	......	12.1	87.9	......	.7	......	......	......	......	15,110	
Mine of Merrimac Anthracite Coal Corp. Composite of samples 94180 and 94181.	C	.... do	94183	28	A	2.1	9.7	71.1	17.1	.5	3.3	74.7	.8	3.6	12,330	7.33
					B	......	9.9	72.6	17.5	.5	3.2	76.3	.8	1.7	12,580	
					C	......	12.0	88.0	......	.6	3.8	92.4	1.0	2.2	15,250	

Analyses of coal of the Valley fields of Virginia—Contd.

Name of mine or operator and location of sample analyzed.	Collector.	Name of coal bed.	Number.	Location number on Plate I.	Form of analysis.	Proximate analysis. Moisture.	Volatile matter.	Fixed carbon.	Ash.	Ultimate analysis. Sulphur.	Hydrogen.	Carbon.	Nitrogen.	Oxygen.	British thermal units.	Fuel ratio FC/VM
Mine of Merrimac Anthracite Coal Corp. Picked sample of "sand coal." September 8, 1923.	C	Merrimac......	94182	28	A	1.6	22.3	50.9	25.2	.3	2.5	57.8	.6	13.6	8,690	2.28
					B	......	22.7	51.7	25.6	.3	2.2	58.8	.6	12.5	8,830	
					C	......	30.5	69.5	......	.4	3.0	79.1	.8	16.7	11,890	
Mine of Merrimac Anthracite Coal Corp. Sample from face of 7th east entry 1,500 feet from slope. October 19,1923.	C	.... do	95616	28	A	2.2	9.4	69.0	19.4	.5	......	......	......	......	11,910	7.31
					B	......	9.6	70.6	19.8	.5	......	......	......	......	12,170	
					C	......	12.0	88.0	......	.6	......	......	......	......	15,170	
Do..	C	.... do	95617	28	A	1.8	9.2	71.3	17.7	.5	......	......	......	......	12,280	7.66
					B	......	9.4	72.5	18.1	.6	......	......	......	......	12,500	
					C	......	11.5	88.5	......	.7	......	......	......	......	15,260	
Prospect near commissary of the Merrimac mine. Face of prospect, 20 feet from mouth. May 23, 1918.	C & H	Langhorne ...	30693	28	A	4.0	10.1	65.5	20.4	.5	......	......	......	......	11,540	6.50
					B	......	10.5	68.2	21.3	.5	......	......	......	......	12,030	
					C	......	13.3	86.7	......	.6	......	......	......	......	15,280	
Mine of J. H. Brunfield. Sample from face of new slope, 150 feet from mine mouth. October 6, 1923.	C	Merrimac......	95619	29	A	2.5	8.8	74.6	14.1	.5	......	......	......	......	12,880	8.51
					B	......	9.0	76.6	14.4	.5	......	......	......	......	13,200	
					C	......	10.5	89.5	......	.6	......	......	......	......	15,420	
COAL FIELDS OF PULASKI COUNTY:																
Parrott mine of Pulaski Anthracite Coal Co. Sample from 100 feet west of slope. April 25, 1914.	H	Merrimac......	19431	35	A	2.4	11.6	63.3	22.7	.7	3.4	67.3	.7	5.2	11,310	5.46
					B	......	11.9	64.8	23.3	.7	3.2	68.9	.7	3.2	11,590	
					C	......	15.5	84.5	......	.9	4.2	89.8	1.0	4.1	15,100	
Parrott mine of Pulaski Anthracite Coal Co. Sample 150 feet SW. of the slope and 2,750 feet from mine mouth. May 24, 1918.	C & H	.... do	30694	35	A	1.6	13.3	61.5	23.6	.7	3.2	67.4	.8	4.3	11,400	4.63
					B	......	13.5	62.5	24.0	.7	3.1	68.5	.8	2.9	11,590	
					C	......	17.8	82.2	......	.9	4.1	90.1	1.0	3.9	15,240	
Parrott mine of Pulaski Anthracite Coal Co. Sample from face of 15th entry, 2,500 feet from slope. September 5, 1923.	C	.... do	94186	35	A	2.1	12.0	61.9	24.0	.5	......	......	......	......	11,230	5.16
					B	......	12.3	63.2	24.5	.5	......	......	......	......	11,470	
					C	......	16.3	83.7	......	.7	......	......	......	......	15,190	
Parrott mine of Pulaski Anthracite Coal Co. Sample from 16th entry, 2,600 feet from slope. September 5, 1923.	C	.... do	94187	35	A	1.6	11.7	61.6	25.1	.7	......	......	......	......	11,170	5.27
					B	......	11.9	62.6	25.5	.7	......	......	......	......	11,350	
					C	......	16.0	84.0	......	.9	......	......	......	......	15,220	
Parrott mine of Pulaski Anthracite Coal Co. Composite of samples 94186 and 94187.	C	.... do	94188	35	A	1.9	11.8	61.7	24.6	.6	3.2	66.9	.8	3.9	11,200	5.25
					B	......	12.0	62.9	25.1	.6	3.0	68.2	.8	2.3	11,410	
					C	......	16.0	84.0	......	.8	4.0	91.0	1.1	3.1	15,240	

Analyses of coal of the Valley fields of Virginia—Contd.

Name of mine or operator and location of sample analyzed.	Collector.	Name of coal bed.	Number.	Location number on Plate I.	Form of analysis.	Proximate analysis.				Ultimate analysis.					British thermal units.	Fuel ratio FC/VM
						Moisture.	Volatile matter.	Fixed carbon.	Ash.	Sulphur.	Hydrogen.	Carbon.	Nitrogen.	Oxygen.		
Cloyd mine. Sample from face of drift, 125 feet west of mine mouth. May 14, 1914.	H	Merrimac......	20722	40	A B C	2.5	10.8 11.1 14.6	63.1 64.7 85.4	23.6 24.2	.4 .4 .6	....	....	....	....	11,250 11,530 15,220	5.86
Mine of Empire Anthracite Coal Co. Sample from face of drift, 250 feet west of mine mouth. May 25, 1918.	C & H	Langhorne ...	30695	43	A B C	3.1	9.8 10.1 12.3	69.9 72.1 87.7	17.2 17.8	1.1 1.1 1.3	....	....	....	....	12,310 12,700 15,450	7.14
Mine of Empire Anthracite Coal Co. Sample from face of 2nd west entry, 500 feet from slope. September 4, 1920.	C	.... do	75888	43	A B C	4.4	10.1 10.6 12.5	71.5 74.8 87.5	14.0 14.6	.5 .6 .7	....	....	....	....	12,520 13,090 15,330	7.02
Mine of Empire Anthracite Coal Co. Sample from 2nd east entry, 600 feet from the slope. September 4, 1920.	C	.... do	75889	43	A B C	4.8	9.7 10.2 12.0	71.0 74.6 88.0	14.5 15.2	.6 .6 .8	....	....	....	....	12,460 13,100 15,450	7.34
Mine of Empire Anthracite Coal Co. Composite of samples 75888 and 75889.	C	.... do	75890	43	A B C	4.6	10.0 10.5 12.3	71.3 74.7 87.7	14.1 14.8	.6 .6 .7	3.7 3.4 4.0	74.3 77.9 91.4	.9 .9 1.1	6.4 2.4 2.8	12,520 13,130 15,410	7.12
Mine of Empire Anthracite Coal Co. Sample from room 48, off 4th W. entry, 2,300 feet from slope. September 3, 1923.	C	.... do	94189	43	A B C	2.5	9.9 10.1 12.7	68.2 70.0 87.3	19.4 19.9	1.6 1.7 2.1	....	....	....	....	11,980 12,280 15,330	6.89
Mine of Empire Anthracite Coal Co. Sample from 5th west entry, 1,400 feet from slope. September 3, 1923.	C	.... do	94190	43	A B C	1.6	9.9 10.0 12.3	70.0 71.2 87.7	18.5 18.8	.4 .4 .5	....	....	....	....	12,240 12,450 15,330	7.12
Mine of Empire Anthracite Coal Co. Composite of samples 94189 and 94190.	C	.... do	94191	43	A B C	2.1	10.2 10.4 12.9	68.7 70.2 87.1	19.0 19.4	1.0 1.0 1.3	3.4 3.2 4.0	72.6 74.2 92.0	.8 .8 1.0	3.2 1.4 1.7	12,110 12,370 15,350	6.77
Mine of Empire Anthracite Coal Co. Sample from 4th level at foot of Slope No. 2. June 17, 1924.	H & T	Merrimac......	A2634	44	A B C	3.8	12.5 12.9 21.6	45.1 47.0 78.4	38.6 40.1	.6 .6 1.0	....	....	....	....	8,180 8,500 14,190	3.60
Mine of High Carbon Coal Co. Sample from main slope, 280 feet from mine mouth, August 30, 1923.	C	Merrimac......	94192	52	A B C	4.5	8.2 8.6 11.3	63.9 66.9 88.7	23.4 24.5	.3 .3 .4	....	....	....	....	10,880 11,390 15,080	7.82

Analyses of coal of the Valley fields of Virginia—Contd.

Name of mine or operator and location of sample analyzed.	Collector.	Name of coal bed.	Number.	Location number on Plate I.	Form of analysis.	Proximate analysis. Moisture.	Proximate analysis. Volatile matter.	Proximate analysis. Fixed carbon.	Proximate analysis. Ash.	Ultimate analysis. Sulphur.	Ultimate analysis. Hydrogen.	Ultimate analysis. Carbon.	Ultimate analysis. Nitrogen.	Ultimate analysis. Oxygen.	British thermal units.	Fuel ratio FC/VM
COAL FIELDS OF WYTHE COUNTY:																
Mine of Summit Coal & Iron Co. Room south of slope, 250 feet from mine mouth. May 25, 1918.	C & H	Gunton........	30696	56	A	3.8	9.4	62.2	24.6	.8	......	......	......	......	10,960	6.64
					B	......	9.7	64.7	25.6	.8	......	......	......	......	11,300	
					C	......	13.1	86.9	......	1.1	......	......	......	......	15,310	
Mine of Pulaski Smokeless Coal Co. Face of 3rd west entry, 70 feet from the slope. August 23, 1923.	C	.... do	93937	59	A	2.9	9.6	63.8	23.7	1.6	......	......	......	......	11,200	6.66
					B	......	9.9	65.7	24.4	1.6	......	......	......	......	11,540	
					C	......	13.1	86.9	......	2.1	......	......	......	......	15,270	
Mine of Pulaski Smokeless Coal Co. Face of 3rd east entry, 150 feet from the slope. August 23, 1923.	C	.... do	93938	59	A	3.1	9.7	66.6	20.6	.7	......	......	......	......	11,700	6.82
					B	......	10.0	68.8	21.2	.7	......	......	......	......	12,080	
					C	......	12.7	87.3	......	.9	......	......	......	......	15,330	
Mine of Pulaski Smokeless Coal Co. Composite of samples 93937 and 93938.	C	.... do	94054	59	A	3.0	9.5	65.3	22.2	1.2	3.3	67.9	.9	4.5	11,470	6.90
					B	......	9.7	67.4	22.9	1.2	3.1	70.0	.9	1.9	11,820	
					C	......	12.6	87.4	......	1.6	4.0	90.7	1.2	2.5	15,320	
Mine of Pulaski Smokeless Coal Co. In rock tunnel, driven west from the Gunton bed. October 17, 1923.	C	Clark..........	95461	59	A	1.8	9.8	60.0	28.4	.6	......	......	......	......	10,530	6.14
					B	......	10.0	61.1	28.9	.6	......	......	......	......	10,730	
					C	......	14.0	86.0	......	.8	......	......	......	......	15,100	
Prospect shaft, west fork of Miller Creek. Face of north entry, 50 feet from shaft which is 40 feet deep. August 4, 1923.	C	Langhorne(?).	93500	62	A	3.1	11.4	66.2	19.3	.5	......	......	......	......	11,920	5.81
					B	......	11.8	68.3	19.9	.5	......	......	......	......	12,300	
					C	......	14.7	85.3	......	.6	......	......	......	......	15,360	
Prospect of Dr. John P. Graham. Picked sample of best coal from stock pile. October 16, 1923.	C	.......(?).......	95620	64	A	1.3	18.3	70.7	9.7	2.3	......	......	......	......	13,830	3.87
					B	......	18.5	71.7	9.8	2.3	......	......	......	......	14,010	
					C	......	20.5	79.5	......	2.5	......	......	......	......	15,520	
Prospect of C. C. Brown. Face of drift, 30 feet from mouth.	C	.......(?).......	93670	70	A	2.8	20.4	53.2	23.6	.6	......	......	......	......	11,330	2.60
					B	......	21.0	54.7	24.3	.7	......	......	......	......	11,660	
					C	......	27.7	72.3	......	.9	......	......	......	......	15,410	
COAL FIELD OF BLAND COUNTY:																
Prospect of T. C. Thompson. In drift, about 20 feet from mouth.	C	.......(?).......	95405	......	A	3.6	12.0	35.2	49.2	1.0	......	......	......	......	6,660	2.95
					B	......	12.4	36.6	51.0	1.0	......	......	......	......	6,910	
					C	......	25.3	74.7	......	2.0	......	......	......	......	14,090	
Prospect of Howard Stowers. Coal bed faced up in side of ravine.	C	.......(?).......	95406	......	A	2.7	12.9	37.5	46.9	1.5	2.7	42.5	.6	5.8	7,280	2.91
					B	......	13.3	38.5	48.2	1.5	2.4	43.7	.6	3.6	7,490	
					C	......	25.6	74.4	......	3.0	4.7	84.5	1.1	6.7	14,460	

[1] In the column headed "Collector" C means Campbell; C & H, Campbell and Howell; C & T, Campbell and Thom; H, Howell; H & T, Holden and Thom; W, Way; W & H, Watson and Holden.
[2] Analyses not made in the electric furnace, and consequently fuel ratios are too high.

Analyses of miscellaneous samples of coal, including the type coals of the Valley fields. A comparison of these analyses will show the basis for classification into ranks, and also their relative value for commercial uses.

General description of sample.	Fig. 17.	Town.	State.	Rank of coal.	Form of analysis.	Moisture.	Volatile matter.	Fixed carbon.	Ash.	Sulphur.	Heating value in British thermal units.	Fuel ratio.
Cannel coal from Johnson County.	A	Flambeau	Ky.	Bituminous	A	2.4	48.4	38.7	10.5	1.2	13,770	.80
					C	......	55.5	44.5	......	1.4	15,800	
Coal from the Pittsburgh bed in Belmont County.	B	Martins Ferry ...	Ohio	Bituminous	A	3.9	39.6	48.0	8.5	3.4	12,960	1.21
					C	......	45.2	54.8	......	3.9	14,800	
Coking coal from the Imboden bed in Wise County.	C	Stonega	Va.	Bituminous	A	2.2	33.7	56.4	7.7	.8	13,790	1.67
					C	......	37.5	62.5	......	.8	15,310	
Coking coal from the Pittsburgh bed in the Connelsville district.	D	Oliphant Fur. ...	Penna. ..	Bituminous	A	2.9	30.9	60.0	6.2	1.0	13,890	1.94
					C	......	34.0	66.0	......	1.1	15,280	
"Smokeless" coal from Sewell coal bed in the New River coal field.	E	Lochgelly	W. Va. .	Semibituminous ...	A	2.2	26.2	69.0	2.6	.6	14,820	2.64
					C	......	27.5	72.5	......	.6	15,570	
Coal from an unnamed coal bed 4 miles west of Bland, Bland County.	F	Bland	Va.	†Semibituminous ...	A	2.7	12.9	37.5	46.9	1.5	7,280	2.91
					C	......	25.6	74.4	......	3.0	14,460	
"Smokeless" coal from the Bloss coal bed in Tioga County.	G	Arnot	Penna. .	Semibituminous ...	A	2.3	20.0	61.6	16.1	.8	12,490	3.09
					C	......	24.5	75.5	......	1.0	15,300	
"Smokeless" coal from Pocahontas No. 3 coal bed in the Pocahontas coal field.	H	Boissevain	Va.	Semibituminous ...	A	2.8	21.3	71.4	4.5	.6	14,620	3.36
					C	......	22.9	77.1	......	.6	15,770	
Coal from unnamed coal bed in prospect, 7 miles NW. of Wytheville, Wythe County.	I	Wytheville	Va.	†Semibituminous ...	A	1.3	18.3	70.7	9.7	2.3	13,830	3.87
					C	......	20.5	79.5	......	2.5	15,520	
"Smokeless" coal from the Lower Kittanning coal bed in the Cambria County coal field.	J	Windber	Penna. ..	Semibituminous ...	A	2.6	17.0	73.7	6.7	1.2	14,240	4.33
					C	......	18.8	81.2	......	1.3	15,700	
"Smokeless" coal from the Barnett coal bed in the Broad Top coal field.	K	Hopewell	Penna. ..	Semibituminous ...	A	1.7	16.7	75.8	5.8	1.5	14,510	4.55
					C	......	18.0	82.0	......	1.6	15,690	
Coal from the Merrimac coal bed at Parrott, Pulaski County.	L	Parrott	Va.	†Semianthracite	A	1.9	11.8	61.7	24.6	.6	11,200	5.25
					C	......	16.0	84.0	......	.8	15,240	
Coal from the Gunton coal bed at Gunton Park, Wythe County.	M	Gunton Park ...	Va.	†Semianthracite	A	2.9	9.6	63.8	23.7	1.6	11,200	6.66
					C	......	13.1	86.9	......	2.1	15,270	

Analyses of miscellaneous samples of coal, including the type coals of the Valley fields. A comparison of these analyses will show the basis for classification into ranks, and also their relative value for commercial uses.—Contd.

General description of sample.	Fig. 17.	Town.	State.	Rank of coal.	Form of analysis.	Moisture.	Volatile matter.	Fixed carbon.	Ash.	Sulphur.	Heating value in British thermal units.	Fuel ratio.
Coal from the Langhorne coal bed in Empire mine, Pulaski County.	N	Empire	Va.	†Semianthracite	A	4.6	10.0	71.3	14.1	.6	12.520	7.12
					C	......	12.3	87.7	......	.7	15,410	
Coal from the Merrimac coal bed at Merrimac, Montgomery County.	O	Merrimac	Va.	†Semianthracite	A	1.8	9.2	71.3	17.7	.5	12,280	7.66
					C	......	11.5	88.5	......	.7	15,260	
Coal from the Merrimac coal bed at Pulaski, Pulaski County.	P	Pulaski	Va.	†Semianthracite	A	4.5	8.2	63.9	23.4	.3	10,880	7.82
					C	......	11.3	88.7	......	.4	15,080	
Coal from No. 5 coal bed in the extreme west end of the Southern Anthracite field.	Q	Lykens	Penna.	Semianthracite	A	1.1	9.6	79.5	9.8	.7	13,590	8.28
					C	......	10.8	89.2	......	.8	15,260	
Coal from No. 9 coal bed in the extreme west end of the Southern Anthracite field.	R	Lykens	Penna.	Semianthracite	A	1.3	8.2	72.3	18.2	1.3	12,130	8.88
					C	......	10.2	89.8	......	1.6	15,060	
Coal from the "B" coal bed in the Bernice basin.	S	Bernice	Penna.	‡Semianthracite	A	3.4	8.5	76.6	11.5	.6	13,160	9.00
					C	......	10.0	90.0	......	.7	15,460	
Coal from the "B" coal bed in the Bernice basin.	T	Lopez	Penna.	‡Semianthracite	A	3.1	8.6	78.1	10.2	.7	13,380	9.10
					C	......	9.9	90.1	......	.8	15,431	
Coal from the Northern Anthracite coal field, Lackawanna County.	U	Scranton	Penna.	‡Anthracite	A	4.4	7.0	77.1	11.5	.8	12,480	11.15
					C	......	8.3	91.7	......	.9	14,820	
Coal from the Northern Anthracite coal field, Luzerne County.	V	Pittston	Penna.	‡Anthracite	A	2.2	5.7	86.2	5.9	.6	13,830	15.22
					C	......	6.2	93.8	......	.6	15,040	
Coal from the Southern Anthracite coal field, Schuylkill County.	W	Pottsville	Penna.	‡Anthracite	A	3.0	3.6	87.6	5.8	.7	....	25.77
					C	......	3.9	96.1	......	.8	....	
Graphitic anthracite from near Fall River, Massachusetts.	X	Portsmouth	R. I.	‡Anthracite	A	13.9	2.5	63.2	20.4	1.3	9,050	28.68
					C	......	3.5	96.5	......	2.0	13,770	
Graphitic anthracite from near Providence.	Y	Cranston	R. I.	‡Anthracite	A	7.3	1.7	73.1	17.9	.1	10,360	43.32
					C	......	2.3	97.7	......	.2	13,860	

† Local coals.
‡ Analyses not made in electric furnace, volatile matter too low.

RANK OF THE VALLEY COALS.

The classification of the high-rank coals in use in this country is that proposed by Henry D. Rogers[1] in 1858. Rogers' statement regarding these ranks and the names to be applied to them is as follows:

> "Subdividing the whole class of substances we call coal in accordance with their most natural characters, we find them to arrange themselves into the following four principal groups in the order of diminishing carbon and augmenting hydrogen: Anthracites, Semianthracites, Semibituminous coals, and Bituminous coals[2]."

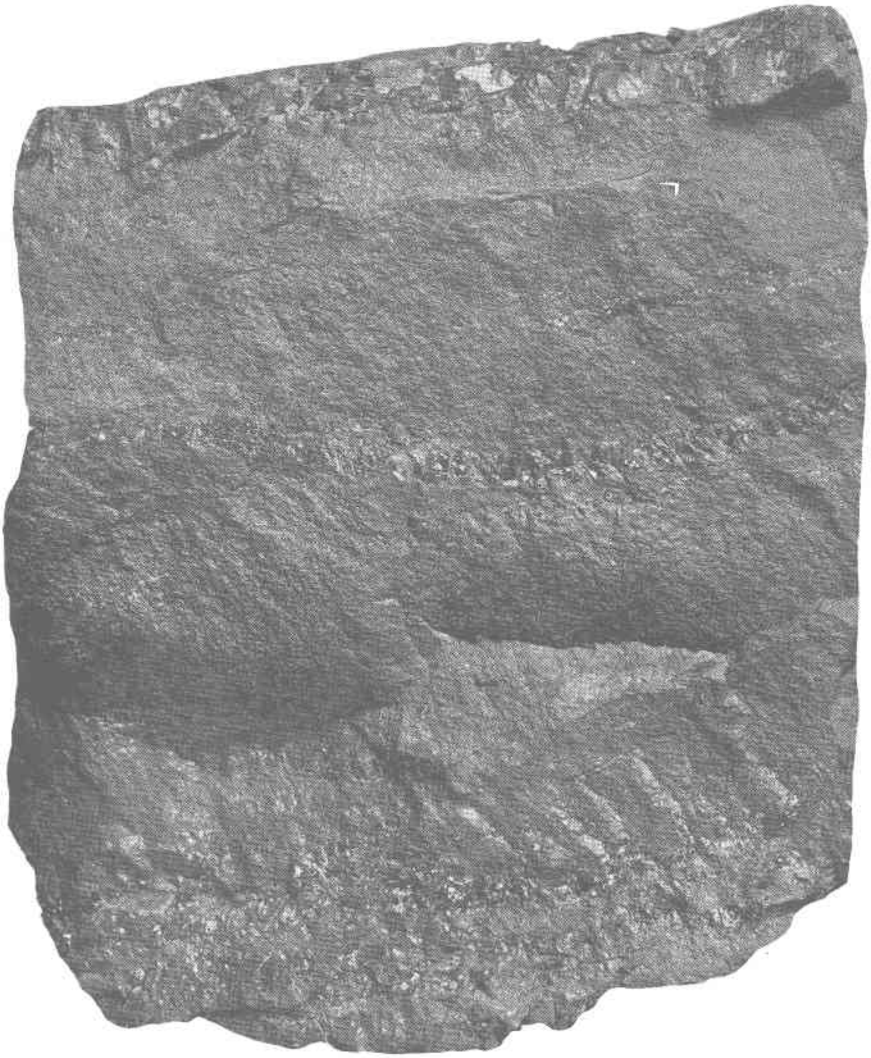
Theoretically such a classification seems a perfectly logical one to make, for we are all more or less familiar with bituminous coal which is so abundant in the great coal fields of the eastern United States, and which is the coal used in most of the manufacturing plants in this region. We think of a bituminous coal as burning generally with a long flame and with a heavy sooty smoke,—features due to the large percentage of volatile combustible matter it contains. Equally prominent, and even of greater importance from a commercial point of view, are the so-called "smokeless," "Navy," or semibituminous coals, which are recognized throughout the world as ideal steam coals, particularly where high heating value and the minimum amount of smoke are factors of prime importance. These coals burn with a short yellow flame intermediate in character between the long yellow flame of the bituminous coals and the short blue flame of the anthracites. We also are more or less familiar with anthracite and we think of it as a hard coal that ignites with difficulty, but when fully ignited burns with a bluish flame producing little or no smoke or soot.

The three ranks of coal noted above have long been recognized by the trade as fairly distinct units or groups and it is a good principle in seeking to establish definite ranks of coal to study mining and marketing conditions first and see how the coal is classed as it goes to market, because dealers appreciate the value of a good trade name for their coal and they are not slow to apply such names to the coal they are handling. As the writer understands the trade usage to-day the ranks of bituminous,

[1] Op. cit., p. 988.

[2] At that time Rogers was not familiar with the great group of coals of lower rank than bituminous, which occur so extensively in the western part of the United States.

"Sand coal" from Price Mountain coal field, Va.



"Sand coal" from Price Mountain coal field, Va.

semibituminous, or "smokeless," and anthracite (though these particular names may not be used) are well established and without question should be retained. The other rank (semianthracite) proposed by Rogers, is much less important and were it not for the fact that the coals of the Valley fields of Virginia belong to this rank, and are the largest body of coal beds belonging to it in this country, the writer might be willing to see the term semianthracite abandoned. However, this question will be considered more fully on a later page. The writer is, therefore, willing to grant that Rogers had good grounds for proposing the four ranks of *bituminous, semibituminous, semianthracite,* and *anthracite,* but the difficulty comes in establishing criteria for their separation and classification.

If the bituminous rank is characterized by the abundance of volatile combustible matter it contains, and anthracite is characterized by its absence or by the very small amount of volatile matter it contains, then it is obvious that if two other ranks are to be interpolated between them, the uppermost of these two ranks should strongly resemble anthracite, and the lowermost one resemble bituminous coal, and as the primary distinction between bituminous and anthracite is the amount of volatile matter contained, then the principal criterion by which to recognize semibituminous and semianthracite and to separate these ranks from the bituminous and anthracite which limit them below and above, must rest upon the same basis. If this conclusion is correct, and the writer feels very strongly that it can not be gainsaid, then all that remains to be done is to work out a scheme of classification for these ranks based entirely on their relative percentages of volatile matter and fixed carbon, independent of their exact physical characteristics or of the other ingredients which are all in the nature of impurities.

It may be urged that physical as well as chemical properties should be taken into account in determining the various ranks, especially the property of hardness which is supposed to be characteristic of anthracite and semianthracite. The writer can not deny that anthracite is generally hard, but he will not admit that hardness is a necessary property of anthracite and that a coal no matter how high it may run in fixed carbon, if it is soft, can not properly be assigned to that rank. In fact the writer recalls having sampled a coal in the West that is anthracite in chemical composition, but is so soft that it may be crushed in the hand. Such coal, if briquetted, would pass for anthracite without a question. Similarly he can recall many kinds of splint coal and block coal of bituminous rank that are as hard as any anthracite in the Pennsylvania fields.

In view of these discrepancies, the writer is not willing to admit that great hardness is the determining characteristic of anthracite and softness or friability a characteristic alone of bituminous coal. It is true that anthracite is generally hard, but there are so many exceptions to this rule that it seems to be more reasonable to consider physical characteristics as neither distinctive nor reliable features upon which to base a scheme of classification.

Many persons, not thoroughly familiar with the various kinds of coal may imagine that it is an easy task to distinguish one kind from another, because in their experience they have had to deal only with well-marked members of one or more ranks. Such persons fail to understand that any attempt at classification and separation into ranks or groups is entirely a man-made proposition, for his own convenience and made without regard to the processes nature used in their production. Does any one suppose that nature has made one distinctive and separate group of coals called bituminous; another, called semibituminous; and another, semianthracite and so on? As the processes by which the composition of coal is changed is a continuous and ever-operative process, it is only reasonable to assume that the products of this change, the coals with which we have to deal to-day, are a continuous series running from the lowest to the highest with not necessarily a single break in their continuity.

It is, therefore, manifest that there can be no definite and well-marked line of division between different ranks of coal based on chemical composition or on other characteristics. Hence there can be no sharp break expected between anthracite and semianthracite, between semianthracite and semibituminous, or between any of the ranks from anthracite down to lignite, the division must be made arbitrarily at such a point as best suits the uses to which the coal is put. Thus, as anthracite is essentially a domestic fuel, the lower limit of this rank must be established at, or as near as possible to, the point at which the coal begins to lose its distinguishing characteristics. The distinguishing features are not hardness nor any other physical property, but difficulty of ignition, freedom from smoke, and the absence of a yellow flame when burning. The generally smokeless character is common to several ranks of coal, but there is only one rank,—the so-called "dry anthracite"—that does not contain enough volatile combustible matter to ignite readily or to form a yellow flame, but burns with a blue flame from gases derived mainly from carbon. These, to the writer, seem to be the distinguishing characteristics of anthracite and the ones that must be considered in its classification.

With this point settled, the next question is what is the lower limit of the group expressed in terms of the volatile matter or fixed carbon. How large a percentage of volatile matter is essential to the production of a yellow flame? The answer to this question can be made only after a thorough study of the composition of the coals of northeastern Pennsylvania, but unfortunately there are very few reliable analyses published, especially of the lower rank anthracites or the higher rank semianthracites, and the writer knows of no adequate discussion of the character of these coals that will throw light on the situation.

The scheme proposed by Persifor Frazer[1] of the Second Geological Survey of Pennsylvania is as follows:

Frazer's classification of coals.

	Limiting fuel ratios.[2]
Hard dry anthracite	99 to 12
Semianthracite	12 to 8
Semibituminous	8 to 5
Bituminous	5 to 0

Curiously enough, when one begins a study of what constitutes anthracite, he at once runs up against the fact that, although the development of the anthracite fields of Pennsylvania dates back 150 years and they have achieved great prominence in both an economic and an engineering way, very few reliable analyses of the coal are available. The same condition prevailed in 1883 when the Second Geological Survey of the State began operations in the anthracite region and Persifor Frazer, who was delegated to make a study of coal classification, was compelled to base most of his work on analyses made by Henry D. Rogers and published in 1858. It is needless to say that it is very difficult, if not impossible, to

[1] Second report of progress of the laboratory of the survey, Second Geol. Survey of Penna., report MM, p. 144, 1879.

[2] The term "fuel ratio" was applied by Professor Frazer to the quotient of the fixed carbon divided by the volatile matter. This form of expressing the relation of the fixed carbon to the volatile matter is very convenient as it is the same in all the forms of analysis given in the table pp. 108-115, and may be obtained from the proximate or common analysis.

harmonize the results of analytical work done at such widely different dates and by chemists who did not have the advantage of modern laboratory equipment and a trained staff of assistants.

In attempting to size up the anthracite situation, one is impressed with the fact that here is a compact group of coal fields which to all intents and purposes are a single unit, that they are served by the same lines of railroad, and that the product of the mines in the various fields reaches the same consumers. Any attempt to classify the coal of one field as of different rank from that of the other fields would be extremely difficult to maintain, considering the unity mentioned above, and an attempt to class the coal of a limited part of an individual field as different from that of the other part would be much more difficult to carry into practical operation.

If, however, such a scheme were carried out, it would be found necessary if the Lykens Valley coals at the western end of the Southern Anthracite field were included in the anthracite rank, to include also the coals of the Bernice basin in Sullivan County and most of the coal of the Valley fields of Virginia. Would not such a classification include in the anthracite rank coals of very different characteristics? It would mean the inclusion in the anthracite rank coals having fuel ratios ranging from 99 down to 5. Would the operators and dealers in the hard, dry anthracites be willing to thus practically do away with a lower limit to the rank of which their coal is the type? The writer would say without hesitation that the producers of high-rank anthracite would and should enter a vigorous protest, for if they did not enter such a protest the term anthracite would be meaningless and all attempts at classification of coal would receive a knockout blow.

It is true that at the present time there is no Government supervision of this feature of the coal trade, but it seems altogether probable that in the not very far distant future there may be a coal-inspection service, similar to the meat-inspection at the present time. Such a service should establish ranks and grades of coal and when a car of coal is to be inspected, simply analyze the coal and stamp the car with the information that it has been found to be of a certain rank and grade. Such a service would be of inestimable benefit to the consumer and in the end the producer would doubtless be willing to grant that it has helped him, because it enables honest dealers to obtain a fair price for good coal and it prevents unscrupulous dealers from foisting off a dirty coal on an unsuspecting public.

To the writer it seems that in the future the classification of coal will play a much more important part in the coal trade than it has in the past and for that reason, if for no other, it is wise not to listen to those who wish to throw down the bars and class any kind of coal as an anthracite so long as it tends to boost their sales.

The author can not pretend to an intimate knowledge of the coals found in the various fields that are known as the anthracite fields of Pennsylvania, but there is one thing that is certain, if any division of this territory is to be made, it should be the lopping off of the Lykens Valley from the main Southern Anthracite field. And this, in the opinion of the writer should be done. To anyone who gives any attention whatsoever to the character of the coal of this field it will be apparent that the Lykens Valley coal, or at least that part which comes from the extreme western end of the northern "fishtail" is distinctly lower in rank than the coal of any of the adjacent fields either on the east or the north. This difference is one of a lower fuel ratio, or in other words, a higher percentage of volatile matter than that which prevails in other parts of the Southern Anthracite field. It is now recognized in the trade as a different kind of coal, but with some excellent qualities, that make the consumer willing to pay a premium of from 50 cents to one dollar a ton for the Lykens Valley coal over and above the price for hard, dry anthracite. The characteristics which mark this coal as different from the hard, dry anthracite are: (1) a higher percentage of volatile matter, (2) lighter weight, which gives to the consumer a greater volume of coal for his money, and (3) probably a lower percentage of ash. The coal is also a much more tender coal than the average of the other fields, but this is not an element in its favor.

As it thus appears that Lykens Valley coal[1] is different from the other coal of the anthracite fields and as an important factor in this difference is the increased percentage of volatile matter, the author feels that he is fully justified in placing the Lykens Valley coal in a rank lower than that of anthracite, and this rank he would call semianthracite

[1] In all references here to Lykens Valley coal, it should be understood that the author is referring to the coal of Lykens Valley No. 5 bed at the town of Lykens.

in accordance with the usage established by Henry D. Rogers. According to the scheme proposed by Rogers, all coal should be classed as semianthracite whose fuel ratio is less than 12, but this seems to the present author as unnecesssarily high and not only that but it is questionable whether there is any good excuse for adopting such a high fuel ratio for the dividing line between the two ranks. Unfortunately the author is not intimately acquainted with the coals lying to the east of the town of Lykens and therefore he is not in a position to recommend a hard and fast line for the base of the anthracite rank. He, however, is of the opinion that a fuel ratio of about 10 is a reasonable one at which to draw a limit which necessarily must be regarded as more or less tentative in character, until a complete series of analyses is available for study.

According to this conclusion, anthracite should be defined as generally a hard coal, containing such a small percentage of volatile matter that it ignites with difficulty and burns with a blue flame. It may be more definitely defined by saying that its fuel ratio ranges from 99 down to 10, but in no case does the fuel ratio fall below the last-named figure.

If the classification proposed above is adopted, then all of the outlying fields of Sullivan County, Pennsylvania, should be considered as bearing coals of semianthracite rank only, and all of the coals of the Valley fields of Virginia would fall into either the semianthracite or semibituminous rank, with the coals of Price Mountain, Pulaski, and Gunton Park, nearer the anthracite rank than those cropping out on the slope of Brushy and Little Walker mountains. Some operators of mines or owners of coal land in the Valley fields may be disappointed that their coal is not classed as anthracite, but the writer feels that if it were so classed it would be an entirely wrong classification, as it would imply that it is identical with Pennsylvania anthracite, whereas every characteristic, whether it be chemical or physical, shows that it is inferior to the Pennsylvania product. In other words, the Virginia coal would be sailing under false colors, and sooner or later the public would resent the imposition thus foisted on it.

Many persons have argued that because the Valley coal is smokeless and sootless it must necessarily be an anthracite. He who advances such a proposition forgets that the producer of Pocahontas coal has much the same grounds for claiming a higher rank for his coal, though every one knows that Pocahontas coal is not an anthracite, not because it is essentially smokeless and sootless, but because it contains enough hydro-carbons to burn with a yellow flame which, as noted previously, is not the case with a true anthracite.

The heating value of certain coals is also misunderstood by many persons, for they fancy that, because anthracite is the coal of highest rank, it must necessarily have the greatest heating value. The work of the Bureau of Mines has shown conclusively that this is not the case and

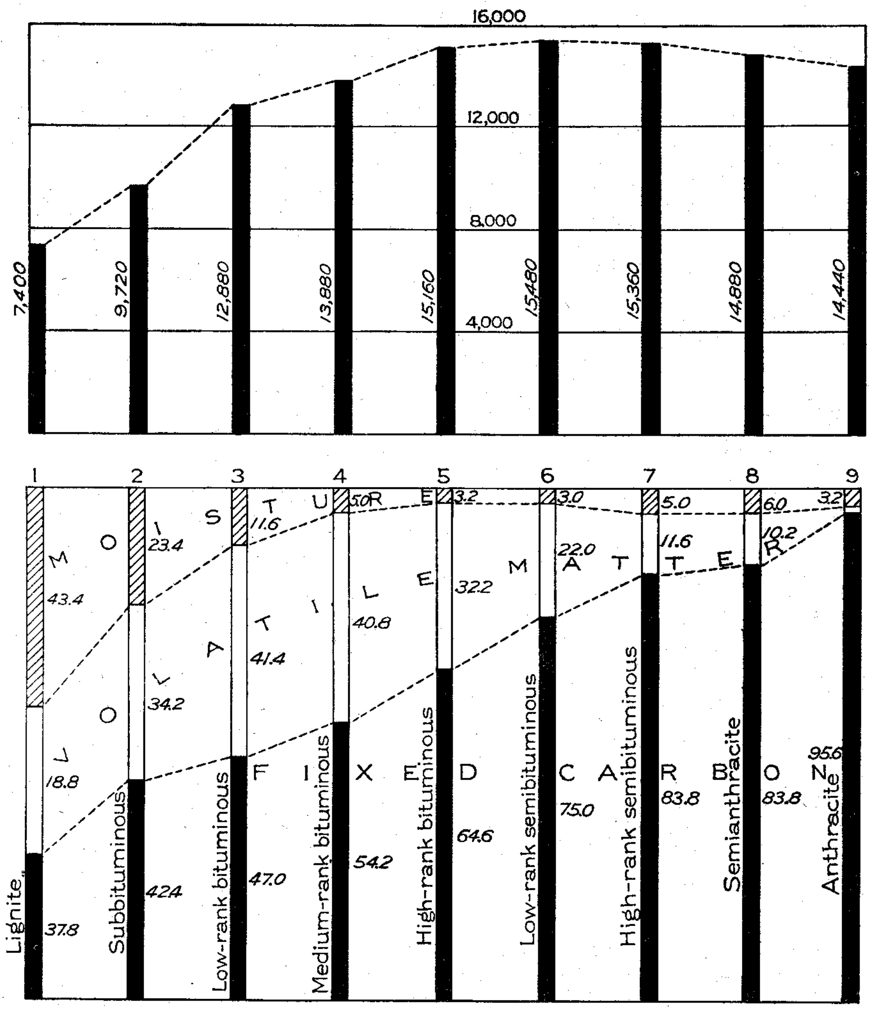


Fig. 15.—Graph showing the comparative heating values and composition of the different ranks of coal.

that the coal having the greatest heating value belongs in the lower part of the semibituminous and not in the anthracite rank. The general composition and comparative heating value of the various ranks of coal from lignite to anthracite are shown graphically in Fig. 15. The heating value given in this figure does not, however, agree with the B. t. u.'s in the table of analyses, for the reason that the ash in coal is almost all due to extraneous earthy matter washed into the old coal swamp and this must be eliminated before just comparisons can be made. The other constituents of the coal — fixed carbon, volatile matter, and moisture — undergo fairly regular changes as the vegetal matter is changed into coal and then as the coal is gradually altered until it reaches the anthracite stage; moisture shrinks rapidly at first and then maintains a fairly uniform percentage of the mass; volatile matter increases at first and then gradually tapers to a very few per cents in the highest rank; whereas fixed carbon increases steadily throughout the entire series of changes.

The upper diagram shows that the heating value of coals increases rapidly from the lignitic stage, reaching its greatest value at the top of the bituminous or the base of the semibituminous rank and then suffers a gradual decline throughout the remainder of the semibituminous rank and through the semianthracite and the anthracite ranks. The reason for this decline is that the heating value of carbon is not so great as that of hydrogen and also of some hydro-carbons and hence a coal that carries a notable percentage of hydrocarbons has a greater heating value than an anthracite which is composed mainly of carbon. Heating value can not, therefore, be considered as a criterion for the separation of coals into ranks.

The separation of the semianthracites from the semibituminous coals is of equal importance with the separation of the semianthracites from the anthracites, but fortunately many more analyses of the lower rank coals are available and also there is a greater physical difference between these ranks than there is between the higher ranks.

The semibituminous coals were so named by Henry D. Rogers[1] because they contain less—say about one-half—of the bituminous constituents that characterize bituminous coal. They are therefore of higher rank than ordinary bituminous coal, because they have lost much of their bituminous matter, but not so much as to fall into the semianthracite rank. In a commercial way the semibituminous coals are recognized as the most valuable steam-producing coals of the entire series. Their great

[1] Op. cit., p. 988.

value lies in their generally high heating-value, their comparative freedom from tarry matter and consequently their nearly smokeless quality, and their general freedom from spontaneous ignition. They are frequently referred to as "smokeless" coals and, because they have been widely exploited by the Navy, as "Navy" coals. They are known by certain trade names derived from the locality of field in which they were produced, such as "Pocahontas coal," "New River coal," "Georges Creek coal," "Cambria County coal," and "Clearfield coal."

There is no question about the appropriateness of recognizing such a rank; the difficulty arises, however, in defining its limits. In the analysis of coal of highest rank, the question of method of determing the volatile matter is of not much consequence, for when the volatile matter is less than 10 per cent an error in its determination does not materially affect the result, but as the problem in hand concerns coals with a volatile content, on the moisture and ash-free basis of 17 to 19 per cent, any error in its determination may have a decided effect on the assignment of a coal to one or the other of the two ranks,—semibituminous or semianthracite. For this reason the writer has depended entirely upon recent analyses made by the Bureau of Mines in the electric furnace where the temperature can be absolutely controlled. As stated previously, the present analyses made in the electric furnace yield a higher percentage of volatile matter than did analyses made with gas, either natural or artificial, as a fuel in the old practice, so it must be distinctly understood that all limits specified in this paper are based on analyses made according to the present practice of the Bureau of Mines.

In previous publications the writer[1] defined the term "semibituminous rank" as that which includes all coals having a fuel ratio ranging from 3 to 5 or 7. This statement was based largely upon old or rather miscellaneous analyses and also was made before many reliable data were available regarding the composition of the coals of the Valley fields. With the present wealth of material in both the semibituminous and the semianthracite ranks, and also in conformity with modern laboratory practice, the writer would lower both limits of this rank. A tabulation of more than 1,000 analyses of semibituminous coals of the Appalachian fields, made by modern methods shows that with only a few exceptions, the fuel ratio runs below 5.00, and, as most of the known semianthracites have a fuel ratio greater than 5.00, that figure is regarded as the lower limit of the semianthracite rank.

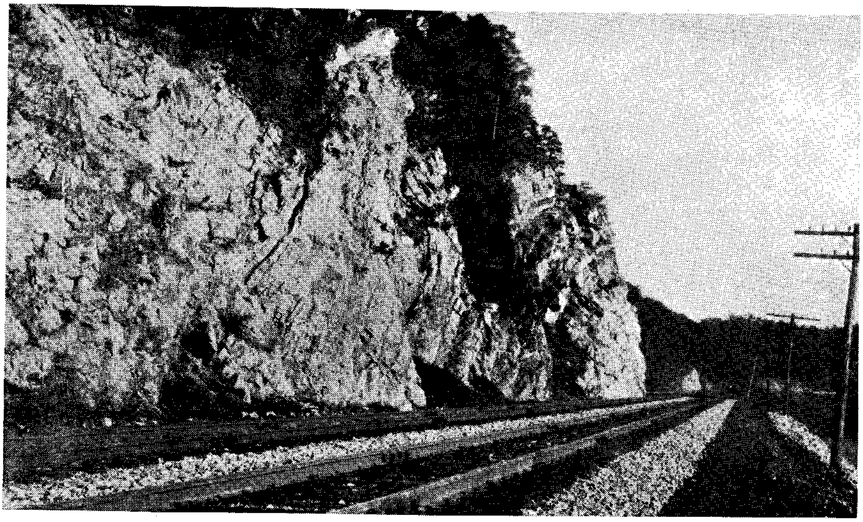
[1] U. S. Geol. Survey Prof. Paper 100-A, p. 5, 1917.

In accordance with the conclusion just stated, semianthracite rank may be defined as including coals which are generally harder than ordinary bituminous or semibituminous coals, but which are separated from the lower coals because of the smaller amount of volatile matter that they contain. The coal can also be distinguished by the fact that when first ignited it burns with a short yellow flame which soon turns to blue, whereas the flame of a semibituminous coal is always yellow and an anthracite always blue. They are also separated from coals of the anthracite rank, as previously stated, by the greater amount of volatile matter or the smaller amount of fixed carbon. Semianthracite rank may be more accurately defined as including all coals whose fuel ratios range from just under 10 down to and including 5.

The lower limit of the semibituminous rank should, because of the general lowering of fuel ratios by modern laboratory practice be placed below 3. A careful comparison of all analyses of recognized semibituminous coals shows that, in only a few cases, does the fuel ratio fall below 2.50, therefore, that figure is taken provisionally as marking the base of the semibituminous rank.

Semibituminous rank may therefore be defined as including all coals having a fuel ratio ranging from just under 5 down to and including 2.50. They are generally much more friable than the coals of higher rank and they burn with a short yellow flame. As they burn with only a thin yellow smoke when first fired, they are generally spoken of as "smokeless."

A study of the table of analyses on pages 108-113 shows that the fuel ratios of the coals of Montgomery and Pulaski counties and that part of Wythe County which lies south of the Reed Creek field, range from a minimum of 3.60 to a maximum of 8.07. It also shows clearly that the coal of highest rank is contained in the fields which lie farthest to the southeast. Thus in the Price Mountain field, the fuel ratios range from 7.09 to 8.07, with an average of 7.55. It is, therefore, apparent that the coal of this field, without any exception, should be classed as of semianthracite rank. Similarly, the fuel ratio of the coal from the Langhorne bed in the Empire mine at the west end of the Little Walker Mountain field ranges from 6.77 to 7.34 with an average ratio of 7.06. This coal is also clearly a semianthracite. The fuel ratio of the coal at Pulaski is 7.82 and so it is of the same rank as that of the Empire mine and of the coals of the Price Mountain field. The coal of Slusser and Doss, near the head of Mill Creek at the east end of the Brushy Mountain field in Montgomery County with a fuel ratio of 6.97 is also, without doubt, of

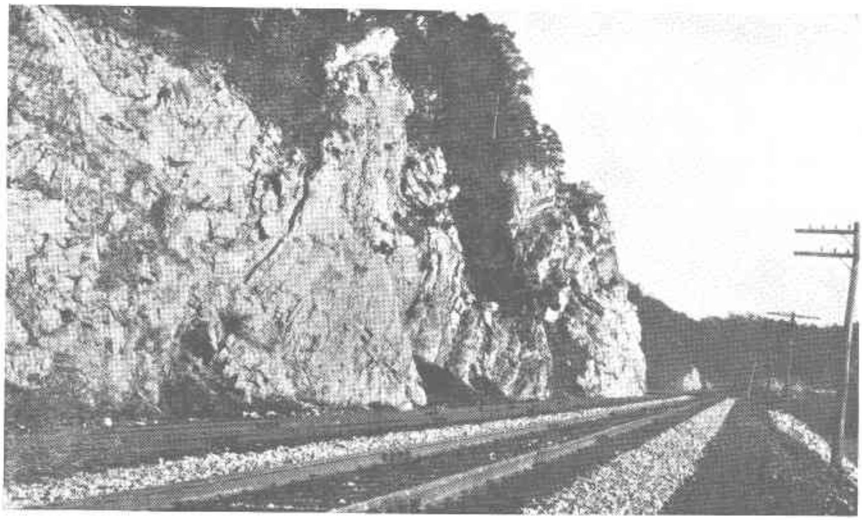


(A) Limestone cliff below Peppers Ferry.

Photograph by Marius R. Campbell.

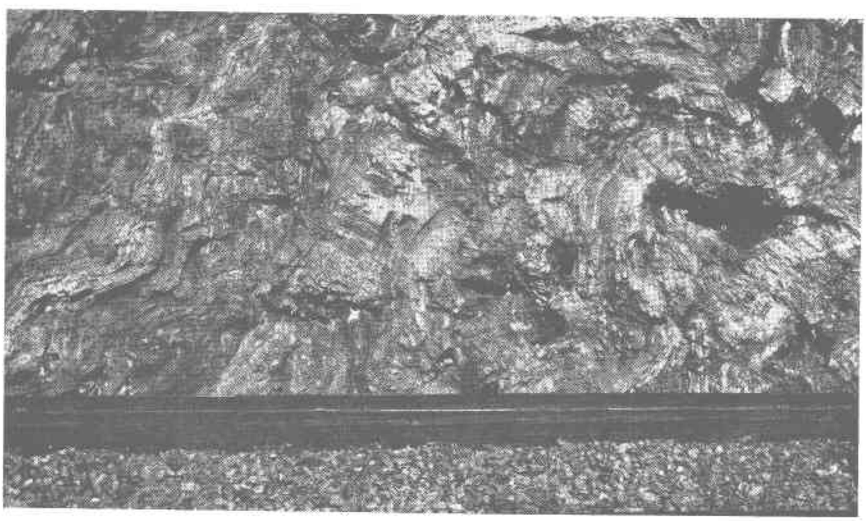
(B) Intricate folding in the limestone shown in Plate 11-A.

Photograph by Marius R. Campbell.



(A) Limestone cliff below Peppers Ferry.

Photograph by Marius R. Campbell.



(B) Intricate folding in the limestone shown in Plate 11-A.

Photograph by Marius R. Campbell.

semianthracite rank, but the main bulk of the Brushy Mountain and Little Walker Mountain coal is of distinctly lower rank, some of it even falling below a fuel ratio of 5.00, which has been provisionally accepted as the lower limit of this rank. According to the table of analyses, the coals of these fields, excepting that of Slusser and Doss and the Langhorne bed in the Empire mine, range in fuel ratio from 3.60 to 5.94 with an average of 5.30. Judging by the lowest fuel ratio of the group, these coals would fall into the semibituminous rank, but when they are considered in the aggregate it will be found that only six samples show a fuel ratio less than 5.00, whereas 19 samples show fuel ratios of more than that number.

The question then arises, shall the base of the rank be taken exactly as 5.00 and shall part of the coal of the Brushy Mountain field be considered as semianthracite and part semibituminous, or shall it be recognized that the various ranks may overlap slightly, and hence factors other than that of fuel ratio should be taken into consideration in settling this question.

As far as physical characteristics are considered, the coal of the Brushy Mountain and Little Walker Mountain fields is a unit and it would seem unreasonable to class the coal of one part of these fields as distinctly different from that of the other part. In a general way, the lowest fuel ratios characterize the coal in the vicinity of the Blacksburg-Newport road, but in the mines on either side of this road part of the samples have fuel ratios greater than 5.00 and part have less than 5.00. It is manifestly absurd to think of classifying the output of a single mine as of different ranks, and as the coal is practically as hard and as well adapted to domestic use as the coal either to the northeast or the southwest the coal of both the Brushy Mountain and the Little Walker Mountain fields will be considered by the author as belonging to the semianthracite rank, but he recognizes that the coal in the area specified above is lower in rank than the other coals of these fields.

The most striking feature of the coals of Pulaski County is the unusually high rank of the coal of the Langhorne bed in the Empire mine. As stated above, coal from the Merrimac coal bed in this mine has a fuel ratio in one analysis of only 3.6 whereas coal from the Langhorne bed which lies only 14 feet higher in the formation has a fuel ratio, as determined by averaging five analyses, of 7.1. The probable reason for this great difference in rank will be more fully considered in the part of this report dealing with the Little Walker Mountain coal field.

As would be expected the rank of the coal increases in a southerly direction as shown by a fuel ratio of 7.82 in a sample obtained in the mine of the High Carbon Coal Co. at Pulaski. This increase, being in the direction from whence came the main thrust which produced the Pulaski fault, is in perfect harmony with the general increase in rank across the entire Appalachian region and is in accord with the theory of the application of stresses in this region.

The coal of the Max Meadows field is fairly comparable in rank with that of the Little Walker Mountain field of Pulaski County and the Brushy Mountain field of Montgomery County, except that in this field there seems to be a marked tendency to decrease in rank westward. Such a decrease would be in accord with the westward decrease in the Little Walker Mountain field noted on a previous page, if it can be assumed that the reported fuel ratio of coal from the old Altoona mine is much higher than would be the case were it determined by modern methods of analysis. In this connection it may be interesting to point out that the westward decrease in rank is very marked in the Reed Creek field of Wythe County and as this field may be considered as the westward continuation of the Little Walker Mountain field, the whole line of evidence at present available indicates a regional change in a westerly direction.

The coal of the Reed Creek field and also that of the Bland field, according to the few analyses at hand, is of semibituminous rank and therefore would have to be classed with Pocahontas coal rather than with the semianthracites of the other Valley fields. It must be understood, however, that the samples collected in the Reed Creek and the Bland fields are of more or less weathered coal and hence the results may indidicate lower rank than the analyses would show if the coal were perfectly fresh. An increase in rank is, therefore, a possibility if new mines were opened at which perfectly fresh coal could be obtained for analysis, but the author does not believe that even the freshest coal would yield very different results from that which was obtained from the samples collected by him during the examination of these fields.

In order that the reader may have before him most of the data used by the writer in trying to settle the question of the rank of the coal of the Valley fields a second table of analyses has been prepared which shows the composition of coals in adjacent fields or of what may be considered as type coals of the country as well as the coal produced at most of the principal mines in the Valley fields. These analyses are shown in two forms: (A) the coal as received at the laboratory, and as the sample

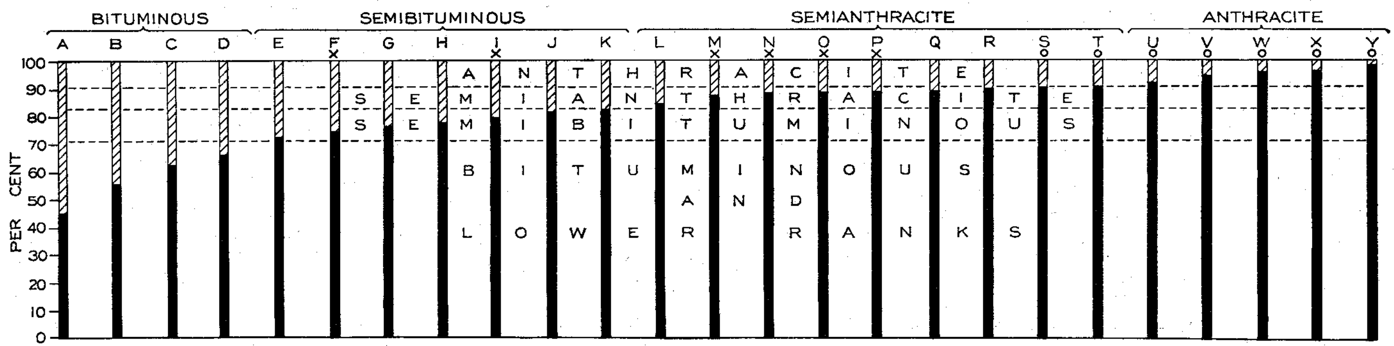


Fig. 16.—Graph showing, in the moisture and ash-free form, the proportion of volatile matter to fixed carbon of the type coals of the Valley fields and also of other coals with which they may have to compete. The blocks marked X represent coals of the Valley fields. Those marked O were plotted from old analyses and probably show a smaller percentage of volatile matter than they would if the analyses had been made in the electric furnace. The letters at the top indicate the kind of coal and the field which the blocks represent; they are the same as those used in the table on pp. 114-115.

is sealed in an air-tight can it means in the same condition as it was in the ground; and (B) what may be considered as the composition of the coal substance without the obvious impurities of water and ash. The first form (A) should be used in all cases where the coal is being considered as a fuel, and the second form (B) where it is desirable to compare the real coal substance.

The composition of the C-form is still further illustrated by the graph, Fig. 16. This shows the relative amounts of volatile matter and fixed carbon of the various coals listed in the second table and they are arranged so that the volatile matter decreases gradually from a maximum of 55.5 per cent in sample A to a minimum of 2.3 per cent in sample Y. The fixed carbon shows an increase in the same direction from 44.5 per cent in sample A to 97.7 per cent in sample Y. The fuel ratios show an increase from .80 in sample A to 43.32 in sample Y. Applying the limits of classification as worked out previously it is found that samples A-D are bituminous; samples E-K are semibituminous; samples L-T are semianthracite; and samples U-Y are anthracite.

DESCRIPTION OF COAL FIELDS

FIELDS OF MONTGOMERY COUNTY.

By Marius R. Campbell, Ralph W. Howell, and Kent K. Kimball.

General description.

Montgomery County is essentially an agricultural county. The limestone soil in the broader and more open part of the Valley is well adapted to the raising of hay and grain and consequently in the past the principal industry has been stock-raising, but recently more attention has been given to horticulture and now orchards of apples and peaches abound in many parts of the county. There are no large towns in the county; Christiansburg, the county seat, and Blacksburg, the seat of the Virginia Polytechnic Institute, are about equal in size, the former together with the tributary district around it being rated in the census of 1920 as having a population of 5,717 and the latter, a population of 6,100. The entire county had a population in 1920 of 18,595.

The coal-bearing territory of Montgomery County is naturally divided into two parts: (1) that area of the coal-bearing formation which lies along the base and south slope of Brushy Mountain, entirely across the county from the east boundary north of McDonalds Mill to New River at the station of McCoy on the Virginian Railway, and (2) the area of coal-bearing rocks on the north and south slopes of Price Mountain, a small ridge about 3 miles in length which lies midway between Christiansburg and Blacksburg, but to the west of the road connecting these towns. The first of these two areas will be called in this report the Brushy Mountain coal field, and the second, the Price Mountain coal field.

Surface features.

The surface features of Montgomery County are those which are generally characteristic of the Valley of Virginia. They consist of a broad valley floor with an undulating surface which is largely cultivated, bordered on both sides by ridges, more or less regular and continuous, that have been heavily forested, but now are almost denuded of forest trees, and densely covered with a tangled growth of small trees and underbrush.

In Montgomery County the valley is not quite typical as its rolling surface is interrupted by a number of ridges or mountain masses which are generally distinctly separated from the regular valley walls. These masses greatly reduce the width of the valley floor and in places separate it into two distinct valleys which, however, must be considered as parts of the "Valley," as it is generally known throughout the State.

In this county the valley-like character of this feature is not so apparent as it is in many other places, because it contains portions of two drainage basins—New River on the west and Roanoke River on the east—and these parts have very different aspects. The part lying in the New River basin is a rolling plain ranging in elevation from 2,100 feet to 2,400 feet above sea level, and in this plain New River has cut a narrow valley from 300 to 700 feet in depth. The Valley here is wide and is interrupted by only one small ridge—Price Mountain (Pl. V B)—lying 4 or 5 miles north of the Norfolk and Western Railway. The part lying in the drainage basin of Roanoke River is quite different in appearance and elevation. In the first place the valley is divided in a longitudinal direction by a great canoe-shaped mountain mass which extends from a few miles northeast of Christiansburg to north of Roanoke. As this group of mountain ridges has a breadth ranging from 4 to 6 miles, the valleys on either side are quite narrow, and as a consequence one scarcely realizes that these narrow valleys can be the representatives of the great expanse that characterizes the Shenandoah section of the "Valley" further to the northeast. The dissimilarity in the two sections is also heightened by the ruggedness of this part of the Roanoke basin as compared with that of the New River basin and also by the sharp ascent which one makes when he passes up the river from LaFayette on the eastern boundary of Montgomery County at an elevation of about 1,250 feet above tide to the divide near Christiansburg at an elevation of about 2,100 feet.

This difference in elevation is not due to a difference in the character of the rocks, for the Shenandoah limestone is exposed continuously along the Norfolk and Western Railway entirely across the county in an east-west direction, but it is the result of peculiar drainage conditions which in the past have prevented Roanoke River from cutting through this divide and robbing New River of its headwaters. At the present time, however, Roanoke River is actively at work on this divide and if conditions do not change the robbery will be accomplished some time in the future. The encroachment of Roanoke River has produced a very steep slope from Christiansburg down to Big Spring that serves as a decided handicap in the hauling of heavy freight westward, but fortunately does not interfere with the eastward movement of coal which constitutes the greatest tonnage hauled by the Norfolk and Western Railway.

When one stands upon the high land just south or west of Christiansburg he realizes that he is standing on what appears to be a plain cut in the Shenandoah limestone at an altitude of about 2,200 feet. The surface he sees to-day is not a plain because it is seamed by numerous stream valleys that are sunk from 100 to 400 feet below the general level, but were the valleys to be filled to an altitude of about 2,200 feet then the surface would indeed be a plain whose surface is broken only by low knobs and ridges that rise above its level, and, because they are still covered with trees, appear as islands in a sea of cultivated ground. This surface, as it appears to-day is shown in Pl. 5B, which is a view from the wagon road running south from the village of Vicar on the Norfolk and Western Railway, 5 miles west of Christiansburg. The photograph was taken from a point on this road where it surmounted the first low crest of Berringer Mountain. The camera is probably 100 feet above the level of the plain just described and the low ground in the foreground and middle distance is part of its surface. The photograph shows the country due north and northwest of the observer. The wooded ridge on the right is Price Mountain, the knob in the middle of the picture is a hill near the west end of the Price Mountain coal field. Another view of this plain west of Blacksburg is shown in Pl. V A.

The conditions which would permit of the cutting of such a perfect plain throughout a broad area of the Valley of Virginia must have been very different from those which prevail to-day, for at the present time the small streams, even those draining into New River are actively at work deepening the valleys. It is possible, however, that should the crust of the earth here remain stationary, neither moving up nor down for an immensely long period of time, New River and all its tributaries as well as the Roanoke and its tributaries would cut their channels well down toward sea level, and if the undisturbed conditions continued long enough the interstream areas would also be reduced nearly to the level of the major streams and a surface would be produced which might not be a perfect plain, but would resemble one so strongly that it might be called a peneplain (an almost plain), a name physiographers have adopted for a surface of this kind produced in the manner outlined above. As the upland surface here described was probably produced by stream erosion and as it was never a very perfect plain, it will hereafter be called the Blacksburg peneplain because of its excellent development about that town.

The Blacksburg peneplain is well developed on the Shenandoah limestone at an altitude of 2,200 feet from New River eastward to a point about 4 miles east of Christiansburg and in the valley between Paris and Brushy mountains, entirely across the county and for a distance of 5 or 6 miles in Roanoke County. East of the limits specified above no trace of such a feature can be found at this altitude, hence it is either destroyed by recent erosion or it has been deformed since its completion by earth movements that have reduced it toward the east to a lower level. Physiographers do not agree as to the northeastward extension of this surface, but the writers are fully convinced that the peneplain was developed about Roanoke and Fincastle, and that it has not been uplifted here to the same extent that it has on New River.

The development of the Blacksburg peneplain was an important event in the Tertiary history of this region for it not only produced a fairly level surface across the valley, but also greatly enhanced the value of the land for agricultural purposes. This was brought about by the extremely long exposure of the surface to the processes of weathering which permitted of deep decay of the limestone but, owing to the low gradient of the stream valleys, the materials resulting from the decomposition of the limestone were not all carried away, but remained practically in the place in which they were derived. The peneplain is easily identified to-day by the lack of rock exposures at the surface and by rock debris,—residual clay—that is the striking characteristic of this surface. When one passes from the surface of the peneplain into the ravines that have been cut below its surface, he is surprised at the amount of limestone and calcareous shale showing at the surface, as compared with the almost absolute lack of such exposures on the surface of the peneplain. Another feature of great interest on the peneplain surface about Blacksburg is the occurrence of cobblestones, as much as 6 inches in diameter, which have been left stranded on the highest ridges west of the town. As these cobbles are composed of rocks that occur in the Blue Ridge province to the southeast, it is evident that either New River or Little River has wandered widely over the peneplain, their courses at that time undoubtedly being quite different from what they are to-day.

After the formation of the Blacksburg peneplain which seemingly was developed throughout the entire Valley of Virginia, regardless of drainage basins, and which therefore must have required a long period of time for its formation, the land was uplifted 100 feet or more and the valley of New River was widened in places to a mile or more in breadth, indicating that the epoch in which the earth's crust remained stationary and the wide valley was produced was of considerable duration, but not nearly so prolonged as the epoch in which the Blacksburg peneplain was in process of formation. In the second epoch New River evidently swung to the east near the mouth of Toms Creek and flowed in a great meandering curve over the country to the northwest of Whitethorn. Great quantities of gravel and boulders were swept into this region by the river and at present they, together with an overlying deposit of silt, cover much of the country northwest of Toms Creek that is crossed by the road leading from Price Forks to McCoy.

Still another pause in the general elevation of this country is recorded in a fine terrace about 100 feet above New River which is particularly well shown in Pl. 2B as it is developed back of McCoy and also in the bend of the river opposite East Radford. At the last named locality the terrace, which is only a fragment of the floor of the old broad valley of the river, is developed on a point of the upland projecting into a pronounced bend of the river, but in the first named locality the entire valley of the river was widened for some distance even in a place where the river encountered the hard rocks forming Brushy Mountain, so that on passing along the river on either the Virginian or the Norfolk and Western railway one does not see Brushy Mountain coming to the brink of the river as does Little Walker Mountain, which is really the westward continuation of this ridge. This terrace is well shown on Pl. 2B, which is a view taken from the Norfolk and Western Railway about one-quarter of a mile below the Parrott coal mine. In the view the end of Brushy Mountain shows in the distance, standing distinctly above the nearly level terrace in the middle distance.

There is still a lower terrace at several points on New River, but the present remnants of this terrace are limited in area and apparently it was developed only in favorable localities, either where the rocks are soft and were easily cut away or where the river, because of the direction of its course above, has been diverted from its old pathway, leaving a remnant of its flat bottom to mark its previous course and also as a record of a period of stability of the earth's crust in this region.

The Blacksburg peneplain and the terraces at lower levels afford considerable level land that is either deeply covered with residual clay resulting from the decay of the limestone or with sand and gravel carried and deposited by the river in places where the current was not strong enough to transport them farther. These tracts are generally cultivated, but the knobs and ridges standing above the peneplain level, because of the hardness of the rocks forming them, and the ravines cut below the level land, because of the steepness and rocky character of the slopes, are not generally cleared and farmed, and the rocks are more or less abundantly exposed.

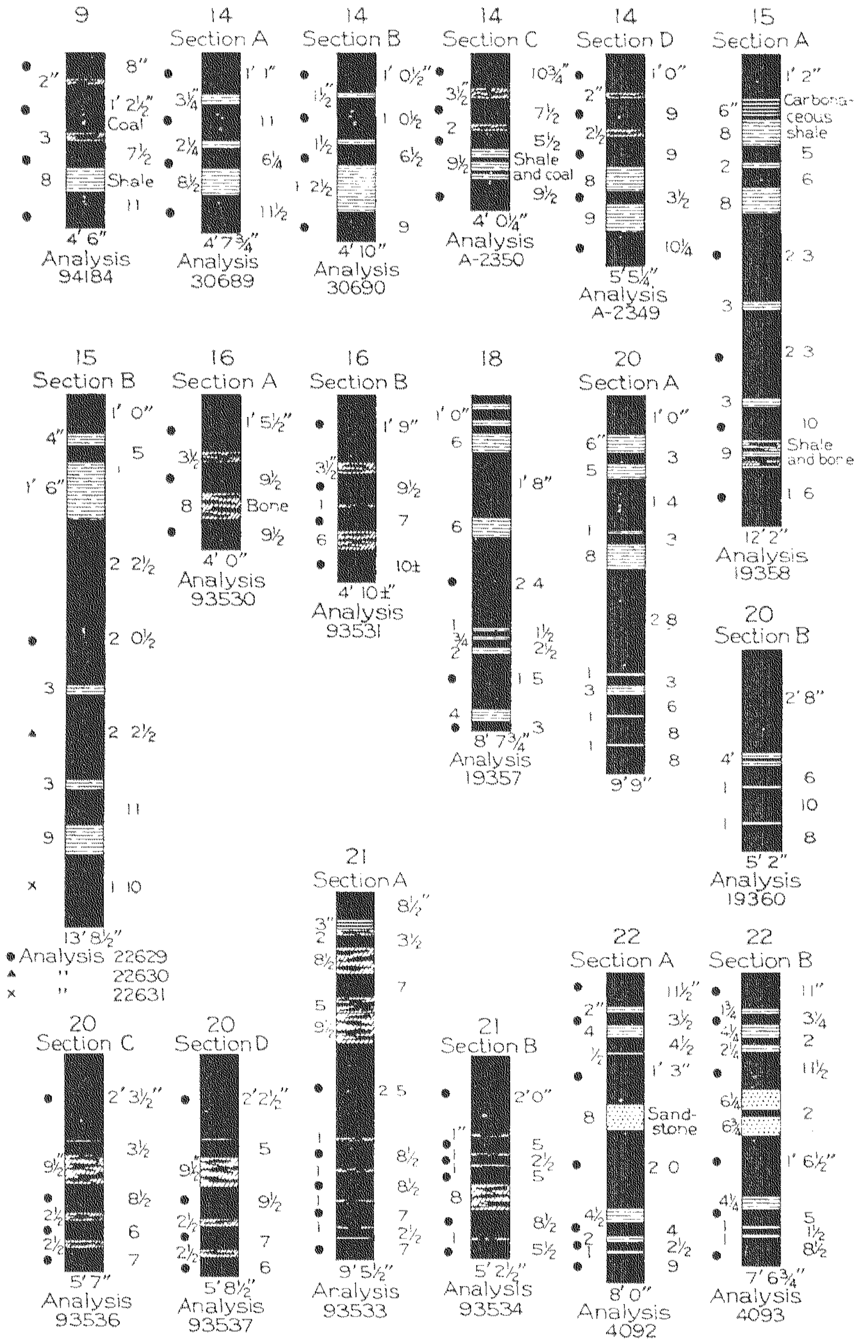
Transportation facilities.

The formation of the Blacksburg peneplain on the more soluble rocks of Montgomery County has very much simplified the question of building lines of transportation—both railroads and highways—across the country, especially in an east-west direction. The country is crossed by both the Norfolk and Western and the Virginian railroads. The former approaches from the east up the valley of Roanoke River and its South Fork, which it follows nearly to Shawsville. Here it leaves the main stream and climbs the steep slope of the divide between the Atlantic drainage on the east and the Mississippi drainage on the west. The actual divide is crossed about half-a-mile east of the railway station at Christiansburg (Cambria P. O.). From this point it follows down Crab Creek to Walton near New River where the line divides, the old or Bristol branch turning up the river to East Radford and the Bluefield or main line turning down stream and two miles below crossing the river into Pulaski County on the west. A branch of the Norfolk and Western running from Christiansburg to Blacksburg is the only part of this system actually entering the coal fields of this county. This branch passes through the Price Mountain coal field and at Blacksburg is so near the Brushy Mountain field that considerable coal has been trucked in and loaded at its station. The Virginian Railway enters the county by the valley of Roanoke River, the same as the Norfolk and Western, but instead of following the South Fork it follows the North Fork and near Yellow Sulphur Springs tunnels through the dividing ridge mentioned before and follows down Lick and Stroubles creeks to New River which it reaches in the vicinity of Price. From this place it follows the east bank of New River beyond the north line of Montgomery County. The Virginian Railway crosses the entire length of the Price Mountain field in an east-west direction and it also crosses the Brushy Mountain field at New River.

The county is not well supplied with improved highways. The old State Road passing through Shawsville, Christiansburg, and on to the west to Ingles Ferry is passable for automobiles, but it is not well suited to a pleasure trip. This road is now being rebuilt by the State and doubtless in the near future there will be a first-class road across the county which, however, will cross New River at Radford rather than at Ingles Ferry as was done by the old State Road. The State Road between Plum Creek and Ingles Ferry is in bad condition and is traveled only by those who have local business in that section. An excellent road connects Christiansburg and Blacksburg and from Blacksburg two improved roads lead, one in a westerly direction to Price Station on the Virginian Railway, and the other to Newport which is hard-surfaced as far as the crossing of Toms Creek with a branch to the east that is improved for a distance of about 3 miles. There are two improved roads leading south from Christiansburg but they extend for distances of only a few miles.

The unimproved roads of the county are very poor and are generally avoided by tourists unless they have business with some of the local farmers or fruit growers.

Blacksburg is the seat of the Virginia Polytechnic Institute and is a typical college town. It is beautifully situated in a rich farming and fruit-growing region with coal mining carried on both on the north and the south. These surroundings make it an almost ideal location for a polytechnic school, as the students may find in the adjacent country ample opportunity for the application of the studies they are pursuing within the institution.



Sections of coal bed in the Brushy Mountain coal field, Montgomery County, Va.

Geologic structure.

In the chapter on Geologic structure the broader structural relations of the geologic formations have been considered and the method of their formation has been discussed at some length, but in that chapter the structure of the coal fields has been considered entirely from a theoretical point of view, without stopping to determine its bearing upon the local conditions of coal-mining. As the prime object of this paper is to present all of the facts that have been obtained in the field bearing upon the questions of the distribution of the coal at the surface and the extension of the coal beds underground, the structure in or adjacent to the fields of Montgomery County will be reviewed and additional details given that may have a bearing on the development of the coal beds.

The faulted anticline on the northwest side of the Craig Creek syncline is one of the most significant structures in the eastern part of Montgomery County. This anticline has been almost obliterated by the great thrusts from the southeast that have affected the rocks of the region at several epochs of the past, and now all that remains of it is the Millers fault with the Shenandoah limestone bordering it on the southeast. The very fact that this fault cut as deeply as the middle of this great limestone mass and as high as the Price formation indicates that the anticline was no small affair. Although the greatest development of this fold, as it shows to-day, lies east of Montgomery County, there is some indication that it once extended farther west and it seems possible that it may represent the northeastward extension of the Price Mountain anticline, or some of the other folds in that neighborhood that were partly developed prior to the Pulaski overthrust. The presence of the upper part of the Shenandoah limestone in the great embayment of Brushy Mountain at the head of Mill Creek is strongly suggestive of such a southwestward extension but if it was once connected to the southwestward with some fold in the vicinity of New River, the eastern part must have been shoved many miles out of a direct line. This great northward shove in the formations in the vicinity of Blacksburg is indicated by the peculiar distribution of the sandstone member of the Shenandoah limestone shown on Pl. I. The two bands of this sandstone from near Trinity Cross Roads to the vicinity of Shiloh Church in Roanoke County indicate anticlinal structure which has been faulted and one limb shoved over the other until all trace of the anticline, as such, has disappeared. If the shape of this small fold is any indication of the shape of the larger fold to the northwest, then it may confidently be said that there is some probability that the Craig Creek anticline was originally nearly in line with the eastward extension of the Price Mountain anticline and may have been the continuation of that fold.

The reader may be wondering what effect the presence or absence of a crushed anticline in the region east of Blacksburg may have on the extension of the coal bed beneath the surface. The possible bearing is this: if it can be shown that originally there was an anticline extending northeastward from the vicinity of Blacksburg of the magnitude that this crushed anticline seems to have had, then it seems fairly certain that the probability of the Price formation extending toward the south indefinitely from the outcrop at the base of Brushy Mountain is decidedly slim, or rather that there is hardly one chance in a thousand that it does extend in this direction indefinitely. Therefore, the writers conclude that it is hopeless to expect coal at a depth south of a line extending from Blacksburg to the point of Cove Mountain, northeast of Shiloh Church, but even along this line the coal may be too deep for economical mining.

The extent to which mining can be carried in these fields can not be settled in an arbitrary manner. It is more of an engineering question than a geological one and data for the solution of the engineering problem have not been obtained. So far as the writers have seen, there appears to be no inherent difficulty in these fields in carrying mining to a considerable depth, and they are inclined to believe that it is an economic rather than an engineering question after all, for the depth will probably be determined by the cost of mining and raising the coal and water. Just at what point the cost would become prohibitive the writers are unable to say, but it seems probable to them that mining here will ultimately be carried to a depth of at least 2,000 feet vertically below the surface. Such a depth is attained in the anthracite field of Pennsylvania at the present time but in the Virginia field it would not be considered feasible. It is assumed, however, that mining methods will improve and that when a large plant with the best modern machinery is established, ways and means will readily be found to continue the work to a depth of at least 2,000 feet, or until the selling price of the coal is less than the cost of mining plus a reasonable profit for the operator.

West of Blacksburg the structural conditions are much more easily interpreted than they are east of that place, but even here there are many factors that have not been determined and hence the problem of the depth and extent of the coal bed below the surface can not be said to have been solved. So far as the writers can judge, there does not seem to be any doubt that there is a rather shallow and flat trough—the Toms Creek syncline—lying between Price Mountain on the south and Brushy Mountain on the north. This syncline seems to be deepest in the vicinity of Blacksburg and grows more and more shallow toward New River. Its termination west of New River is one of the unsolved questions of this particular area and one that seemingly can not be definitely answered until deep drilling has been done in the limestone area south of the Pulaski fault. While the writers are perfectly willing to admit that they have not succeeded in solving this question, they have obtained some evidence that may have a bearing on the question and may possibly afford some indications of the probable structure beneath the limestone and the extension of the coal beds in that direction.

If the limestone and the underlying coal-bearing formation have been affected by the same forces and similar structures produced in them, as is apparently the case in the Price Mountain coal field, then the most promising line of attack is the limestone itself to see if there are not some controlling structures in it that will give a clue to the structure in the underlying rocks. The most pronounced structure in the limestone in the vicinity of New River is a deep syncline whose axis crosses the river at the point where the bridge of the Norfolk and Western Railway is located a little more than a mile below Peppers Ferry. The rocks are well exposed in the railroad cuts in the river bluff and the writers were able to measure foot by foot the 1,800 feet of limestone that compose the southern limb of this trough, extending from the Pulaski fault a short distance above Peppers Ferry, shown in Pl. IX B, down to the axis of the syncline which, as stated above, is at the railroad bridge about one mile north of Peppers Ferry. North of the axis the beds can not be followed so closely as they can south of the axis, but southward dips were observed almost continuously along the railroad as far north as Belspring.

As the axis of this fold trends nearly east-west it is manifestly the syncline which separates the two anticlines of the Price Mountain and the East Radford fensters. West of New River the axis was observed on the Radford-Belspring road at the bend 2 miles north of New River, but beyond this point it is lost in the poor exposures in the upland south of Back Creek. The north limb of the syncline can be traced somewhat beyond Belspring, possibly as far as Back Creek, but the structure in the Back Creek valley was not studied carefully enough to make its interpretation possible. It seems probable, however, that immediately north of the north limb of the syncline the limestone is so broken that its structure is almost beyond conception, and if that is the case little can be expected from additional surface work. The principal point, however, is that the syncline south of Price Mountain extends westward at least as far as Belspring and probably to Back Creek. The presence of this deep syncline in the overthrust Shenandoah limestone would seem to indicate that any coal-bearing rocks that may lie below the limestone are either absent here, or if present, they are carried to such a great depth that the mining of the coals is a physical impossibility.

The definite limitation of this syncline in a northerly direction suggests that the broken character of the rocks in this region may be due to the formation, only a short distance below the surface of an anticlinal fold that may be the prolongation of the Price Mountain anticline or of another fold of the same general character. If it be granted that the broken condition of the limestone indicates an anticlinal fold north of the syncline just described, then such an anticline would trend a little north of west from the extreme west end of the Price Mountain anticline through Belspring and would strike the Pulaski fault at a point about one mile up Back Creek. This hypothetical anticline would limit the Blacksburg syncline on the south and would without much doubt mark approximately the southern limit of the coal-bearing formation under the Shenandoah limestone. It is on this supposition the sections C-C′ and D-D′ on Pl. 1 have been drawn, and it is on this basis that the writers would estimate the thickness of the overthrust sheet of limestone in the Toms Creek syncline. The estimated thicknesses are as follows: section A-A′, 1,800 feet; section B-B′, 1,900 feet; and section C-C′, 1,800 feet.

The southward extent of the coal bed under the Shenandoah limestone on the south side of the Price Mountain coal field is another of the important unsolved structural questions regarding these coal fields. The writers did not hear this subject mentioned in the field, so it is probable that the operators on this side of the mountain are counting on the presence of the coal bed in a workable condition for an indefinite distance to the south, but the writers are far from being satisfied that such a conclusion is justified. The basis for this doubt is formed by the following facts to be gathered from a close study of the outcrops, both in the zone of the outcrop of the Carboniferous rocks and of the Shenandoah limestone.

The presence of the coal-bearing part of the Price formation in the Price Mountain anticline and its probable absence in the East Radford anticline shows that it must terminate at some place between these two folds. East of New River, as explained in the description of the Price Mountain coal field, the limit of this formation is supposed to be near the present location of the fault on the south side of the Price Mountain fenster. As it is the rule in Appalachian structure that the formations involved in a fold are faulted in the overturned southeastern limb of a syncline and as the syncline showing in the limestone on New River is not overturned on its southeastern limb, it seems altogether probable that there is a sub-surface fold north of the syncline just described which is overturned and that it is in the south limb of this fold that the coal-bearing formation is faulted off. This assumption receives some support from the unsymmetrical form of the Price Mountain anticline, for if the thrust from the south was sufficient to push over the axial plane of this anticline past the vertical, it is highly probable that the accompanying syncline on the south would be similarly affected and hence such an upturn or overturn would be the logical place for the termination of the coal-bearing rocks by the faulting of the upturned edge of this syncline which is now possibly concealed by the overthrust Shenandoah limestone.

The recent field work carried on by the writers in this locality brought to light some structural evidence which, if correctly interpreted, tends to show that the Merrimac coal bed is limited in a southerly direction to a rather narrow belt of territory, and that, instead of continuing to descend indefinitely to the southward, it will be found to turn up abruptly and be broken off by a fault at a distance of about 2 miles from the mouth of the Merrimac slope.

The evidence bearing on this question is as follows: For some time the senior author has been aware that conglomerate is exposed on the southeast limb of the Price Mountain anticline, beginning near the shaft which was sunk during the excavation of the summit tunnel of the Virginian Railway and extending northeastward to the point of the fenster, as shown on Pl. I. This conglomerate had been seen at only a few points and its significance was not realized until about the close of the past season when this part of the field was visited by Professor Holden and the senior author. This examination revealed the fact that the conglomerate is practically continuous along the line specified above and that to the north of the conglomerate is a coal bed or beds which have been prospected at a number of places, and on the southeast side of the conglomerate is a band of what must originally have been an earthy limestone carrying fossils. A small collection of these fossils was placed in the hands of George H. Girty,[1] of the United States Geological Survey, who with but slight hesitation pronounced them to be of Devonian age. If one should start on the outcrop of the Merrimac coal bed at the east end of its exposure just east of the Merrimac mine and travel southeastward he would pass upward through the upper part of the Price formation, then into the band of Maccrady red shale, then down through the crushed and greatly thinned formations in reverse order passing through the Price formation, the Ingles conglomerate and then into the Devonian sandstone and shale a short distance to the Pulaski fault.

Only one explanation is possible in this case and that is the interpretation given on section A-A′, Pl. I. This section shows that here is a remnant of an overturned syncline on the southeast side of the Price Mountain anticline and the lowest rocks exposed on this overturned limb are some fossiliferous beds at the top of the Devonian system. Some person may object that, as shown by the section, there is not sufficient room for all of the Price formation on the overturned limb. This contention will be readily granted, but the slight thickness of the formation here is due rather to stretching and thinning on the overturned limb of the syncline than to clear-cut faulting. Such thinning on overturned limbs of folds is of common occurrence in the Appalachians and is regarded by those who are familiar with such structure as a perfectly normal phenomenon.

As stated previously this overturned limb can be traced westward until it is concealed by the overthrust Shenandoah limestone just west of the railroad which connects Christiansburg with Blacksburg. It would seem that an overturn occurring so near the Merrimac mine would to some extent at least affect the attitude of the coal bed in that mine. Curiously enough, such an effect is shown by lessening dips in the eastern part of the mine, but the operator of the mine has not yet realized that the decrease in the dip in that part of the mine means that he is approaching the end of his coal bed, but such is undoubtedly the case and it would be the part of wisdom for the management to sink some drill holes in advance of the workings so as to determine the exact amount of coal still available. The dips in the western part of the mine do not

[1] Personal communication.

show any tendency to flatten, although the workings in this part of the mine are at about the same distance from the outcrop as are those in the east part of the mine. This probably means that the upturn is farther removed in the west than it is in the east, but even in the west part it probably will be found to be not many hundreds of feet farther away.

Those who desire to understand the structure of this part of the field should make a careful study of the geologic section exposed in the cuts along the Christiansburg-Blacksburg Railroad south of the crossing of the Virginian Railway. In passing southward from this crossing the rocks first encountered are those of the upper part of the Price formation and are generally free from a distinctive red color. These rocks dip south at an average rate of about 24°. In the far end of the first deep cut red shale and sandstone appear; as this is a separate and distinctive band of red interbedded with yellowish-green shale it is considered to be within the Price formation, but at the farthest end of this cut the red shale makes its appearance in a formation of solid red. This occurs at a point about 715 feet south of the Virginian Railway and this point is regarded as marking the boundary between the Price formation and the Maccrady shale. At this point the dip is about 20°.

Southward from the crossing of this boundary the dip of the Maccrady shale grows less and less, until at a distance of 1,950 feet from the Virginian Railway the low dips are suddenly terminated and replaced by dips of 50° to 60° to the south. This change of dip evidently marks the point at which the overturn of the south limb of the syncline begins and this overturn, marked by steep but variable southward dips, continues to the beginning of the Shenandoah limestone which marks the great Pulaski fault. Near the contact of the limestone the red shale grows inconspicuous and the rocks showing at this place seem to be the greenish sandstone of the upper part of the Price formation.

There seems to be no question about the interpretation of the structure shown in this section being an overturned syncline with the Maccrady shale in the bottom of the trough, but the structure west of this railroad is somewhat puzzling and the writers are not certain that they have interpreted it correctly. From the Norfolk and Western Railway westward to the wagon road that crosses the end of the mountain and leads from Price Forks to Vickers the red shale is found in a narrow band, dipping 30° to 35° to the south. In many places this band has a width of not more than 400 feet and toward the west end of the field the red shale is bounded on the south by a pronounced band of yellow shale, much like the shale in the upper part of the Price formation. The yellow shale dips in the same direction and at about the same angle as the red shale, but near the limestone the dip increases, in places, to as much as 70°.

The writers failed to get sufficient evidence to enable them to determine the structure of this belt. The data collected is subject to two interpretations: (1) that the band of Maccrady shale, shown on the geologic map, Pl. I, is on the axis of a syncline and the yellow shale to the south is the upturned upper part of the Price formation; or (2) that the band of red shale is a distinct layer near the base of the Maccrady shale and the yellow shale to the south is merely a band of that kind of material in the Maccrady. In the event that the first interpretation is accepted as correct, the structure would be the same as that at the east end of the fenster, already described, but if the second interpretation is accepted, then the coal-bearing formation, instead of turning up as it does farther east, turns down and its southern limit can not be determined. One objection to the last interpretation is that, as shown previously, the coal-bearing rocks are cut off somewhere between the Price Mountain and the East Radford fensters and if the formation turns down, it is difficult to understand what would cut if off. On account of this difficulty the writers have accepted provisionally the first explanation and the structure sections on Pl. I are constructed on that basis.

There is an exposure of black shale on Geeses Creek near the west end of the fenster just below the Peppers Ferry road and a similar exposure near the top of the ridge on the road east from Vickers that presented one of the most difficult problems that was encountered in the field. The shale strongly resembles the Devonian black shale, but in each locality mentioned it lies directly below the Shenandoah limestone. East of Vickers the black shale appears to rest upon yellow shale of the Price formation, but on Geeses Creek the black shale rests upon or against another mass of Shenandoah limestone. At the latter locality the writers interpreted the two masses of limestone as indicating the presence of a normal fault with the downthrow on the north, and the geologic map has been drawn to harmonize with this interpretation. The difficulty with this interpretation is to account for the presence of Devonian shale here where the only shale that is known is of Carboniferous age. If this shale is really Devonian, and the writers are inclined to believe that it is, then the only method of accounting for its presence here is on the assumption that the shale represents a thin wedge of Devonian which with the overlying limestone has been overthrust upon other rocks—in one place Shenandoah limestone, and in the other, the Price formation or Maccrady shale. If the overturned syncline was originally present throughout the whole extent of the Price Mountain anticline, it means that throughout the coal field the Merrimac coal bed extends only slightly south of the present margin of the limestone and that in consequence the field is considerably restricted in this direction.

The coal beds.

The Price formation in this field contains many beds of coal, but most of them are so thin and so irregular in distribution as to be considered worthless. There is one bed, however, that seems to be of workable thickness throughout the county, where its thickness has not been affected by movement within the rocks. About 99 per cent of the mining already done has been in this bed which on account of its thickness has generally been referred to as the "Big Bed." Below the "Big Bed" at a distance ranging from 20 to 70 feet, is a thin but quite persistent bed which, by comparison, has been universally known as the "Little Bed." As such names are not at all satisfactory for names of coal beds, the writers have taken the liberty of renaming them, giving to each a distinctive name which shall not only serve to identify it, but, at the same time, by implication, indicate a type locality. The names here applied have also a historic value as they are derived from some of the early efforts to develop the coals of these fields.

As the larger of the two beds under consideration is best known from the fact that it is the bed worked in the Merrimac mine in Price Mountain, the name "Merrimac" is here proposed for it. In a historical way this name is also appropriate because coal from this mine is said to have been used on board the Confederate frigate *Merrimac* in her memorable fight with Ericsson's *Monitor* in Hampton Roads in 1862. Similarly, the name "Langhorne" is proposed for the "Little Bed," because its best development is in the Empire mine in the Little Walker Mountain coal field, which was originally opened by Daniel G. Langhorne of Pulaski.

Brushy Mountain coal field.

GENERAL DESCRIPTION.

As the coal beds of this field occur in the Price formation, they are necessarily limited in their surface exposures to the outcrop of that formation. The principal belt of outcrop is on the south side of Brushy Mountain and, as the rocks of the formation dip to the south, or to be more exact, about south 15° east, and as the basal conglomerate of the formation is generally the most resistant stratum in either this part of the Carboniferous system or in the upper part of the Devonian system, the lower boundary of the Price formation, in many places, forms the crest of the mountain and the other rocks, including the coal beds, make up the south slope. If the dips are more than 30° or the conglomerate less resistant than is usually the case, then the line marking the lower limit of the formation may follow a bench on the side of the mountain or shoulders on the spurs. The coal beds, however, occur some distance above the base of the formation, hence in only a few places do they crop out on the slope of the mountain, but rather on a bench at its base which is a remnant of and marks the position of the Blacksburg peneplain.

STRUCTURAL RELATIONS.

In places the upper limit of the coal-bearing rocks is marked by the red beds of the Maccrady shale, but in other places the Shenandoah limestone has been thrust up from the southeast to such an extent that it covers all of the Maccrady shale and even in places approaches very closely, if it does not actually conceal, the coal. As described under the heading "Geologic Structure," the great break in the rocks which has resulted in the overriding of the Shenandoah limestone is known as the Pulaski fault.

For many years those familiar with the field, and particularly those who have operated coal mines have indulged in speculations regarding the relationship of the Shenandoah limestone to the coal and the possibility of finding coal beneath the limestone. The surface relationship is shown diagrammatically in Fig. 17, with the coal bed cropping out at the point A on the south slope of Brushy Mountain and dipping to the southeast at an average rate of about 28°. It is obvious from the figure that the effect of the limestone on the coal beds depends altogether upon the attitude of the fault plane which separates them. If the fault plane dips in conformity with the coal-bearing rocks, as shown by the line C D in Fig. 17, the fault plane will not cut the coal beds, no matter how far they are extended, unless the dip of one or the other changes, but if the dip of the fault plane is steeper than that of the underlying formations, the fault plane will cut the coal bed at some point below the surface, the location of the point of contact depending upon the relative dips of the coal bed and the fault plane. If the dip of the fault plane is 45°, as shown by the line C B and the dip of the coal bed about 28° (A B, fig. 17) the coal bed will be cut off by the fault at the point B. If the dip of the fault plane is very steep, point B will be

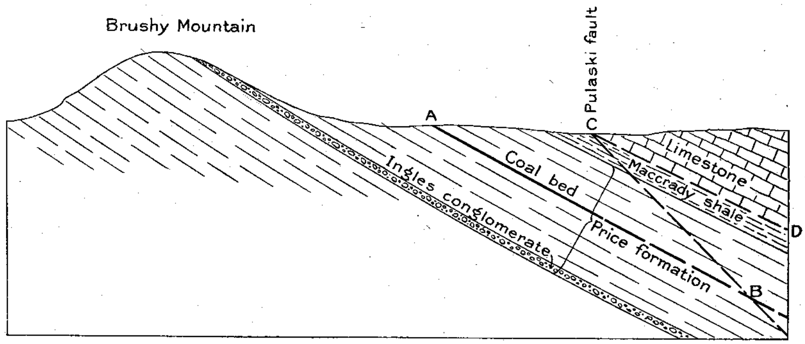


Fig. 17.—Section showing the relation of the Pulaski fault to the Merrimac coal bed in the Brushy Mountain coal field.

located only a little distance south of the margin of the limestone, but if the dip of the fault plane is at a low angle then the point B may be some distance south of the limestone boundary.

Until 35 or 40 years ago, geologists working in the Appalachian region regarded all faults or breaks in the rocks as having steeply dipping planes, corresponding to the line C B in Fig. 17, and consequently the idea was generally held in this field that the coal beds were cut off at or near the edge of the limestone, and that it was useless to search for them south of the line marking the northernmost position of the limestone. As a result of this almost universal belief, tracts of coal land, whether for lease or for sale, generally extended from the top of Brushy Mountain to the edge of the limestone. Now it is generally recognized that the faults common in the region are of the overthrust type, as shown in the sections on Pl. I, and that the plane or surface on which the limestone mass has been overthrust dips very slightly to the southeast or may be practically horizontal. As most of the movement on such a fault plane took place along the bedding planes of the rock, it is customary to find the beds of both the overriding and the overridden masses dipping in the same direction and at approximately the same degree of inclination. Thus, in a general way, where the sandstones and coal beds of the Price formation dip to the southeast at, say 30°, the overriding limestone dips in the same direction at about the same rate.

If this general rule is applied, however, to actual outcrops in the Valley coal fields, it will be found in many places contrary to the facts, for frequently the limestone at the fault appears to have a steeper dip than the coal bed has in nearby mines and prospects. This may be explained by the generally broken condition of the limestone near the fault line and by thrusting that has occurred since the main epoch of movement in this part of the region, as shown in Fig. 18B. It is probable that if a second epoch of thrusting occurred after the limestone had overridden the coal-bearing rocks, all of the rocks along the contact would be more or less crushed and the limestone probably would be thrust into the soft shale of the Price or Maccrady formations. This would tend to give to the edge of the limestone the appearance of dipping more steeply at the contact than it does a short distance away from the contact or more steeply than the fault plane dips when considered in a broad way.

It is now generally conceded by geologists familiar with the region that the Pulaski fault is a very flat overthrust and consequently it is more nearly represented in Fig. 17 by the line C D than it is by the line C B; as a consequence it is probable that in most places the coal bed, if followed far enough down the dip, would be found to lie beneath the limestone. The distance it extends beneath the limestone is entirely problematical and can be determined only by extensive and deep drilling. It is probable that, as explained on another page, the coal beds do not continue indefinitely under the limestone, their actual extent depending upon whether they are folded and disturbed or whether they lie approximately flat. The evidence at the surface seems to indicate that in places the coal beds may extend to a distance of several miles from their lines of outcrop, but that in other places they may be cut off in a comparatively short distance. This can be told only by drilling in advance of mine workings.

There is also a common belief in the field that, if mine workings were extended far enough down the dip of the coal beds, the coal would be found to lie approximately flat. This appears to be a belief born of hope rather than founded on fact, for there is little or no geologic evidence to bear on such an hypothesis. The condition of a coal bed beneath the limestone depends entirely upon the condition of the rocks before the great overthrust occurred. If the rocks were practically flat and undisturbed, they may be found in that condition to-day or whenever deep mining is carried beneath the limestone mass, but if they had been previously compressed and thrown into folds, then the rocks below the limestone may be folded and disturbed as greatly as the surface rocks are in nearby localities.

Although it is true, as just stated, that drilling alone will tell the story, it is equally true that there is considerable geologic evidence to show that the rocks in this region were deformed before the great overthrust, and consequently, that the minable coal beds are liable to be seriously affected below the surface—even to the extent of being cut off entirely in certain places.

During the progress of the present field work, attempts were made to determine the thickness of the limestone southeast of Brushy Mountain, but without very satisfactory results. From New River to the Blacksburg-Newport road the limestone resting on the Carboniferous rocks appears to be of Cambrian age and this limestone is probably near the bottom of the overthrust mass. This would seem to indicate the relative thinness of the sheet of limestone lying between Brushy Mountain and the Blacksburg-Price Forks road, but the writers were unable to come to any definite conclusion regarding the thickness of these beds because of their broken and jumbled condition. A section along the Virginian Railway, where the side-hill cutting has revealed most of the details of the rocks, failed to solve the question, for any given dip was found to hold only a few hundred feet, and frequently the attitude of the beds is such as to show clearly that they are separated by faults. The impression one gets in traversing this section is that, with the exception of the rocks on the point west of Whitethorn, the limestone is in such a broken condition that it is doubtful whether the true structure could ever be determined.

Northeast of the Blacksburg-Newport road the conditions are quite different from what they are to the southwest of that road, for here the overthrust mass of rock is folded into a great syncline or trough whose northwest limb is marked by Catawba Mountain, and on that account it will here be referred to as the Catawba syncline. This syncline makes its first appearance in the low-dipping limestones of the ridge which lies east of Blacksburg. This ridge trends nearly north-south and the rocks composing it dip gently to the east into the west end of the Catawba syncline.

The great mass of calcareous and sandy shale overlying the Shenandoah limestone in this syncline makes its appearance about a mile south of Trinity Cross Roads. From this place it trends to the north a few miles and then swings to the northeast around the spoon-shaped end of the syncline. The shale is easily followed for it is soft and easily eroded and in it the North Fork of Roanoke River has cut a valley some 300 feet below the plateau level at the foot of Brushy Mountain. This valley is followed in its western part by the North Fork of Roanoke River and in its eastern part by Catawba Creek, a tributary of the James.

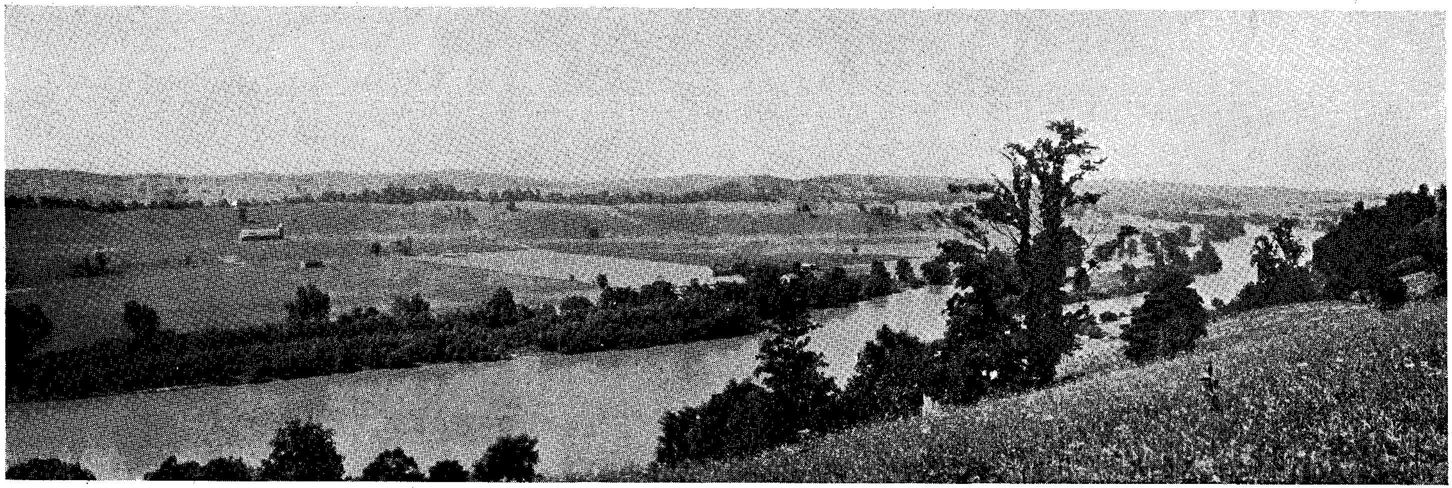
Southeast of or within the concentric shale valley just described, is a pronounced ridge of sandstone or quartzite which is known as Catawba or Paris Mountain. Within this mountain is another valley eroded in black shale (Devonian) which belongs still higher in the geologic column and finally on the southeast side of Roanoke or Fort Lewis Mountain are sandstone and shale which are the equivalent of the Price formation of Montgomery County. Here there is an unbroken sequence of rocks from well down in the Shenandoah limestone to the Price formation of Carboniferous age, a section that must be at least 8,000 feet thick. If the coal bed of Brushy Mountain should continue down under this mass of rocks it would be more than 7,000 feet below the surface, and therefore entirely out of reach.

The most interesting point is not the total depth to which the coal beds may descend, but how far one would have to go down the dip from the outcrop until the bed would be too deep for economical mining. If the dip is assumed to average 30°, the coal bed would reach a vertical depth of 1,000 feet at a distance of 1,750 feet back from the outcrop, and a depth of 2,000 feet at a distance of 3,500 feet.

The great depth of the syncline east of Blacksburg and the comparatively shallow depth to the west, as shown in the section D-D′ on New River, seems to indicate a gradual thickening of the overthrust mass from about 900 feet on New River to at least 7,000 feet in the Catawba syncline. If these figures are only approximately correct, then it can readily be calculated that the coal will be out of reach for mining operations in the lowest part of this trough in the region east of Blacksburg.

(A) Section across Pulaski fault on Tract Fork, showing small coal bed in the limestone.

Photograph by Marius R. Campbell.

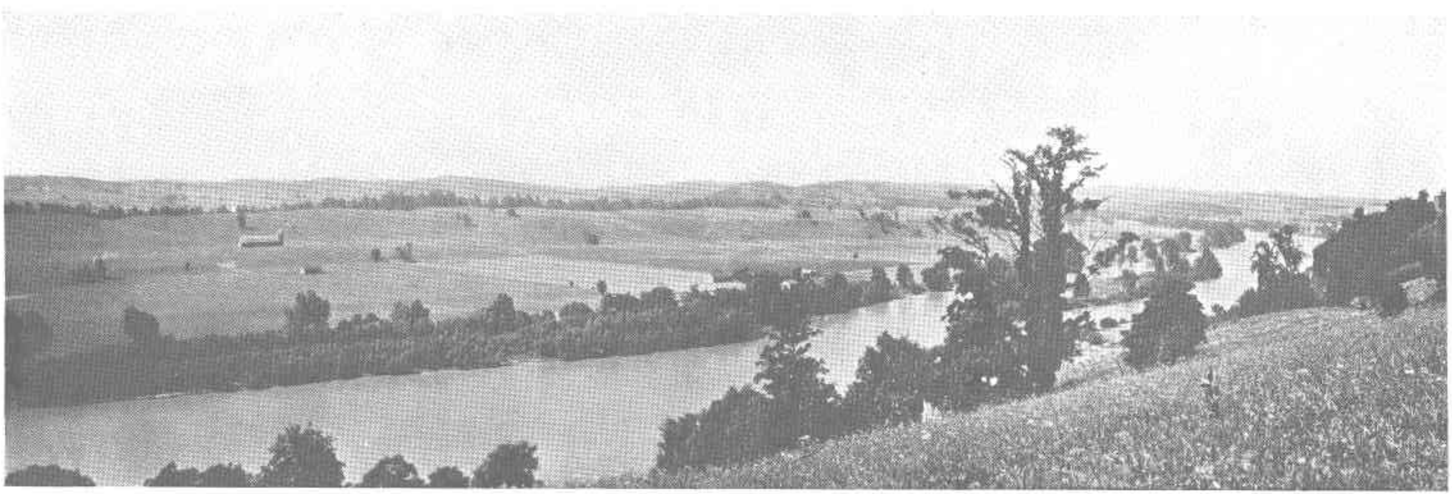


(B) Great bend in New River opposite Whitethorn.

Photograph by Kent K. Kimball.

(A) Section across Pulaski fault on Tract Fork, showing small coal bed in the limestone.

Photograph by Marius R. Campbell.



(B) Great bend in New River opposite Whitethorn.

DESCRIPTION OF COAL MINES AND PROSPECTS.

In the description of the coal beds in the Montgomery County fields the beds will be described as they appear in mines and prospects beginning at the eastern extremity of a field and continuing westward in systematic order as nearly as this plan can be carried out.

At the east end of the Brushy Mountain coal field, as it is identified in Montgomery County, the coal beds are very uncertain. No clear exposure was found within two miles of the county line, although reports of coal and even some fragments of it were seen. The finding of fragments of coal is no certain indication that coal in workable proportions is present and the writers incline to the belief that the principal bed is here covered by the limestone and that the coal reported is that occurring lower in the Price formation than the Merrimac bed.

In passing westward from the county line the first prospect noted is at loc. 1 on a small head branch of Pepper Run. The outcrop of a coal bed is shown here by an old prospect which is now so badly caved that it is impossible to form any definite conclusion regarding the thickness of the coal bed or the steepness of its dip. Residents in the neighborhood report that a small amount of coal was dug here many years ago but no coal was seen cropping at the surface and very little could be found on the dump heap which marks the location of the pit. The position of the prospect relative to the Pulaski fault and the edge of the overthrust limestone was not determined, but judging from exposures in this same general region, loc. 1 must be very close to the fault. The close proximity of the prospect to the fault is also indicated by the narrowness of the outcrop of that part of the Price formation exposed here. If the base of the formation and the position of the fault are platted in their correct relations, it will be found that there is just room for that part of the Price formation lying below the Merrimac coal bed to be present, provided the dip of the beds is not less than 40°. As this is about the general dip in this part of the field, it seems safe to assume that the coal bed once opened at loc. 1, is probably the Merrimac bed.

No information was obtained that will throw direct light on the condition of the coal bed, but owing to its nearness to the limestone it is probable that the coal bed is badly crushed, possibly so badly crushed that it is worthless as a commercial proposition. This may seem to owners of this coal a far-reaching conclusion based on entirely insufficient evidence. The writers readily acknowledge that such appears to be the case, but from wide experience in this field, they have concluded that such generalizations are warranted.

The possible effect on the coal when lying close to an overthrust fault may be illustrated by Fig. 18, in which section A shows the coal bed cut off by a slight change in the dip of the fault plane and section B, the coal bed crushed and rendered valueless by the crushing of the limestone into the coal by horizontal pressure after the limestone had been thrust over the coal-bearing rocks. It is possible, of course, that in places the fault plane, instead of changing to a steeper dip, may become flatter, and in that case it would depart more and more from the coal bed with depth, but the chances of such a change seem to be rather remote and hardly

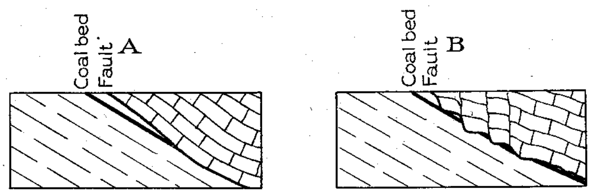


Fig. 18.—Sections showing how the Shenandoah limestone may affect the Merrimac coal bed below the surface: (A) by change of dip, and (B) by crushing due to subsequent movement on the fault plane.

worthy of consideration. Repeated observations on the fault contact in this region have convinced the writers that the limestone generally shows evidence of having been crushed and now dips more steeply than does the fault plane, when viewed in a broad way, and this steepening of dips is supposed to have been accomplished as shown in B, Fig. 18, by pressure since the main fault occurred.

The next exposure of coal is at loc. 2 on the westernmost branch of a small stream that lies between Pepper Run and Dry Creek. This exposure is very similar to that just described as loc. 1. Coal is reported to have been dug here, but it was many years ago and the prospect pit has caved and nothing remains to tell the tale, except a heap of badly weathered coal from which one can gain little information regarding the quality of the coal or the thickness of the coal bed. It is very close to the limestone and for that reason the writers are inclined to consider it of very doubtful value.

The next place at which prospecting has been done is at loc. 3, on Dry Creek. Here both coal beds appear to be present. The Merrimac bed, which crops out only a few feet from the edge of the limestone, was opened years ago by a slope. This slope, when visited by Howell in 1914, was full of water and the thickness and character of the coal bed could not be determined, but one of the men who mined the coal reported that the bed dips to the southeast at an angle of about 45° and is followed by the slope for a distance of 87 feet to a point where it is cut off by the fault, the coal abutting directly against a wall of limestone. The conditions here appear to be similar to those represented by B, Fig. 18. This man reported the section of the coal bed as follows:

Section of Merrimac coal bed at loc. 3.
(Reported.)

	Ft.	In.
Shale, sandy, gray		
Coal		?
Shale		?
Coal	1	6
Shale		8
Coal	2	0
Shale, hard		

The upper part of the coal bed was not exposed, but apparently it consisted of another band of shale and also of coal before the roof was reached. The Langhorne ("Little") bed lying about 65 feet below the Merrimac bed is scarcely 2 feet in thickness. Coal has recently been dug from a pit in this bed, but the bed is so thin that it can hardly be considered of workable proportions.

In summing up the situation from the eastern boundary of Montgomery County to Dry Creek Church the writers are impressed with the generally poor condition of the coal outcrop and unhesitatingly express their opinion as unfavorable to any development of the coal on a commercial scale in this part of the county. It is probable that this same objection applies to the coal throughout all of the drainage basin of Dry Creek as the outcrop of the coal bed probably does not depart widely from the fault until it passes the divide between Dry Creek and Mill Creek.

Around the head of the Mill Creek drainage basin the outcrop of the coal bed departs from the edge of the limestone farther than it does east of this drainage basin, but here, even at a greater distance from the fault, the coal is in places so badly crushed that its commercial value is greatly affected. The first prospect noted by the writers on entering this basin from the northeast is at loc. 4 on one of the eastern branches of Mill Creek. This prospect has been abandoned for many years and little data regarding the coal bed could be obtained except that it dips 30° to the southeast. The coal fragments on the old dump make a good appearance and it is thought that the quality of the coal is about the same as it is at loc. 5.

The most important prospects on Mill Creek are at locs. 5 and 6, on the farm of W. W. McClung. At loc. 5 the prospect indicates that a rather large mine had been in operation at some time in the past as coal has been taken out of a drift and also a slope, the bed in the slope striking N. 65° E. and dipping S. E. about 30°. That part of the coal bed now visible is badly crushed, being squeezed into lenses a foot or two thick and 4 or 5 feet long. The result is that no two sections of the coal, though measured not more than 10 or 20 feet apart, agree either in the number of the layers of coal or the thickness of the various layers of coal or shale. This is illustrated by the following sections measured only a short distance from the surface:

Sections of the Merrimac coal bed at loc. 5.

	Section A.		Section. B.	
	Ft.	In.	Ft.	In.
Coal	1	10		
Bone		3½		
Coal	1	0	2	6
Shale	1	3½	2	2½
Coal	2	1	3	3½
Thickness of bed	6	6	8	0
Thickness of coal	4	11	5	9½

Section A was measured in first left entry, 20 feet from the slope, and section B was measured about 100 feet from the mouth in an old drift. The same coal bed was seen in another old drift at loc. 5, where the following section was measured:

Section of Merrimac coal bed at loc. 5.

	Ft.	In.
Coal	1	7
Bone	1	½
Coal		11
Thickness of bed	3	6½
Thickness of coal	2	6

At loc. 6 the coal bed is so imperfectly exposed that no section could be measured. It is probably badly crushed as the prospect is near the limestone and in all probability the coal bed has been even more affected than has the coal at locs. 4 and 5. The writers greatly desired a sample from these prospects for analysis, but the coal seemed so badly crushed and so badly decomposed by the weather that the value of a sample for determining the rank of the coal was regarded as too doubtful to be considered. Part of the crushed condition of the coal observed about the headwaters of Mill Creek may be due to the northward bend in the outcrop of the coal bed and to the corresponding bend in Brushy Mountain. Such bends mean that the beds have been stretched in places to accommodate themselves to the greater arc of the circle and in other places compressed to adjust to a reduced arc. The writers have marked the increased distortion of the coal beds wherever there is a change in direction of the outcrop and feel sure they can recommend this as a general criterion that will well repay the attention of engineers and prospectors.

The coal bed was not definitely fixed at loc. 7, but the writers found an old prospect at this place with a small amount of coal on the dump. This may not be the outcrop of the Merrimac bed, but if not it doubtless represents a thin bed not very far removed from the big bed. Similarly no good exposure of the coal bed was seen at loc. 8 on the next branch to the west, but croppings of coal were found here that doubtless mark the position of the Merrimac bed.

At loc. 9 the writers found the first mine in operation that they had encountered in approaching from the east. This is a small mine and was being worked for the local wagon trade by Messrs. Slusser and Doss. The coal is obtained by drifting into the hillside on the bed where it dips 25° to the southeast. A sample for analysis was cut in this mine about 100 feet back from the mouth, where the coal has only about 25 feet of cover. The section at the point of sampling is as follows:

Section of Merrimac coal bed in mine of Slusser and Doss, loc. 9.

	Ft.	In.
Coal, sampled		8
Bone		2
Coal, sampled	1	2½
Bone		3
Coal, sampled		7½
Shale		8
Coal, sampled		11
Thickness of bed	4	6
Thickness of coal	3	5

For graphic representation of this section see Pl. XII. The analysis of the sample obtained is given on page 108 as No. 94,184. It is interesting to note that although this sample was obtained where the cover does not exceed 25 feet, the fuel ratio is greater and consequently the rank of the coal is higher than that of any other coal in the Brushy Mountain coal field of which we have a reliable analysis. There is an old prospect, loc. 10, on a more westerly branch of the stream upon which is situated the mine of Slusser and Doss, but it is badly caved and the coal bed is inaccessible.

In the block of territory lying between loc. 10 and the Blacksburg-Newport highway the Merrimac coal bed has been opened in every ravine crossing its outcrop and at several other places where it is not so exposed. Most of these old mines and prospects are now caved so that they are inaccessible and they throw no light upon the character or thickness of the coal bed or upon the quality of the coal. Their chief value is in indicating the position of the outcrop of the coal bed. The various prospects numbered 11, 12, 13, and 15, will not be described in detail, but the main attention will be given to the mine at loc. 14.

Before entering into the consideration and comparison of sections of the Merrimac coal bed it is well to caution the reader about the lack of accordance in nearby sections measured by different men and in some cases by the same man. In fact, the writers have gone so far as to say that they do not believe they can separate the coal bed into definite layers of coal and bone twice alike. The reason for this is that the bony impurities are not distributed in regular layers in the bed, but are irregular in thickness and composition, and even if their character were such that they could be readily distinguished from the good coal, it is doubtful if the thin bony layers would be twice grouped in the same way. But when it is understood that in many cases it is extremely difficult to distinguish bone from coal the difficulty of separating the coal bed into benches that may be recognized by another or even oneself at another time of sampling is very much enhanced and the reader should take each section here given as merely the interpretation of the one making the measurement as to the best manner in which to class the various materials composing the coal bed.

The writers are free to confess that the Merrimac coal bed is composed of the most heterogeneous mixture of coal and bone that they ever saw. Nothing is regular and persistent about the bed except its heterogeneity. Some parts of it are composed of soft flaky coal, some of hard massive layers, and some of mixed hard and soft. The hard coal passes by insensible gradation into layers of extremely hard "sand coal" or "splint coal" with 25 per cent or more of ash, or into clear bone with a still higher percentage of ash. Pl. X shows a block of so-called "sand coal" and Pl. XV B a block of "splint coal." Pl. VII shows a block of coal the bedding planes of which are covered with mineral charcoal.

With these preliminary remarks on the variability of the coal bed the writers will pass on to the consideration of the coal bed as revealed by measured sections in the Slusser mine. Four of these sections measured at the time samples of the coal were cut for analysis are given graphically on Pl. XII.

The Slusser mine, operated by the M. C. Slusser Coal Co. has been in more or less continuous operation for the last 15 or 20 years. The original point of opening (loc. 15) is on the north side of the Blacksburg-Newport road just east of the place where this road now crosses Toms Creek. From this opening a drift was driven up a slight grade, forming a natural haulageway and drainageway for the mine. The following sections were measured in the old or western part of the mine:

Sections of the Merrimac coal bed in the western part of the Slusser mine (loc. 15).

	Section A. Ft.	Section A. In.	Section B. Ft.	Section B. In.
Coal	1	2	1	0
Shale	1	2		4
Coal		5		5
Shale		2		
Coal		6		
Shale, roof of mine		8	1	6
Coal	a 2	3	a 2	2½
Shale		3		
Coal	a 2	3	2	½
Shale		3		3
Coal	a	10	b 2	2½
Shale and bone		9		3
Coal	a 1	6		11
Shale, with some coal				9
Coal			c 1	10
Thickness of bed	12	2	13	8½
Thickness of coal mined	6	10	9	2½

For graphic representation of these sections see Pl. XII. That part of section A which is mined was measured by Howell in a lateral entry on the north side of the mine, 900 feet from the mine mouth and the part above the roof of the mine was given by the owner. The sample obtained from the different benches marked *a* gave analysis 19358 on page

108. That part of section B which is regularly mined was measured by Professors R. J. Holden and J. T. Watson in the aircourse about 1,075 feet from the mouth of the mine (loc. 15) on May 14, 1914; the section of the roof coal, which is rarely exposed, was furnished by the owner. The minable coal was measured and sampled here because of its unusually thick development. The analysis of sample *a* is given under number 22629; sample *b*, under number 22630; and sample *c*, under number 22631 on page 108. Professor Holden was inclined to believe that the great thickness of the coal bed at this place is due to the buckling of the bed and the shoving of one section up onto the other, thus practically duplicating the coal bed. Mr. Murray C. Slusser, however, does not agree with this explanation, for he says that the partings in the bed were not disturbed as they would have been if the bed were broken. According to Mr. Slusser the most reasonable explanation is that the great thickness is due to original deposition and that it was present only in a very limited area.

Soon after the sampling by Professors Holden and Watson the drift entry was abandoned and a slope was sunk at loc. 14 from which mining operations have been carried on ever since.

In recent years four more mine samples have been cut by Government geologists and four sections measured of the part of the bed that is worked. These sections are as follows:

Sections of the Merrimac coal bed in the Slusser mine, loc. 14.

	Section A.			Section B.			Section C.			Section D.		
		Ft.	In.		Ft.	In.		Ft.	In.		Ft.	In.
Coal	w	1	1	x	1	½	y		10¾	z	1	0
Bone			3¼			1½			3½			2
Coal	w		11	x	1	½	y		7½	z		9
Bone			2¼			1½			2			2½
Coal	w		6¼	x		6½	y		5½	z		9
Shale and coal			8½		1	2½			9½			8
Coal	w		11½	x		9	y		9½	z		3½
Shale												9
Coal										z		10¼
Thickness of bed worked		4	7¾		4	10		4	0¼		5	5¼
Thickness of coal		3	5¾		3	4½		2	9¼		3	7¾

For graphic representation of these sections see Pl. 12.

Sections A and B were measured and the samples taken by Campbell and Howell in 1918 and sections C and D were measured by Campbell and W. T. Thom, Jr., in 1924. Section A was measured 100 feet northeast of the slope and section B, 200 feet southwest of the slope, and the analyses of the samples corresponding to them will be found under numbers 30689 and 30690 on page 108. Section C was measured on the water level, 800 feet east of the slope and section D, in the aircourse, 30 feet above water level and 650 feet from the slope. The analyses of the samples collected at these points will be found under numbers A-2349 and A-2350 on page 108.

Above the highest bench of coal in these sections there are two or three layers of coal, but as the coal of these bands is high in ash and as

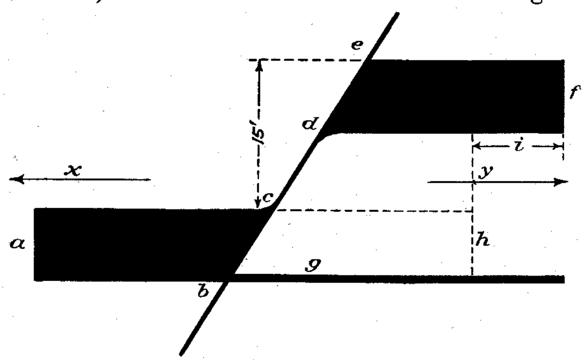


Fig. 19.—Normal fault cutting coal bed in the Slusser mine.

the bands are included between thick bands of shale, they are not mined and are revealed only where a fault is encountered or there is a serious fall in the roof.

In this mine the coal bed is cut by a number of normal faults, such as are represented in Fig. 19. Generally these faults do not displace the coal bed more than its own thickness, but one fault was noted that caused a displacement of the bed amounting to about 15 feet. This fault is represented by the diagram in Fig. 19. In this diagram the coal bed before faulting is represented by the block *a h*. The bed was then subjected to a pulling or tension stress represented by the arrows *x* and *y*. This stress became so great the rocks could not withstand it further and they broke to accommodate themselves to it. As the stress was one of tension the beds must occupy a greater horizontal space after faulting than they did before that event occurred; hence the break or fault is not perpendicular to the bed, but oblique, and the pulling movement resulted in the breaking of the coal bed and the upward movement of the block *a b c* on the oblique fault plane *b e* to the position *d e f*. By this movement the original block of coal *a h* has been elongated by the distance *i*, so that it now occupies the space *a f*.

This fault was encountered by the miners in driving the main entry from *a* toward *b*; when they reached the point *b* they found themselves against a solid wall of rock. They explored this wall and found a thin stringer of coal a few inches in thickness continuing along the floor toward *g* and they assumed that this was the representative of the large coal bed on the left. This stringer was followed for some distance in the hope that it would expand to the normal thickness of the main bed, but it showed no such tendency and finally work on it was abandoned. If these miners had been familiar with the law of normal faults they would have known that the rock wall meant a fault and, as all normal faults dip toward the downthrow side, the place to look for the continuation of the bed *a b c* is up, and not down, or even on the level.

When work was abandoned at *g* search was more carefully made of the rock wall that terminated the coal at *b c* and the suggestion of a continuation of the coal bed was found at *c* on what is known as the "drag" of the fault—a thin stringer of greatly crushed coal on the fault plane. This was followed for 8 or 10 feet to the point *d*, where it was found to expand into the regular coal bed *d e f*.

As normal faults are common in all of the mines in this region, it is well to understand their character and where the coal is to be sought beyond the wall of rock that marks the fault plane. For this reason the fault in the Slusser mine is taken as the type, because it differs only in magnitude from the numerous faults or "jumps" that are met in every mine in these fields, and the same rules apply to them as to the case here described.

The next mine to the southwest of the Slusser mine is that at loc. 16 on Toms Creek three-quarters-mile below the Blacksburg-Newport road. This mine, in the development stage in 1923, was operated by the Diamond Coal Co. The output of the mine was either sold for local consumption or trucked to Blacksburg for shipment on the railroad. At the time it was visited for the purpose of securing samples for analysis, the mine consisted of a rock tunnel driven into the hill on the south side of Toms Creek. At a distance of 75 feet the coal bed was pierced and there a slope was sunk in the coal on a dip of 22° for a distance of 100 feet. At this level entries were driven in both directions, but at the time of examination these entries had not reached a length of 100 feet.

Two measurements of the coal bed were made here: section A at the face of the west entry, 75 feet from the slope; and section B at the face of the east entry, 12 feet from the slope. The measured sections are as follows:

Sections of the Merrimac coal bed in mine of the Diamond Coal Co., loc. 16.

	Section A.		Section B.	
	Ft.	In.	Ft.	In.
Coal, a	1	5½	1	9
Bone		3½		3½
Coal, a		9½		9½
Bone		8		1
Coal, a		9½		7
Bone				6
Coal, a				10
Thickness of bed worked	4	0	4	10
Thickness of coal	3	0½	3	11½

Graphic representation of these sections will be found on Pl. 12. Benches marked *a* were sampled for analysis. The sample secured at the place where section A was measured will be found under No. 93530, and the one where section B was measured, as No. 93531, on page 109.

A comparison of the sections measured in this mine with those measured in the Slusser mine shows clearly that they represent only the lower or workable portion of the coal bed, and that this part of the bed is about the same as it is in the Slusser mine. A visit to the field in June, 1924, revealed the fact that operations in this mine had been discontinued and probably the mine has been abandoned.

From loc. 16 southwestward as far as loc. 18 the Merrimac coal bed has been prospected in almost every ravine crossing its outcrop, but none of the mines that have been worked in the past were in operation in 1914 or 1923. It is currently reported that the failure to maintain working mines in this district is due entirely to the poor condition of the coal bed. It is generally spoken of as being too much broken, but whether it is really badly crushed and shattered, or thin and broken by numerous partings is not known. Howell found an outcrop of the Langhorne coal bed in Clements Hollow (loc. 17) in 1914. The bed is here 30 feet below the Merrimac bed and at that time was opened by a drift 100 feet long. At the face of this drift the following section of the coal bed was measured:

Section of the Langhorne coal bed at loc. 17.

	Ft.	In.
Coal	1	9
Shale		2
Coal		1
Shale and coal interbedded		4
Thickness of bed	2	4
Thickness of coal	1	10

A short distance southwest of loc. 17, Plunkett and Wall were operating a mine in the Merrimac bed (loc. 18) in 1914. This was examined by Howell, who noted that the mine consisted of a slope in the coal which here has a strike of N. 70° E. and a dip of 28° to the southeast. A sample was taken from a point about 100 feet northeast of the slope on a level which leaves the slope 300 feet down from the mine mouth. Only a part of the bed was mined, as shown by the following sections:

Sections of the Merrimac coal bed in mine (abandoned) of Plunkett and Wall, loc. 18.

	Section A.		Section B.	
	Ft.	In.	Ft.	In.
Coal, shaly	1	0		10
Shale		6		8
Coal	1	8		2
Shale, roof of mine		6		7
Coal	a 2	4		11
Shale		1		5
Coal		1½	1	7
Shale		0¾		1
Coal		2½		1
Shale		2		2
Coal	a 1	5		3
Shale		4		1
Coal	a	3		2
Shale				1
Coal				6
Shale				1
Coal				6
Thickness of bed	8	7¾	7	2
Thickness of coal mined	4	4	4	0

A graphic representation of section A will be found on Pl. XII. This section was measured at a point 300 feet down the slope and 100 feet northwest on a lateral entry. The analysis of the sample collected from the benches marked *a* will be found under No. 19357 on page 109. Section B was measured on the slope about 80 feet below the lateral entry in which section A was measured.

Judging from these two sections the lower or workable part of the coal bed is quite regular in its aggregate thickness, but when its composition is studied in detail, there is found to be little agreement in the number and thickness of its various benches of coal and shale. This lack of agreement is probably more apparent than real, for, as previously stated, no two persons will classify the material composing this coal bed in the same manner, and it is doubtful if the same person will classify the material found in any section twice the same way. The upper part of the coal bed is more broken by shale and bone partings than is the lower part and it also appears to be more variable in its aggregate thickness.

The Langhorne bed was not worked here by Plunkett and Wall, but a rock tunnel was driven through the strata separating the two coal beds which showed that the Langhorne bed is about 33 feet below the Merrimac bed.

The next operation to the southwest is at locs. 19 and 20. The original mine, opened at loc. 20 in Faulkner Hollow by Seymour Price, consisted of a slope on the Merrimac coal bed where it has a dip of about 28°. The slope was driven for a distance of about 350 feet, to the lower line of the property, and from this point a lateral entry has been run eastward along the property line. Howell examined this mine in 1914 and measured the following sections:

Sections of the Merrimac coal bed in mine of Seymour Price at loc. 20.

	Section A.		Section B.	
	Ft.	In.	Ft.	In.
Coal, soft	1	0		
Shale		6		
Coal, soft		3		
Shale		5		
Coal	1	4		
Shale		1		
Coal		3		
Shale, roof of mine		8		
Coal	2	8	a 2	8
Shale		1		4
Coal		3		6
Shale		3		
Coal		6		
Shale		1		1
Coal		8	a	10
Shale		1		1
Coal		8	a	8
Thickness measured	9	9	5	2
Thickness of coal worked	4	9	4	8

These sections are represented graphically on Pl. XII. Section A was measured on the rib of the slope about 150 feet from the mine mouth; section B, which includes only the part mined, was measured about 50 feet from the slope in the entry which extends to the northeast from the foot of the slope. The benches in section B marked *a* were sampled and the analysis of the sample is shown under No. 19360 in the table on page 109.

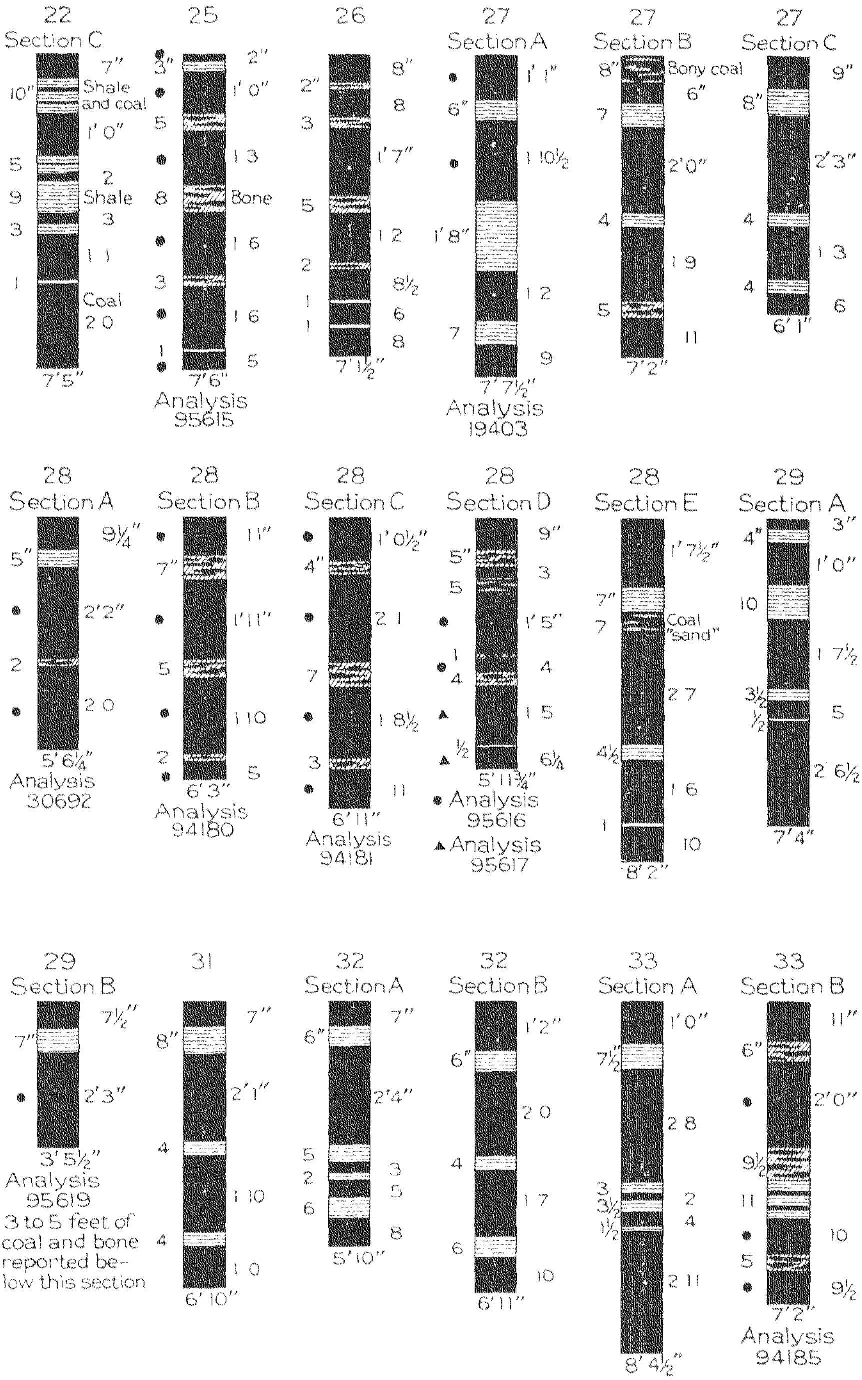
In 1923 Campbell visited this mine, which was then controlled by the Virginia Polytechnic Institute at Blacksburg. Two sections of that part of the coal bed which was mined were measured and samples of the coal were taken for analysis. The sections measured at the points where samples were cut are as follows:

Sections of the workable part of the Merrimac coal bed in mine of the Virginia Polytechnic Institute, loc. 20.

	Section C.		Section D.	
	Ft.	In.	Ft.	In.
Coal	a 2	3½	a 2	2½
Coal, mining		3½		5
Bone		9½		9½
Coal	a	8½	a	9½
Bone		2½		2½
Coal	a	6	a	7
Bone		2½		2½
Coal	a	7	a	6
Thickness of bed	5	7	5	8½
Thickness of coal	4	4½	4	6

These sections are represented graphically on Pl. XII. Section A was measured in the north entry at a point 950 feet from the slope and the sample secured here from the benches marked *a* furnished analysis No. 93536 on page 109. Section B was measured in the same entry at a point 1,050 feet from the slope and the sample secured here from the benches marked *a* furnished analysis No. 93537 on page 109.

The coal bed in this mine is generally regular and undisturbed, so that the shale and bone partings can readily be traced along the walls of the rooms and entries, but in a few places the coal is broken and one part is lifted or the other part depressed nearly the thickness of the bed, and these offsets cause irregularities in the mine workings. Two such disturbances were seen in the northeast entry, which must be regarded as incipient faults, although, as they appear in the mine, they partake more of the nature of a fold than of a fault. A sketch across one of these incipient faults is shown in Fig. 20. In driving the gangway from *a* the roof of the coal bed was found suddenly tc bend down until it practically reached the level of the floor, thus almost completely cutting off the coal bed. After reaching this point the roof continues hori-



Sections of coal bed in the Brushy Mountain and the Price Mountain coal fields, Montgomery County, Va.

zontally in the same direction as though no offset had occurred. If the movement which produced these offsets had continued a little farther it would have resulted in a decided and clear-cut break along the line *b c* and this break would have had the effect of offsetting the coal bed as shown in Fig. 19. The incipient fault shown in Fig. 20 did not cause any great trouble and expense in mining, as the bed was easily followed to its new position, but the gangway which had been driven in from *a* was obliged to turn abruptly in the direction of the rise of the bed and proceed until it came to the level of the coal bed in its new position.

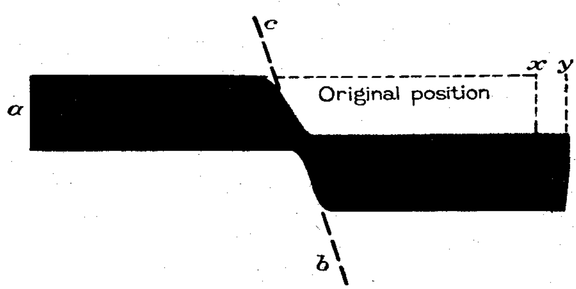


Fig. 20.—A "jump" or incipient normal fault in the coal bed.

The horizontal extension of the coal bed due to this incipient fault is measured by the difference between the original position of block *ax* and its new position *a y*. In Fig. 20 this movement is represented by the distance between the points *x* and *y*. These breaks trend at right angles to the general strike of the formation, or in a direction about N. 20° W.

The coal composing the Merrimac bed in this mine is of heterogeneous composition and characteristics, but in a general way it is hard and blocky, yielding on careful mining, a rather large percentage of lump coal. Some of the harder layers are the so-called "sand coal" (Pl. X), and some are fine-textured and resemble gray splint coal (Pl. XV B). A sample of the splint-like coal from this mine was submitted for analysis with the result given under analysis No. 95621 on page 109.

In the summer of 1923 Linkous and Kipp opened a mine in the Merrimac coal bed at loc. 21 in the Sally Kanode Hollow, about one-third of a mile west of the College mine. The mine of Linkous and Kipp consisted, at the time it was visited, of a slope driven down the Merrimac coal bed a distance of about 150 feet on a dip of 23°, and an entry turned off at the bottom to the northeast for a distance of only a few feet. The roof and floor of the mine are excellent, but of course the mine lacks railroad connection and hence must depend upon the local trade for the disposition of its output.

Two sections of the coal bed were measured in this mine: one of the entire bed, and the other of the part only that is mined. The sections are as follows:

Sections of the Merrimac coal bed in the mine of Linkous and Kipp, loc. 21

	Section A. Ft.	Section A. In.	Section B. Ft.	Section B. In.
Coal		8½		
Shale, carbonaceous		3		
Bone		2		
Coal		3½		
Bone		8½		
Coal		7		
Bone and coal		5		
Bone, roof of mine		9½		
Coal	a 2	5	a 2	0
Bone		1		1
Coal, mining	a	5	a	5
Coal	a	3½		
Bone		1		1
Coal	a	8½	a	2½
Bone		1		1
Coal	a	7	a	5
Bone and coal		2½		8½
Coal		2½	a	8½
Bone				1
Coal	a	7	a	5½
Thickness of bed	9	4½		
Thickness mined	5	5½	5	2½
Thickness of coal mined	5	0	4	2½

A graphic representation of these sections will be found on Pl. 12. Section A was measured on the slope, the mining part being measured at the foot and the roof coal at a point about halfway down where a fall exposed the entire bed. The benches of coal marked *a* were sampled and the analysis of the sample will be found under No. 93533 on page 109. Section B, which includes only the part mined, was measured 25 feet northeast of the foot of the slope, and the analysis of the samples of the benches of coal marked *a* will be found under No. 93534 on page 109.

In the mine of Linkous and Kipp the coal bed shows few indications of disturbance other than the small-scale faults which are common in most of the mines and prospects in this field. One break of this character is reported to be present in Craft or Surface Hollow, the first hollow east of the Sally Kanode Hollow in which this mine is located. None of the authors saw this fault, but it is reported as cutting the coal bed in a direction about N. 20° W., or approximately at right angles to the general strike of the formations.

The most favorable places for the development of mines in the Brushy Mountain coal field are where streams have cut water-gaps through the ridge, thus exposing the rocky formations better than elsewhere, and in general providing a better route for the transportation of the product of the mine. A lower water-table is also encountered in water gaps and this is advantageous in local mining, for it means that the coal can be worked to a lower level without having to resort to pumping, as would be the case if the water-table were at a higher level.

The most notable water gap in Brushy Mountain is that of Poverty Gap, so named because it has been cut by Poverty Creek, the principal northern tributary of Toms Creek. The date of the development of the first mine in this gap is not known to the writers, but, judging from present appearances, it must have been long ago, as the remains of old drifts and dump heaps are in evidence at several places on the outcrop of the coal bed. At the time the field was examined in 1923 only one mine was in operation in a small way. This was not examined because a mine here was visited by K. M. Way of the U. S. Geological Survey on October 31, 1906, and a report of his measurements and sampling is contained in Bull. 22 of the Bureau of Mines, page 821. The mine examined by Way was operated by the Virginia Anthracite Coal Co. and it was of considerable extent as the samples for analysis were obtained in the main southwest entry, 1,765 feet from the drift mouth. The measured sections of the coal bed were both in this entry, section B being at the distance specified above, and section A, 15 feet nearer the mine mouth. The sections are as follows:

Sections of Merrimac coal bed in mine in Poverty Gap, loc. 22.

	Section A.		Section B.	
	Ft.	In.	Ft.	In.
Coal	a	11½	a	11
Shale		2		1¾
Coal	a	3½	a	3¼
Shale		4		4¼
Coal		4½		2
Shale		0½		2¼
Coal	a 1	3	a	11½
Sandstone		8		6¼
Coal	a 2	0		2
Shale		4½		
Sandstone				6¾
Coal	a	4	a 1	6½
Shale		2		4¼
Coal	a	2½	a	5
Shale		1		1
Coal		9	a	1½
Shale				1
Coal			a	8½
Thickness of bed	8	0	7	6¾
Thickness of coal	6	2	5	3¼

These sections are shown graphically on Pl. XII. In section A the sample for analysis was obtained by cutting a channel across the benches of coal marked in the section by the letter *a* and the analysis of this sample is given under No. 4092 in the table on page 110. Similarly the sample cut where section B was measured yielded analysis No. 4093, shown on the same page as that of No. 4092. The great detail shown in the sections measured by Way is not due to a greater number of partings here than elsewhere, but rather to his attempt to separate more accurately the coal from the impurities. After considerable experience in sampling coal in these fields the writers have come to the conclusion that such a detailed classification of the materials composing the Merrimac bed is not worth the time and trouble required to make it, and even when made, the writers would question whether it is of any practical value, because such a separation is not possible in mining, and consequently the analysis of a sample of the various coal benches measured in this manner does not come any nearer representing the coal that is mined than a sample which includes general benches of coal with their inherent impurities.

Howell, in visiting Poverty Gap in 1914, found one of the old drifts open and in it measured the following section of the coal bed, which dips about 15° to the southeast:

Section C of Merrimac coal bed in old mine entry in Poverty Gap, loc. 22.

	Ft.	In.
Coal		7
Shale and coal		10
Coal	1	0
Shale and coal		5
Coal		2
Shale		9
Coal		3
Shale		3
Coal	1	1
Shale		1
Coal	2	0
Thickness of bed	7	5
Thickness of coal	5	1

This section is shown graphically on Pl. XIV. In Poverty Gap the Langhorne coal bed, lying at a distance of about 36 feet below the Merrimac bed, has been prospected in a number of places. Howell, in 1914, found an open prospect in which he made the following measurements:

Section of the Langhorne coal bed at loc. 22. Section at mouth of drift.

	Ft.	In.
Coal	1	8
Shale	1	10
Coal		1
Thickness of bed	3	7

At the end of the drift the thickness of the coal bed is only 1 foot, 7 inches.

Nearly a mile west of Poverty Gap a branch of Poverty Creek, known as Nortons Lick Creek, cuts through Brushy Mountain, forming the second water gap in this ridge. In this gap both the Merrimac and Langhorne coal beds have been prospected. The opening in the Merrimac coal bed is closed, but those in the Langhorne coal bed were accessible when they were visited by Howell in 1914 and by Campbell in 1923. The sections measured here are as follows:

Sections of the Langhorne coal bed on Nortons Lick Creek, loc. 23.

	Section A.		Section B.	
	Ft.	In.	Ft.	In.
Coal		9		3
Shale or bone		1		1
Coal		8		11
Thickness of bed	1	6	1	3

Section B was measured in a small mine operated by J. H. Keister. This mine consists of a drift 125 feet long and the measurement was taken at the extreme end. Mr. Keister claims that the coal bed is here normally 1 foot, 10 inches thick, but that its thickness where the measurement was made, was greatly reduced by a slip in the rocks. The analysis of the sample collected here from the two coal benches will be found under No. 93539 on page 110. Although the Langhorne coal bed is here very thin the coal mined from it commands a ready market, being preferred to coal from the Merrimac bed because it is harder and contains a smaller percentage of ash.

The Merrimac coal bed was next seen on a branch of Nortons Lick coming in from the west about one-third of a mile below the Keister mine. A local mine has been opened here, but it is so difficult of access that but little coal has been mined and marketed. The coal bed dips about 28° to the south, but no measurements were made to determine its thickness or composition.

West of Nortons Lick Creek the Merrimac coal bed has been opened in many places between this creek and New River, but most of the mines have been abandoned and they have caved so badly as to prevent an examination of the coal bed.

In 1920 the Superior Anthracite Coal Co. began the development of a mine about 1½ miles up the small creek that enters New River at the station of McCoy on the Virginian Railway. A slope was sunk at loc. 24 and a tramroad built over which the product of the mine could be transported to the railroad. At a later date this property was taken over by the Big Vein Anthracite Collieries Corporation, which proceeded to open a new slope at loc. 25 and also connect by drift the old and new workings. This development work was under way when the mine was visited in 1923, so the mine was not sampled as carefully as the other mines of the district.

A sample for analysis was cut in a room off the main drift, driven to connect the two mines, at a distance of 700 feet from the drift mouth at loc. 25, but owing to the slight depth to which the valley is cut below the surrounding upland, the coal at the point of sampling was scarcely more than 50 feet from the surface. The coal bed is regular in this drift and shows little or no evidences of crushing or being cut by faults. It dips to the south about 25° and the section at the point where the sample was cut is as follows:

Section of Merrimac coal bed in mine at loc. 25.

	Ft.	In.
Coal		2
Shale		3
Coal	1	0
Bone		5
Coal	1	3
Bone		8
Coal	1	6
Bone		3
Coal	1	6
Bone		1
Coal		5
Thickness of bed	7	6
Thickness of coal	5	10

This section is shown graphically on Pl. XIV. The analysis of the sample taken from the benches of coal shown in the section given above is shown under No. 95615 on page 110.

Between the mine of the Big Vein Anthracite Collieries Corporation (loc. 25) and New River the Merrimac coal bed has been prospected and mined at several places, as shown on the map (Pl. I), and it also shows as a bloom in the highway leading from Toms Creek to McCoy. None of the mines is in operation at the present time, but there are rumors that one of the old mines (loc. 26) on the Virginian Railway is to be reopened at an early date.

At the time this part of the field was visited by the writers the coal was inaccessible, but a section of the bed, reported on good authority, is as follows:

Section of Merrimac coal bed in mine at loc. 26.
(Reported.)

	Ft.	In.
Coal, shaly		8
Bone		2
Coal		8
Bone		3
Coal	1	7
Bone		5
Coal	1	2
Bone		2
Coal		8½
Bone		1
Coal		6
Bone		1
Coal		8
Thickness of bed	7	1½
Thickness of coal	5	11½

This section is represented graphically on Pl. XIV. From this section it is apparent that the Merrimac bed holds its thickness at least as far as New River, and a comparison of this section with those measured in the Parrott mine, just across the river in Pulaski County, shows that it continues in much the same condition west of the county line.

From the data presented in the preceding pages, it is obvious that under present conditions of the trade and of mining, the Merrimac bed is not workable entirely across Montgomery County, the workable part being limited to an area northeast of the Blacksburg-Newport road, controlled by the M. C. Slusser Coal Co. and a much larger area lying between Kanode's old mill and New River. Whether or not the "broken" condition of the coal bed as reported at the surface in the area between Kanode's old mill and the Newport road is sufficient to prevent mining is not known and probably can not be determined except by driving a slope or shaft down into the deeper part of the basin, or rather extensive core-drilling in the limestone area. It is possible that the coal bed may be in better condition at some distance down the dip and tests should be made to determine this point.

It is also desirable that deep wells should be drilled in the trough lying between Brushy and Price mountains, even where the coal is in good condition at the outcrop, to determine the amount of available coal at a depth. Before mining operations are begun on a large scale it would pay the operators who are strong financially to do this exploratory work, and if it is undertaken the writers would recommend that drilling be carried out from the known to the unknown. In other words, begin drilling just north of the fault which bounds the limestone on the north side and then continue it at rather short distances down the dip as far as practicable.

The writers feel confident that the shallowest part of this basin in Montgomery County is near New River and consequently, drilling in that part of the field would be most likely to give favorable results. East of Kanode's old mill the writers are skeptical about the possibility of carrying mining far down the dip, for although the dips at the outcrop in this part of the field are less than they are on New River, still the chance for a flattening of those dips is not nearly so good as it is farther west, and consequently, the coal bed, even where dipping at a low angle, would soon pass below the limit of practicable mining.

The Merrimac coal bed, with the exception of the great thickness shown locally in the Slusser mine, sections A and B, page 158 and Pl. XII, increases in thickness from east to west across the county, and this tendency to increase in thickness in a westerly direction can be observed in the mines and prospects of Pulaski County, as described on other pages devoted to a description of the coal fields of that county.

The Langhorne ("Little") coal bed is generally so thin in the Brushy Mountain coal field that it is of little value, except for local use. The coal from this bed is generally harder than that from the Merrimac bed and the percentage of ash is materially lower. On account of these facts the coal of the Langhorne bed is much sought after, but the thinness of the bed precludes its general use.

QUALITY OF THE COAL.

The quality of the coal in the Merrimac bed in the Brushy Mountain field is extremely uniform in a very general way, but, of course, varying greatly in different parts of the bed, even in a single mine. The ash is the most variable content of the coal and the variation in this constituent depends largely upon whether the coal bed is unbroken and lying in an undisturbed position, or is crushed and distorted. If the former condition prevails many of the bony partings can be separated by the miners and "gobbed" in the mine, but if the latter prevails, the bony partings are more or less broken and the resulting fragments of shale or bone may be so intimately mixed with the coal that their separation is difficult and expensive, if not impossible.

Curiously enough the coal of highest rank—that is, lowest volatile constituents—in this field is that from the mine of Slusser and Doss (loc. 9). The fuel ratio (fixed carbon divided by the volatile matter) of this coal is 6.94, whereas the average of all the other fuel ratios for the field is 5.40, with the highest individual sample only 5.94. The high fuel ratio at loc. 9 is doubtless due to greater pressure having been exerted here than to the west of this point, but the geologic conditions give no clue as to why the pressure should have been greater here than elsewhere.

Fuel ratios of coal of the Brushy Mountain field.

Location.	No. of analyses.	Fuel ratios.			
		Average.	Highest.	Lowest.	No. below 5.00.
9	1	6.94	....	....	..
14 & 15	8	5.22	5.75	4.54	3
16	2	4.94	5.25	4.62	1
18	1	5.45	....	....	..
20	3	5.71	5.94	5.50	..
21	2	5.77	5.94	5.60	..
22	2	6.00*	6.13*	5.86*	..
23	1	5.80	....	....	..
25	1	5.10	....	....	

*Analyses made by old method and fuel ratios too high.

In comparing fuel ratios, it must be understood that analyses 4092 and 4093 of samples obtained at loc. 22 were made by the old method, explained on page 102, and that the fuel ratios obtained from these analyses will be correspondingly higher than the other fuel ratios given in the table. If, therefore, the average fuel ratio of loc. 22 be reduced to that of loc. 21, which is a reasonable reduction, then the average for the entire field is 5.50. As semianthracite rank has been defined (p. 126) as including coals having a fuel ratio ranging from 5 to 10, but including 5, then it will be seen that the average fuel ratio of the coals of the Brushy Mountain field is near the lower limit of the rank. In fact some of the individual ratios fall below 5 and these low fuel ratios raise interesting questions of classification. Shall the specifications noted above be adhered to rigidly even though such a procedure might exclude the coal of a single mine from the rank of semianthracite?

Such a question as that just proposed is difficult to answer. In a general way the authors believe that where the criteria used are definite and it is a clear-cut case that a certain coal does not come within the specifications, then the coal should be excluded, unless there are extenuating circumstances which may throw doubt upon the accuracy of the determination. On the other hand it would be extremely unfortunate to have to class the coal of one part of a field as different in rank from the coal of another part, and particularly so where the low-rank coal occurs in the midst of high rank coal, and the physical properties are uniform throughout.

In the present case there is not a clear-cut difference, for though the average fuel ratio of two samples cut at loc. 16 is only 4.94 this is the average of one sample at 5.25 and another at 4.62. If the rule were strictly followed the coal in one part of this mine should be called semianthracite and the other semibituminous, but manifestly such a division would be like splitting hairs and would not be practicable in commercial work. As there is disagreement in the analyses and as this mine is apparently in the midst of a field, the fuel ratio of whose coal averages 5.50, it is more reasonable to class the coal as semianthracite, unless future mining should show that there is in this vicinity a well-marked area of low-rank coal. It will, therefore, be considered to be of semianthracite rank despite the fact that its average fuel ratio is only 4.94.

The low rank of some of the coal at locs. 14 and 15 does not present such a difficult question as the low fuel ratios at loc. 16. At locs. 14 and 15 eight mine samples are available; five of which show fuel ratios of more than 5 and three of less than 5. The average for the lot is 5.22. Here the preponderance of evidence is in favor of classifying the coal as a semianthracite but the low fuel ratios indicate that the coal is very close to the lower limit of the rank.

From the close areal relation of these two mines it seems altogether probable that the generally low fuel ratio of the coal is indicative of an area, probably to the west or southwest, in which the coal has not been metamorphosed as much as it has in other parts of the field. It is even possible that this assumed area may roughly coincide with the area of much broken coal that is reputed to lie southwest of the Blacksburg-Newport road. This is merely a suggestion based alone upon the theory that in places the crushing of the rocks and coal bed has served as a release of pressure and in such places the coals and rocks may not have their internal structure and composition changed to the extent that rigid rocks which received the brunt of a thrust may be changed without apparent fracture or bending.

The percentage of ash varies from 14.7 per cent to 26.3 per cent in the samples as they were cut in the mine, excepting only such analyses as represented a single bench of impure coal, with an average of 17.8 per cent. As the samples were generally cut in such a manner as to exclude the distinctly bony layers, picking of the coal when it reaches the breakers would not materially reduce the percentage of ash given above, for the pickers would remove only the obviously bony fragments in the mined coal and these have already been excluded from the samples analyzed. Washing is the only method of cleaning the coal that would materially reduce the percentage of ash below the average of 17.8 per cent. Recent tests of ash in Pennsylvania anthracite, as determined by samples obtained from coal in the open markets, have shown that the cleanest anthracite tested contains 10 per cent of ash. The semianthracite of the Brushy Mountain field, in order to successfully compete with the Pennsylvania product, should be made more attractive to purchasers and consequently its ash content should, if possible, be reduced below the figures given above. The senior author has advocated the reduction of ash to 8 per cent, and he still believes that this should be the ideal to be obtained if possible in the Virginia fields.

The sulphur in the analyses of samples from the Brushy Mountain field is extremely low, averaging in 24 analyses .5 per cent.

Price Mountain coal field.

GENERAL DESCRIPTION.

The Price Mountain coal field is a rudely elliptical area, southwest of Blacksburg, Va., its longer diameter trending in an east-west direction from about a mile west of the Blacksburg-Christiansburg road to within a like distance of New River. As shown on Pl. I, the ellipse bounded by the outcrop of the Merrimac coal bed is only about 4 miles in length by 1½ miles in breadth, but this is contained in an elliptical exposure of lower Carboniferous rocks 7½ miles long by 2¼ miles broad.

As explained in the chapter on Geologic Structure the Carboniferous rocks form an anticline or elongate dome with the hard sandstones at and near the base of the system forming a low wooded ridge in the midst of the fertile farming lands of the surrounding limestone region. The exposure of Carboniferous rocks is a fenster or in other words a "window" or opening in the Shenandoah limestone which originally was thrust from the southeast over this region and was subsequently slightly folded into arches and troughs and then the arches of the limestone were eroded leaving the underlying Carboniferous rocks containing the coal exposed to view. As a consequence of this structure the coal dips away from the axis of the fold both to the north and the south and also on the ends to the east and the west and the limestone has a similar structure, though it can be seen only around the margin of the ellipse for it has been eroded from the ellipse itself.

Originally the coal was supposed to be cut off by the fault that surrounds the Price Mountain fenster and consequently coal lands and leases generally extended from the summit of Price Mountain to the margin of the limestone on either side. Now it is known that the limestone merely overlies the Carboniferous rocks and consequently that there is every reason to suppose that the coal bed extends some distance at least beneath the limestone, unless it has been terminated by some unseen fold or fault that occurred prior to the epoch in which the limestone was thrust over this region. On account of this supposed extension of the coal bed beneath the limestone it seems altogether probable that the northward dipping coal bed on the north side of Price Mountain connects with the southward dipping bed on Brushy Mountain, but the depth at which this possible connection is made is the most uncertain element in the problem.

The writers hold the view expressed above and the cross-sections on Pl. I have been drawn to represent their conception that the coal does connect across this rock trough and the depth at which it may be found at the lowest point in the trough. Thus where section A-A′ crosses the trough west of Blacksburg, the coal is supposed to lie at a maximum depth of 3,100 feet; where section B-B′ crosses, at a depth of 2,900 feet; and where section C-C′ crosses, at a depth of 2,900 feet. The writers caution the general public not to regard these depths as well determined, but merely as the best estimate that can be made from the geologic evidence at hand. It is to be hoped that before long, deep drilling will be done so that we may know whether or not the coal is present here and, if present, at what depth it may be found.

The Price Mountain coal field is served by the main line of the Virginian Railway which passes along the southern side and the Blacksburg branch of the Norfolk and Western Railway which crosses the eastern end.

DESCRIPTION OF MINES AND PROSPECTS.

The only coal bed of workable proportions in the Price Mountain coal field is the Merrimac bed, which has been given this name by the senior author, because the Merrimac mine is the largest one in operation in the field and also because this mine received its name from the fact that it furnished fuel for the Confederate frigate *Merrimac* or *Virginia* in its famous battle with the *Monitor* in Hampton Roads in 1862.

The Merrimac coal bed has been mined or prospected in almost every ravine heading on Price Mountain and extending either to the north or south. Most of the old mines have been abandoned and at the time they were examined nothing remained to tell their story except a caved slope and a dump pile of waste coal and country rock. In 1923 only three mines were in operation: the Merrimac mine (loc. 28), and the Brumfield mine (loc. 29), on the south side of the mountain at the east end near the crossing of the Virginian and the Norfolk and Western railways, and the Kinzar mine (loc. 33) on the north side near the west end of the field.

The description of mines and prospects in the Merrimac coal bed will begin at the east end of the field and proceed westward along the southern

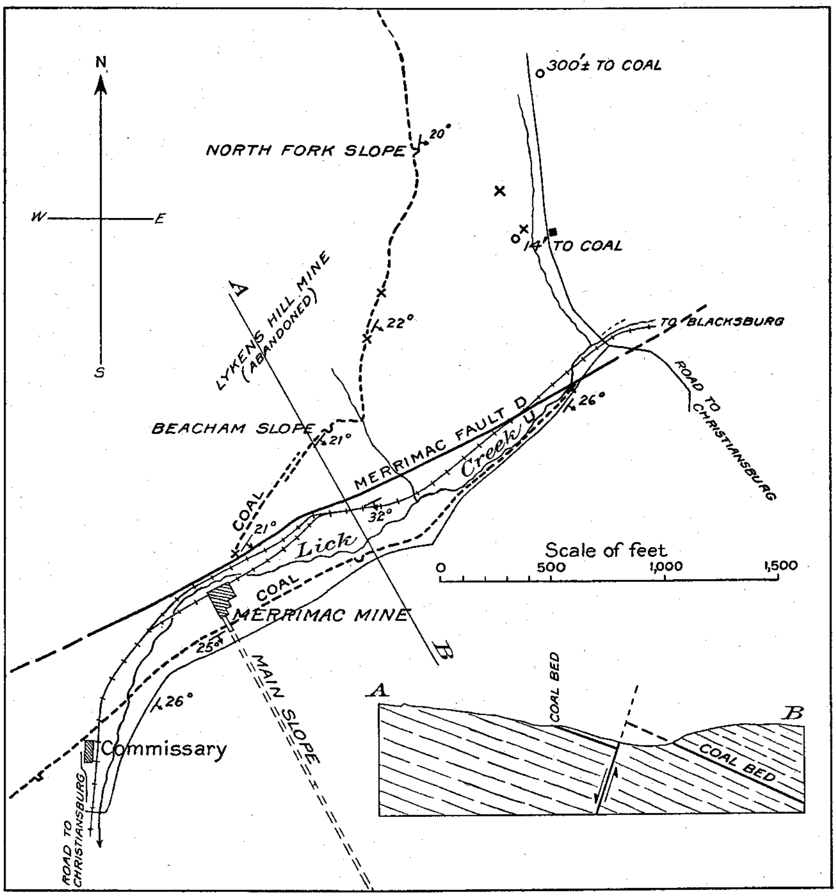


Fig. 21.—Sketch map of the Merrimac fault where it causes a repetition of the outcrop of the Merrimac coal bed.

line of outcrop to the west end, then it will drop back to the east end and continue on the northern outcrop in a westerly direction.

The easternmost mine in the field was the Lykens Hill mine at loc. 27. This mine was situated on the coal bed where it changed from its general course along the south side of Price Mountain and turned northward around the point of the anticline. The dip at this point is 26° nearly due east, but in a short distance to the north the outcrop is supposed to turn abruptly and follows a nearly due west course for two miles. As would naturally be expected where such a sharp bend occurs, the coal is badly broken and on the south side it is cut by a fault which raised the block of strata to the south resulting in the duplication of the outcrop of the Merrimac bed as shown in Fig. 21. In general the Blacksburg branch of the Norfolk and Western Railway follows the fault for some distance by the breaker of the Merrimac mine, the Lykens Hill mine being confined to the territory north of the railroad.

Little information could be obtained regarding the Lykens Hill mine as it has been abandoned for a number of years. The mine was unfortunately situated for the block of coal in which it was being developed is bounded on the south by the Merrimac fault, as shown in Fig. 21. The mine was located on the upland north of Lick Creek and consisted of two slopes: the Beacham slope on the hill overlooking Lick Creek and the North Fork slope about 1,200 feet to the north. As the coal bed dips from 20° to 22° to the southeast and east the slopes were driven in those directions. The Beacham slope must have soon struck the Merrimac fault and this would mean that the miners would be brought up abruptly facing a solid wall of rock as shown in section A B in Fig. 21. It is probable, therefore, that most if not all of the coal was mined out in the southern part of the property, but in the northern part two exploratory wells were put down, one near the store, finding the coal bed at a depth of 14 feet, and the other farther north, at a depth of about 300 feet.

As this mine was abandoned before the authors began work in the field, it was impossible to examine it thoroughly, but in 1914 Howell managed to crawl down the old slope 300 feet and into the east entry about 200 feet where he cut a sample of coal for analysis. The thickness and composition of the coal bed at this point are shown in section A, as follows:

Sections of the Merrmac coal bed at loc. 27.

		Section A. Ft.	Section A. In.	Section B. Ft.	Section B. In.	Section C. Ft.	Section C. In.
Coal, shaly					8		9
Coal	a	1	1		6		
Shale			6		7		8
Coal	a	1	10½	2	0	2	3
Shale		1	8		4		4
Coal		1	2	1	9	1	3
Shale			7		5		4
Coal			9		11		6
Thickness of bed		7	7½	7	2	6	1
Thickness of coal		4	10½	5	10	4	9

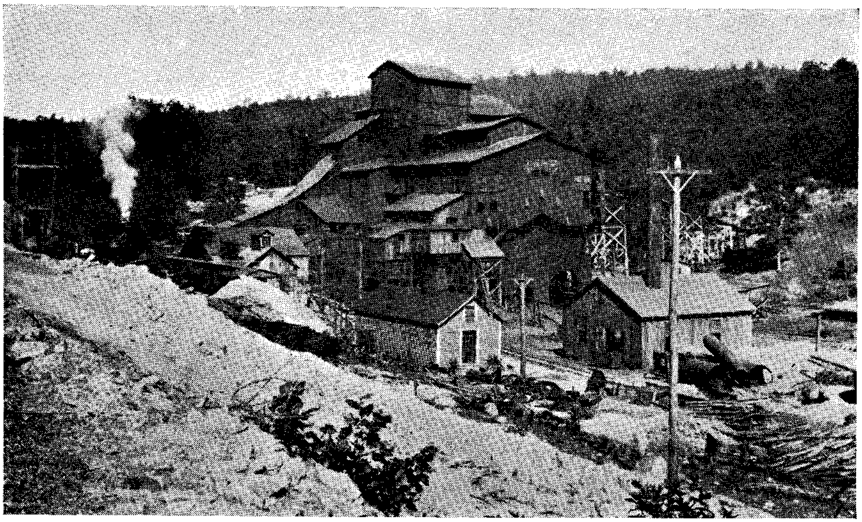
These sections are shown graphically on Pl. XIV. The analysis of the sample of the two benches of coal marked *a* is shown under No. 19403 on page 110. This sample, although taken long after the mine had been abandoned, does not show any effect of weathering and so it is regarded as typical of the coal of this mine.

Two other sections of the coal bed in this mine, section B and section C, are given on the authority of J. M. Patteson and E. B. Burwell, students of the Virginia Polytechnic Institute, in a thesis (unpublished) submitted in partial fulfillment of the requirements for the degree of B. Sc. in 1916. Section A was measured by the writers of the thesis and section B is given on the authority of the foreman of the mine.

South and a little to the west of the Lykens Hill mine is the Merrimac mine, whose breaker is shown in Pl. XV A. This mine is a slope mine on the uplifted block south of the fault which separates it from the old Lykens Hill mine. Originally the mine of the Brushy Mountain Coal Co., owners of the land in which the present Merrimac mine has been developed, was on the north side of Price Mountain and the coal was brought across the mountain to the present breaker that was built to accommodate coal coming from the north rather than from the south.

The Merrimac mine has had a checkered history, as have most mines in this region. The present mine has resulted from the taking-over of a number of earlier mines, each of which had worked out the more accessible coal near the outcrop. The mine was carried down to about the fourth level before 1909, and it was then shut down and allowed to fill with water until 1918, when it was unwatered and it has been more or less continuously in operation since that time.

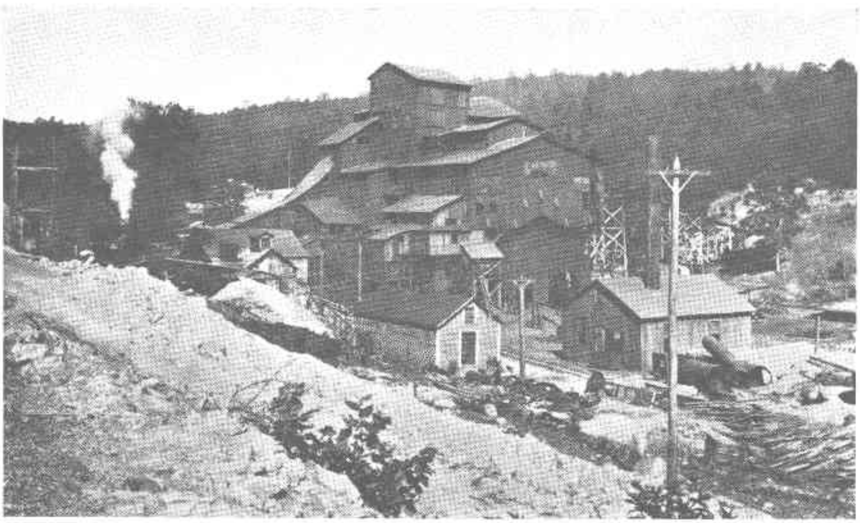
Mr. Howell and the senior author visited the mine in 1918 when it was only partially unwatered and succeeded in cutting a sample for



(A) Breaker at the Merrimac mine, Price Mountain coal field.

Photograph by Kent K. Kimball.

(B) Block of "splint" semianthracite from Montgomery County.



(A) Breaker at the Merrimac mine, Price Mountain coal field.

Photograph by Kent K. Kimball.

(B) Block of "splint" semianthracite from Montgomery County.

analysis and in measuring a section at a point on the fourth west gangway, 2,150 feet from the slope. The section of the coal bed at this place is given in section A as follows:

Sections of the Merrimac coal bed in Merrimac mine, loc. 28.

	Section A.		Section B.		Section C.		Section D.		Section E.	
	Ft.	In.	Ft.	In.	Ft.	In.	Ft.	In.	Ft.	In.
Coal		9¼	b	11	c 1	0½		9	1	7½
Shale or bone..		5		7		4		5		7
Coal								3		
"Sand" coal...								5		7
Coal (probably containing "sand" coal in upper part)..	a 2	2	b 1	11	c 2	1	d 1	5	2	7
Bone		2		5		7		1		4½
Coal								4		
Bone								4		
Coal	a 2	0	b 1	10	c 1	8½	e 1	5	1	6
Bone				2		3		0½		1
Coal				5	c	11	e	6¼		10
Thickness of bed	5	6¼	6	3	6	11	5	11¾	8	2
Thickness of coal	4	11¼	5	1	5	9	5	1¼	7	1½

These sections are represented graphically on Pl. XIV. The analyses of the samples noted above are given in the table on pages 110 and 111 as follows: sample a, analysis 30692; sample b, analysis 94180; sample c, analysis 94181; sample d, analysis 95616; and sample e, analysis 95617.

Section B was measured 850 feet from the slope in 7 east entry which leaves the slope at a point 1,100 feet from the mine mouth. Section *c* was measured at a point 900 feet west of the slope in 7 west entry which is turned off from the slope at the same place as 7 east entry. Section D was measured at a point 1,500 feet from the slope in 7 east entry and two samples were taken at this point to see if there is any marked difference in the chemical composition of the coal in the different parts of the bed. Section E was measured at the face of 7 west entry about 600 feet from the slope.

One of the most important problems confronting the operators in this part of the field is that regarding the extent of workable coal before them or that may be available for mining in the future. This question is of the greatest importance, for it has to do with the life of the mine and on the life of the mine will depend largely the money that may judiciously be expended upon equipment and in betterments. The writers understand that mining operations on the north side of the mountain have proved to be very expensive and uncertain because in places the coal bed increases in dip very materially down the dip and is reported to stand in nearly a vertical position in some of the mines. The coal also was found to be badly broken and altogether the prospects for future mining at a profit seemed so slight that all of the larger operations on that side of the field have been abandoned and mining now is almost entirely confined to the south side, where the conditions appear to be much more favorable for long continued mining, at least as far as dip of bed and character of the coal are concerned. Apparently the operators on this side of the mountain have not thought it necessary to look ahead and to be sure that a reasonable amount of workable coal lies before them. It seems to have been assumed that the dip of the coal bed showing at the surface or in the mines continues indefinitely downward to the south, and consequently, that the limit of mining will be controlled entirely by the limit of depth below which mining is impracticable on account of the great cost.

The view just expressed regarding conditions at a depth in the Merrimac and other mines on the south side of Price Mountain is perhaps the natural one to be taken, but to the geologist it does not seem to be entirely in accord with the facts. In the first place, the dips in the Merrimac mine, which is now down on the coal bed a distance of 1,200 feet, are not constant and the variation, when considered in connection with surface indications, seems to point to a very different conclusion. The dip at the portal of the Merrimac mine is about 22° and, although elevations do not appear on the mine map, it seems probable that the inclination of the slope is fairly constant from the surface down to the lowest point to which it has been driven. In the west entries, however, the dips, although probably somewhat irregular, show a general increase, as indicated by a dip of 26° measured on 7 west entry at the point where section C was taken. On the other hand, the dips in the eastern part of the mine are decreasing, as shown by a dip of 16° measured at the point where section D was taken. This difference of 10° in the dip of the coal bed in the two parts of the mine appears to be indicative of a change in general structure but the available evidence in the mine does not appear to be sufficient to determine the meaning of the change. It is necessary, therefore, to continue the observations on the surface in order to be able to know what this difference really means.

As shown on Pl. I, and as described in the chapter on geologic structure, one of the most important results of the present examination of the Price Mountain coal field is the determination that east of the Christiansburg-Merrimac road there is positive evidence of the upturning of the formations composing the Price Mountain anticline. This evidence consists in the finding of coal beds, the Ingles conglomerate, and fossiliferous Devonian sandstone between the red Maccrady shale and the Limestone. The geologic structure necessary to account for this overturned sequence of formations is shown in section A-A′, Pl. I. In this structure the Maccrady shale lies in a trough, the southeastern side of which is overturned and lies upon the normal side. The line along which the overturn makes itself apparent occurs in the red shale and is indicated on the map by a broken line. If this line is followed to the west it is found to cross the Blacksburg branch of the Norfolk and Western Railway at a point about 1,850 feet south of the crossing of the Virginian Railway and here there is a decided and sudden change in the dip of the red shale from 8° to the south to 60° to the south. Beyond this point of change the dips are steep, ranging from 45° to 60°. This change in dip undoubtedly marks the overturn of the south limb of the syncline which is well shown at the surface a little farther east.

The easternmost workings of the Merrimac mine are approaching the axis of this syncline and soon after it passes that line the coal will be found to turn suddenly upward and doubtless in the severe compression and bending that it has suffered it is badly broken, possibly so badly that it will not be workable beyond that point. The observed flattening of the dips in the eastern part of the Merrimac mine indicates that the workings in this part are so much nearer the bottom of the syncline than the workings in the west part that they are experiencing a change in the dip, but it is the writers' opinion that some time in the future the miners will encounter this upturn throughout the entire extent of the Merrimac mine, and if they do, it probably will mean the end of mining operations here.

The writers would strongly advise those who control the operation of this mine that drilling should be done in advance of the mine workings in order that the management might know how much coal they have ahead of them and approximately how long it will last. If core-drilling is done here it should be clearly understood that the coal in the axis of this trough may be 1,000 to 1,200 feet below the surface and the management should be prepared to go at least to that depth.

The map presented herewith is not accurate enough to enable one to say at just what distance the upturn will be encountered, but any engineer could easily determine the point of upturn in the red Maccrady shale by measuring down the Norfolk and Western Railway from the crop line at the commissary to the point where the dip of the red shale changes suddenly from 8° to 60° to the southeast. The upturn in the coal bed will not be north of this point, but presumably it will be at some little distance beyond the upturn as shown at the surface.

Westward from the main slope of the Merrimac mine old slopes have been sunk on the coal bed every 300 or 400 feet. Most of these mines were worked down to drainage level and then abandoned. Several such old mines are included in the property now under the control of the Merrimac Anthracite Coal Corporation. The old workings have been walled off to keep out water and the present workings on No. 7 level are distinctly below the part worked out years ago.

At the Merrimac mine the Langhorne ("Little") bed has been prospected in several places. It occurs about 40 feet below the Merrimac bed, but is generally too thin to work, although it is supposed to contain harder coal than that of the Merrimac bed. As exposed back of the commissary at Merrimac, the Langhorne bed has the following section:

Section of the Langhorne bed at Merrimac (loc. 28).

	Ft.	In.
Coal, shaly	1	0
Shale	3	6
Coal		8¾
Shale		1
Coal	1	5
Thickness of bed	6	8¾
Thickness of coal	3	1¾

Campbell and Howell cut a sample from the bottom bench of coal in this prospect in 1918 and the analysis will be found under No. 30693 on page 111. Judging from the analysis, there is little difference in the coals of the two beds, but it is likely that the sample of the Langhorne bed was weathered and therefore may not have yielded as good an analysis as it would if the coal had been perfectly fresh.

The only other mine on the south slope of the mountain that was in operation in 1923 is the mine of the Brumfield Coal Co. (loc. 29), located just west of the Merrimac property and having an outlet to the Virginian Railway by a short haul down the ravine. Mr. Kimball measured the following section of the coal bed in the Brumfield mine:

Section A of the Merrimac bed in the Brumfield mine (loc. 29).

	Section A. Ft.	In.
Coal		3
Shale		4
Coal	1	0
Shale		10
Coal	1	7½
Shale		3½
Coal		5
Shale		0½
Coal	2	6½
Thickness of bed	7	4
Thickness of coal	5	10

A graphic representation of this section will be found on Pl. XIV.

Later in the season the senior author visited this mine for the purpose of securing a sample for analysis, but he found the mine partly dismantled and the company was in the process of sinking a new slope. The old workings were inaccessible, so a sample was cut across the two uppermost benches of the coal which here have the following thickness:

Section B of part of Merrimac bed in the Brumfield mine (loc. 29).

	Ft.	In.
Coal		7½
Shale		7
Coal	2	3
Thickness of benches	3	5½

A graphic representation of this section will be found on Pl. XIV. The analysis of the sample cut here from the two benches of the coal bears the number 95619 and it will be found on page 111.

Since the authors completed their field work in Price Mountain, they have received a report of some core-drilling that has been done at the siding of Shelby on the Virginian Railway, about a mile west of the crossing of the Blacksburg branch of the Norfolk and Western Railway. This drilling was done with the expectation that, if the coal bed was found to be in good condition and at not too great a depth, a shaft would be sunk and a shipping mine developed. According to the report two holes were drilled, one only a short distance from the outcrop of the coal bed where the dip is nearly 40° and the other just south of the railroad. The coal bed was shown to be in a satisfactory condition, but the depth, though not given out definitely, is understood to be somewhat less than the estimated depth, based on the dip at the outcrop and the depth of the coal bed in the hole drilled near the crop line. No figures of depth are available, but the fact that the coal was found nearer the surface than was expected seems to indicate that the dip is growing less toward the south. This agrees with the tentative conclusion reached in this report that the structure here is that of a rather shallow syncline, upturned and possibly overturned on its south limb.

Many old mines and prospects can be seen on the outcrop of the coal bed west of loc. 29, but these have not been worked in recent years and as a consequence they are caved and the coal is inaccessible. There is a general feeling among the operators in this field that the coal in the west end of Price Mountain, particularly that on the south side of the mountain, is poor and much broken and disturbed by crushing and faulting. This opinion is apparently borne out by the condition of the coal bed as seen at several places on the outcrop, but the writers are somewhat uncertain whether the coal was originally poor in this part of the field or whether most of the trouble arises from the fact that it has been terrifically squeezed and in many places has been crushed to only a fraction of its normal thickness or squeezed out altogether.

Only one section of the coal bed in this part of the field is available and that was measured by Howell in 1914 in an old mine slope at loc. 30. The coal was badly weathered and owing to the condition of the mine, it was difficult to measure the benches accurately, but it appeared to have the following section:

Section of Merrimac coal bed at loc. 30.

	Ft.	In.
Coal		10
Shale		3
Coal		1
Shale		4
Coal		2
Shale		4
Coal		5
Shale, coaly		6
Coal	1	2
Shale		4
Coal		6
Thickness of bed	4	11
Thickness of coal	3	2

The crushed and faulted condition of the coal bed at the extreme west end of the field is indicated by the difficulty of tracing its outcrop around the point of the field at the junction of Lick Creek which parallels in a general way the outcrop on the south side of the field with Stroubles Creek which occupies a similar position on the north side. This outcrop does not appear to be continuous, but is interrupted here and there as though the coal bed were reduced to such proportions that it is unrecognizable or is wanting altogether.

In the past most of the mining activity in this field has been restricted to the north side of Price Mountain because it was believed there was much better coal on that side than there was on the south side. Unfortunately, at the present time there are not enough analyses of coal from the north side to make a comparison of the chemical composition of the coals on the two sides possible, and the writers are inclined to the belief that this is one of the fallacies of which there are many afloat in almost every coal field in the country.

In describing the old mines and prospects on the north side the writers will begin at the east and follow the line of outcrop westward to the end of the field.

The writers found it impossible to trace the outcrop of the Merrimac coal bed continuously from loc. 27 to loc. 31. There is a report current in the field to the effect that the coal bed is wanting, having been cut out by a fault at the point where the outcrop sharply bends from due north at loc. 27 to due west at loc. 31. As the coal does not show between these points the writers found it impossible to determine, without surface prospecting or drilling, whether the coal bed is faulted, as generally believed, or is badly crushed on the turn and effectually concealed. In view of the lack of data on the subject, the outcrop is shown on Pl. I as being continuous between these points.

The first operation on the north side on which the writers were able to get reliable information is the old Beacham mine (loc. 31). The coal from this mine was carried by tram across Price Mountain to the breaker at what is now the Merrimac mine. The reported section of the coal bed in this mine is as follows:

Reported section of the Merrimac coal bed at loc. 31.

	Ft.	In.
Coal		7
Shale		8
Coal	2	1
Shale		4
Coal, mining		9
Coal	1	1
Shale		4
Coal	1	0
Thickness of bed	6	10
Thickness of coal	5	6

For graphic representation of this section see Pl. XIV. The section of the coal bed given above was measured on the rib of the main slope, at the fifth level. The coal bed here strikes east-west and dips N. 21°.

A short distance west of the Beacham mine is the mine of the Kipp Anthracite Coal Co. (loc. 32). This mine has been abandoned for a number of years, but Howell in 1914 succeeded in descending the old slope about 100 feet and then penetrated an east entry for a distance of 250 feet where he measured section A, as given below. Section B was not measured by the writers, but is given on what is regarded as good authority. The sections are as follows:

Sections of the Merrimac coal bed in the mine of the Kipp Anthracite Coal Co., loc. 32.

	Section A. Ft.	Section A. In.	Section B. Ft.	Section B. In.
Coal		7	1	2
Shale		6		6
Coal	2	4	2	0
Shale		5		4
Coal		3		
Shale		2		
Coal		5	1	7
Shale		6		6
Coal		8		10
Thickness of bed	5	10	6	11
Thickness of coal	4	3	5	7

Graphic representations of these sections are given on Pl. XIV. Although the dip is only about 27° to the north, the coal bed in the slope is much disturbed, being pinched down in some places to almost nothing.

West of the Kipp mine the coal bed has been mined in almost every ravine that heads up in the mountain to the south. Most of these old slopes and drifts are now fallen shut or are in such a condition that it is not safe to attempt to enter them, but it is generally understood that the coal bed holds its thickness in most of these openings.

The only mine in operation in 1923 was the mine or mines of the Eureka Coal Co. This is a small company catering alone to the wagon trade and mining coal in at least two of the ravines at loc. 33. The mine is usually known as the Kinzar mine. Section A was measured in this mine by Kimball early in the summer of 1923. Section B was measured by Campbell late in the summer of 1923 on the rib of 1 east entry, 50 feet from the surface and 50 feet from the slope. At this place a sample was cut from the three benches, indicated in the section, for analysis and the result will be found under number 94185 on page 110. The sections are as follows:

Section of the Merrimac coal bed in the Kinzar mine, loc. 33.

	Section A.		Section B.	
	Ft.	In.	Ft.	In.
Coal	1	0		11
Bone		7½		6
Coal	2	8	a 2	0
Bone		3		9½
Coal		2		
Shale		3½		
Coal and shale				11
Coal		4	a	10
Bone		1½		5
Coal	2	11	a	9½
Thickness of bed	8	4½	7	2
Thickness of coal	7	1	4	6½

For graphic representation of these sections, see Pl. XIV.

West of the Kinzar mine there has been only one other mine worked in recent years, and that was known as the Price mine which was situated in the bend of Stroubles Creek at loc. 34. It was connected with the Virginian Railway by a tramroad, remains of which are still to be seen on the hillside above the wagon road that follows Stroubles Creek to the mouth of Lick Creek. The coal bed at the surface dips 50° to the north, but it is reported that at some distance down the slope the dip increased until the coal bed stands vertical. This is not surprising as the evidences of the overturning of the anticline increases westward and the coal bed is much more disturbed and faulted in this end of the mountain than it is at the east end.

QUALITY OF THE COAL.

The quality of the coal of the Price Mountain field has already been considered in the general chapter on that subject and little more can be added to that statement, except to repeat the statement that so far as rank is concerned the coal of this field stands first in the coals of the Valley fields. As stated in the previous discussion, the fuel ratio (the fixed carbon divided by the volatile matter) is used as the basis for the classification of the high-rank coals. As the analysis of the coal from the Price Mountain field, shown on pages 110-111, gives the highest fuel ratio as 8.51 and the average of all the analyses for the field as 7.46, it is evident that the coal is of slightly higher rank than its nearest competitor, Pulaski and the Empire districts, and very much higher in rank than most of the other coals found in the fields on the north side of the Valley.

The coal in the Price Mountain field is not so hard as the Empire coal, but this difference is not one of a regional character; it is due entirely to the fact that in the Price Mountain field mining is limited to the Merrimac coal bed, whereas at Empire nothing is mined but the Langhorne bed which everywhere contains harder coal than that composing most of the Merrimac bed.

As far as ash and sulphur are concerned, there is little difference in the coals of the different fields or parts of fields, and that of the Price Mountain field has no advantage over the coal from other fields of Pulaski and Montgomery counties. Careful picking and washing is necessary at all mines in order that the ash may be reduced to a point where it will be considered by the consuming public as a reasonable amount.

FIELDS OF PULASKI COUNTY.

By Marius R. Campbell and Ralph W. Howell.

General description.

The citizens of Pulaski County, like those of the counties to the east and the west, are largely devoted to agricultural pursuits, but the surface of the country being more diversified than it is in Montgomery County, farming and horticulture are somewhat limited in their areal distribution, being restricted largely to the limestone region (Pl. XIII B). In the past, metal mining has been an important industry in this county, but the mines were located largely in the southern part of the county and consequently the industry had little direct effect upon the area here being considered, except that much of the ore from these mines was smelted in Pulaski and that business has been one of the important elements in the building up of this town to its present important commercial position. Zinc and lead smelting has been abandoned for some time and recently the iron furnaces have gone out of blast so that the smelting industry seems to be largely a thing of the past. It has given way to general manufacturing, mining and shipping of coal, and the varied industries incident to a town in the center of a rich agricultural district.

The population of the county, which is necessarily largely restricted to the area underlain by limestone, is, according to the census of 1920, 17,111, the population of the town of Pulaski (Pl. XIX A), including the surrounding district being 7,996, and that of Dublin, including the surrounding district, 3,414.

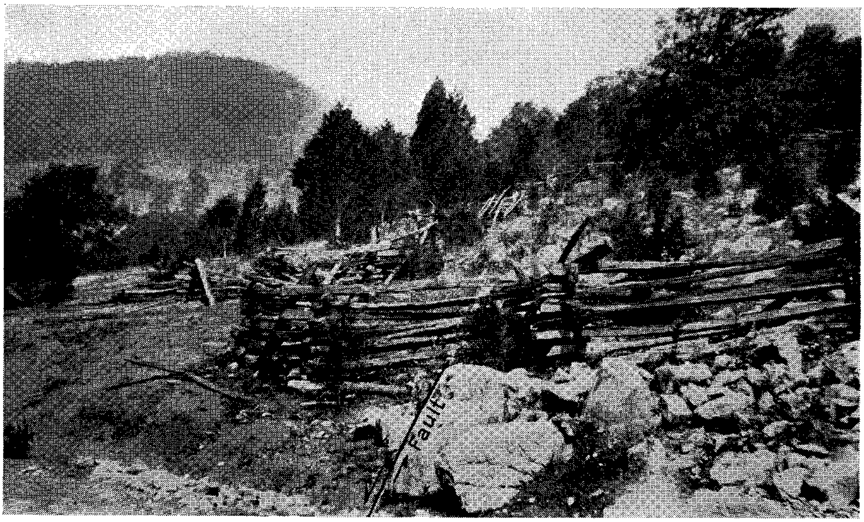
The coal fields of Pulaski County consist of a continuous belt of exposure of the Price formation with its contained coal beds from the Parrott mine on New River, below Belspring, southwestward along the foot of the southern slope of Little Walker Mountain to the reentrant angle formed by the junction of this mountain on the northwest with Tract Mountain on the south. At this junction it turns eastward along the north slope of Tract Mountain to its extreme end where it again turns back to the southwest and follows the valley of Peak Creek to a point 4 miles above Pulaski. At this point it turns again sharply to the east and continues in this direction until it is concealed by the overthrust mass of Shenandoah limestone in the southeastern quarter of the town of Pulaski.

The belt of outcrop of the formation just described is continuous, but in places the formation is faulted and the coal beds may be concealed by the overthrust material. For convenience of description and reference, this irregular outcrop will be divided arbitrarily into two parts: (1) the outcrop along the southeastern slope of Little Walker Mountain and such outcrop as may occur on the north slope of Tract Mountain being regarded as one field, here called the Little Walker Mountain coal field; and (2) that part south of the eastern point of Tract Mountain lying in the drainage basin of Peak Creek, as the other, called for convenience the Pulaski coal field.

Surface features.

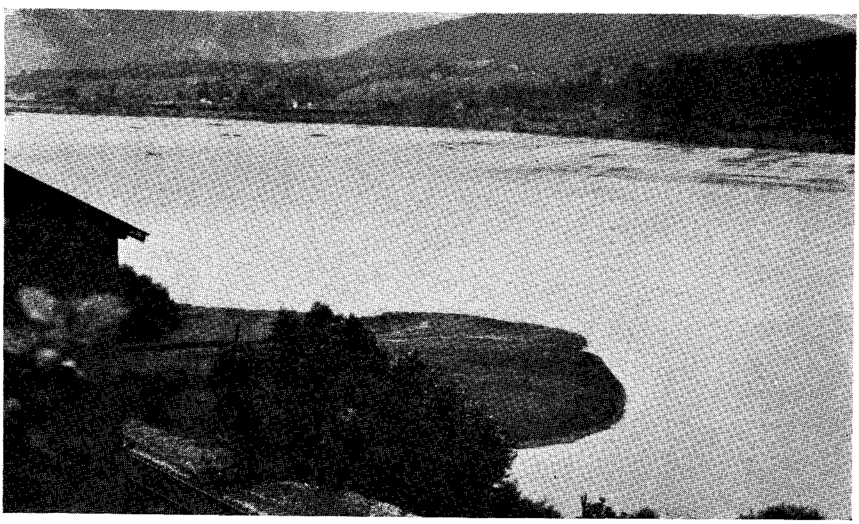
The surface features of that part of Pulaski County embraced in the coal fields or adjacent thereto are in general much the same as the surface features of the coal fields of Montgomery County, described on pages 131 to 135. The coal fields proper lie at the base of ridges and therefore have in many places a rather rugged surface which, on account of its infertility, is rarely cleared and farmed. The region in front of the coal fields through which mining machinery, supplies for the mines, and food for the miners and their families have to be transported and the coal carried away from the mines to the main lines of railroad, is an open country of farms and orchards on the Shenandoah limestone. The surface of this limestone region is fairly flat or gently rolling and the rocks are deeply decayed, showing that it has been exposed to the weather for a long, long time. Near New River the upland surface is at an elevation of about 2,200 feet above the sea level, and evidently it is a part of the Blacksburg peneplain previously described as showing so well in Montgomery County. Farther from the river, as in the reentrant angle between Little Walker and Tract mountains, the surface is higher than it is near the river, reaching in places an elevation of 2,500 feet above sea level. These areas of high land do not appear to have been reduced to the level of the Blacksburg peneplain, probably because they are farther from the trunk stream of the region and because the drainage of the tributary streams has not been so active here as it has been in other parts of the region. Owing to the long period of time that this surface has been exposed to the action of the weather, the limestone is deeply decayed and consequently is seldom seen at the surface. The soil is deep, being composed of the residual clay that was left when the lime was carried off in solution by atmospheric moisture and running water.

East and south of the area described above, the Blacksburg peneplain is much less perfectly preserved, as New River, the main trunk stream of the region, has cut its channel, as shown in Pl. VIII B, about 400 feet below the peneplain level and the small tributary streams, in their efforts to keep pace with the downward cutting of the river, have eroded deep valleys or ravines, leaving only narrow interstream areas that stand at the peneplain level, and many of these, because of the favorable drainage conditions, have been reduced considerably below the elevation they attained when they constituted a part of the peneplain. West and southwest of Tract Fork the surface rocks consist largely of sandstone and sandy shale which are so resistant that they were not reduced to the same level as the limestone in the Blacksburg epoch of peneplanation, except some of the softer shale in the immediate valley of Peak Creek, and the result is a wild and rugged region that has been cleared in only a few places and even where the timber has been removed, farming is not very successful on account of the poor character of the soil. Travelers on the railroad unfamiliar with this region are generally much surprised in their westward journey by the abrupt change from the broad rolling limestone region through which they have journeyed for many miles to the almost unbroken wilderness which they encounter almost immediately after leaving Pulaski, or if they are traveling in the opposite direction, after leaving Gunton Park.



(A) Normal fault terminating limestone outcrop at mouth of Mill Creek.

Photograph by Marius R. Campbell.

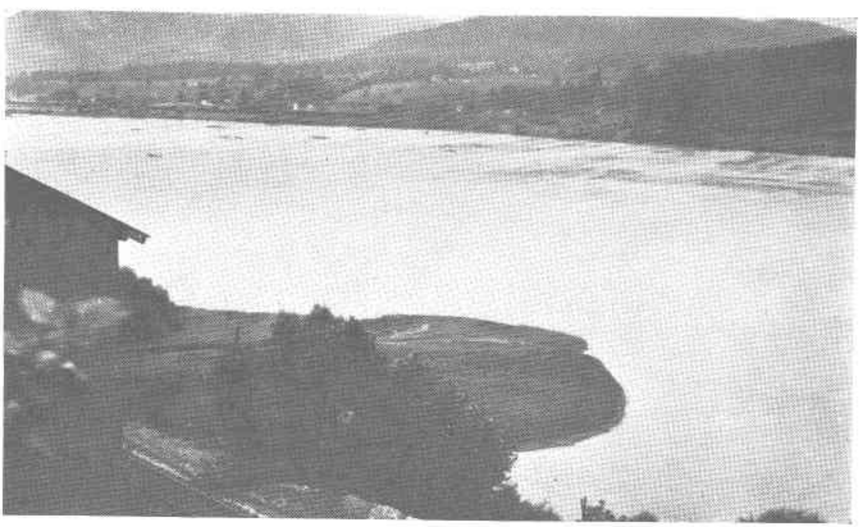


(B) Delta of coal refuse formed below the washery at the Parrott mine on New River.

Photograph by Marius R. Campbell.

(A) Normal fault terminating limestone outcrop at mouth of Mill Creek.

Photograph by Marius R. Campbell.



(B) Delta of coal refuse formed below the washery at the Parrott mine on New River.

Photograph by Marius R. Campbell.

Transportation facilities.

The coal fields of Pulaski County are well served by the main line of the Norfolk and Western Railway which enters the eastern edge of the county at the gap of Walker Mountain on the west bank of New River. This road crosses the outcrop of the coal-bearing formation before it reaches the mouth of Back Creek and south of this place it is in the Shenandoah limestone, tunneling the ridge in the great bend of New River (Pl. XIII B), 2 miles above Belspring and joining the other branch of the road at Walton a mile or more above Peppers Ferry. On the Bristol branch of the Norfolk and Western Railway the logical shipping point for the western end of the Little Walker Mountain coal field and for the Pulaski field is the town of Pulaski, unless perchance a mine were developed on the railroad at the point of the syncline about 4 miles above the town. The western end of the Little Walker Mountain field is made accessible by a tramroad up Tract Fork which was built many years ago by the Bertha Mineral Co. to bring coal from its Altoona coal mine which was situated almost at the angle where Little Walker and Tract mountains unite. Recently this tramroad has been extended northward up Bentleys Branch to the Empire coal mine at the foot of Little Walker Mountain. The railroads, so far described, give ready access to the Pulaski field at all points and to the east and west ends of the Little Walker Mountain field. The remainder of the last mentioned field could be reached by a branch road up Back Creek with branches or tramroads up the ravines to the mines that may be established on the coal outcrop at the foot of Little Walker Mountain.

The coal beds.

The workable coal beds of Pulaski County are essentially at the same geological position as the workable coal beds of Montgomery County, occurring near the middle of the Price formation. A thick bed with many partings has been mined and prospected throughout the Little Walker and the Pulaski fields and this bed is without much doubt the westward continuation of the Merrimac bed of Montgomery County. This bed is well known in the Parrott mine on New River and recently it has been uncovered at the surface in Slope No. 2 of the Empire mine. The bed in this exposure (shown in Pl. XVIII) has a thickness of 20 feet 4¾ inches, as shown graphically on Pl. XVII. As the Merrimac coal bed at New River has a thickness of not to exceed 8 feet and at Empire a thickness of more than 20 feet, it is evident that the bed has more than doubled in thickness in a distance of 13 miles. If, however, the section shown on Pl. XVII be studied carefully, it will be seen that at Empire the exposure may be considered as two coal beds or benches with the following section:

Generalized section of the Merrimac coal bed at Empire mine (loc. 44).

	Ft.	In.
Coal bed	4	7½
Shale and coal	8	10¼
Coal bed	6	11
Thickness of bed	20	4¾

This possible division into two beds is extremely interesting and significant, in view of the presence at Gunton Park in Wythe County of two coal beds separated by an interval of only about 12 feet of country rock, as described on page 233.

Another point of striking difference between the coal beds of Montgomery and Pulaski counties is the lenticular swelling of the Langhorne coal bed from a thickness of less than 3 feet east of New River to 7 or more feet in the Empire mine north of Pulaski. This great increase in thickness appears to be extremely local as it decreases rapidly both to the west and the east from the Empire mine to a thickness of less than 3 feet. The outcrop of the Langhorne coal bed at Slope No. 2 of the Empire mine is shown in Pl. XVIII.

There are other coal beds in the Price formation in both these fields, but so far as known, they are supposed to be too thin for commercial mining, at least at the present time.

Little Walker Mountain coal field.

GENERAL DESCRIPTION.

The Little Walker Mountain coal field is the southwestward extension across New River of the Brushy Mountain coal field of Montgomery County. It includes the outcrop of the Price formation along the foot and south slope of Little Walker Mountain from New River on the east to the Cove fault which terminates the outcrop of the coal beds on Tract Fork near the apparent junction of the two ridges—Little Walker Mountain on the north and Tract Mountain on the south. In addition to this main line of outcrop of the Price formation, the writers have added the outcrop of the coal beds on the north side of Tract Mountain east of the point where the Cove fault first develops from the overturned Crockett anticline. The reason for including this extra territory is that, while present information does not warrant the assumption that deep mining will be carried from mines at the foot of Little Walker Mountain under the limestone to the eastern point of Tract Mountain, we must recognize that such a development is possible and when it occurs it would be much more logical to consider the outcrop of the coal bed on the two sides of the syncline as parts of one field rather than to consider the two limbs as belonging to different fields.

The limit of the Little Walker coal field down the dip of the rocks is controlled entirely by the geological structures that may be found beneath the great overthrust sheet of Shenandoah limestone and by the limit of depth to which economic mining may be carried. As neither of these points can be determined at the present time, it is impossible to set limits upon what may be called the width of this field.

STRUCTURAL RELATIONS.

The broader features of the geologic structure of the Little Walker Mountain coal field have already been given, so all that is necessary here is to consider some of the minor points, especially with reference to their bearing upon the commercial development of mines in this field.

The map and sections on Pl. I show clearly that throughout the entire length of the field from New River to the point where the coal outcrop is cut off by the Cove fault, the coal beds with their associated rocks dip more or less steeply to the south or southeast and pass beneath the great mass of Shenandoah limestone that has been overthrust upon them. At New River the general dip is light, for though the coal where first opened by the Parrott mine has a dip of a little more than 36°, it flattens down the slope, as shown in Fig. 22, to a dip of about 8°, in a distance of 2,850 feet from the mouth of the mine. This decrease in dip is not regular, and the profile may be divided into three parts: (1) from the mine mouth to the 7th entry a distance of approximately 750 feet with an average dip of 23°; (2) from the 7th to the 16th entries, a distance of 1,400 feet, with a dip of 10°; and (3) from the 16th to the 18th entries, a distance of a little more than 700 feet, with an average dip of 6°.

With this profile before him, one can not blame the operators of the Parrott mine for believing that they are approaching the bottom of a broad syncline in which the Merrimac coal bed lies nearly flat for a long distance. Nevertheless, one can but question whether or not this is the most probable conclusion to be reached regarding the structure ahead of the

Parrott workings. The senior author, after assembling all the data that have been accumulated in this field by the two authors of this part of the report, feels very doubtful about the best interpretation to be put upon the known facts. He thought possibly some critical facts had escaped notice and, to make assurance doubly sure, made another visit to the field in 1924, particularly to study the outcrops of the Price formation and the Maccrady shale between New River and the Dublin-Pearisburg road. This examination was made, but the new facts that were observed, instead of clarifying the situation, seemed to indicate that it is more complex than was supposed, and consequently that no definite conclusion could be reached at the present time.

The senior author found, in studying the Maccrady shale from the mouth of Back Creek to the Dublin-Pearisburg road that, while at Parrott there is a definite band of red shale nearly half a mile wide lying in contact with the Shenandoah limestone on the south, at a distance of a little more than 1½ miles to the west the band of red shale veers off to the north, allowing a band of yellowish shale to come in between the fault and the distinctly red shale of the Maccrady formation. The band of non-red shale increases in width reaching a maximum of about 1,700 feet a little more than halfway to the Pearisburg road.

The situation is similar to that on the south side of the Price Mountain fenster, as described on pages 141-145. Manifestly there are two possible interpretations: either that the Maccrady shale in certain parts of this region is characterized by an absence of red shale in its upper part, or that the beds are upturned and the non-red shale is really the upper part of the Price formation repeated on the south and overturned limb of the syncline. The first explanation seems the simpler, but it involves some difficulties which render it unacceptable.

The difficulties may be summed up as follows: (1) wherever a good section of the Maccrady shale has been seen it is red throughout; (2) although observed dips in either the Price or Maccrady formations are fairly steep (the coal generally dipping from 40° to 55°), the breadth of outcrop is so great that one must at once conclude that the structure is far from simple. Thus for several miles west of New River the outcrop of the Price formation ranges in width from 3,850 feet to 5,000 feet, but the formation at most is not more than 1,800 feet thick. In order to make an outcrop 5,000 feet wide the dip of the formation if regular would have to be not over 19°, but a dip as low as 19° is rarely observed in the belt; (3) the coal bed in the old Belle Hampton mine (loc. 36) is reported on good authority to have been much crushed and broken which, if true, is a strong argument in favor of considerable disturbance in the rocks of this belt; (4) the drill hole put down at loc. 38, if one can believe the numerous reports current in the field regarding it, does not substantiate the idea that the rocks dip gently and fairly regularly to the south, at least, as far as the Pulaski fault. According to report this hole reached a depth of about 1,400 feet and some who are supposed to know say that the Merrimac bed was pierced at a depth of about 900 feet.

If the log of this well were available it would probably throw much light on the underground structure of this region and this would mean information regarding the possible extent of the Merrimac coal bed south of Back Creek. The two possible interpretations are well illustrated in Fig. 6. If the rumor that the Merrimac coal bed was found in the drill hole at loc. 38 at a depth of 900 feet is correct, then interpretation A seems to be the only one that is appropriate, but if the coal was struck at or near the bottom of the well, then interpretation B seems to be the more appropriate one. From a consideration of the general structural features of the region, the writers are inclined to accept interpretation A as the more probable of the two.

The acceptance of this interpretation even in a provisional manner means the acceptance of the idea that there is an anticline in the coal-bearing rocks somewhere under the edge of the limestone and that this minor wrinkle is growing less and less in a westerly direction and that it probably dies out before it reaches the Empire mine at loc. 43.

If interpretation B proves to be correct, it means that as the coal bed is followed down from the outcrop many minor wrinkles, if not faults, will be encountered, and then when approaching the locality of the drill hole, loc. 38, the coal bed will take a downward plunge on a 40° dip and continue indefinitely at about that inclination. Such a change of dip within the mine would necessarily make mining expensive as it would require an inside hoisting plant to raise the coal up the slope to the break in grade and then through a shaft or another slope to hoist it to the surface.

Either interpretation of the structure of this region will involve difficulties in mining which make it very desirable to obtain additional information before much money is invested in a mining plant on the outcrop of the coal bed or in a shaft which would reach the coal at a depth. The writers would strongly advise core-drilling in advance of extended mining operations, for otherwise the mining condition might be found to be so bad that the entire plant would have to be abandoned.

On account of the disappearance of the minor wrinkle just described it is probable that at Empire the coal bed dips steadily with but little interruption into the deep trough lying between Little Walker Mountain on the north and Tract Mountain on the south, as shown in section F-F′ on Pl. I. The depth of this trough has never been determined, but all of the geologic evidence at hand seems to indicate that it is very deep and that the possibility of mining out the coal in this trough depends almost entirely upon whether mining can be carried to such a depth at a cost that is not prohibitive, and whether or not engineering difficulties would be so great as, in themselves, to be prohibitive.

The other detail of structure that has not previously been described is that which marks the juncture of the two ridges, Little Walker Mountain and Tract Mountain. The overturned Empire syncline which appears to be so well marked in section F-F′ becomes rapidly shallower and narrower toward the west, but this pinching in of the syncline does not occur gradually and regularly, for it has resulted in cross wrinkles of considerable dimensions. This structure is particularly well shown in the coal beds, the outcrop of which forms a pronounced loop in the vicinity of the old Altoona mine (loc. 47). This bend in the structure can be clearly seen from the crest of Little Walker Mountain just above loc. 47. The old tramroad to the mine was extended across the mountain and for a number of years has been in active operation, bringing out lumber and logs from the valley on the north side of Little Walker Mountain. The Ingles conglomerate is well exposed on this tramroad at the crest and for some distance down on the south slope of the mountain and in this stretch the strike of the beds is north-south, whereas on the same tramroad below loc. 47, the strike for a long distance is east-west. So far as structure is concerned the location of the old Altoona mine was about the worst that

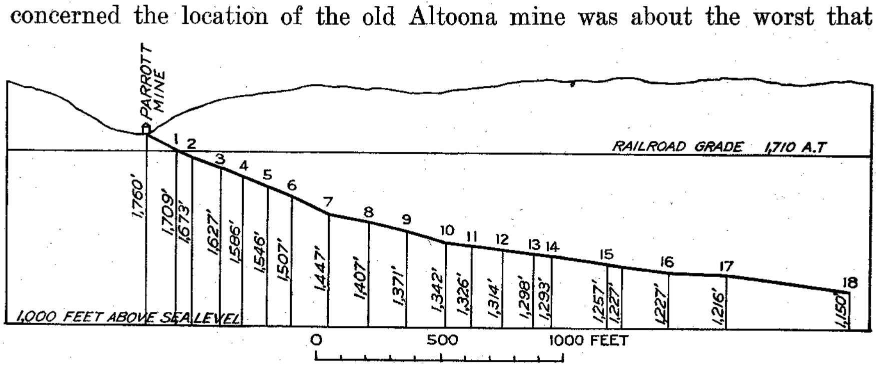


Fig. 22.—Profile of the main slope of the Parrott coal mine.

could have been selected, for it is here that the most pronounced bend occurs and, as is usually the case, the coal bed is the member that suffers most in such a disturbance. This is borne out by the reports in circulation that in this mine the main coal bed (Merrimac?) ranges in thickness from 5 to 40 feet with an average of 7 feet, but it is also reported that in places the coal was so bunched that it attained a thickness of 125 feet.

DESCRIPTION OF MINES AND PROSPECTS.

The coal beds of the Little Walker Mountain field are the westward continuation of the beds already described in the Brushy Mountain field of Montgomery County. At New River the boundary between the two counties, the Merrimac coal bed is the only one worked at the present time. It is generally recognized that the Langhorne bed contains cleaner and harder coal than the Merrimac bed but the Langhorne bed seldom exceeds 2½ feet in thickness and consequently can not be considered as the basis for the establishment of a large mining enterprise and so is left to be mined only for a local supply.

The principal mining operation in the Merrimac coal bed in the Little Walker Mountain field is the Parrott mine of the Pulaski Anthracite Coal Co. This mine has been in almost continuous operation since 1902. It is on the main line of the Norfolk and Western Railway and the slope extends southward parallel with the railway for a distance of 2,850 feet. As the property of this company lies entirely west of New River it was impossible to drive the main slope directly down the dip which is here about S. 28° E., consequently the slope is not quite so steep as the dip of the coal bed. The profile of the slope, based on distances and elevations on the mine map, is given in Fig. 22. At the surface the pitch of the slope is 36°, but this flattens to about 6° at entry 17.

The mine workings have been carried westward a distance of more than 4,000 feet and the mine map shows some interesting structural details which may have a bearing upon the theories advanced in this report. Fig. 23 shows the general arrangement of the mine with only the slope and the main lateral entries represented. The lateral entries are driven nearly along the strike of the coal bed, so they may be taken in a general way as structure contours, but with unequal intervals between them. In using them in this manner it must be understood that they descend to the main slope, but this descent is only sufficient to permit of the easy haulage of loaded cars in that direction and the return of empty cars to the rooms where mining is carried on. On account of this grade, the far ends of the entries are considerably higher than the points where they join the main slope, and consequently a contour line drawn through the point of juncture of the lateral with the main slope will at all other points fall below the lateral entry.

Fig. 23 shows that the coal bed dips with considerable regularity and that few if any disturbances were encountered down as far as entry 15, except that entry 10 is marked as terminating in disturbed coal. As entries 7 and 8 terminate along nearly the same line and that line does not coincide with the property line, it seems highly probable that work was discontinued because they also encountered broken coal. In line with the same disturbance is a change in direction of the rooms on entries 14 and 15 from N. 25° W. to N. 72° W. This change indicates that the direction of the dip of the coal bed changes about 45° on a line which is the continuation of the line mentioned before that marks disturbed conditions in entries 7, 8, and 10, but the greatest effect of this structural disturbance is shown in the change of course of entry 16 which evidently encountered a decided fold in the coal bed with indications that the movement had been much more severe on the north side than on the south side of the fold. The evidence consists of broken coal and disturbed conditions of the roof and the sharp swing of the entry from a course a little north of west to a course a little east of south and then in a sigmoidal curve bending around into a nearly normal course. All of the entries, however, which have passed across this fold have beyond it a nearly westerly course and this is not the normal course for structure contours in this part of the field. It seems apparent that in passing over or around the fold they are feeling its effect more than they are the effect of the major structure of the region and consequently they follow for an unknown distance a westerly course, but this course will change to a southwesterly direction where they pass beyond the influence of the minor fold.

So far as one can judge from the mine map the minor fold described in the preceding paragraph is increasing in magnitude southeastward, hence it will be interesting to see what effect it may have on the main slope when the slope crosses its pathway which probably will be 250 to 300 feet beyond entry 18.

The Merrimac coal bed in the Parrott mine seems to be even more broken by shale and bony partings than it is in Montgomery County, but, as stated on a previous page, the number of partings reported in a section of this coal bed depends largely upon the person taking the measurements

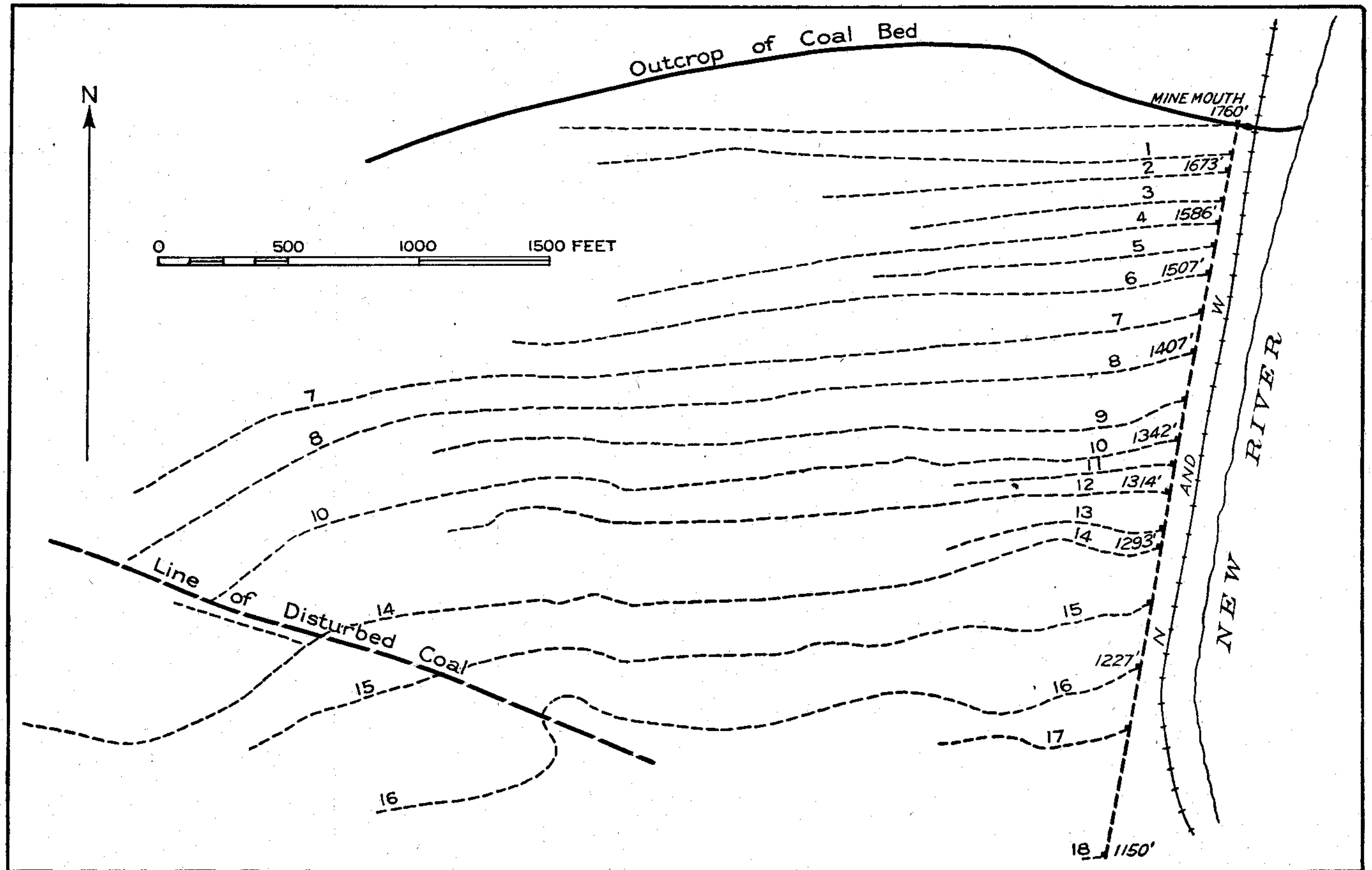


Fig. 23.—Outline map of the Parrott coal mine, showing a line of disturbance in the coal bed.

and making the classification of the material composing the bed. The following sections, which are also shown graphically on Pl. XVII, give an excellent idea of the heterogeneous character of this bed:

Section of Merrimac coal bed in Parrott mine, loc. 35.

	Section A.		Section B.		Section C.		Section D.		Section E.		Section F.	
	Ft.	In.	Ft.	In.	Ft.	In.	Ft.	In.	Ft.	In.	Ft.	In.
Bone								3		4		
Coal, shaly ...		1	a	2								
Shale		2		2								
Coal		9	a	9	a 1	0¾	a	6	a	8	1	2
Shale or bone..		4		3		3¼		3		3		3
Coal		3	a	3	a	2¾						
Shale		1¾		1		2						
Coal		8	a	7	a	3½	a 1	6	a 1	6	1	9
Shale		0¾		1		2						
Coal			a	2								
Shale				1								
Coal	1	0	a	4	a	7						
Shale		1										
Coal		7½										
Shale or bone..		8		6		5¼		6		6		6
Coal	1	3	a 1	4	a 1	6½	a 1	4½	a 1	6	1	7
Shale		0½										
Coal		4½										
Shale or bone..		3		5		3¼		1½		5		3
Coal		10	a 1	10	a	8¼	a 1	1½	a 1	7		8
Shale or bone..		2				1¼		1		2		1
Coal		3½			a	5	a	9	a	2		5
Shale or bone..		1				0½						1
Coal		4			a	4¾						5
Thickness of bed	8	5½	7	0	6	8	6	5½	7	1	7	2
Thickness of coal	6	5½	5	5	5	2½	5	3	5	5	6	0
Analysis No... (See p. 111)			19431		30694		94186		94187			

These sections are represented graphically on Pl. XVII. Section A is reported by the owners as having been measured in the air course near the fan house, practically at the outcrop. Section B was measured by Howell in 1914 on 3d entry, 100 feet from the slope. Section C was measured by Campbell and Howell in 1918 on the 15th entry, 150 feet from the slope. Section D was measured by Campbell in 1923 on the 15th entry, 2,500 feet from the slope. Section E was measured by Campbell in 1923 at a point in the 16th entry, 2,600 feet from the slope. Section

F is reported by the owners as measured in 1924 at the face of the main slope, then at the 18th entry, about 2,850 feet from the mine mouth. The analyses of samples obtained from benches marked *a* in sections B, C, D, and E are given on page 111 as indicated above.

The coal bed in the Parrott mine is generally but little disturbed, but in places there are wrinkles in it which make it necessary to change the direction of the entries and in places the coal and roof have been so crushed that mining is impossible. On the whole, however, these areas of disturbance are small and few in number and have had little effect upon the systematic development of the mine which, as before stated, is down, as measured on the main slope, a distance of 2,850 feet.

The coal as it comes from the mine is picked of the larger pieces of bone and shale, then screened and the smaller sizes are washed to get rid of the finer particles of impurities which, as shown in Pl. XVI B, form a small delta in New River. The finest coal is briquetted with the addition of pitch and in the form of briquettes has found a fairly ready market.

West of the Parrott mine there are numerous old mines and prospects on the outcrop of the coal bed, but in this part of the territory the land has been held in larger tracts and consequently there are not so many old workings per mile as there are along Brushy Mountain in Montgomery County.

The first mine of importance west of the Parrott mine is the Belle Hampton mine (now abandoned), loc. 36, which was connected with the Norfolk and Western Railway by a standard-gauge branch line, 2½ miles in length. The tipple is still standing and the railroad could be put in running order without great expense, as it was laid with fairly heavy rails which are still on the ground. It is reported, on what seems to be good authority, that the main slope of this mine was carried down on a dip of 50° for a distance of about 400 feet and lateral entries of a similar length were run both eastward and westward from the slope. Considerable crushed coal was encountered and it is assumed by the writers that it was largely because of this unfavorable condition of the coal bed that mining was stopped and the entire plant abandoned.

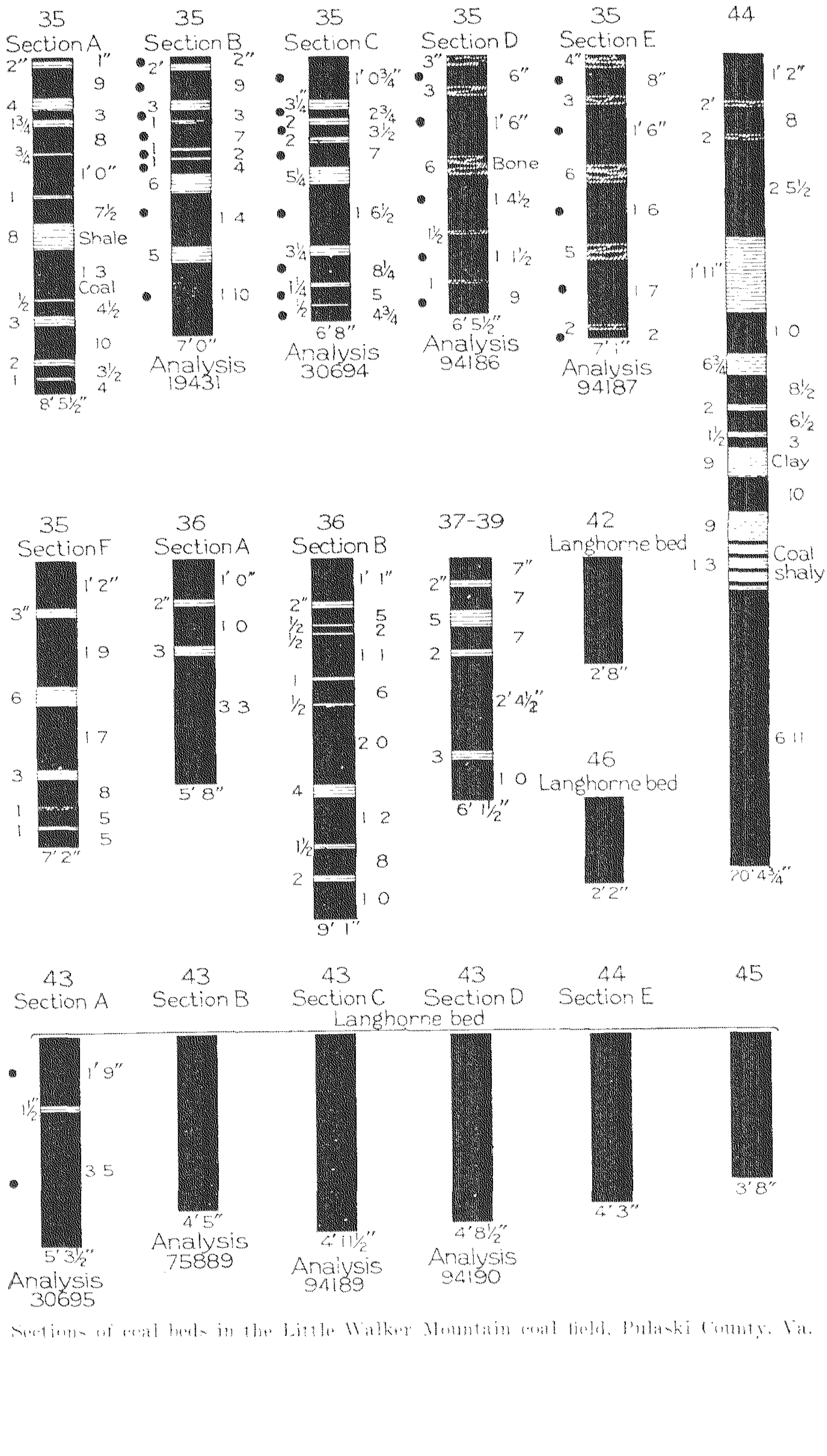
The slope was open at the time it was visited by the writers, but it was not considered safe to attempt to go down far enough to make a reliable measurement of the coal bed. An unsigned report obtained by Howell gives two sections of the coal bed in this mine, which, if they can be depended upon, show great variations in the coal bed that are doubtless due to movement at the time the rocks were upturned. The sections are as follows:

Sections of the Merrimac coal bed in the slope of the Belle Hampton mine, loc. 36 (reported).

	Section A. Ft.	Section A. In.	Section B. Ft.	Section B. In.
Coal	1	0	1	1
Shale		2		2
Coal	1	0		5
Shale				0½
Coal				2
Shale				0½
Coal			1	1
Shale				1
Coal				6
Shale		3		0½
Coal	3	3	2	0
Shale				4
Coal			1	2
Shale				1½
Coal				8
Shale				2
Coal			1	0
Thickness of bed	5	8	9	1
Thickness of coal	5	3	8	1

These sections are represented graphically on Pl. XVII. Section A is supposed to have been measured in the slope 250 feet from the mine mouth, and section B at the bottom of the slope 400 feet from the mine mouth. The section measured at the bottom of the slope compares favorably with similar sections obtained in other mines on the Merrimac coal bed and it is regarded as fairly reliable. Section A is evidently far below the normal thickness of the coal bed and either represents a part of the bed only or was measured at a point where the thickness of the bed is greatly reduced by squeezing or stretching.

A fairly good section of the rocks is exposed in the cuts made in grading for the branch railroad line running to this mine. The upper mile is directly across the strike and one can gain a fairly good idea of the condition of the formations by a study of this section. The writers did not take the time to construct a detailed section along this road, but enough notes were taken to show conclusively that the rocks do not dip regularly nor are all dips in the same direction. A number of anticlines



Sections of coal beds in the Little Walker Mountain coal field, Pulaski County, Va.

and synclines were noted which, if they extend down to the coal bed, and there seems to be no reason for supposing that they do not, will possibly carry the coal bed in much of this stretch in a nearly horizontal position, but with so many minor wrinkles that the coal bed must be badly broken and crushed.

In connection with the development of the Belle Hampton mine a core drill was put down at the mouth of a small branch coming into Back Creek from the north, about 2 miles above the railroad (loc. 38). According to report this well was drilled to a depth of 1,380 feet, but no reliable information could be gained regarding the depth at which the coal bed was encountered. Some thought it was at 900 feet, and some, that it was at the bottom of the hole. As stated previously, the log of this well would probably throw considerable light on the geologic structure of this part of the field, but the writers have been unable to obtain it.

A mine was once opened in the ravine next west of the one in which the well just described was sunk, but fully a mile to the north, or near the foot of Little Walker Mountain. The old tramroad by which the coal was transported from the mine is still visible but is badly overgrown, showing that the mine must have been abandoned a great many years ago.

West of the old mine just noted the writers were unable to find any open prospects or mines in which a measurement of the coal bed could be obtained, but a private report on this part of the field gives a section that probably was measured in a prospect about midway between locs. 37 and 39. The section of the bed measured 30 feet below the surface is reported as follows:

Section of Merrimac coal bed at locs. 37-39.
(Reported.)

	Ft.	In.
Coal		7
Shale		2
Coal		7
Shale		5
Coal		7
Shale		2
Coal, some very soft	2	4½
Shale		3
Coal	1	0
Thickness of bed	6	1½
Thickness of coal	5	1½

This section is shown graphically on Pl. XVII.

Other mines and prospects were found between this place and the Dublin-Pearisburg road, but at no place could the writers get a reliable section of the coal bed or secure a sample of the coal fresh enough to be worthy of analysis.

The Langhorne coal bed is being mined in a number of places between New River and the Dublin-Pearisburg road for local consumption. The coal of this bed is harder and cleaner than that of the Merrimac bed but, as the thickness generally ranges from 24 to 30 inches, it does not afford a basis for extensive mining operations.

The Merrimac coal bed is well exposed where it crosses the Dublin-Pearisburg road and the dump heaps of an old mine are visible just below this road at loc. 39. The "bloom" of the coal bed in the road is large, but no reliable measurement of the thickness or character of the coal bed could be made. A small mine is in operation in the next ravine, about 500 feet to the east where the part of the coal bed that is mined has a thickness of 3 feet 6½ inches, but it is apparent that there is considerable coal above the roof of the mine. On the road the coal bed dips south about 43°.

About a quarter of a mile west of the Dublin-Pearisburg road, a small mine, known as the Cloyd mine, has been in operation for a number of years. Howell visited this mine in 1914, secured a sample of coal for analysis, and measured a section of the coal bed which is shown graphically on Pl. XVII. The measurement is as follows:

Section of Merrimac coal bed in Cloyd mine (loc. 40).

		Ft.	In.
Coal	a		6
Shale and coal			9
Coal	a		10
Shale and coal			9
Coal	a		7
Shale			4
Coal, soft	a		10
Coal, hard	a	1	6+
Thickness of bed		6	1+
Thickness of coal		4	3+

The analysis of the sample collected from the benches marked *a* is shown under No. 20722 on page 112. This section was measured at the face of the drift, 125 feet from the mine mouth. At loc. 40 the coal bed strikes N. 65° E. and dips 42° to the southeast.

West of the Cloyd mine old prospects on the outcrop of the coal bed are not so numerous as they are further east, but enough were found to indicate that the outcrop continues in nearly a straight line toward the Empire mine at loc. 43. Traces of the outcrop were seen at loc. 41 on the road crossing Little Walker Mountain a little more than 1½ miles east of the Empire mine. The exposure in this road is poor and gives no idea of the thickness or number of the coal beds.

West of loc. 41 there are few good sections of the Merrimac coal bed obtainable. In the Empire mine, which is operating in the Langhorne coal bed, a rock tunnel was driven through 14 or 15 feet of rock to the overlying Merrimac bed. The senior author visited this mine, but could not get a section of the Merrimac bed because its upper part was concealed by timbers that were set to support the roof. The management, however, reported that the bed where cut is nearly 20 feet thick. Fortunately, at a visit to this mine in June, 1924, a complete section of both the Langhorne and Merrimac coal beds was obtained at No. 2 slope, a view of which is shown in Pl. XVIII. Although somewhat weathered, the section is quite complete, and substantiates the reported thickness of the bed where cut lower down in the mine. The section here is as follows:

Section of Merrimac coal bed at mouth of No. 2 Slope, Empire mine, loc. 44.

	Ft.	In.
Coal, shaly	1	2
Bone		2
Coal		8
Bone		2
Coal	2	5½
Shale	1	11
Coal	1	0
Clay		6¾
Coal		8½
Shale		2
Coal		6½
Shale		1½
Coal		3
Clay		9
Coal		10
Clay		9
Coal, shaly	1	3
Coal	6	11
Thickness of bed	20	4¾
Thickness of coal	15	9½

A graphic representation of this section is given on Pl. XVII.

As the only place in the western part of the Little Walker Mountain field for getting a sample of the Merrimac coal for analysis is in the Empire mine, W. T. Thom, Jr., and R. J. Holden cut such a sample on the 4th level at the foot of No. 2 slope. Only the lower part of the bed is accessible, and consequently the sample should not be regarded as representative of the entire thickness of the coal bed. The section exposed at the point of sampling is as follows:

Partial section of the Merrimac coal bed in the Empire mine, loc. 44.

		Ft.	In.
Coal	a	1	1
Bone			6
Coal	a		8
Bone			10
Coal	a	1	0
Bone			2½
Coal	a		5
Thickness of section		4	8½
Thickness of coal		3	2

The analysis of the sample obtained from the benches marked *a* will be found under number A-2634 in the table on page 112. This analysis shows that the coal is exceptionally high in ash, therefore, it should not be regarded as representative of the coal of the entire bed.

The section of the Merrimac coal bed, exposed at Slope No. 2 of the Empire Anthracite Coal Co. suggests that this great bed is undergoing in a westerly direction a division into two beds. This tendency is more strongly marked in, if not absolutely proved by, a core-drill hole recently put down by this company not very far distant from loc. 44. The section of the coal bed as revealed by the log of this well which has been kindly furnished by the Empire Anthracite Coal Co. is as follows:

Section of Merrimac coal bed in drill hole near loc. 44.

(Through the courtesy of the Empire Anthracite Coal Co.)

	Ft.	In.
Coal	5	6
Shale		2
Coal	2	4
Shale, carbonaceous	1	9
Coal		8
Shale	3	9
Coal	1	0
Shale		9
Coal	6	6
Thickness of bed	22	5
Thickness of coal	16	0

This section is represented graphically on Pl. XX. It shows a clear separation into two benches or beds: an upper bench 10 feet 5 inches thick, and a lower bench 8 feet 3 inches thick, separated by a bench composed mostly of shale 3 feet 9 inches thick. This great thickness of coal bed, together with its division into two distinctive benches or beds throws considerable light on the conditions prevailing in the Max Meadows field, as will be explained in the description of the coal beds of that field on pages 225-226.

Probably the most striking feature of the Little Walker Mountain coal field, and certainly the most important from a commercial point of view, is the sudden thickening of the Langhorne coal bed to workable proportions in and near the Empire mine, locs. 43 and 44. The change in thickness, or rather the lens-like character of the coal bed in this locality is well brought out graphically on Pl. XVII. The coal bed at loc. 42 is only 2 feet 8 inches thick, as reported by the Empire Anthracite Coal Co., but it increases in thickness rapidly westward as shown by sections A, B, C, and D, which were measured by the writers in the Empire mine, loc. 43, and by section E measured at Slope No. 2, loc. 44.

Sections of the Langhorne coal bed in the Empire mine, locs. 43 and 44.

	Section A.		Section B.		Section C.		Section D.		Section E.	
	Ft.	In.	Ft.	In.	Ft.	In.	Ft.	In.	Ft.	In.
Coal	a 1	9								
Shale		1½								
Coal	a 3	5	4	5	4	11½	4	8½	4	3
Thickness of bed	5	3½	4	5	4	11½	4	8½	4	3
Analysis No.	30695		75889		94189		94190			

The analyses of samples collected from the benches marked *a* in section A and from the entire bed in sections B, C, and D will be found on page 112. Section A was measured by Howell and Campbell when the mine was first opened in 1918 by Daniel W. Langhorne of Pulaski. The mine then consisted of a rock tunnel about 25 feet long driven horizontally northward through the Merrimac coal bed into the Langhorne bed below. The section was measured and a sample of the coal was taken for analysis at the face of the west entry, 250 feet from the rock tunnel. Section B was measured by Campbell at the face of 2nd east entry, 600 feet from the slope and 250 feet down the dip from the surface. Section C was measured by Campbell in room 48, off 4th west entry, 2,300 feet from the slope and 500 feet down the dip. Section D was measured by

Campbell at the face of 5th west entry, 1,400 feet from the slope and 720 feet down the dip. Section E was measured in 1924 by W. T. Thom, Jr., and R. J. Holden at the mouth of Slope No. 2 (Pl. XVIII), but the coal was not sampled as it is too badly weathered to be typical of the bed below the surface.

The greatest thickness recorded in these sections is 5 feet 3 inches, but the management claims that deeper in the mine the coal, at one place, reaches a thickness of 7 feet 4 inches. The writers have not visited this great development, but see no reason for doubting the accuracy of the statement.

Westward from the Empire mine the bed decreases in thickness on the outcrop, reaching 3 feet 8 inches at loc. 45 and 2 feet 2 inches at loc. 46 (see Pl. XVII). It is not known to be of workable thickness at any other place in the Little Walker Mountain coal field, except that, as stated on page 212, it is reported to be 6 feet 1 inch thick on the eastern end of Tract Mountain.

The measured distance between the Merrimac and the Langhorne coal beds at loc. 44, as shown in Pl. XVIII, is as follows:

Section of rocks lying between Merrimac and Langhorne coal beds, loc. 44.

	Ft.	In.
Shale, sandy	3	8
Shale, black, carbonaceous	2	6
Sandstone, thin-bedded	4	6
Sandstone, hard	3	3½
Thickness of section	13	11½

West of the Empire mine the Merrimac coal bed shows in natural outcrop or has been slightly prospected in a number of places, but at none of them can the entire thickness of the bed be seen and measured, nor is the coal fresh enough to warrant sampling for analysis. One of the earliest developments of mining enterprise in this field was the opening of a coal mine by the Bertha Mineral Co. of Pulaski, some time between 1880 and 1890, for the purpose of supplying their zinc smelter at Pulaski with fuel. The Altoona mine was opened at loc. 47 and a tramroad built up Tract Fork of Peak Creek into the angle between Little Walker and Tract mountains.

No reliable account of the coal in this mine has been obtained by the writers, but it is reported that three coal beds were cut in the mine workings, the uppermost bed being what is generally known as the "Big"

Bed" which is said to have ranged from 5 feet to 40 feet in thickness, though there are also current reports that in places this bed was as much as 125 feet thick. Two other beds were found below the "Big Bed," but no information could be obtained regarding either their thickness or the distance they are below the "Big Bed." From the accounts it is apparent that the coal beds are greatly disturbed in this part of the field and owing to the crushed condition of the coal and the intimate mixing of the partings with the good coal, it is doubtful if mining in a commercial sense can be carried on. The only available analysis of this coal is one made by Andrew S. McCreath and published in The Virginias, vol. 6, April, 1885. This analysis shows an ash content of 39.8 per cent, but as it is not accompanied by any statement as to what the sample included, its value is but slight. It is, however, generally conceded that the coal was very impure, and while it answered the purpose of the Bertha Mineral Co. as a fuel in their smelting operations, it probably would not have fared well if it had been offered for sale on the open market.

The senior author is not at all surprised that the coal bed should have been found to be greatly crushed and distorted in the Altoona mine, for from a geological point of view the location of the mine is probably the worst that could have been selected in the Little Walker Mountain coal field. The basis for this statement is the disordered condition of the rocks in the vicinity of the mine and also the well-known fact that the coal beds are always seriously affected wherever there is a decided bend or angle in the mountains outlining the field.

Formerly it was supposed that the outcrops of the coal beds as they approached the angle in the mountains from the east would turn sharply back upon themselves and be found on the north slope of Tract Mountain, but now it is fairly well established that such is not the case, for the development of the Cove fault near the east end of Tract Mountain and its increase in magnitude westward, as shown in Pl. I, has cut out the coal-bearing rocks or they have been concealed by the overthrust mass of the Devonian sandstones and shales. For that reason it seems hopeless to search for coal beds on the north side of Tract Mountain, except at its eastern end.

Although the actual break in the outcrop of the coal beds occurs in the angle between Little Walker and Tract mountains, the writers have thought best to include in the Little Walker Mountain coal field all coal beds outcropping on the north side of Tract Mountain, for the reason that coal beds dipping to the north on the north side of Tract Mountain may be found in future mining operations to pass under the Shenandoah limestone and connect directly with the coal beds cropping out in the vicinity of the Empire mine. If that should happen it would be logical to consider all of the coal as being in one field and as it is more directly connected with the field to the north than with the Pulaski field, it is here considered as a part of the Little Walker Mountain field.

The writers have little definite information regarding the coal bed on the north side of Tract Mountain, but the outcrop was observed to come in about 1¼ miles west of the southward course of Tract Fork and from that point it can be easily followed eastward until it swings to the south around the point of the Crockett anticline. On the north side of the ridge there are no open prospects on the coal beds, but at loc. 48 the coal shows as a bloom dipping to the N. 67°. At the point of the anticline both beds have been opened, but no place was seen by the writers at which sections of the beds could be measured or samples obtained for analysis. The writers have, however, heard a vague report that both the Merrimac and the Langhorne coal beds have been opened on the anticlinal point north of Pulaski by a shaft and that the Merrimac bed in this shaft has a thickness of 14 feet 8 inches and the Langhorne bed, a thickness of 6 feet 1 inch. It seems probable, however, that the bed here called Langhorne is really only the bottom bench of the Merrimac coal bed. This supposition is strengthened by a comparison of the thicknesses reported here with those furnished by the Empire Anthracite Coal Co. in their drill-hole near loc. 44, as shown on Pl. XX. Thus the two beds reported as showing on the point of the anticline have an aggregate thickness of 20 feet 9 inches and the Merrimac coal bed, as shown by the drill record mentioned above, with the exception of the band of shale, 3 feet 9 inches thick, separating the two parts, is 18 feet 8 inches.

One of the most remarkable showings of coal in the Little Walker Mountain coal field may be seen on the north side of the road leading from Empire to Pulaski, about ½-mile east of the point where the road from Empire joins the road from Mechanicsburg, which is on the north side of Walker Mountain. The coal is exposed in an old quarry on the north side of the road and it appears to be included within some jagged masses of Shenandoah limestone on the plane of the Pulaski fault. Pl. XIII A shows this quarry and its relation to the Shenandoah limestone, the Pulaski fault, and the Maccrady shale. The formations dip to the left or north about 55°. The line separating the Maccrady shale from the Shenandoah limestone is about as indicated on the plate, but the coal shows considerably to the left of this fault. As a matter of fact this is a good illustration of the complexity of most of these great overthrust faults. Few, if any of them, are clean-cut breaks, but along the fault plane there are many places in which fragments of one or the other of the adjacent formations are intermingled with fragments of the other formaiton, or a fragment of one formation is included in a mass of the other formation. In the quarry referred to and shown on Pl. XIII A the coal seems to be included in a great mass of limestone.

Such an occurrence is not at all surprising when one stops to consider how far the limestone on the left has been shoved over not only the Maccrady shale but also other formations before it reached its final resting place in this locality. The surprising thing is that such occurrences are not more commonly seen in the field, but in this case no one would have noticed the outcrop of the coal as it was obscured by soil and vegetation until it was uncovered by the excavation of the rock for road-building purposes.

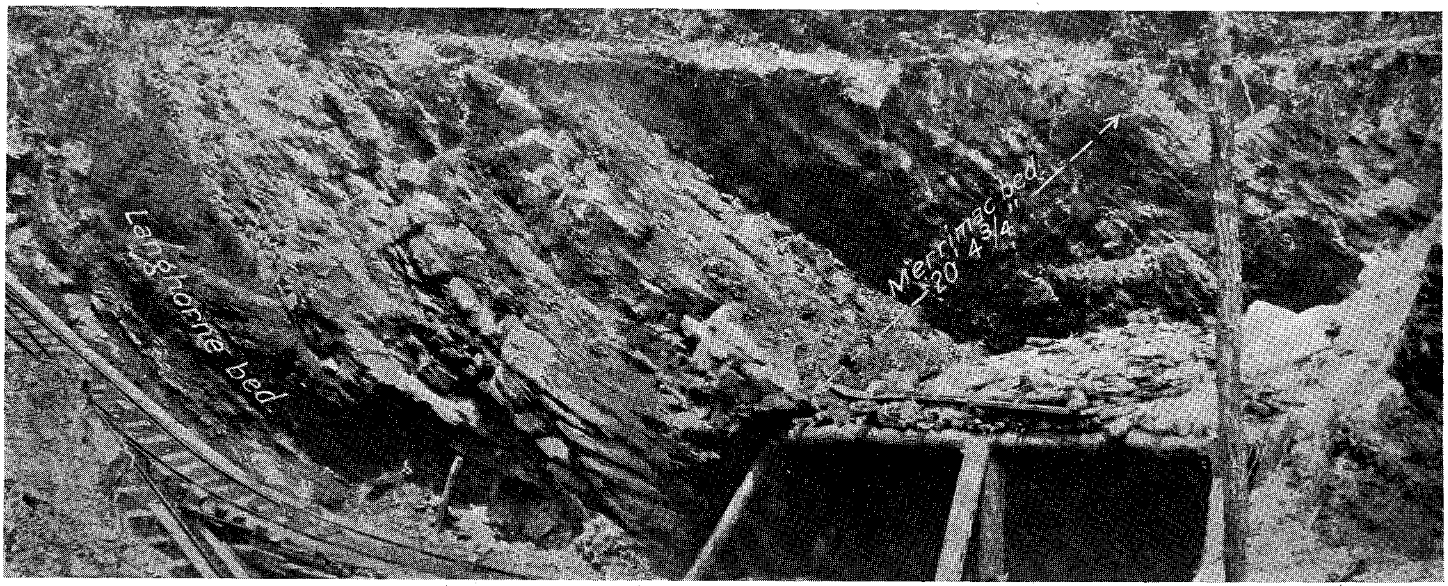
One can not resist the temptation to speculate regarding the place from whence this coal was derived. If the limestone in the overthrust mass moved toward the northwest at right angles to the general structural lines of the Valley, as it seems reasonable to suppose, then the limestone showing in Pl. XIII A must have come from the vicinity of Draper on the south side of Draper Mountain, over the place where the town of Pulaski has been built and so on to its final resting place. In this journey it must have crossed the outcrop of the Merrimac coal bed at least once and that crossing was just to the south of the town of Pulaski. It seems, therefore, altogether probable that the coal fragment was broken from that outcrop and carried in a cleft of the limestone to the place where it is seen to-day. If it be granted that this hypothesis is the most reasonable one that can be proposed to account for the coal, then its presence here can not be used as an argument in favor of the occurrence of workable coal in a nearby locality.

QUALITY OF THE COAL.

One of the puzzling questions of the Little Walker Mountain coal field is the exceptionally high rank (high fuel ratio) of the coal of the Langhorne bed in the Empire mine. As shown by the table of analyses (pages 108 to 112) the fuel ratio of the coal of the Merrimac bed in the Brushy Mountain coal field of Montgomery County and in that part of the Little Walker Mountain field lying east of Empire, ranges from 4.54 to 5.94, with an average of 5.36. The fuel ratio of the Langhorne coal bed in the Empire mine ranges from 6.77 to 7.34, with an average of 7.06. The question then is, why should the coal of the Langhorne bed in the Empire mine have a greater fuel ratio than the coals of this same general belt of outcrop to the east? Is it due to regional metamorphism which has affected only the western part of this field, or is it due to a difference in the vegetation that formed the two beds?

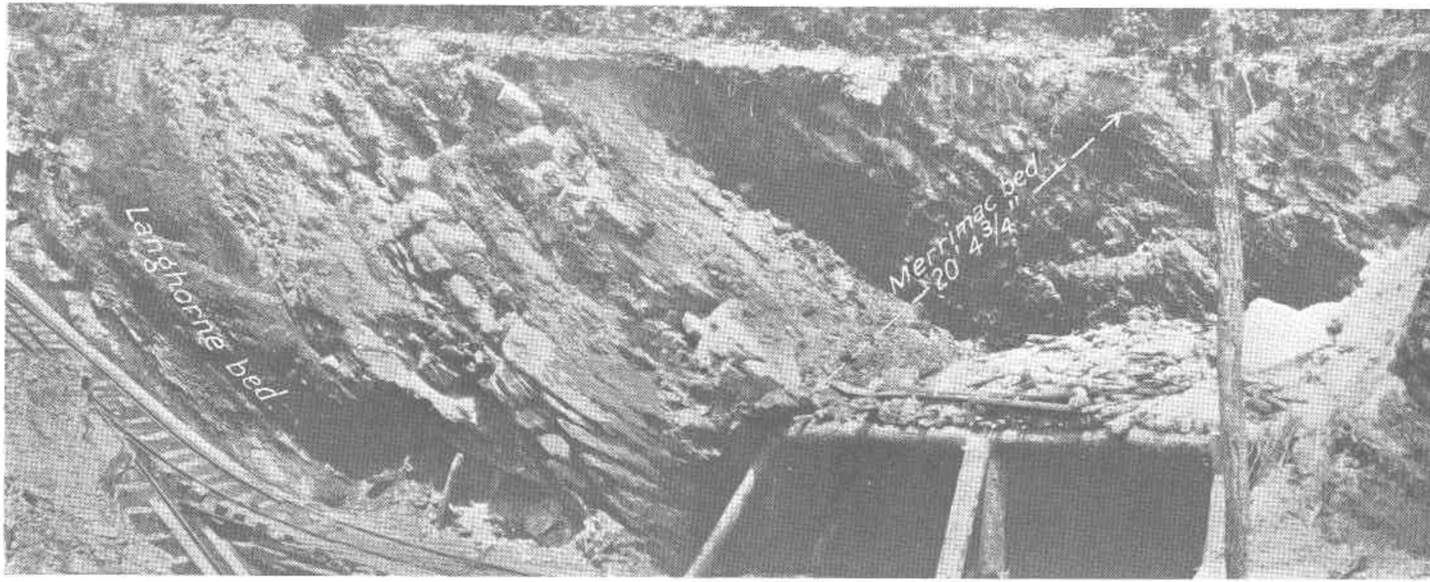
In order to answer this question a sample of coal was obtained from the Merrimac coal bed in the Empire mine (see page 112, and Pl. XVII) and the analysis of this sample gave the surprisingly low fuel ratio of 3.62. As this is even lower than the fuel ratios of samples obtained farther east, it shows clearly that the high rank of the coal of the Langhorne bed in the Empire mine can not be due to regional metamorphism, unless the Merrimac bed in the vicinity of the Empire mine has, in some manner, been protected from the metamorphosing action of the stresses in the rocks that has affected the coal of the Langhorne bed. This hardly seems possible in view of the fact that the two coal beds are separated by only 14 feet of rocky strata and neither bed is greatly disturbed in this mine. The proposition that the difference in fuel ratios may be due to difference in the composition of the original vegetal material composing the two beds will also lead us into difficulties as insurmountable as that of regional metamorphism, for the reason that both of these coal beds have distinctive characteristics that are evidently due to such an original difference in the materials composing them, but these characteristics hold throughout the two counties here being considered and in all other localities the chemical composition of the coal from the two beds is practically identical. Why then should there be a difference in the composition of the beds in the Empire mine, which does not show at any other place?

Analyses 30693 and 93539 show that the coal of the Langhorne bed in the Price Mountain field and also in the Brushy Mountain field of Montgomery County is essentially the same as the coal of the Merrimac coal bed in the same localities; therefore it is evident that the two coal beds have been similarly affected by all of the processes that tend to change the character of the coal and also that there is no essential difference in the composition of the beds, so far as it affects their chemical constituents. We are therefore forced to the conclusion that the dif-



Langhorne and Merrimac coal beds, exposed at the mouth of Slope No. 2, Empire mine.

Photograph by Marius R. Campbell.



Langhorne and Merrimac coal beds, exposed at the mouth of Slope No. 2, Empire mine.

Photograph by Marius R. Campbell.

ferences observed in the Empire mine are really due to regional metamorphism, but that there has been some modifying influence which has permitted the forces to act upon the Langhorne bed but which has pretected the Merrimac bed and prevented its coal from being altered to a high rank.

When the two coal beds in the Empire mine are studied it will be at once apparent that they have very different surroundings. The Merrimac bed is composed of very soft, friable coal and it is not closely confined by hard and resistant beds, except possibly on the lower side, whereas the Langhorne coal bed is composed of very hard and resistant coal and it is held between walls that are remarkable for their hardness and ability to resist earth movements of any kind. It seems, therefore, that the explanation of the present difference of the coal of the two beds is to be found in their ability to resist thrusts, or in other words, as to whether or not they are competent or incompetent beds. The Merrimac bed is typically an incompetent stratum, whereas the Langhorne bed, together with its very resistant roof and floor, forms a very remarkable group of competent beds, able to withstand or transmit almost any thrust that may have been directed toward it. Under severe pressure the Merrimac coal bed has been crushed and deformed, but the Langhorne bed has not suffered either of these results and consequently it has been affected more by internal stresses than would be possible in an incompetent stratum. As a result the coal in it has been altered to a much greater extent than has that of the Merrimac bed and consequently has lost more of its volatile constituents with a corresponding increase in its content of fixed carbon, and an increase in rank.

If any one doubts the reasonableness of this explanation of the variable effects of pressure on coal he has but to study the conditions in Pennsylvania and West Virginia to be satisfied that similar effects have been produced there on a large scale. Thus a map of the coal fields of the United States (see map accompanying U. S. Geological Survey Professional Paper 100 A) shows that the Broad Top field of Pennsylvania and the Meadow Branch field of West Virginia lie as far east of the Allegheny Front as the anthracite fields of Pennsylvania, but the coals of these isolated fields have not been metamorphosed to the extent that the coal of the anthracite fields has been metamorphosed. The coal of the Broad Top field is only a semibituminous coal and the coal of the Meadow Branch field is a semianthracite. There is no question in the minds of geologists that the alteration of the coals has been due to stresses in the rocks that in most cases found expression in great rock folds in places thousands of feet in their original magnitude. Were the stresses different in the fields here being considered? An examination of the reports of the Second Geological Survey of Pennsylvania shows clearly that the rocks of the anthracite fields are folded, but that the folds have not very great magnitude. On the other hand, it is a well-known fact that the rocks in the southern part of Pennsylvania and the eastern part of West Virginia have been thrown into great folds whose magnitude is many times that of the folds in the anthracite fields of Pennsylvania. The formation of great folds naturally required greater force than the production of small folds, but the mere fact that the folds are large means that they are supported by competent strata which were subjected to very severe stresses and the incompetent strata were relatively free from stresses. As the coal-bearing rocks in the southern fields are not specially resistant they were not competent to transmit thrusts and so they were free from great pressure and the coal beds contained in them are not altered to the anthracite stage. On the other hand, the rocks containing the coal beds of the anthracite fields of Pennsylvania include many beds of dense conglomerate that are very resistant and consequently the coal-bearing formations were the ones that withstood the great stresses that were forced upon them from the southeast and, though no great folds were formed, the rocks were altered very materially and the coals were changed from bituminous to anthracite.

Pulaski coal field.

GENERAL DESCRIPTION.

That part of the coal-bearing territory of Pulaski County here designated the Pulaski coal field has the form of a reclining letter V with its apex in the valley of Peak Creek about 4 miles above Pulaski, and the limbs stretching northeastward and eastward for a distance of about 3 miles. The northern termination of the field is arbitrarily assumed to be at the point where the Merrimac coal bed swings sharply around the anticlinal point of Tract Mountain, and the eastern termination, where the outcrop of the coal bed is cut off by the Pulaski fault and the coal bed concealed by the overthrust mass of Shenandoah limestone.

STRUCTURAL RELATIONS.

The reason for the irregular outline of this field is that the two legs of the V are formed of coal-bearing rocks on the opposite limbs of a syncline that pitches rather sharply toward the northeast, thus bringing in the higher formation on the axis of the trough or syncline. As the axis of this syncline corresponds closely with the valley of Peak Creek it will here be called the Peak Creek syncline. It is true that Peak Creek occupies the syncline for only a few miles, but still the name seems to be appropriate for the syncline for the reason that the part of Peak Creek which coincides with the axis of the syncline is the part best known to the general public, as it is the part followed by the Norfolk and Western Railway.

In a somewhat broader view of the geologic structure of the region west of Pulaski, the syncline just described might be considered as continuous with the pronounced syncline extending eastward from Max Meadows to Gunton Park. Each is bounded on the north by a low ridge called Brushy Mountain and each is limited on the south by Caseknife Ridge, which though somewhat more broken, is composed of the same kind of rocks. It is generally recognized that these two ridges composed of Devono-Carboniferous rocks are the limbs of a rather broad synclinal trough which contains the Peak Creek syncline on the east and the Max Meadows syncline on the west, but when the region is examined more closely it is found that the two synclines just mentioned do not join. The axis of the Peak Creek syncline follows Peak Creek and the railroad rather closely up to the point where the creek enters from the north and beyond that point the axis is north of the railroad, whereas the axis of the Max Meadows syncline after crossing the railroad at Gunton Park entends eastward on the south side of the railroad and consequently the two do not meet and can not be considered as one and the same fold.

Although both the Crockett anticline and the Peak Creek syncline are open folds, involving dips generally less than 50°, it is probable that the rocks composing them are badly crushed and deformed in certain places where the movement was such that it tended to crush the rock rather than to increase the magnitude of the fold. As the coal is the softest member of the formation it seems highly probable that the coal, particularly that in the Merrimac bed, is much crushed and disturbed in certain parts of this field.

The relation of the Shenandoah limestone to the coal-bearing rocks is different in different parts of the field. Around the point of the Crockett anticline the limestone rests on the Maccrady shale and apparently nearly or quite the full thickness of that shale is present. In the Peak Creek syncline the limestone has been thrust to the southwest until it rests on the Price formation, having completely overridden the Maccrady shale. In the town of Pulaski the fault cuts closer and closer to the coal until in the eastern part of the town it crosses the outcrop and in a short distance conceals the remainder of the Price formation, including the Ingles conglomerate member.

DESCRIPTION OF MINES AND PROSPECTS.

But little mining has been done in the Pulaski coal field and the coal beds have not been sufficiently well prospected to afford much information regarding their condition and the quality of the coal. At the present time only one mine—the mine of the High Carbon Coal Co.[1] in the outskirts of Pulaski—is producing coal in a commercial way, and even at this mine the operation is on a small scale and the product is distributed by team or truck to residents of the town of Pulaski. A few of the more important prospects will now be described.

At the north end of the field the first prospect (loc. 49), as far as the writers are aware, is the one just above the Empire tramroad at the extreme eastern end of Tract Mountain. Recent prospecting has been done here but the coal bed is not well exposed. It is, however, reported (see page 212) that the coals have been exposed here by a shaft which shows that the Merrimac bed has a thickness of 14 feet 8 inches and the Langhorne bed a thickness of 6 feet 1 inch. The authors, as stated on a previous page, are inclined to believe that the two coal beds reported here do not include the Langhorne bed, but are merely two benches of the Merrimac bed. The coal bed at this location must, however, be so sharply bent around the point of the anticline that in all probability it has been squeezed and may have lost all semblance to the undisturbed bed. Such a location is, for this reason, a very poor one in which to develop a mine and it is not surprising that no further work was done here.

South of location 49 there has apparently been very little done in the way of prospecting the coal bed. The most important opening is on the farm of Mr. Hurd, where a mine (loc. 50) was in operation many years ago to supply the local demand for coal, but the demand seemingly did not warrant the continued operation of the mine and it was allowed to cave, completely concealing the coal bed. According to reports this mine was opened in a body of coal about 12 feet thick which

[1] Since the statement regarding this mine was written the authors have been informed that the property has changed hands and the mine has been abandoned.

evidently represents the whole or a part of the Merrimac coal bed. There was considerable fine coal on the mine dump, but it had been so long exposed to the weather that it was not considered as suitable for analysis. The coal bed strikes north-south and dips 17° east.

The mine was opened as a drift on the edge of a small creek flowing into Tract Fork of Peak Creek. Recently the creek has been cutting against the bluff in which the mine was opened and a slide has exposed most of the rocks above the coal bed for a distance of 50 or 60 feet. The exposure is too steep to permit of a detailed examination, but a casual inspection from below showed that the rock is mostly dark shale, but interbedded here and there with small coal beds or benches. These upper beds or benches may represent the expanded upper part of the Merrimac bed, for by comparison of the sections of this bed on New River with that exposed at the Empire mine, at Gunton Park, and on Miller Creek in the Max Meadows field, it seems probable that the Merrimac bed does thicken and break up into two beds in a westerly direction from the type locality. The evidence for and against this assumed correlation will be more fully considered in the description of the Max Meadows coal field.

Location 50 is interesting as it affords at least two species of beautifully preserved fossil ferns in the shale overlying the coal. No especial effort was made to obtain this material and it is quite possible that a more extended search would reveal the presence of other species and possibly of other genera.

The outcrop of either a very large coal bed much broken by shale and bone partings, or several beds separated by shale and bone was seen in the road located on the point of high land between Peak Creek and Tract Fork, but no prospect was found in this vicinity which would throw light on the character of the coal bed, except that noted above. From this place westward to the point of the syncline, as outlined by the principal coal bed the coal has been dug at a number of places indicated on the map, Pl. I, by prospect symbols. These prospects are generally caved and give little or no information regarding the coal beds, except to mark the position of their outcrops.

At loc. 51 at the extreme western point of the syncline in the coal bed, there is an old prospect exposing about 6 feet of coal so badly broken by partings as to be practically worthless. Nearby on the flood plain of Peak Creek a shaft was at one time sunk to the coal, but aside from some fragments of coal on the dump, it gave no indication of what was found below. Inquiry in the neighborhood also failed to elicit any information regarding the coal, other than that noted above.

A comparison of this coal bed with the thick sections north of Pulaski makes it seem probable that the coal noted above as showing on Peak Creek is really the upper part of the Merrimac coal bed and that the coal bed reached by a shaft on the floodplain of the creek is the lower bench.

Recently a core drill was put down on the south side of Peak Creek about one mile from loc. 51 in search of the Langhorne coal bed, which it was hoped would be found of workable thickness and containing as good coal as it does in the Empire mine. The hole was started on the outcrop of the Merrimac bed which dips gently to the northeast toward the axis of the Peak Creek syncline. The Merrimac coal bed is reported to be somewhat broken here, but shows about the same thickness that it does at loc. 52, described in the next paragraph. The hole was sunk to a depth of 140 feet, but without finding a trace of a coal bed that could be identified as the Langhorne. The drill was finally stopped when it reached the massive sandstone which is generally recognized as underlying both beds of coal, where both are present, in this general region and which makes such a prominent showing where the railroad has driven a tunnel through it one-half-mile above loc. 51.

From the drill hole just mentioned the outcrop extends nearly due east on the south limb of the syncline to loc. 52 in the outskirts of Pulaski. The outcrop between these two places was not examined in detail, but no prospects were found and none are reported.

At loc. 52 by the side of the road leading from Pulaski across Draper Mountain to Draper Valley is the site of an old coal mine which recently has been rehabilitated by a company bearing the name of the High Carbon Coal Co. At the time this mine was examined by the senior author the slope was down only about 240 feet on a dip of 40°, having been carried only a short distance below the old workings. The coal in this slope shows the effect of weathering due to the proximity of the old workings, but despite this effect, a sample was cut on the wall of the slope for analysis. The coal here is greatly disturbed, the partings being badly broken and mixed with the coal. The measured section of the coal bed at the place where this sample was cut is as follows:

Section of Merrimac (?) coal bed in mine of the High Carbon Coal Co., loc. 52.

	Ft.	In.
Coal	1	0
Bone		3½
Coal	4	11
Bone		3½
Coal		6
Thickness of bed	7	0
Thickness of coal	6	5

This section is represented graphically on Pl. XX. The analysis of the sample obtained from the three benches of coal represented in this section is given under number 94192 on page 112. It seems probable, in view of the great increase in thickness of the Merrimac coal bed in the northern part of this county, that the section exposed in this mine is only a part of that bed and that the other part will be found above or below the one that is now being mined.

The Merrimac coal bed has also been opened in the southeastern part of the town of Pulaski (loc. 53) near the point where it is concealed by the Shenandoah limestone on the north side of the Pulaski fault. A shaft has been sunk here and coal taken out for local use, but as the coal bed stands nearly vertical, it is probable that the coal is more badly crushed than it is at loc. 52. No measurements were made here, but the coal bed appears to be more than 7 feet thick.

QUALITY OF THE COAL.

It is manifestly difficult, if not impossible, for the writers to form any opinion regarding the quality of the coal in the Pulaski field, because they found only one mine opened in such a way that fairly fresh coal could be obtained. As stated on a previous page this sample was obtained in the mine (loc. 52) of the High Carbon Coal Co., at Pulaski, and its analysis is given under No. 94192 on page 112. As this analysis shows a fuel ratio of 7.82, we must conclude that, as far as rank is concerned, the coal is much the same as the coal of Price Mountain in Montgomery County and of Empire in Pulaski County. In other words, the coal at Pulaski contains a relatively large percentage of fixed carbon and a small percentage of volatile matter. This would place the coal near the upper limit of the semianthracite rank. In this respect it differs greatly from the coal of the Merrimac bed at Empire for this coal, as shown by analysis No. A2634, page 112, has a fuel ratio of only

3.62 and therefore, on a strict basis of classification, should not be considered as a semianthracite at all, but a semibituminous coal with the same rank as Pocahontas and New River coals of the bituminous fields to the northwest.

For practical purposes, however, the percentage of ash in these coals is of more importance than the percentage of fixed carbon, for the amount of ash in a coal affects the pocketbook of the consumer much more seriously than does the percentage of fixed carbon or of volatile matter. The percentage of ash in this coal is rather large, running more than 20 per cent. The presence of a large percentage of ash in analysis 94192, loc. 52; analysis No. A2634, loc. 44; analysis 94054 and 95461, loc. 59 seems to indicate that the Merrimac coal bed or its equivalent in Wythe County and the western part of Pulaski County contains more ash than it does in Montgomery County and the eastern part of Pulaski County.

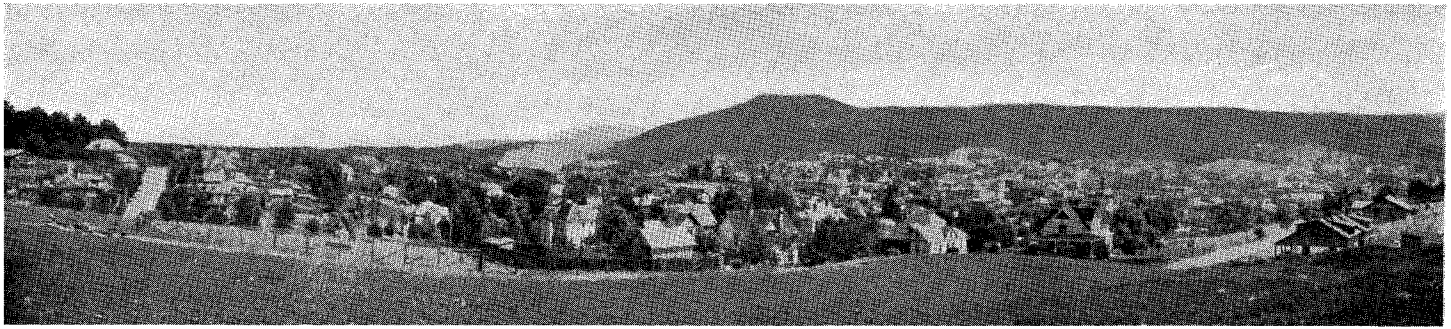
The higher percentage of ash in the Pulaski field does not necessarily mean that the coal can not compete with the coal mined to the east, but it does mean that operators in the Pulaski field must be prepared to make even more vigorous efforts than the operators farther east to remove a large part of this excessive ash if they wish to compete with the product of nearby mines or with mines in the so-called "smokeless" coal fields of the bituminous region to the northwest.

As the mine at Pulaski is located in the extreme southern part of the Pulaski field, and as the coal bed here is more strongly tilted than it is in other parts of the field, it is reasonable to assume that the coal at Pulaski has the highest rank in the field, but no generalizations can be made regarding the relative amounts of ash in different parts of the field, except to say that it seems highly probable that all of the coal of the Merrimac bed in this field will be found to contain not less than 20 per cent of ash.

FIELDS OF WYTHE COUNTY.

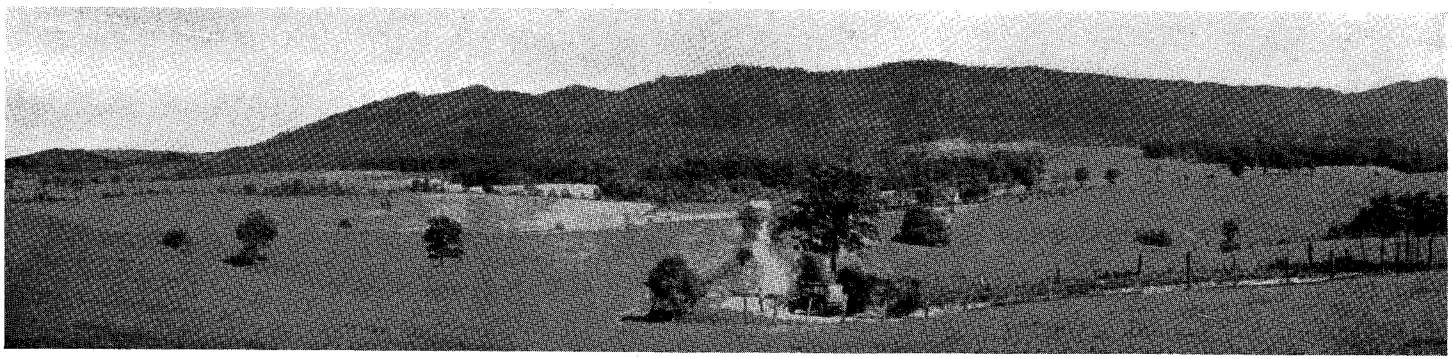
General description.

Wythe County is essentially a valley county, for most of its surface is made up of the Shenandoah limestone. Aside from iron and zinc mining in the southern part, the chief industries in the county are agriculture, fruit growing, and stock raising. The population of the county, according to the census of 1920, is 20,217. The largest town is Wytheville which, together with its surrounding district, has a population of 4,973.



(A) City of Pulaski and Draper Mountain, showing Peak Creek Knob at the east end of the mountain.

Photograph by Marius R. Campbell.

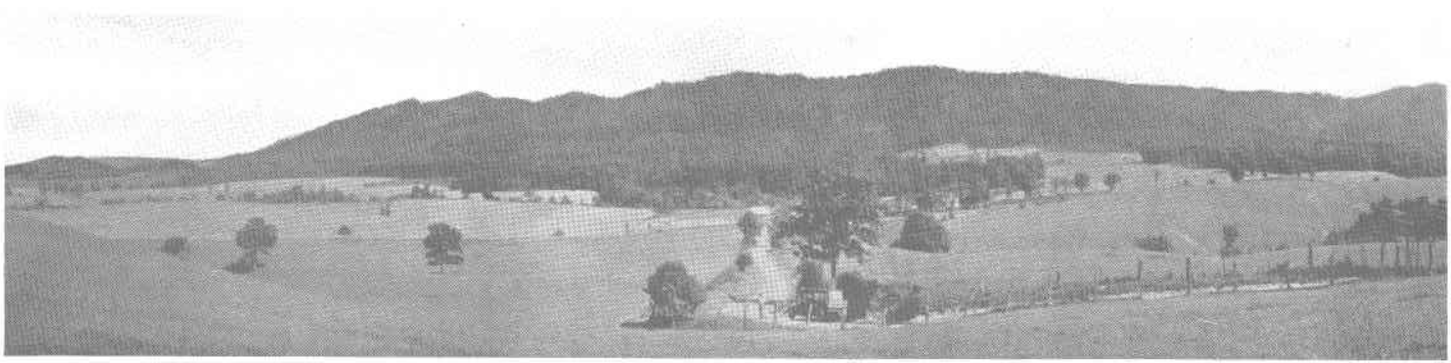


(B) West end of Draper Mountain showing the Locust Hill iron mine at the extreme left.

Photograph by Marius R. Campbell.

(A) City of Pulaski and Draper Mountain, showing Peak Creek Knob at the east end of the mountain.

Photograph by Marius R. Campbell.



(B) West end of Draper Mountain showing the Locust Hill iron mine at the extreme left.

Photograph by Marius R. Campbell.

The coal fields of Wythe County are two in number, one lying in an isolated syncline just north of Max Meadows and extending from Gunton Park on the east to Cove Creek on the west, and the other occupying a narrow zone on the south side of Little Walker and Brushy mountains from a point nearly due north of Queens Knob to the west line of the county. The former, because of its proximity to Max Meadows and because that town is the logical shipping point for most of the field, will here be called the Max Meadows coal field; and the latter, because it lies almost entirely in the drainage basin of Reed Creek, will be called the Reed Creek coal field.

Surface features.

The surface features of Wythe County in and adjacent to the coal fields mentioned above are varied, but, for the most part, they consist of the broad limestone floor of the Valley of Virginia, as shown in Pl. XXI. The remainder is made up of ridges of the Clinch and associated sandstones, and of the upper Devonian and lower Carboniferous sandstones, and of lower broken country made of the lower Devonian shale.

The most prominent feature connected with the coal fields is Little Walker Mountain which is the westward extension of the ridge bearing the same name in Pulaski County, and its westward continuation—Brushy Mountain—in the western part of the county and in the adjacent part of Smyth County. The coal-bearing formation lies on the south side of this ridge. A higher, but much shorter ridge—Cove Mountain—extends eastward from Queens Knob (Pl. XXI A) to the headwaters of Peak Creek, near the east line of the county. South of the east end of the Max Meadows coal field lies the rather high ridge of Draper Mountain which terminates at the west in Hamilton Knob, one of the conspicuous landmarks of this region and at the east in an equally conspicuous knob (see Pl. XIX A) known as Peak Creek Knob. A somewhat lower ridge, known as Brushy Mountain, lies on the north side of the Max Meadows coal field, and extends westward across the boundary line from Pulaski County into Wythe County, terminating in a prominent knob on Cove Creek northeast of Wytheville. West of Wytheville is a low narrow ridge which roughly parallels the main road to Marion and Bristol for a distance of 9 miles, but this ridge lies entirely outside of the coal fields and its only bearing on the northernmost, or Reed Creek field, is in its effect upon the building of branches from the main line of the Norfolk and Western Railway to this coal field.

The country about Wytheville, with the exception of the low ridge just mentioned, consists of a broad rolling plain underlain by the Shenandoah limestone. The aspect of this plain in the town and to the north and northwest is shown in Pl. XXI. This upland plain extends eastward and southeastward to the south of Hamilton Knob and Draper Mountain, but a small projecting prong of the limestone carries the plain through Max Meadows and on to Gunton Park where it terminates in a narrow point in the midst of a rather rugged landscape, carved in the upper Devonian rocks. This rolling plain stands at an elevation of about 2,400 feet above sea level and is probably the westward extension of the Blacksburg peneplain which, in the type locality has an elevation of about 2,200 feet above sea level. In this upland plain New River has cut a valley, but little wider than the stream itself, to a depth of 500 feet. Its affluent, Reed Creek, which drains most of Wythe County, has cut at its mouth a valley of equal depth, but its grade is rather steep and where it crosses the main highway west of Wytheville the creek is flowing only about 250 feet below the general upland level, and at the point where it cuts through Brushy Mountain it is nearly at the level of the upland plain.

Transportation facilities.

The only railroad crossing that portion of Wythe County in which the coal fields are situated is the Bristol branch of the Norfolk and Western Railway which follows up Peak Creek from the town of Pulaski to the great bend in that stream where it breaks through Brushy Mountain from the north. From this point on to the eastern line of Wythe County the railroad follows a small western affluent of Peak Creek to its head at Gunton Park or Clarks Summit, as it was formerly called. After crossing the low dividing ridge at Gunton Park it descends to Beaverdam Creek which it follows to the town of Max Meadows.

West of Max Meadows the railroad occupies the valley of Reed Creek to Wytheville, gradually climbing, however, to the surface of the upland plain which it reaches just beyond that town. From this point westward through Rural Retreat the railroad generally follows a shallow valley, less than 100 feet below the highest points on the surface of the valley upland. At Rural Retreat the road crosses the divide separating the drainage basin of New River on the east from that of Holston River on the west. It then descends the valley of the last named stream westward through Groseclose, Atkins, Marion, and other towns on its way to Bristol on the south line of the State.

From the main line of the railroad, branch lines could easily be built to almost any point in the Max Meadows coal field, and somewhat more extended lines could reach any part of the Reed Creek field.

Coal beds.

The coal beds of the Wythe County coal fields are so poorly exposed that it is difficult, if not impossible, to make definite correlations with the coal beds of Montgomery and Pulaski counties. In a general way, the beds that have been prospected in Wythe County occur near the middle of the Price formation at approximately the same position as that of the Merrimac and Langhorne beds farther east, but instead of there being only two coal beds, as there are in Montgomery and eastern Pulaski counties, there appear to be at least three beds, two of which are generally of workable proportions, and the other one probably of workable thickness in parts of the field. In addition to there being a greater number of beds here than there are in the counties to the east, one of the beds in this county seems to be much thicker than any bed that has been mined in either Montgomery or Pulaski counties.

More information is available regarding the coal beds of the Max Meadows field than there is regarding the coal beds of the Reed Creek field, because actual mining operations are in progress there and the coal beds are better exposed. At the east end of the Max Meadows field two coal beds, separated by only 12 feet of sandstone, are shown in mine workings, and from the fact that the uppermost one of these beds carries "sand coal" similar to the "sand coal" of the Merrimac bed in Montgomery County, it is suggested that these two beds represent a greatly expanded development of the Merrimac bed which takes place in a westerly direction from the type locality. Both of these beds are of workable thickness in the vicinity of Gunton Park, and the lowermost one of the two is apparently the thickest coal bed that is known in this general region. Beneath this very thick bed another bed is reported to be present, with a thickness ranging from 3 to 5 feet which seemingly might with propriety be correlated with the Langhorne bed of Pulaski County. A later report, however, indicates that the driving of a rock tunnel in the mine at loc. 59 for 200 feet in a horizontal direction northward from bed No. 1 failed to disclose the presence of the third bed of coal.

At the west end of the Max Meadows field these beds have been prospected, but the exposures are so poor and the beds are so badly squeezed that one can not form a very definite idea regarding their thickness or the arrangements of the bony partings in them. If the uppermost bed here is the same as the uppermost bed at the east end of the field, it apparently deteriorates in a westerly direction, because it does not appear to be of workable thickness and composition at the west end of the field, although it is so reported by G. L. Armbrister and J. B. Allison of Max Meadows, who have conducted most of the exploratory work in this field. The middle bed is apparently somewhat thinner at the west end than it is at the east end of the field, but the general appearance and composition of the bed is similar in the two localities. The lower bed, where it has been prospected at the west end of the field, is so variable in thickness, due to the movement within the bed when the basin was produced, that it is difficult to determine its true character and thickness, but in a general way it does not appear to be unlike the lowermost bed that is reported at Gunton Park and also the Langhorne bed, as the latter is developed in Pulaski County.

Although this correlation of the coal beds of the Max Meadows field with those of Montgomery and Pulaski counties can not be definitely established, it is here accepted in a provisional manner as the best correlation that can be made at the present time, or probably can be made in the future, until mining and prospecting have been carried on in a much more elaborate scale than they have been in the past. At the present time these beds are known as No. 1, No. 2, and No. 3, the uppermost being called No. 1. As this system of nomenclature is not satisfactory, it seems desirable to assume definite correlation with the coal beds farther east, and consequently, to use the names there in vogue, or to apply new names in the Max Meadows field where the beds seem to be different from those recognized farther east. Thus, as stated previously, coal beds 1 and 2 in the Max Meadows field are regarded as probably equivalent to the Merrimac bed of Montgomery County, consequently that name can not be applied here and new names will have to be given. As the uppermost bed was originally opened in the vicinity of Gunton Park by W. B. Gunton, it will here be called the Gunton coal bed, and similarly the middle bed or No. 2 will be called Clark, because of its great thickness in the vicinity of Gunton Park, which formerly was known as Clarks Summit. As the lowest bed in the field is supposed to be the same as the Langhorne bed of Pulaski County, that name will be retained. If future work should show that it is not equivalent to the Langhorne bed of Pulaski County, then a new name should be given to this bed in the Max Meadows field.

Other coal beds above and below the group just described show in many places in this county, but they appear to be too thin to be worked on a commercial scale, and consequently they will not be given names.

Max Meadows coal field.

GENERAL DESCRIPTION.

The Max Meadows coal field is different from the other coal fields of this region in that it consists of a syncline, separate and distinct from the other coal fields of the region. The length of this field is about 6¼ miles and its width about 1¼ miles. It extends from Gunton Park on the east to Cove Creek on the west and lies about 1 mile north of the village of Max Meadows on the Norfolk and Western Railway.

The field is limited on the north by Brushy Mountain, a low ridge that is really the westward extension of Tract Mountain of Pulaski County. This ridge, though lower, and therefore less conspicuous than Little Walker or Brushy Mountain east of New River, is still a rather pronounced barrier to travel in a north-south direction. In the interval between the east end of Tract Mountain and Cove Creek this ridge is notched in only two places: one by the main Peak Creek where it comes in from the north, and the other north of Max Meadows where Miller Creek has made a passageway through it. The former is entirely east of the Max Meadows coal field and the latter is near its western end.

The coal field is bounded on the south by a rather rugged upland carved largely from the same kind of rocks as those making Brushy Mountain on the north, but south of the Max Meadows field they do not form so definite a ridge as they do on the north. That part of the field underlain by coal beds is generally a rolling shale upland, or a similar upland carved on the Shenandoah limestone.

No streams of any consequence cross or are formed in this coal field. The largest stream is Miller Creek, but in seasons of drought there is scarcely more than a trickle of water running in its channel. Reed Creek at Max Meadows is the largest stream in or near the coal field. This is quite a large creek, draining a basin underlain by limestone and as a consequence it is fed by a great number of strong springs whose flow fluctuates little from month to month or from season to season. Reed Creek, accordingly, carries a fair volume of water which would be available for washing coal provided a washery were erected on the railroad at or near Max Meadows.

STRUCTURAL RELATIONS.

A knowledge of the geologic structure of this field is all-important to any one who is engaged in, or contemplates being engaged in, mining coal, for upon the geologic structure depends directly the depth below the surface, the attitude, and the areal extent of the coal beds; and a knowledge of the structure of other coal fields of this region will be of little or no assistance in understanding this field, for the structure here is different from that of any other field in this part of the Valley region.

On the north or principal line of outcrop of the coal beds, shown on Pl 1, the dip ranges from 15° to 25° to the south; consequently, the structure must be that of either an open syncline or a shingle-block, dipping to the south. The structure of the field is best interpreted from the section exposed on Miller Creek, about a mile north of Max Meadows.

If one passes down Miller Creek from the longitudinal valley in Devonian shale on the north side of Brushy Mountain, he passes through successively higher and higher strata from the black shale of the Devonian up through reddish sandstones to the Ingles conglomerate which is encountered as a ledge or as blocks scattered on the surface a little south of the main crest of Brushy Mountain. Still farther south one finds an old prospect (loc. 61) on a coal bed dipping S. 20°, and at or near the forks of the creek he encounters for the first time the Maccrady red shale. It is evident that one has been constantly ascending in the series of rocks, and that up to this point the succession is normal and the dip fairly constant. The Maccrady shale may be seen along the creek for a distance of about 1,000 feet and then is succeeded on the south by a coal-bearing formation which can be no other than the Price formation, dipping to the south at an angle of about 35°.

When one passes in ascending order through the outcrop of the Price formation, across a band of the Maccrady shale, and then into the Price formation again, one either passes across the axis of a syncline or across a fault. If the structure is synclinal, the south limb of the fold must be overturned for the dips are to the south in both limbs; if, however, the structure is a shingle-block then one in passing down the stream would cross the Price formation in ascending order in both exposures.

With these facts in mind it is easy to determine the true structure by continuing the section across the outcrop of the second band of the Price formation. When this is done one finds the coal beds (loc. 63) near the middle of the formation and fragments of the Ingles conglomerate almost at the lower end of the gorge and almost immediately below are traces of black shale of Devonian age. From this it is apparent, as shown in section I-I′ on Pl. I, that all of the rocks below the outcrop of the Maccrady shale are not in their normal attitude, but are turned upside down with Devonian rocks overlying the Carboniferous. This clearly indicates that the true structure here is that of a syncline with the south limb overturned to the north so that all of the rocks dip in a southerly direction and the Devonian shale so crushed that the black shale normally near its base is here in contact with the Carboniferous. This interpretation is corroborated by the finding at the east end of the fold of similar conditions.

The section at the east end of the field is particularly interesting. If one crosses the fold directly south from the mine of the Pulaski Anthracite Co. (loc. 59) he passes through the upper part of the Price formation which dips to the south at angles ranging from 26° to 15°, the latter dip prevailing near the axis of the fold. At the top of the ridge is a band of the red Maccrady shale dipping to the south but changing in dip from 10° on the north side of the band to 40° on the south side. Such a change of angle of dip suggests a change in structure, which is confirmed by the finding to the south of the red shale, rocks belonging to the Price formation, with a coal bed showing in the railroad cut (loc. 57) a short distance west of the station of Gunton Park. As the rocks in the cut dip about 50° to the south, it is evident that they form a part of the overturned limb of the syncline as shown in section H-H′, Pl. I. The writer has given the above description of the structure in considerable detail for the reason that a proper understanding of this structure, as shown on Miller Creek and at Gunton Park, makes the interpretation of the structure in other parts of this coal field a comparatively easy matter.

In each section that has been described it is apparent that the south limb of the syncline has been overturned and that the rocks composing it have been badly crushed and deformed. As the sections H-H′ and I-I′, Pl. I, are located at nearly the extreme ends of the syncline it is safe to conclude that the south limb of the fold has been overturned throughout the entire length of the field, despite the fact that a large part is covered by the overthrust mass of Shenandoah limestone. It is also obvious that this sheet of limestone was thrust into its present position after the syncline was formed, for the limestone rests indifferently upon both the normal and the overturned limbs, but it seems probable that it has experienced another epoch of movement which has accentuated the dip of the fault plane and caused the edges of the limestone to rest with almost vertical contact against the coal-bearing rocks. This is well shown in the railroad cut near Gunton Park.

The presence of the limestone makes it extremely difficult to locate the position of the synclinal axis between the two sections described above and also to determine the extent of the overturned limb. Thus the upturned coal bed showing in the railroad cut near Gunton Park (loc. 57) is taken to mean that the great group of workable coal beds is here sharply upturned. If this assumption is correct, then the lower part of the Price formation, 1,000 feet thick, must fill the space under the limestone between the railroad and the boundary line of the Price formation to the south, as shown in Pl. I. As this distance is about 2,800 feet, it is difficult to understand how it can be filled by a formation only 1,000 feet thick.

A similar condition prevails a mile to the west, where the south limb of the syncline swings even farther to the south, indicating either a fold of very irregular outline or the presence of a secondary syncline lying on the south side of, but probably connected with, the main fold. The writer endeavored to find some evidence by which this point could be settled, but at all critical places either the limestone conceals the coal-bearing rocks or the latter fail to show at the surface. The writer is in doubt as to which of these assumptions to accept, but as the hypothesis that there is a subordinate fold on the south most easily explains the facts found here, he has accepted it and the cross sections on Pl. 1 are drawn in accordance with this idea. It is to be hoped that deep drilling will soon be done in this debatable territory to determine whether or not the group of coal beds is present and, if so, at what depth.

West of Miller Creek the overturned limb of the syncline is plainly visible in contact with the overthrust Shenandoah limestone and a little west of loc. 62 the group of workable coal beds is engulfed in this overturned and crushed limb of the fold. The overturned limb can be traced as far as Cove Creek where the syncline, as far as it affects the Carboniferous rocks, comes to an end.

DESCRIPTION OF COAL MINES AND PROSPECTS.

The coal beds of the Max Meadows field are not at all adequately prospected and consequently any statement regarding their correlation, continuity, character, and the quality of the coal can be made only in a tentative manner, which doubtless will be changed to a greater or lesser extent when mines are in active operation in various parts of the field and core-drilling has been done in the deeper parts of the syncline, especially in that part covered and concealed by the Shenandoah limestone.

Although the presence of coal in the rocks of this trough has been recognized for a great many years, little has been done in the way of systematic prospecting and still less in the development of mines. This apathy on the subject of the development of the natural resources of the region has been due to many conditions, chief of which has doubtless been the inability in adjacent fields to make mining yield a fair return on the money invested, to lack of local capital to develop mines, to lack of information regarding the distribution and attitude or structure of the coal-bearing rocks, and to ignorance about the extent of the field and its relation to fields in adjacent districts.

Several years ago Mr. W. B. Gunton became greatly impressed with the showing of coal at what was then called Clarks Summit, the point on the railroad where it crosses the low divide between Peak Creek on the east and Beaverdam Creek on the west. Mr. Gunton opened a thick but quite impure bed of coal by the side of the railroad at loc. 56. This is now generally known in the field as coal bed No. 1 because it is the uppermost workable bed in this part of the field, but the writers here propose and shall use the name Gunton for this bed in honor of the man who first developed it. The coal bed in the opening at loc. 56 was sampled by Campbell and Howell in 1918 and the section of the coal bed measured at the point of sampling, which was in a room on the south side of the slope and 250 feet from the mouth of the mine, is as follows:

Section of the Gunton coal bed at loc. 56.

		Ft.	In.
Coal and bone		2	2
Coal	a		5½
Shale			3
Coal	a		5½
Shale			1
Coal	a		6
Bone			2
Coal	a	1	4
Bone			0½
Coal	a	1	6¼
Thickness of bed		6	11¾
Thickness of coal		4	3¼

This section is represented graphically on Pl. XX. The analysis of the sample obtained from the benches of coal marked *a* is shown under number 30696 on page 113. The coal bed at loc. 56 dips west about 20°, showing that this location is at the eastern end of the synclinal trough. Considerable desultory prospecting has been done since the prospect described above was opened, but it was not systematically planned and carried out, and consequently has yielded little real information regarding the number and thickness of the coal beds. The writers are in considerable doubt about the correct location of this old prospect at loc. 56. On the map, Pl. I, it is located with reference to the railroad, but no data are at hand to show where the county line crosses the railroad. As shown on the map, loc. 56 is in Pulaski County, but it is possible that the county line crosses east of this point and if so it would be in Wythe County. As in this respect the map is not accurate and as the larger part of the Max Meadows field is in Wythe County, it has been assumed that all of the coal shown on Pl. I is in that county.

Mr. Gunton was very optimistic regarding the value of the coal in the Max Meadows field, but he lacked the capital necessary for its successful development, and he did not seem to be able to enthuse others to the point of investing in its exploitation. In the desultory prospecting which he carried on he found a large coal bed below No. 1, but he was unable to open it up in such a manner that it would show its full thickness or the quality of the coal. Unfortunately, he did not live to see the two beds adequately opened and tested in a commercial way.

In 1923 a mine was opened by the Pulaski Smokeless Coal Co. on the north rim of the trough at loc. 59 on what is supposed to be the Gunton coal bed. This mine consists of a slope some 400 feet in length, driven down the coal bed on a dip of about 26°. From the foot of the slope lateral entries have been driven in both directions a short distance. Two sections were measured in this mine in 1923 as follows:

Sections of the Gunton coal bed in the mine at loc. 59.

	Section A.		Section B.	
	Ft.	In.	Ft.	In.
Bone and coal			2	0
Coal	3	8½	1	11
Bone		1		3½
Coal		6	1	1
Bone		3½		2½
Coal	1	8½	2	2½
Thickness of bed	6	3½	7	8½
Thickness of coal	5	11	5	2½
Analysis numbers	93937		93938	

This section is shown graphically on Pl. XX. Section A was measured at the face of 3rd west entry, 70 feet from the slope and the analysis of the sample obtained from the three benches of coal is given under number 93937 on page 113. Section B was measured at the face of 3rd east entry, 850 feet from the slope and the analysis of the sample obtained from the three benches of coal is given on page 113 under number 93938.

The sections given above compare favorably in general thickness and in the arrangement of the partings with the Gunton bed at loc. 56. They also resemble the uppermost bench of the Merrimac coal bed in the section at Slope No. 2 (loc. 44) of the Empire mine and the section of the same bench in the drill-hole sunk nearby. On account of this similarity of section the writers feel that the probability of the correlation being correct is so strong that they have accepted it with but little reservation.

As the desultory prospecting noted previously had developed the presence of a thick coal bed below the Gunton bed a rock tunnel was driven in the mine at loc. 59 so as to cut the bed and determine its thickness and quality. After piercing 12 feet of solid rock a coal bed was encountered which the writer is calling the Clark bed. The coal in this bed is very much crushed and distorted so that it is practically impossible to determine the bedding or the real top or bottom of the bed. The author measured the bed as best he could and after making due allowance for the dip found that it had a thickness of 25 feet 9 inches and of this great thickness, 16 feet 5 inches is coal. As the tunnel seemed to cut the coal bed in a "roll" or greatly disturbed area it is not likely that the measurement is correct, for in the bed are great wedges of sandstone, one hanging from the roof and another rising from the floor, as though originally they had constituted a parting in the bed but now are offset to the extent of several feet. It is evident, however, that the Clark bed is here a thick bed—possibly the thickest bed in the Valley fields. Future prospecting or core-drilling alone will reveal its true condition.

After the mine was visited by the author it is understood that the rock tunnel was continued to a total distance of 200 feet with the idea of finding just how many coal beds underlie the Gunton bed and what is their thickness. It is reported that no coal was struck below the Clark bed. This does not agree with a number of reports that were heard in the field of a third bed about 4 feet in thickness which it was said had been prospected in the vicinity of the mine. As, however, the tunnel was driven until it encountered the massive sandstone that is usually regarded as underlying this group of coal beds, it must be taken as positive proof that a bed is not present under the Gunton and Clark coal beds. Since this agrees with the evidence recently obtained by the sinking of a core-drill on Peak Creek, 3 miles above Pulaski, as noted on page 220, it will be regarded as positive evidence that the Langhorne coal bed is not present in the southern part of the Pulaski coal field and in the east end of the Max Meadows coal field.

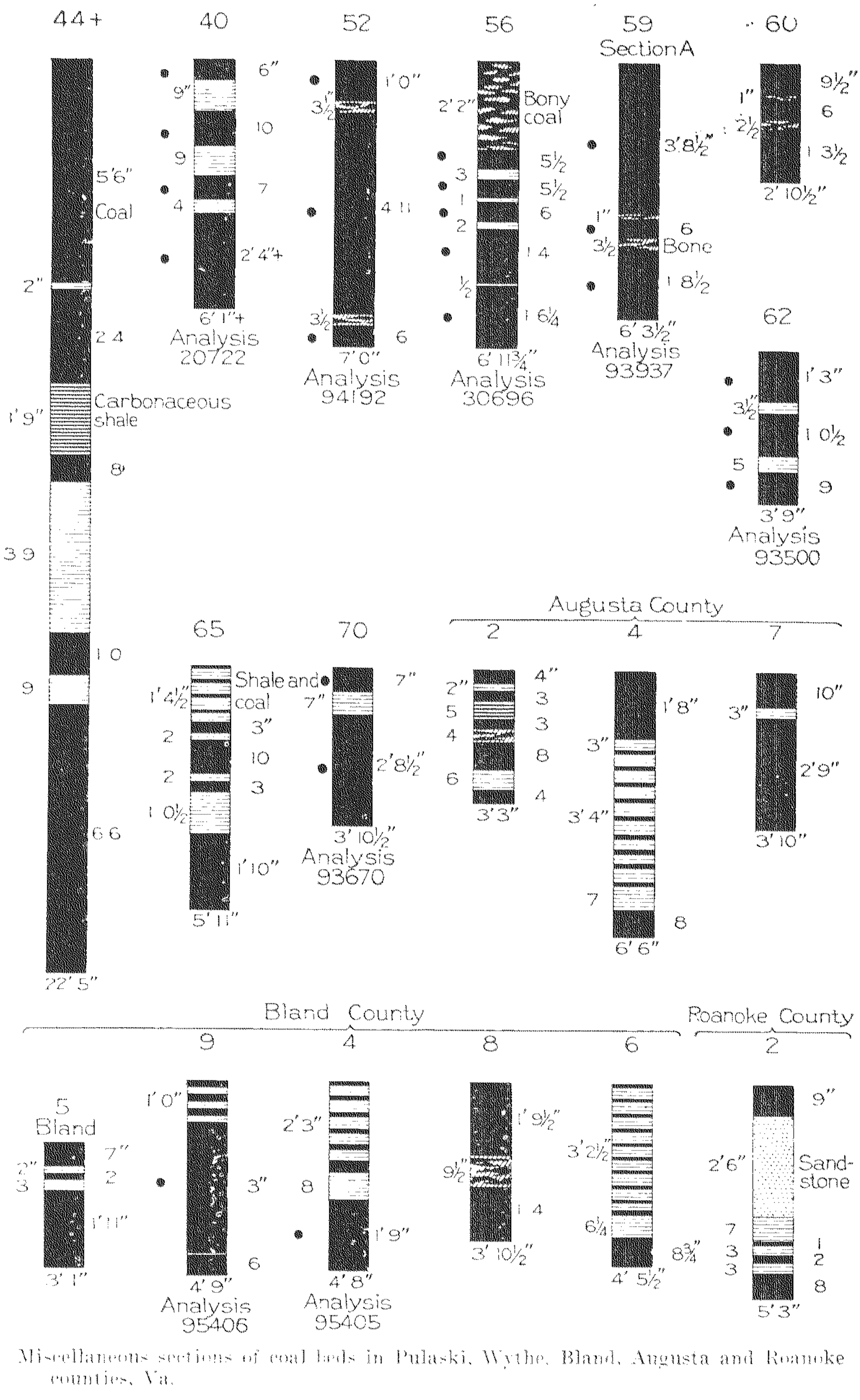
West of the mine at loc. 59 there are several prospects, but those east of Miller Creek show little of interest. The writer visited one at loc. 60 in which the coal bed strikes east-west and dips 9° to the south. The section of this bed, as shown graphically on Pl. 20, is as follows:

Section of coal bed at loc. 60.

	Ft.	In.
Coal		9½
Bone		1
Coal		6
Bone		2½
Coal	1	3½
Thickness of bed	2	10½
Thickness of coal	2	7

Whether or not this bed is the representative of one of the two beds at loc. 59 the writer was unable to determine.

The most extensive prospecting in this belt is that which has been done on Miller Creek at the extreme west end of the syncline. Here, near the head of the west branch of the creek, G. L. Armbrister and J. B. Allison, of Max Meadows, prospected two coal beds that outcrop above water level and sunk a shaft 40 feet in depth to a third bed which does not show at the surface. This prospecting was done from 10 to 40 years ago and as a result the prospects above creek level are badly caved and the shaft has been full of water for the last 10 years. In anticipation of the present examination, the shaft was unwatered and the old prospects were cleaned out to some extent so that the author could measure the beds and secure a sample of coal for analysis, but owing to the deep weathering of the coal exposed above water level and to the bunching of the crushed coal by movement when the trough was formed, he was unable to satisfy himself that his measurements are correct and represent the undisturbed coal bed and that the sample he secured is really typical of the coal of this region.



Miscellaneous sections of coal beds in Pulaski, Wythe, Bland, Augusta and Roanoke counties, Va.

The only place where a satisfactory sample of coal for analysis could be obtained was in the shaft where the protective cover of water which, though it had softened the coal to some extent, had not permitted it to oxidize and so had held it in nearly its original condition. The coal thus protected is at the bottom of the shaft, loc. 62. A section was measured of this coal bed at a point 50 feet from the shaft, at the face of an entry driven to the north. This section, which is represented graphically on Pl. XX, is as follows:

Section of coal bed in shaft at loc. 62.

	Ft.	In.
Coal	1	3
Shale		3½
Coal	1	0½
Shale		5
Coal		9
Thickness of bed	3	9
Thickness of coal	3	0½

The analysis of the sample obtained from the three benches of coal will be found under No. 93500 on page 113. Armbrister and Allison state that when the shaft was first dug an entry was driven 50 feet or more to the west and in this entry the coal bed is 10 feet thick. The author does not question this statement, for at all of the prospects on the west branch of Miller Creek the coal bears abundant evidence of having been twisted and squeezed, so that if mining were undertaken here it is highly probable that the coal beds would be found to vary greatly in thickness in short distances. The cause of this disturbance will be pointed out later.

The upper 6 or 8 feet of the shaft were cut through a much larger coal bed than the one at the bottom, which is now largely concealed by the timbers lining the shaft. The distance between this bed and the one at the bottom of the shaft is about 30 feet and this interval is made up entirely of sandstone and sandy shale. Armbrister and Allison claim that the large bed is in places at least 10 feet thick and that in every opening made by them there was exposed at least 6 feet of nearly clear coal. Howell examined an adjacent prospect in 1914 and reports the bed over 9 feet thick, but regarded the upper 3 feet or more as containing too much shale to be of value; the lower 3 or 4 feet he found to be fairly good coal, though badly crushed and greatly weathered. At the request of the author one of the old prospect drifts was partly cleaned out so that he was able to see about 5 feet of quite good-looking coal, but he would hesitate about pronouncing this to be the normal thickness of the coal bed, as the crushing and bunching of the coal makes only one measurement wholly unreliable.

The indications are, however, that in the west end of the Max Meadows field there is at least one rather thick coal bed which resembles very strongly the lower part of the Merrimac coal bed, as it is known in Pulaski County. This view is to a certain extent corroborated by the prospect on the main or east fork of Miller Creek. At present this prospect slope is completely caved, but in 1914 Howell reports that the coal bed showed near the mouth of the slope. Although at that time the coal was badly weathered from long exposure, he cut a sample across a mass of coal 5 feet 8 inches thick, but he states clearly that the measured thickness is unreliable, if not positively misleading, for in the short distance of 10 or 12 feet the bed varies greatly, consisting of irregular lenses of coal. In places the bed was almost completely pinched out and in other places bunched into a thick mass. On account of the weathered condition of the sample taken here, the analysis is not given, as undoubtedly it does not represent the actual quality of the coal.

Twelve or fifteen feet above the thick coal bed just described, is another which in this end of the field makes a rather poor showing. In some prospects it is 4 or 5 feet thick, but on weathering it is clearly seen that about half of this thickness is made up of shaly or clayey layers which are so intimately mixed with the coal that it is doubtful if they could ever be separated.

The question of the correlation of these beds with the ones that have been prospected and mined at Gunton Park is most interesting and the author ventures to suggest that perhaps the uppermost and rather unsatisfactory bed on Miller Creek is the diminished representative of the Gunton bed of the other end of the field; that the thick bed at the west end may be the same as the Clark bed at the east end; and that the bed at the bottom of the shaft on the west branch of Miller Creek may be the same as a 4-foot coal bed reported as being present at the mine of the Pulaski Smokeless Coal Co. at Gunton Park. If this correlation is granted, then why should not the lowest bed on Miller Creek be correlated with the Langhorne bed of Pulaski County and the two upper beds be regarded as a much expanded development of the Merrimac bed as suggested by the section given for the Empire mine (loc. 44) in Pulaski County?

Some bed, probably the largest of the coal beds just described, has been opened at loc. 63, lower down on Miller Creek, but as this prospect is in the overturned limb of the syncline, the coal is so badly crushed that it is impossible to identify it as any particular bed of the group.

Coal beds below this group are known at several localities in the Max Meadows field. These are noted on the map (Pl. I) at locs. 55 and 58. At loc. 55 the coal shows in what was known years ago as the "Peppers Ferry road," nearly a mile east of Gunton Park. The bloom of this is rather conspicuous on the road as it leads up to the divide which separates Beaverdam Creek from one of the southern tributaries of Peak Creek, but the coal bed is probably less than 18 inches thick. At loc. 58, which is in the forest about 300 feet south of Beaverdam Creek, the coal shows in the bed of a small branch, apparently lying nearly horizontal, but owing to the swampy condition of the ground it was impossible at the time it was visited to explore it far enough to determine its thickness. From the general geology of the surrounding region the author is inclined to the belief that this is an exposure of a bed much lower in the Price formation than any of the beds that have been prospected or mined in this field.

In the Max Meadows field many prospectors have been misled by the fact that the black shale near the base of the Devonian carries some coal, but in no place known to the writer is this coal thick enough to work even for local consumption. The most striking case of this kind is an old prospect tunnel that was once driven in this black shale just under the ledge of quartzite (which is here overturned) at the creek crossing above the washery of the Locust Hill iron mine at the west end of Draper Mountain. It is reported that the man who dug this tunnel found coal which he burned in a blacksmith's forge. As a result of this occurrence considerable time and money have been spent in digging prospect pits in this shale, both here and in other parts of the field, but without success. The writers do not question the correctness of this reported "find" but feel very positively that time and money spent in such undertakings are simply wasted for thousands of prospect pits have been dug in this shale in various parts of the Appalachian region without finding coal in commercial quantity.

Those who have been most instrumental in prospecting the west end of the Max Meadows coal field do not seem to have a correct conception of the limitation of the coal beds in a westerly direction. They argue that, because Brushy Mountain, which bounds their field on the north extends as far as Cove Creek, the coal beds must necessarily do, the same. In fact the writer has been assured many times that such is the case and the opinion has been backed up by the statement that coal is known at such and such a place or that so and so has dug coal somewhere within a mile of Cove Creek.

The writer made a careful investigation in order to determine this point as the possible westward extension of the coal beds a mile or more beyond their present known limit is a very important matter. The question was finally definitely settled by following an old road from loc. 62 which leads to the west from the prospect shaft and then turns to the south through the forests and fields to the neighborhood road on McGavock Creek. Soon after leaving the shaft the writer found a bed of sandstone that evidently underlies the coal beds exposed in the shaft and that is well exposed on and beside this road. The road turned gradually toward the south and the ledges of sandstone turned in a similar manner as indicated by the dip symbols on Pl. I. The sandstone bed dipping to the southeast was followed until it was lost in rocks that are so disturbed that it was impossible to determine their dip and strike. These rocks are evidently a part of the overturned and crushed southern limb of the syncline and it is perfectly evident to one familiar with geologic phenomena that the coal beds must follow the same curve that is taken by the sandstone bed until they too are lost in the broken southern limb of the syncline.

If this interpretation is correct, and the writer is willing to stake his reputation on its correctness, there is no hope of finding the coal beds west of this road, and any time and money spent in such a quest will be wasted. It is true that some coal beds lower in the formation may be found in the direction of Cove Creek, but, as far as these beds are known, they are not worth considering for commercial purposes. Most of the prospects in this part of the field to which the writer was directed proved to be exposures of the black shale which occurs near the base of the Devonian system, but which in the violent overturning and crushing of the south limb of the Max Meadows syncline was thrust out of place and forced into contact with the Ingles conglomerate member of the Price formation. As stated previously small stringers of coal may be found in this shale, but nowhere is it known to carry coal beds of workable proportions; in this place, even if the coal beds were as large as the Merrimac bed in western Pulaski County, it would not be workable because of the great crushing the rocks have undergone by the overturning of the south limb of the syncline.

QUALITY OF THE COAL.

The quality of the coal of the Max Meadows field is fairly well indicated by the analyses on page 113, but the number of analyses are not sufficient to show in detail the variations from place to place or from bed to bed.

The analyses of samples from the mine of the Pulaski Smokeless Coal Co. (loc. 59) show that the composition of the coals of the Gunton and Clark beds is practically the same, except in their ash content, and this difference may possibly be explained by the different conditions under which the samples were obtained. The fuel ratios of the samples from this mine—6.66, 6.82, and 6.14, with an average of 6.54—indicate a coal intermediate in rank between most of the coals of the Brushy Mountain and Little Walker Mountain fields, with the exception of coal of the Langhorne bed at Empire. As indicated by the one analysis of coal from the west end of the field, the coals diminish in rank westward, having at the west end a fuel ratio of only 5.81. This difference may possibly be due to the weathered condition of the sample from loc. 62, but the writers are more inclined to attribute it to a general westward decrease due to diminishing metamorphism of the rocks in that direction; this is also indicated by the low rank of coal in the west end of the Reed Creek coal field, as shown by analysis No. 93670.

The factor in the composition of this coal that will most affect its salability is the large percentage of ash that characterizes every sample that was taken in this field. This means that operators in the fields of Wythe County must clean their coal more thoroughly by picking and washing than the operators in other fields where there is a lower percentage of ash. The handling of so much ash means greater expense in mining and in preparing for the market than is necessary with coals having a smaller content of ash.

The writers do not mean to imply that the coal can not be satisfactorily cleaned, but they do mean to impress upon present and prospective operators the importance of adequately cleaning the coal and that this means a large supply of water which may not be available at every mine location. In estimating the cost of mining, allowance should be made for the added expense of cleaning and mines should not be opened without suitable equipment being provided for picking and washing the output of the mine.

Reed Creek coal field.

GENERAL DESCRIPTION.

In Wythe County there is a narrow belt of outcrop of the Price or coal-bearing formation stretching nearly across the county from east to west along the southeast side of Little Walker or Brushy Mountain. This belt of rocks is not limited to Wythe County, but extends westward into Smyth County as far as Bear Creek, northeast of Marion. So far as known, however, the workable coals in this belt of outcrop are confined to the terrritory lying between Crockett Cove and the west line of Wythe County. As all of this coal territory is drained by Reed Creek or some of its numerous tributaries, the field is here called the Reed Creek coal field.

As the coal beds in general dip towards the south and as they crop out on the south slope of the ridge known east of Reed Creek as Little Walker Mountain and west of Reed Creek as Brushy Mountain, it naturally follows that the northern boundary of the coal field may be taken as the crest of this ridge and the southern boundary as the great fault which separates the coal-bearing rocks from the limestone on the south. This fault is in reality a combination of two faults: (1) the Cove fault which originates in Crockett Cove, and (2) the Pulaski fault, which is much more extensive, and passes through the town of Pulaski and to the south of Cove Mountain.

The extent of the coal beds along the mountain is determined largely by the position of the fault. Where the fault is some distance south of the outcrop of the coal beds the latter are but little disturbed, but where the fault encroaches on the coal beds the latter may be covered and entirely concealed by the overthrust mass of limestone. This condition is particularly pronounced at the eastern end of the field, for here the fault gradually encroaches on the coal outcrop in an easterly direction, coming closer and closer to the coal until finally, about a mile west of the direct Bland-Wytheville road, it covers the outcrop of the coal and east of this place there is no coal, except possibly small beds so far beneath the limestone that they may be regarded as inaccessible.

Any coal mined in the Reed Creek field might reach the railroad either at Wytheville or Rural Retreat, but the natural route on a water-grade would be by means of a branch railroad down Reed Creek. Owing to the fact that Reed Creek drains practically all of the field that is known to contain workable coal beds, such a railroad, with branches up the many tributary streams, would be sufficient to carry all of the coal produced in the field.

GEOLOGIC FORMATIONS.

The coal beds of the Reed Creek field occur in the Price formation and probably they are the westward continuation of the beds already described in Montgomery and Pulaski counties, but they are so imperfectly exposed that exact correlation is impossible. The best beds, however, occur near the middle of the formation with the same general relations that they exhibit in the counties to the east. The base of the formation is here marked by a thin bed of conglomerate, or rather by scattered quartz pebbles in a matrix of white or gray sand, similar to the Ingles conglomerate of Montgomery County. The other beds composing the formation are indistinguishable from those which characterize it farther to the east.

The Price formation here rests on brown flaggy sandstone of Devonian age, which in every respect is similar to the sandstone that underlies the Price formation in its type locality. The Devonian sandstones and shales appear to be thinner here than they are in Montgomery County, but as no section has been carefully measured, the figures given for their thickness should be regarded as provisional only, except that it is well known that these formations do thin materially toward the west. The maximum thickness in this field is assumed to be about 4,000 feet.

Adjoining the outcrop of the Price formation on the south is a narrow band of outcrop of the Maccrady shale which appears to be identical with the same formation in Montgomery County. The fault on the south cuts this formation so close that at no place within the field is its full thickness present. In the outcrops examined, there seems to be room for only about 300 feet of the Maccrady shale, but its full thickness is probably in the neighborhood of 500 or 600 feet. This is the highest formation exposed in the Reed Creek field, hence it is concluded that in all probability no higher formations were ever deposited here and that deposition ceased at the close of the Maccrady epoch.

STRUCTURAL RELATIONS.

In the Reed Creek coal field the most important geological feature is that of structure or the lay or attitude of the rocks. All who are familiar with the field or who have attempted to mine or prospect its coal beds understand that at no place in the field do the rocks lie flat, but that they dip at various angles to the south or southeast. One also soon realizes that the position of the Shenandoah limestone relative to the coal beds is not the same in all parts of the field, but that its proximity to a coal bed probably means that there may be difficulty in mining that bed down the dip far to the south.

The geologist understands that the rocks of this field have assumed their present attitudes as the result of the formation of great folds in the rocky crust of the earth and that in most cases the stresses were so great that when the folds reached a certain stage of their development the rocks could stand the stress no longer, and they broke, allowing a part of the fold to be thrust forward over the other part and in places over other folds for an indefinite distance, in some places as much as 8 or 9 miles. The mode of formation and the breaking of such folds is more fully explained on pages 69-74.

In the Reed Creek field the rocks of Walker and Brushy or Little Walker mountains constituted the northwestern limb of one of these great folds and consequently the rocks in these mountains dip toward the southeast. Originally they were folded into an anticline and a syncline as represented by Fig. 2M. With the continued application of the thrust from the southeast, the rocky fold broke and overrode the limb of the next fold to the northwest, until the Shenandoah limestone rested on the Price formation as we see it to-day. This means a stratigraphic displacement[1] of about 18,000 feet and a horizontal displacement of probably several miles.

[1] By stratigraphic displacement is meant the thickness of the formations that have been eliminated by the fault. Thus in the case in hand, if the base of the Shenandoah limestone is faulted so as to rest upon the Price formation, then the Shenandoah has been thrust up over all of the intervening formations which, according to the columnar section on Pl. 1, measures about 18,000 feet. By horizontal displacement is meant the horizontal distance that the overthrust mass has moved in the process of faulting. This is not always easy to estimate for it is difficult to determine the location of the overthrust mass before the movement began. If, however, the dip of the fault plane is 30°, then in order to move vertically upward 18,000 feet, the mass would have to be thrust forward or toward the left a distance of 6.8 miles. If the dip of the fault plane is less than 30° then the distance would be greater.

In most of the Reed Creek field there is no suggestion of the presence of a syncline such as is shown in Fig. 2M, for the fault has so nearly obliterated the structure that the synclinal character is not noticeable, but at the extreme west end, near Bear Creek in Smyth County, the field does not come to an end because the Price formation is cut off by the fault, as happens at many other places, but the field comes to an end because the Price formation, which here lies in the form of a long narrow trough, rises toward the west and just east of Bear Creek lies near the tops of the hills and the formation is cut off by natural erosion.

The appearance of the outcrops of the coal beds in this field depends upon the form of the trough and the extent to which the surface of the ground has been lowered by erosion. Since the trough grows deeper and deeper as one travels from the western or Bear Creek end, it is manifest that the outcrops of the coal beds will appear at the point where the trough is deep enough to catch them and that west of that point there will be no need of prospecting for coal, for none, except possibly some very small beds near the base of the formation, will be found. At the extreme west end the conglomerate or basal bed only of the formation is present, but in passing eastward the trough deepens gradually and at locs. 69 and 70 the coal beds appear and have been prospected. The arrangement of these old prospect holes shows clearly that the coal beds partake of the synclinal structure, but that they are cut on the south side by the great fault which has obliterated the south limb of the syncline.

From locs. 69 and 70 eastward there is no trace remaining of the synclinal structure and the coal beds dip to the south with a fairly regular and persistent dip. The limestone gradually encroaches upon the outcrop of the beds, until on the headwaters of Goose Creek it covers the coal and no outcrops are known east of this point.

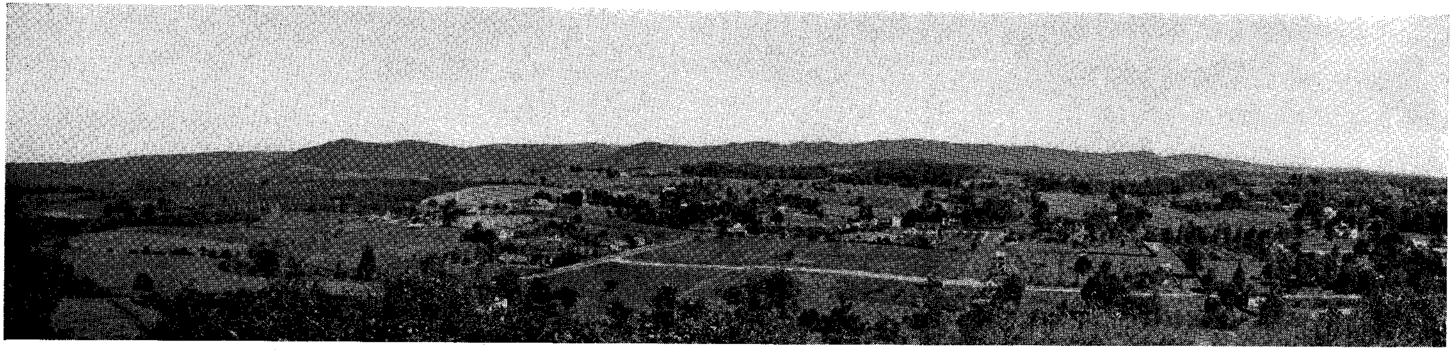
From a geological point of view it is perfectly clear that the fault at the base of the Shenandoah limestone does not necessarily cut off the coal beds but has permitted the limestone to override them, and consequently the coal beds in many, if not all places, extend some distance beneath the limestone mass. Until deep drilling is done, no one can say positively how far under the limestone the coal beds extend, but it seems safe to assume that where they are unbroken, they probably extend downward until they are too deep to be economically mined.

The condition of the coal beds in the Reed Creek field is apparently affected greatly by crustal movements that occurred after the great folds had been formed and the faults produced. As pointed out on page 260 in that part of this report dealing with the Bland coal field, the rocks in that field as well as those in the Reed Creek field have been profoundly affected by a cross-fold or buckle, extending from near Blacklick in a northeasterly direction, passing just west of Griffith Knob and through the big bend of Walker Mountain southeast of Effna, and on through the bend in the Bland fault about four miles southwest of Bland, as shown in Fig. 24. It is difficult to conceive of this cross-fold as having been produced at the same time that the great longitudinal folds were formed, for in most cases in the Appalachians irregular stresses that might produce such a cross-fold and fault, have generally produced great anticlinal domes, such as Burk Garden, or synclinal basins, such as the wilderness drained by Kimberling Creek. In the present case the disturbance has affected not only the longitudinal folds and remnants of folds, but also the longitudinal faults by which they are separated. For that reason it is assumed that the disturbance which produced the cross-fold occurred at a later date than the formation of the great longitudinal folds and faults.

The writer did not have time to work out all of the details of this cross-fold, but a glance at the map is sufficient to show that the disturbance was greatest in Little Walker Mountain and that it died out gradually in a northeasterly direction. Little Walker Mountain is regular in its development east of Stony Fork, but just west of that creek the crest of the mountain turns at right angles and swings into a course nearly due north, culminating in Browns Peak. A spur on the main crest turns west from Browns Peak, then southwest to within about a mile of Reed Creek. Here it ends and it is not connected with any ridge on the west side of Reed Creek. In the west part of the field, Brushy Mountain trends, with considerably regularity, about northeast from near Bear Branch to Reed Creek, but its crest at Reed Creek is distinctly south of the crest of Griffith Knob, and besides there is a decidedly low place in the ridge in this vicinity. The only explanation of this anomalous relationship is that the rocks forming the ridge are cut off at Reed Creek by a cross-fault, as shown on Pl. I, which affects the ridge for about three-fourth of a mile.

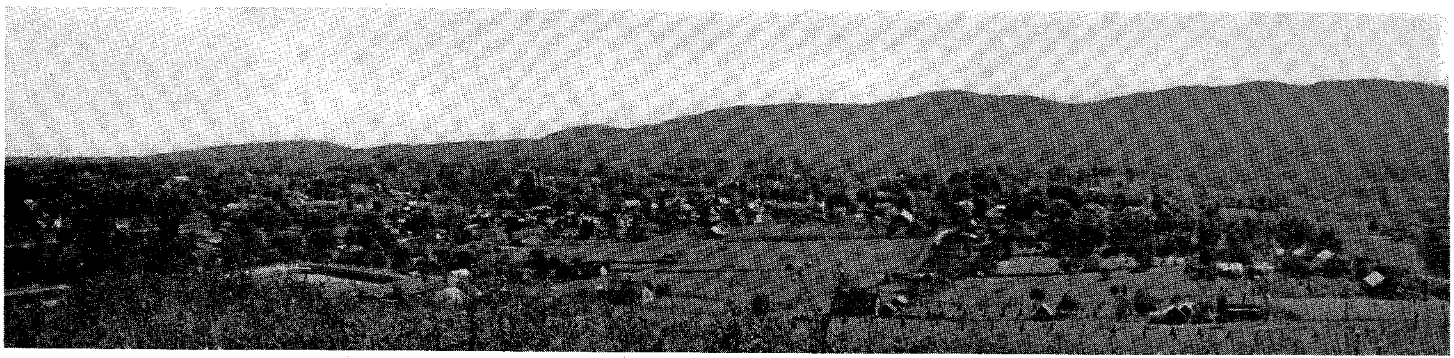
In mapping the Pocahontas quadrangle in 1893 the writer[1] noted a fault cutting Walker Mountain at the point where it is crossed by the Stony Fork-Sharon Springs road. This fault was mapped as trending in

[1] Geologic Atlas of the United States, folio 26, 1894.



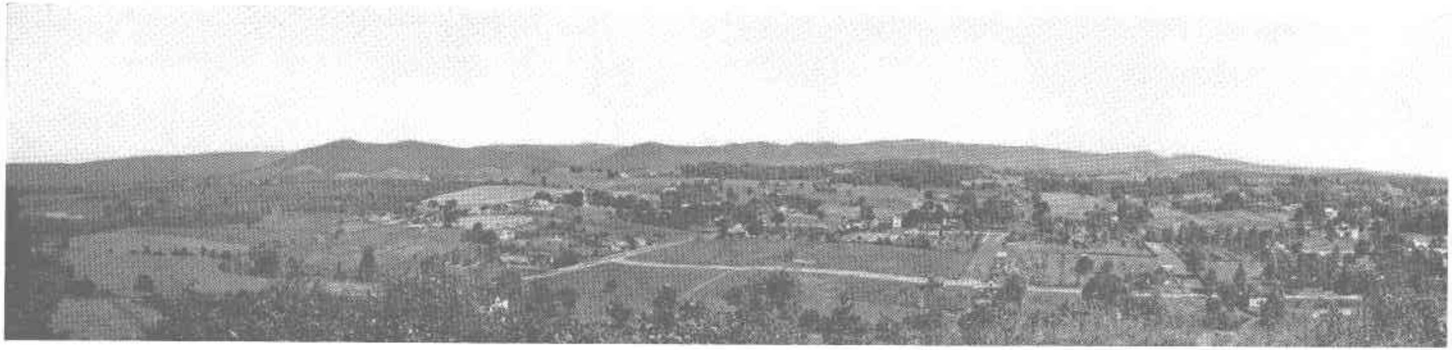
(A) Wytheville, Va. View north from the reservoir, showing Cove Mountain in the middle distance with Queens Knob at its left end.

Photograph by Marius R. Campbell.



(B) Wytheville, Va. View southeast from the reservoir, showing Lick Mountain on the right.

Photograph by Marius R. Campbell.



(A) Wytheville, Va. View north from the reservoir, showing Cove Mountain in the middle distance with Queens Knob at its left end.

Photograph by Marius R. Campbell.

(B) Wytheville, Va. View southeast from the reservoir, showing Lick Mountain on the right.

Photograph by Marius R. Campbell.

a northwest-southeast direction, but on reviewing the evidence, the writer is satisfied now that the fault trends northeast-southwest and that in all probability it is the continuation of the fault cutting Little Walker Mountain on Reed Creek. At the crossing of Walker Mountain the rocks on the right of the fault are offset to the northeast and the same movement has occurred in the rocks of Little Walker Mountain on Reed Creek. As no trace of a fault was seen where this disturbance offsets the Bland fault, the cross-fault is supposed to die out in the limestone on the north side of Walker Mountain. The presence and position of the fault where it crosses Reed Creek is well shown by the different attitude of coal beds on the two sides of the fault plane. As shown by the location of old prospects on the main coal bed west of Reed Creek it is apparent that the coal outcrop crosses Reed Creek in a northeasterly direction. The coal does not show at the present time on Reed Creek, but the writer was informed, on what appears to be thoroughly reliable evidence, that at one time a large coal bed was exposed in the west bank of the creek; that the bed dips to the southeast and that its outcrop trends in a northeasterly direction. A short distance from the point where the coal is reported to have been exposed in the bank of the creek, another coal bed is exposed about 300 feet to the east. This bed, which is not the same as the one formerly showing in the creek, but is one at about the top of the Price formation, strikes about northwest and dips SW 25°. A glance at the map, Pl. I, will show that these coal beds come together nearly at right angles and consequently must be separated by a fault.

As the upper portion of the Price formation, or the part carrying the coal beds, is cut by the fault and the fault seemingly cuts off the belt of Maccrady shale that stretches from Reed Creek to Stony Fork and still farther east, it seems altogether probable that it also cuts the Shenandoah limestone south of the Pulaski fault, but the time at the writer's disposal did not permit of a thorough examination of the limestone area directly west of Reed Creek. The fault cutting across the outcrop of the formation just described, because of its excellent development on Reed Creek, will here be called the Reed Creek fault.

The assumption that the Reed Creek fault and the buckling of the formations that attended it were produced subsequent to the period in which were produced the great folds and faults of this region, is strengthened by the evidence of similar disturbances subsequent to the faulting in other parts of the Valley coal fields. These have been described under the general heading of structure, but they may be summarized as follows:

(1) the anticlinal fensters on New River; (2) the peninsula-like masses of Carboniferous and Devonian rocks north of Pulaski and Max Meadows dipping under the Shenandoah limestone in nearly all directions; (3) the infolded narrow band of the Shenandoah limestone just north of Draper Mountain; (4) the abnormally steep dips of the limestone on the plane of the Pulaski fault; and (5) the disturbed condition of the coal beds where they lie close to the fault plane.

In addition to the disturbed condition of the coal beds where they come close to the limestone contact, there is another disturbed condition due to the development of the larger structural features of the region. These affect the coal beds for the simple reason that in a general way the coal beds are the softest and least resistant members of the formations and consequently they are in many places crushed and ground to powder where they are caught between two other members of the formation that are competent to transmit the pressure to which the rocks were subjected. The crushing of the coal beds in this manner is of course localized where conditions are particularly favorable for such movement. Local pressure and movement of this character most often develop where there is a decided bend in the structures, although the real amount of deflection from the previous course may not be more than 10°. Where the trend of Brushy or Little Walker mountains is straight for long distances the coal beds are probably free from decided crushing, but where the trend changes, be it either to the right or the left, there the coal beds are liable to have suffered greatly and they may not be in such a condition as to be considered minable.

The writer is somewhat uncertain regarding the relation of the two belts of limestone on opposite sides of the Pulaski fault west of Queens Knob. The junction of these masses was carefully examined to see whether or not the mass coming in from Crocket Cove passes under the mass south of the Pulaski fault, but exposures in critical places are generally difficult to find and consequently there is still some uncertainty regarding the relations of the two limestones. There can be no question about the limestone south of Queens Knob being thrust up over the rocks composing the knob and also over the Sevier shale which outcrops for nearly a mile west of the knob, as the beds of shale strike directly against the Pulaski fault at an angle about 30°. Similarly the limestone underlying this shale on the northwest (see Pl. I) strikes nearly parallel to the strike of the shale and hence it also undoubtedly passes under the limestone south of the fault. A similar relationship was found about 1½ miles east of

Stony Fork, but west of this point the beds of limestone north of the fault are parallel with those south of the fault and it is impossible to determine the exact location of the break. The evidence, while not entirely conclusive, is of such a character as to leave little room for doubt that the limestone south of the fault was thrust over all of the formations making up the Crockett anticline, as is represented in Pl. I.

DESCRIPTION OF COAL PROSPECTS.

Any statement that may be made at the present time regarding the coal of the Reed Creek field is most unsatisfactory for the reason that no mines are in operation, no recent prospecting has been done, and no deep drilling has ever been attempted in the field. Old prospects are numerous, but most of them have caved so that the opening is closed and, though dump heaps show that considerable coal has been taken from some of the drifts, nothing can be seen by which to judge of the thickness or character of the coal bed and no unweathered material can be secured for chemical analysis by which one may form some idea of the quality of the coal. The prospects that were visited will be described, beginning at the east end of the field and proceeding westward.

The most eastern prospect in the Reed Creek field is located on one of the head branches of Goose Creek, about half-a-mile west of the point where the direct road from Wytheville to Bland crosses the summit of Little Walker Mountain. This is an old prospect and little could be seen by which to judge of the value of the coal bed. Mr. Davis, the owner, states that the coal bed is 7 feet thick and that the coal mined here was used for smithing purposes. The rocks in the vicinity strike N. 82° E. and dip 40° SE. The prospect is within 100 feet of the Cove fault, so that probably within less than a quarter of a mile to the east the outcrop of the coal bed is concealed by the overthrust limestone mass.

Inquiries were made about prospects west of the one just described, but none were reported within a distance of about 3 miles. It is probable that prospecting pits have been dug in this interval, but if so, they must have been dug many years ago or they would be familiar to every resident of the district.

The most important prospect west of the one just described is that of Dr. John P. Graham, of Wytheville (loc. 64). In 1922 Doctor Graham spent considerable money in an endeavor to open up a coal bed at loc. 64, two miles east of the Wytheville-Bland road up the Stony Fork of Reed

Creek. At this place the coal bed strikes N. 27° E. and dips SE 45°. A slope was driven down on the bed some distance revealing, according to report, very excellent coal. The writer was assured by Doctor Graham that near the surface the coal bed had a thickness of about 5 feet; but this increased with depth until at the lowest point reached, the coal is 13 feet thick and without noticeable partings. A coal bed about 2 feet thick is reported as lying 20 feet above the large bed and another one 2½ to 3 feet thick, containing much soft coal, 6 feet below the main bed, the material separating the two last mentioned being sandstone. Unfortunately a blast displaced a large quantity of rock material which lodged in the mouth of the slope, completely blocking the mine and preventing access to the coal.

Owing to the inaccessible condition of the mine the writer was unable to examine the coal bed and thus is not in a position to offer any suggestion as to whether 13 feet is the normal thickness of this coal bed or whether the coal may have been squeezed here into a very abnormal thickness. The fact that no partings were noticed seems to indicate that the coal has been badly crushed for when crushing takes place the bony partings in the coal bed are generally so mixed with the coal as to be indistinguishable, especially to one untrained in close scrutiny of such material. Another fact that argues somewhat for the disturbance of the coal bed is the change in direction of the outcrop of the coal on both sides of this prospect. Such changes are found to have a decided effect on the coal bed, for in the bending, torsional stresses are set up which break the coal very badly and reduced it and the partings it contains into an indistinguishable mass. On the other hand a thickness of 13 feet agrees very well with the observed thickness of the upper part of the Merrimac coal bed at Slope No. 2 (loc. 44) of the Empire mine in Pulaski County and in the reported thickness of this bed in the Altoona mine and in prospects north of Pulaski. As the Reed Creek coal field is in strike with the Little Walker coal field of Pulaski County, it seems probable that the coal beds which characterize one field would be found in the other and that they would not be greatly different in thickness. In applying this principle to the Reed Creek field it must be understood that all of the thick coal beds of Pulaski County either thin greatly or break up into a number of coal beds toward the southwest, for in Smyth County no thick beds have been found. So far as the writers can determine the great change comes in west of Reed Creek. If that is correct, then the coal bed exposed in the Graham prospect may have a normal thickness of 13 feet or it may be thinner, say 6 or 7 feet, and attain a thickness of 13 feet only where the coal is bunched.

The good quality of the coal is shown by the character of the coal remaining in a bin and on a dump. This seemed so fresh, though exposed 8 or 9 months, that a sample of the best coal, carefully picked, was taken for analysis and the result is shown under No. 95620 on page 113. The writer hesitates about publishing this analysis, for the reason that it represents a picked sample of coal and therefore shows very much less ash than analyses of other samples which were collected in the regulation way and represent the real character of the part of the coal bed that is or can be mined. In that sense it is not typical and should be used only as a guide as to what might be accomplished if all the mines in Montgomery, Pulaski, and Wythe counties were preparing their coal for market in the best possible way. The sample was taken primarily to determine the rank of the coal of the Reed Creek field and the fuel ratio of 3.87 determined from the analysis is considered accurate.

The mine of Doctor Graham affords quite satisfactory evidence that there are some thick beds of coal in this field, but surface prospecting, especially on a 45° dip, is not a very satisfactory way of demonstrating the thickness and character of the coal bed and the writer would strongly advise the sinking of several core-drill holes in this part of the field to determine the number and character of the coal beds under cover. One hole will not necessarily tell the story as it is little better than one prospect for it reveals the conditions in only one locality and if the beds are of variable thickness, as is presumably the case, one determination of thickness is of little value, but if several holes are put down through the coal then the logs of these wells should afford very reliable evidence regarding the normal thickness and character of the coal beds as well as the quality of the coal and both of these lines of evidence are badly needed in this field. Core-drill holes could be so located that each one need not be more than about 500 feet deep and if property owners combine on such a scheme, the cost to each would not be prohibitive.

As this field is in direct line of strike, though not in the same syncline as the Little Walker Mountain field of Pulaski County, it would not be surprising to find thick coal beds here as the westward continuation of the very thick Merrimac bed exposed at the Empire mine (loc. 44) and reported from the old Altoona mine (loc. 47). In opposition, however, to this line of argument is the well-known fact that a little farther west the coal beds thin very materially and in Smyth County, so far as present knowledge of the beds will warrant an opinion, the coals, because of thinness and the amount of bony partings in them, become practically unworkable. The unknown factor in the problem at the present time is the point at which this thinning begins. Is it between the Little Walker Mountain field and the Reed Creek field or is it in the Reed Creek field east of Reed Creek, or do the coal beds hold their thickness as far west as Reed Creek and then suddenly deteriorate toward the west? The data at hand will not permit of a satisfactory answer and consequently the question must remain open until more and better prospecting work has been done. The same thing is true regarding the correlation of individual coal beds from one field to another and in certain cases from a location in one field to another location in the same field. Careful prospecting would also throw much light on this perplexing and important question which can not be answered at the present time with any degree of certainty, at least as far as it concerns the Reed Creek field.

West of loc. 64 there are old mines and prospects in every ravine crossing the outcrop of the coal beds, but all of these pits were opened many years ago and now it is generally impossible to see the coal bed without great labor in reexcavating the old pits, and this work the writer was in no position to do or to have done. About three-quarters of a mile from loc. 64 there is an open prospect (loc. 65) on a rather poor coal bed where the following section was measured:

Section of coal bed at loc. 65.

	Ft.	In.
Shale and coal	1	4½
Coal		3
Shale		2
Coal		10
Shale		2
Coal		3
Shale	1	0½
Coal	1	10
Thickness of bed	5	11
Thickness of coal	3	2

Dip of the coal bed about 20° SE.

The identification of this coal bed with any that was seen in Pulaski County to the east is difficult; it does, however, strongly resemble the uppermost bed known at loc. 62 in the west end of the Max Meadows coal field. If this correlation is correct one would expect to find a much larger coal bed only a short distance below this bed. On the west fork of the branch upon which prospect 65 is located there is a caved drift, from which a large quantity of coal was obtained many years ago. It is inconceivable that this opening should be on the same bed as that showing at loc. 65, and hence as the outcrop of the bed opened on the west fork is farther north than loc. 65, it is assumed that it is on a lower and probably much larger bed, possibly corresponding to the one opened at loc. 64 and also the middle bed at loc. 62 in the Max Meadows field. If this correlation is accepted, then the lowermost bed, 2½ to 3 feet thick at loc. 64, would be the same as the lowermost bed or the coal bed struck in the shaft at loc. 62 in the Max Meadows field. By analogy also the lowermost bed at loc. 62 may be the Langhorne bed of Pulaski County, and the two beds overlying it together represent the Merrimac coal bed increased in thickness westward and separated into two distinct beds. These attempted correlations must not be accepted as well founded, but as merely suggestive, their value to be determined by future prospecting with a core drill.

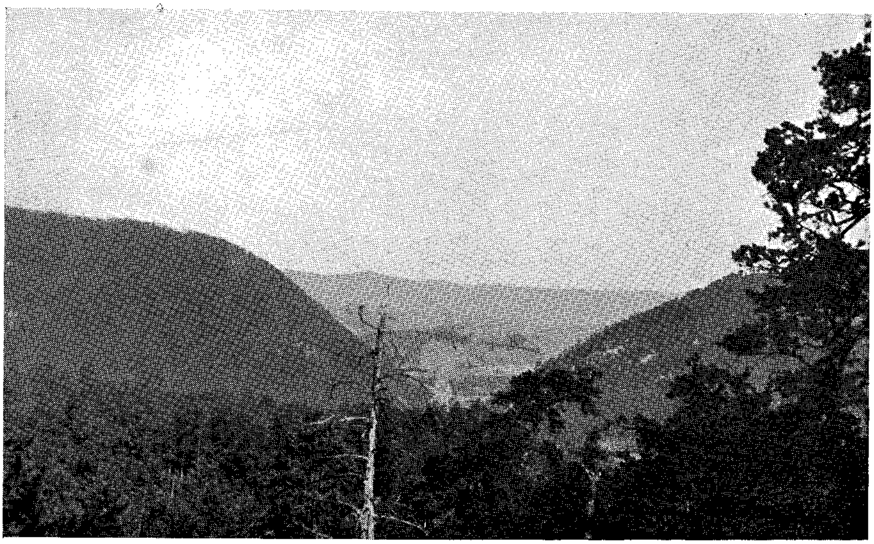
This group of coal beds have been well known for many years at the place where they cross Stony Fork. The writer noted the presence of coal here in 1893 when he made a reconnaissance survey of the Pocahontas quadrangle. Many prospects have been opened here and from time to time mining has been undertaken to supply the local needs, but so far as the writer is aware no mine is open at the present time so as to show the character and thickness of the coal beds, especially of beds more than 2 or 3 feet in thickness. The coal beds, as well as the associated beds of sandstone, dip here 27° to the southeast.

The outcrop of this group of coal beds was traced west of Stony Fork for about one mile where an old prospect was seen on a small branch flowing directly into Reed Creek, but no information could be gained about the thickness of the bed or the quality of its coal. Beyond this exposure no other prospects were found, though it is quite possible that many have been made in the rugged mountain mass formed by the short northward bend of Little Walker Mountain just west of the Stony Fork gap. The structure of this mountain mass was not determined, as the time at the disposal of the writer did not permit of a climb to the crest of the ridge or the exploration of the numerous ravines heading in its forest-covered slopes.

By traversing the road from Stony Fork to Blacklick and the road from Blacklick up Reed Creek, it was found that the geologic formations make a great northward bend in conformity with the change in the direction of the mountain crest. It was found also that the dips, especially on the road up Reed Creek, are variable, indicating that the rocks here are thrown into many minor flexures, which would cause trouble and expense in mining if the coal beds are affected in the same manner. Around this bend in the formations a number of prospects were found on a very small coal bed which lies at the extreme top of the Price formation, several hundred feet higher in the formation than the large beds heretofore described. In a prospect on this bed at loc. 67 the coal bed shows a thickness of 12 to 18 inches and it strikes 33° west and dips 33° southwest. This strike and dip are in perfect conformity with the structure of Little Walker Mountain on the east, but not at all with the structure of Brushy Mountain on the west. This discordant structural relation is extremely important and it is, perhaps, best shown by comparison of the strike and dip of the coal bed just mentioned and that of another outcrop of coal in the west bank of Reed Creek, probably not more than 300 feet distant. The relation of the two coal outcrops can best be understood by first describing the outcrop of the important coal beds on the west side of the creek.

West of Reed Creek enough prospecting has been done on this group of coal beds to enable one to map their outcrop with little difficulty. One of these old prospects, loc. 68, nearly half-a-mile west of the creek, consists of a shaft which reached the principal coal bed where the strike is N. 11° W. and the dip is 25° NE. The writer was assured by the man who opened this prospect that the outcrop of the coal bed swings north and east in a gentle curve and crosses Reed Creek only a few hundred feet from loc. 67 with a strike of N. 55° E. and a dip of 24° southeast, or practically at right angles to the dip and strike of the coal bed at loc. 67. In corroboration of this structure the writer was assured that after the subsidence of a flood a few years ago the coal bed was plainly visible in the creek bank at the point of crossing just west of loc. 67. The coal does not show now in the creek bank, but this position and dip of the bed is in agreement with the surrounding structure and hence is accepted without question, but the writer has no information regarding the thickness of the bed or the quality of the coal composing it.

The above-described relationship of the coal beds on the two sides of Reed Creek is clearly indicative of the presence of a fault, as has been described in the chapter on geologic structure. The effect of this fault on the coal beds is to offset the line of outcrop to the northeast so that, if



(A) Gap where Little Walker Creek flows through Big Walker Mountain, in Pulaski County. The ground cover on Big Walker Mountain at this point is thin and consists principally of worthless shrubs, the result of heavy cutting followed by fires.

(B) Dense stand of promising young growth, due to fire-protection. Montgomery County.

(A) Gap where Little Walker Creek flows through Big Walker Mountain, in Pulaski County. The ground cover on Big Walker Mountain at this point is thin and consists principally of worthless shrubs, the result of heavy cutting followed by fires.

(B) Dense stand of promising young growth, due to fire-protection. Montgomery County.

the outcrop of the main coal group were mapped on the east side of Reed Creek, it would be found to be cut off by this fault nearly half-a-mile northeast of the creek. Not only will the coal beds be found to be cut off here, but on approaching this fault they are in all probability more or less disturbed and crushed. Because of this broken and crushed condition the writer would warn all prospective operators to consider this question carefully before investing much money in mining enterprises here, as mining under such conditions is liable to be expensive if not impossible. The writer would strongly urge the drilling of test holes before mining operations are begun as a few holes may later save the expenditure of many thousands of dollars without adequate returns.

West of Reed Creek the writer found very few indications of coal and these few make such a poor showing that the term coal field seems hardly justified. It is possible, however, that there are thicker and better beds that have not yet been prospected, and hence these may be the basis of a mining industry in the future, but at the present time the prospect does not seem at all hopeful.

The outcrops of the known coal beds west of Reed Creek swing almost due south through loc. 68 and then in a southwesterly direction to loc. 69 on the old road leading across Brushy Mountain from Rural Retreat on the south to Tilson Gap in Walker Mountain on the north. The coal is exposed at one place between locs. 68 and 69, but the exposure is in the bed of a small branch and not more than 18 inches of coal can be seen. The strike and dip change greatly in a short distance, suggesting that the coal has been badly twisted and squeezed until the strike is about N. 28° E. and the dip 40° southeast. There are some indications here of a larger bed under cover, but they are too indefinite and uncertain to warrant the statement that a workable coal bed can probably be found.

At loc. 69 on the road across Brushy Mountain Howell reports old prospects on two coal beds which strike N. 50° E. and dip 22° southeast, but the prospect pits had caved so completely that no part of either coal bed was visible.

West of the road described above three coal prospects were visited by Howell in 1914 and an effort was made by him to reopen some of the most promising pits, but his work did not develop any coal bed that could be considered of workable thickness. The best prospect seen by the writer is the one at loc. 70. This prospect was opened a year or so before it was visited and some coal was mined and hauled to Rural Retreat and sold for local consumption. The old drift is somewhat caved but not so badly as to prevent entrance, the measurement of the coal bed, and the cutting of a sample for analysis. The section of the coal bed is as follows:

Section of coal bed at loc. 70.

	Ft.	In.
Coal	a	7
Shale, carbonaceous		7
Coal	a 2	8½
Thickness of bed	3	10½
Thickness of coal	3	3½

The strike of this locality is N. 47° E. and the dip 25° southeast.

The sample obtained from the two benches of coal was sent to the laboratory and the resulting analysis will be found under No. 93670 on p. 113. The principal object in taking this sample was to have some basis for determining its rank, i. e., whether it should be classed as a semianthracite or whether it would fall into the next lower rank of semibituminous coal. The fuel ratio of 2.60 is surprisingly low and suggests that the weathered condition of the sample may have been the cause. If this ratio is regarded as reliable, then the coal must be considered as belonging at or near the bottom of the semibituminous rank of coals.

Two other prospects in this region were visited by Howell, but little information was gained from them more than to show that the outcrop of the group swings around from a direction of N. 47° E. at loc. 70 to N. 28° E. at the next exposure, and at the second prospect from loc. 70, which is within a few feet of the fault, passes abruptly below the overthrust mass of limestone. West of these prospects no coal of workable proportions is known.

QUALITY OF THE COAL.

There is little to be said regarding the quality of the coal of the Reed Creek field for no really fresh coal was seen by the writer and the coal that was sampled for analysis may have been so badly weathered that it no longer is representative of the coal of this field. Under such conditions one hesitates about even expressing an opinion for fear the opinion may be unjust and may misrepresent the actual conditions.

If, however, one judges the coal of this field by the material at hand, he would certainly come to the conclusion that it does not belong to the semianthracite rank of coals but more nearly resembles, in chemical composition, the coals of the New River and Pocahontas fields of the west than it does the anthracite of Pennsylvania.

FIELDS OF BLAND AND SMYTH COUNTIES.

General description.

The coal of Bland and Smyth counties is largely limited to a comparatively narrow belt of outcrop of the coal-bearing formation on the south side of Brushy Mountain, extending from Point Pleasant, 6 miles east of Bland, to the vicinity of Saltville at the western edge of Smyth County. This belt of coal-bearing rocks is bounded on the southeast by a profound overthrust fault which brings the Shenandoah limestone in contact with the coal-bearing rocks. In places the edge of the limestone is several hundred feet south of the outcrop of the coal beds, but in other places the limestone has been thrust so far toward the northwest that it overlies and conceals the coal as well as a large part of the coal-bearing formation.

The outcrop of the coal-bearing rocks, as shown in Fig. 24, varies considerably in width, but in a general way it is wide enough to contain the outcrop of the lower part of the formation, including the coal beds from Point Pleasant on the east to the vicinity of Sharon Springs on the west. From Sharon Springs to Ceres the belt is very narrow and, though some coal is reported from this part of the field, it seems probable that there is not enough to be considered of any economic importance. For that reason and because the belt broadens southwest of Ceres, the field east of Ceres is regarded as a fairly good unit and is here called the Bland coal field. The Bland coal field is regarded as terminating at the place where Brushy Mountain is crossed by the Ceres–Burke Garden road almost due north of Ceres.

Southwest of Ceres the coal-bearing rocks lie in two distinct belts for a distance of about 10 miles. The southeastern belt is the continuation of the belt from Sharon Spring to Ceres and its accompanying ridge, Brushy Mountain, may be followed the entire distance, though not so pronounced and separated from similar ridges as it is northeast of Ceres. The northwestern belt begins opposite Ceres and it likewise extends in nearly a straight line to the southwest until it is cut off by a great northward bend of the Bland fault which terminates both fields near the mouth of Lick Creek. Because most of the coal-bearing rocks in this distance of 10 miles southwest of Ceres lie in the drainage basin of Lick Creek it will be called here the Lick Creek coal field.

West of Lick Creek Brushy Mountain again makes its appearance as a high ridge which is followed by the north boundary line of Smyth County.

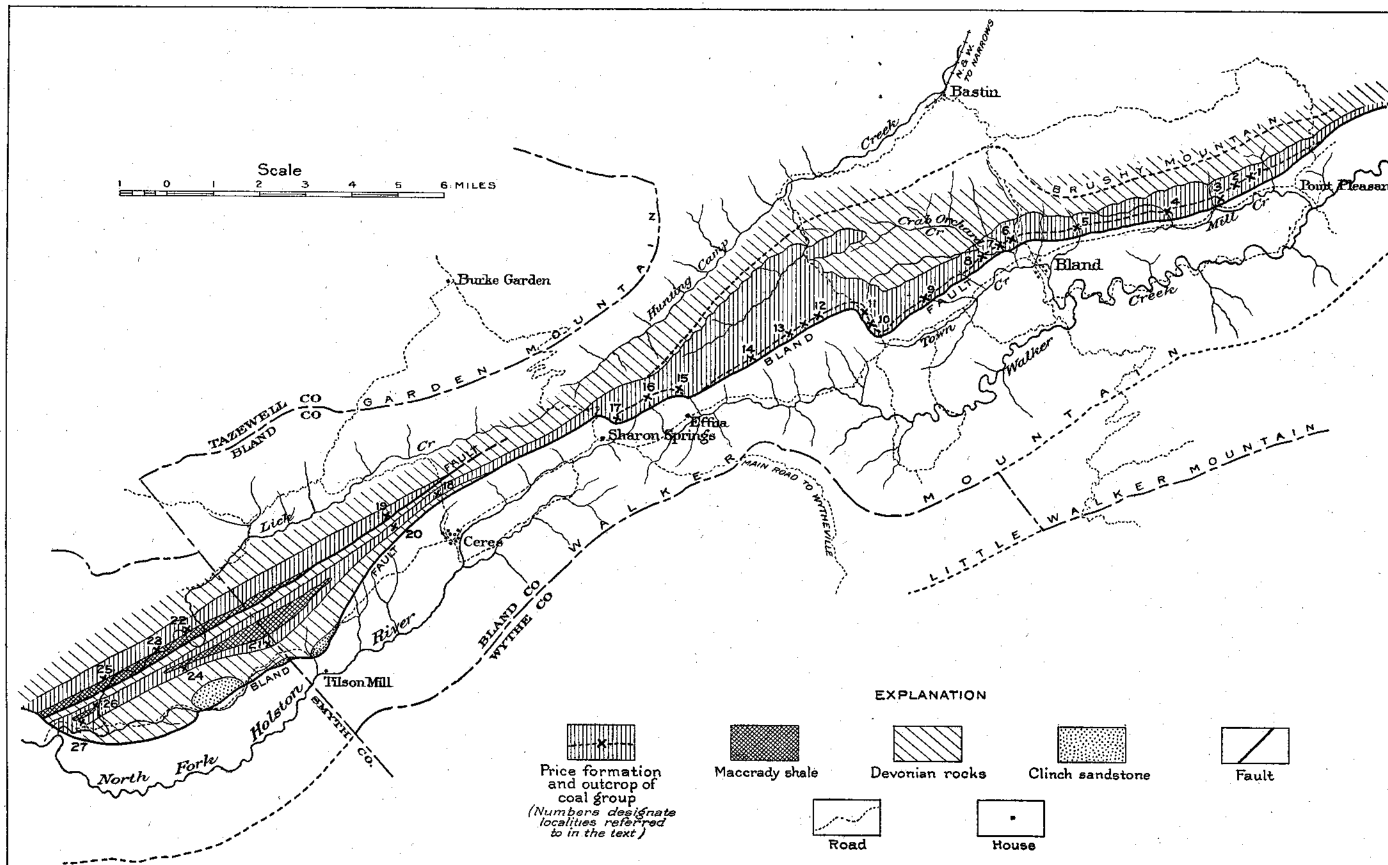


Fig. 24.—Map of the Bland and Lick Creek coal fields in Bland and Smyth counties.

The coal-bearing rocks make their appearance on the south side of this ridge north of Chatham Hill and extend indefinitely westward, but, judging from reports, the value of the coal beds in this part of the region seems very questionable. For convenience of description this part of the belt will be called the Saltville coal field.

Geologic formations.

The rock formation which carries the coal in Bland and Smyth counties is similar in appearance and has the same geologic relations that the Price formation has in Montgomery County, as it overlies the uppermost Devonian rocks and underlies the red shale of the Maccready formation. The red shale, however, is not always present, for in many places it is cut out or rather concealed by the Shenandoah limestone which had been thrust over it. The base of the coal-bearing formation is generally marked by a distinct conglomerate or by white quartz pebbles in layers in or scattered through a coarse white sandstone. This bed is generally resistant to erosion and so forms the main crest of Brushy Mountain, or where it does not reach the crest it forms a secondary crest or shoulders on the mountain spurs. As all of these features are characteristic of the Price formation, the coal-bearing rocks of this field will be regarded as equivalent to the Price formation and hereafter will be called by that name.

No accurate measurement of the thickness of the Price formation has been made in Bland County, but the estimated thickness in the vicinity of the town of Bland is between 600 and 700 feet. Very little of the Maccready shale is exposed above the Price formation, as in most parts of the field it is concealed by overthrust masses of the Shenandoah limestone or Devonian sandstone and shale. The formation thins rapidly westward and in the Lick Creek field in the edge of Smyth County it has a thickness of not more than 300 or 400 feet. In the vicinity of Saltville 17 miles southwest of the mouth of Lick Creek a careful measurement of the Price formation by George W. Stose[1] shows that it has a thickness of between 330 and 435 feet. The full thickness of the Maccready shale directly west of Saltville where it is overlain conformably by the Carboniferous limestone, as determined by Mr. Stose, is 700 feet. This formation is easily recognized in the field for it is composed almost entirely of red shale which bears little resemblance to the rocks of any other formation in the region.

[1] Unpublished report on the north half of the Abingdon quadrangle.

Geologic structure.

In general the structure of the Bland and Smyth counties coal fields is simple, consisting of rocks that dip rather lightly toward the southeast, or in other words, that form a part of the southeastern limb of a great anticline whose axis coincides with the longer diameter of Burke Garden and Round Mountain. Originally the fold was complete, as shown in Fig. 2M, the beds of rocks passing from the anticline into the syncline without a break, but when the pressure from the southeast or from the right in the diagram, became too intense, the rocks of the syncline broke and the Shenandoah limestone was shoved up onto the limb of the anticline.

This break or fault in the formation passes through the town of Bland and, on that account, is called here the Bland fault. This is the fault that generally limits the coal fields of Bland and Smyth counties on the southeast.

East of the town of Bland the Price formation lies on the southeastern limb of an anticline that is subordinate to the main anticline through Burke Garden. The axis of the small anticline corresponds with the crest of Brushy Mountain. In the Pocahontas folio the author[1] mapped this limb of the fold as being simple throughout, but in a recent reconnaissance of the field he found many complications that seriously affect the lay of the coal beds, not only in the areas where the Price formation crops out, but also probably in the areas where the coal beds are under the limestone, thus determining to a certain extent whether or not they may be found beneath the Shenandoah limestone, and if so the depth to which they may descend. The recent examination tends to show that the belt of outcrop of the Price formation lies very close to the axis of the syncline that once existed between Garden and Walker mountains, and that in places remnants of the upturned or even overturned southeast limb of this syncline is preserved, as shown in the following more detailed description of the structure of the different portions of the field.

In his recent examination of this field the author found exposures of rock which suggest that the eastern extremity of the field is not simply determined by the place where the Bland fault cuts out the Price formation, but that the formation probably lies in a syncline and its eastward termination is brought about by the rising of this syncline and the consequent pointing out of the formation in a spoon-shaped structure similar to the structure at the west end of the Reed Creek coal field. The

[1] Geologic Atlas of the United States, folio No. 26, 1894.

evidence of such a termination is not conclusive and, as it does not materially affect the amount of coal here present or the lay of the coal bed, it was not pursued far enough to establish it as more than a probability.

At loc. 3, Fig. 24, however, there are signs of coal within 100 feet of the Bland–Point Pleasant road, which, from the nearly vertical position of the outcrop and its greatly crushed condition, seem to point clearly to the fact that here is a small portion of the southeastern limb of the syncline which has not been obliterated by the great mass of Shenandoah limestone thrust against and upon it, but in some way it has been preserved, though in a much shattered condition. As shown in Fig. 24, this exposure of coal is much too far south to be in line with the prospects on either side, and as these prospects are seemingly without question on the northwest limb of the syncline, it is evident that the coal observed at loc. 3 must lie upon the southeast limb, which is so badly crushed that the other rocks, especially the hard sandstones that usually underlie the coal beds, are not recognizable.

From loc. 3 westward to beyond loc. 9 the structure appears to be simple and all of the prospects visited are on the northwest limb with the dip to the southeast about 23°. The outcrop of the coal bed continues southwestward beyond loc. 9 and crosses the county road, which near the head of Town Creek turns to the northwest and crosses a low divide to Laurel Creek. Immediately after crossing this road the outcrop of the coal group makes a sharp bend to the north and its outcrop almost coincides with the road for a distance of nearly a mile. At this sharp bend the strike of the coal bed changes from S. 60° W. to N. 40° W. with low dips to the southwest. At loc. 11 the coal bed recrosses the road to the north, but a short distance farther on it swings sharply to the southwest along Laurel Creek in a course at right angles to that which it followed across the divide. The trace of the Bland fault is close to the outcrop of the coal bed and it bends in conformity with the bends of the coal outcrop.

This new course of the coal is followed through locations 12, 13, and 14, but about one mile southwest of loc. 14 the coal outcrop as well as the trace of the fault again makes a right-angled bend similar to, though on a smaller scale than, that at the head of Town Creek. From loc. 15 the course of the coal crop follows a direct line to the southwest, but the trace of the fault swings somewhat to the south and encloses, for about a mile, a portion of the southern limb of the syncline which forms a low ridge parallel to and on the south side of Brushy Mountain. The coal lies on the northwest side of this ridge. Just north of Sharon Springs the fault crosses and conceals the southeast limb of the syncline, but the outcrop of the Price formation continues to the southwest, forming the south slope of Brushy Mountain.

The meaning of the right-angled bends of the coal outcrop and the similar bends in the trace of the Bland fault is not clearly understood. The pronounced bend at the head of Town Creek seems to be connected in some way with the similar, though much more pronounced bends in Walker Mountain and in Little Walker Mountain in Wythe County. It seems possible that great earth folds such as are indicated by Walker and Little Walker mountains may have been offset at the time of their formation, but it is difficult to conceive of conditions that would produce similar bends in the traces of the longitudinal faults, such as are clearly visible here not only in the Bland fault but also in the Pulaski fault on Reed Creek. It seems more reasonable to attribute such cross-folds to movement in the earth's crust at a later period of its history than the one in which the great northeast-southwest folds were produced. The writer knows of no data by which the date of this cross-fold may be determined. The effects of the fold are most pronounced in Little Walker Mountain where the movement was so great that it resulted in a cross-fault (Reed fault) which cuts Little Walker Mountain in two, are less pronounced in Walker Mountain, but still great enough to change the general position and trend of the range more than two miles, and offset the Price formation and the Bland fault fully three-fourths of a mile. The trend of this cross-fold is about N. 30° E.

A similar offset occurs where Cove Mountain and Brushy Mountain unite north of Effna. The cause of this right-angled offset in both the coal outcrop and the Bland fault is not so obvious as that which produced the offset just described, but by analogy it seems probable that it is the result of a subordinate wrinkle parallel with the main cross-fold already described. This assumption receives some support from the possible offset in Walker Mountain one mile northeast of Tillson Gap on the southwestern boundary of Bland County, but the inadequate maps of this region render it impossible to say whether this bend in the mountain is real or only existed in the mind of the man who mapped it.

Southwest of the bend in Brushy Mountain near Effna, a small ridge makes its appearance on the southeast side of Brushy Mountain, and it extends parallel with that mountain to within a quarter of a mile of the Sharon Springs–Burke Garden road. This ridge is composed of Devonian flagstones and is a remnant of the southeast limb of the syncline, with coal beds on its northwestern side.

Between Sharon Springs and Ceres, the geologic structure of Brushy Mountain was not accurately determined but, as the outcrop of the Price formation is very narrow, the structure is either monoclinal, i. e., dipping in one direction and therefore probably a part of the southeast limb of the Burke Garden anticline, or a syncline with the southeast limb overturned and crushed nearly out of existence. The latter condition prevails at the crossing of the Burke Garden road north of Ceres, for here the coal has been prospected high on the southeast slope of the ridge and the Devonian black shale has been overturned and crushed in against the Price formation near the foot of the mountain.

Southwest of the Burke Garden road the structure is more complicated, as the coal-bearing rocks lie in two synclines, one of which is the southwestward extension of the one just described as extending in this direction from near Sharon Springs and the other is an entirely independent syncline which is developed on the northwestern side of Brushy Mountain. The structure at loc. 16 about a mile west of the "Double" is shown in Fig. 25, which is supposed to represent a section across the two areas of coal-bearing rocks. Still farther toward the southwest the Bland fault departs more and more from Brushy Mountain and more and more of the syncline appears, until at loc. 20 about 7 miles west of Ceres the structure of the two synclines is as shown in Fig. 26. Here the southeast limb of the southern syncline carries the Clinch sandstone completely overturned and preserved for only a short distance. This limb of the syncline is badly crushed and it is doubtful if the whole of the Devonian sandstones and shales is present. Finally at loc. 25 where Lick Creek cuts directly across the strike the synclines have the structure represented in Fig. 27. In this section the southernmost syncline is complete as far as the Carboniferous rocks are concerned, and the fold is overturned so that both limbs dip toward the southeast.

A little farther to the southwest from the place where the section in Fig. 27 was determined the Bland fault swings sharply to the north cutting off both synclines, but here another fold comes in still farther to the northwest so that the band of coal-bearing rocks is continued past Chatham Hill and on to the southwest in the direction of Saltville.

From Chatham Hill to Maccrady, a short distance northeast of Saltville, the general structure of the Price formation is monoclinal, but southwest of Maccrady the structure is distinctly synclinal, the Carboniferous limestone overlying the Maccrady shale on the axis of the syncline.

Throughout the coal fields of Bland and Smyth counties the southeastern limit of the Carboniferous rocks is marked by the Bland fault. As this fault is of the overthrust variety, it is clear that the Shenandoah limestone, which is the lowest formation in the overthrust mass, is thrust over the Carboniferous rocks and, therefore, for a certain but undetermined distance the Carboniferous rocks (Price formation) underlie it, but at a constantly increasing depth toward the southeast.

This structural relationship is of the greatest importance to anyone attempting to mine the coal beds in the Price formation, for if he is limited in his mining operations to the actual outcrop of the Price formation, he will have a very restricted field down the dip of the coal beds, but if the coal beds pass under the limestone, then the territory available for mining operations may be greatly increased. There is much uncertainty in the minds of citizens living in these fields regarding this point, but judging entirely from the geologic evidence, there can be no question about the coal beds in places passing beneath the limestone, but there is great uncertainty about the distance they extend below the fault line.

Description of coal prospects.

PROSPECTS IN THE BLAND FIELD.

The coal beds in the Bland coal field have been exploited in only a desultory way to find out what they are like, or to supply some local blacksmith with fuel for his forge. Wood has been too abundant and too easily obtained to make it profitable to mine coal on a commercial scale, and most of the drifts that have been driven into the hillsides have been neglected and allowed to cave. Owing to this neglect, the pits are now full of earth and rocks or of water, and it is almost impossible to see the coal in place, to measure the beds or benches, and to secure unweathered samples for analysis. Considerable coal has been mined at the different prospects and the fragments of coal still to be found on the old dump heaps indicate that there are at least some benches of good hard coal. The crosses (X) on the map, Fig. 24, show the location of prospects that were visited, but there are doubtless many more, though they are probably caved, or the geologist would have heard of them. Only those prospects will be described in which sections of the coal bed were measured, or other information of value was obtained. The prospects will be described in regular order from east to west beginning near the village of Point Pleasant.

In passing westward from the east end of the Bland coal field the first prospect to be noted is that at loc. 1 (see fig. 24), about a mile west of Point Pleasant. Howell visited this prospect in 1914 and reports that it had caved, but some bright coal was still showing on the dump heap. At loc. 2 there have been some pits opened by the side of a small branch but, at the time they were visited, these pits were inaccessible and the only coal in sight is a bed about 14 inches thick, exposed in the bed of the branch. The dip of this coal bed could not be definitely determined, but it appeared to be nearly perpendicular and the coal to be badly crushed. At loc. 3, as already described, there is a natural outcrop of a coal bed which is thin and greatly crushed because it is in the upturned southern limb of the syncline. It is so badly crushed that economic mining would be impossible.

The next prospect of importance is that on the land of T. C. Thompson (loc. 4). This prospect consists of an entry driven into the hillside just above the level of the creek, for a distance of more than 100 feet. The mouth of the drift was closed by material caved from the roof, but a little digging enabled one to enter. The last work had been done many years ago and the coal appears to be badly weathered, at least it is very much softer than fresh coal would be. Owing to the extent of weathering, especially of the upper benches, it did not seem worth while to cut a sample entirely across the bed in the ordinary way, but a small quantity of coal was dug from the lower bench, which in normal times is under water, and this was regarded as sufficiently fresh to be worthy of analysis, particularly as the object of the analysis was to determine the percentage of ash and the rank[1] of the coal. The analysis of this sample, shown as number 95405 on page 113, indicates that the coal is semibituminous in rank, though somewhat harder than coal of a similar rank from the Pocahontas or New River field of West Virginia. A rough section of the coal bed measured about 50 feet from the mouth of the drift is as follows:

Section of coal bed at the Thompson prospect, loc. 4.

	Ft.	In.
Shale, roof.		
Coal and shale	2	3
Shale		8
Coal	1	9
Thickness of bed	4	8
Thickness of coal	1	9

[1] For definition of the word rank see p. 98.

The upper bench consists of about equal amounts of coal and shale in five layers. The coal of the bottom bench appears to be harder and better than that of the upper bench and therefore was sampled as noted above. The shale roof, although exposed to the weather for a great many years, is excellent, showing only a few insignificant falls. The coal bed strikes east-west and dips south 27°.

In 1914 Howell visited the prospect of C. Leslie (loc. 5) about 1 mile east of Bland. The coal is much crushed, but the following section was obtained:

Section of coal bed at loc. 5.

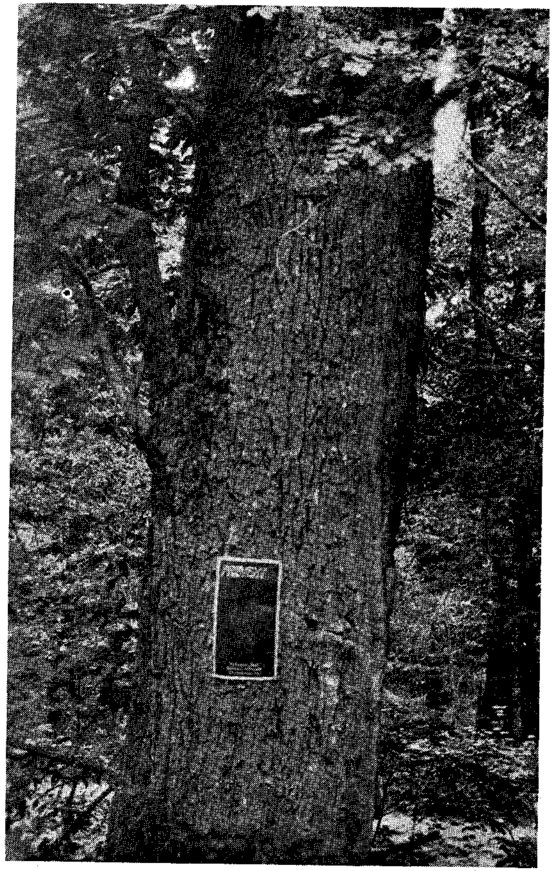
	Ft.	In.
Coal, hard		7
Shale		2
Coal, hard		2
Shale		3
Coal	1	11
Thickness of bed	3	1
Thickness of coal	2	8

The coal, according to report, was once prospected at loc. 6, but the old prospect is caved and the coal can not be seen. A little farther west, however, at loc. 7 on Crab Orchard Creek a drift in the hillside on the property of D. W. Dunn, revealed a very poor coal bed, as shown by the following section:

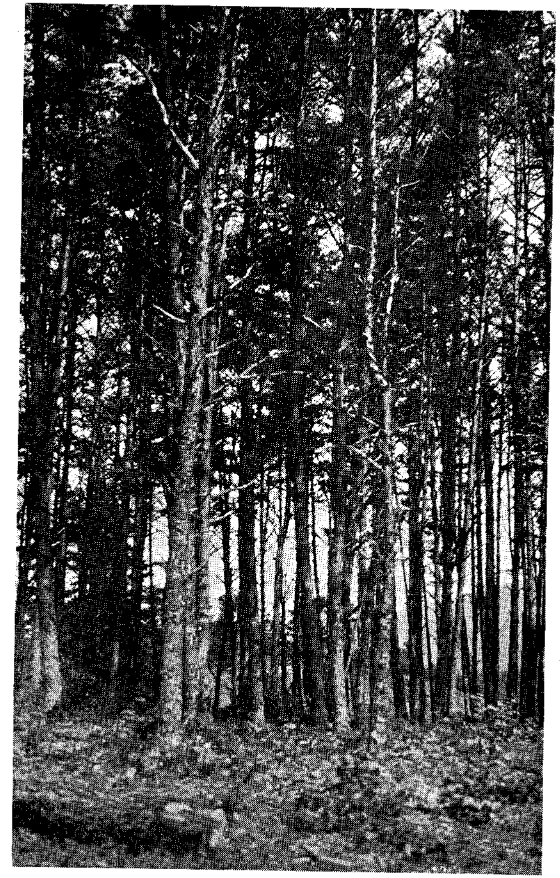
Section of coal bed at loc. 7.

	Ft.	In.
Coal and shale interbedded	3	2½
Shale		6¼
Coal, hard		8¾
Thickness of bed	4	5½

This bed dips to the south 23°. It is reported that a coal bed was once opened just across the hill to the east of loc. 7, from which good coal was obtained for the use of local blacksmiths. The coal was obtained from pits in the bottom of the ravine and no one knows the thickness of the bed. These old pits were not visited, but, judging from the description given, they appear to have been on a lower and better coal bed than that shown at loc. 7. About one-quarter of a mile farther up Crab Orchard Creek and in strike with loc. 7 an old drift (loc. 8) shows the following section:

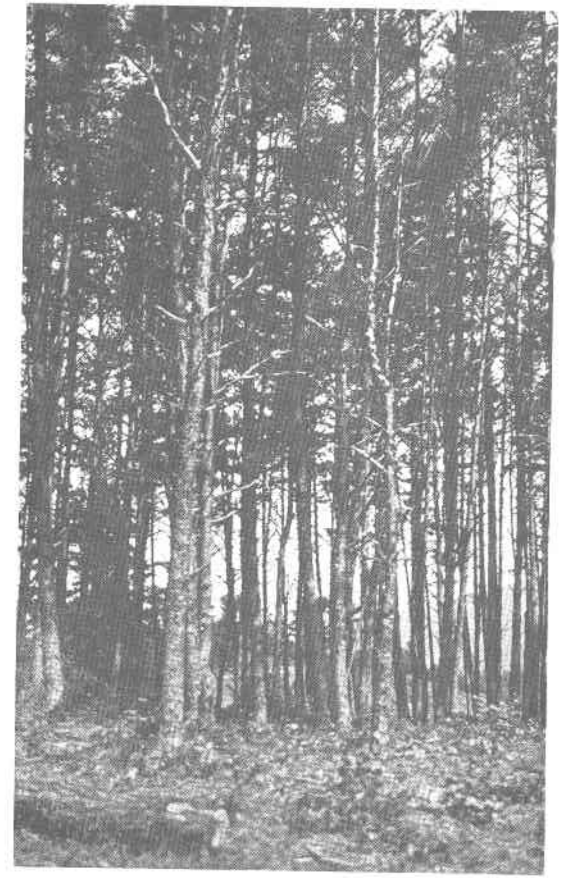


(A) A specimen of the original growth. A veteran chestnut oak, on a northern exposure. Montgomery County.



(B) Young stand of scrub pine with some shortleaf pine, such as commonly comes in on the abandoned fields. On Little Walker Mountain, north of Wytheville.

(A) A specimen of the original growth. A veteran chestnut oak, on a northern exposure. Montgomery County.



(B) Young stand of scrub pine with some shortleaf pine, such as commonly comes in on the abandoned fields. On Little Walker Mountain, north of Wytheville.

Section of coal bed on Crab Orchard Creek at loc. 8.

	Ft.	In.
Coal	1	9½
Bone		9
Coal	1	4
Thickness of bed	3	10½
Thickness of coal	3	1½

The next place at which the coal bed was seen is on the Howard Stowers farm at loc. 9. Here a coal bed has recently been faced up in the steep side of a ravine where it dips south 22°. The upper limit of the coal is uncertain as the shale overlying the coal has weathered to a tough clay. The section here is as follows:

Section of coal bed on the Howard Stowers farm, loc. 9.

	Ft.	In.
Shale, carbonaceous (?).		
Coal, shaly		3
Coal, laminated		9
Coal	a 3	3
Coal, hard		6
Thickness of bed	4	9
Thickness of coal	4	6

As the coal at this exposure appeared fairly fresh, though doubtless more firable than it would be under thick cover, a sample was cut of the bench marked *a* for analysis. The result of the analysis is shown as number 95406 on page 113. The section of the bed given above does not resemble in any respect the sections previously given and hence it is concluded that the bed showing at loc. 9 is not the same as those seen farther east, but may be the bed that was mentioned as having been worked near loc. 7.

Southwest of loc. 9 the coal bed continues parallel with the main road as far as the road which turns off from the main valley road near the head of Town Creek and crosses the divide to Hunting Camp Creek. Immediately after crossing this road the outcrop of the coal bed swings about at right angles to its previous course and runs parallel to the Laurel Creek road across the divide. The northwestward course of the outcrop is marked a short distance north of the turn by an old prospect (loc. 10) which now is so badly slumped that the coal bed is not visible. A short distance farther on the outcrop crosses the road (loc. 11) and lies for a few hundred yards on the east side of the road.

As indicated on Fig. 24 the outcrop again makes a right-angled bend and resumes a course parallel with, but about a mile farther northwest than its former course. Prospects were visited at locations 12, 13, and 14, but all were so badly caved that no coal, except that showing on the old dump heaps, could be seen. The coal bed here dips gently to the south at an angle not to exceed 15°.

At loc. 14 the outcrop of the coal bed is very close to the Shenandoah limestone and it is probable that a mile or more to the southwest, as shown on Fig. 24, it is overriden and concealed by the limestone. Near loc. 15 north of Effna the outcrops of coal beds make a sharp bend to the northwest similar to, but much smaller than, the bend at the head of Town Creek.

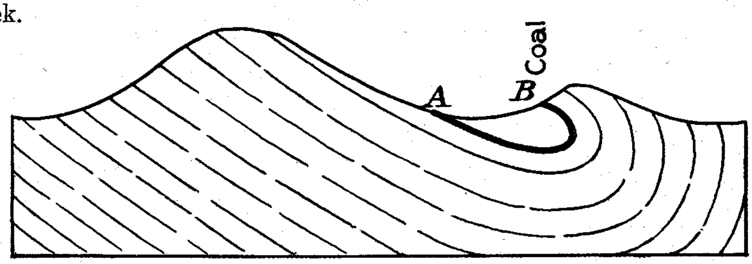


Fig. 25.—Sketch section showing structure at loc. 16 in the Bland coal field.[1]

At loc. 15 there have been a number of prospects on the coal, but all are caved now and inaccessible, but from this place southwestward, through locations 16 and 17, the southeast limb of the syncline is preserved, though badly squeezed. This limb of the fold is marked by a ridge of Devono-Carboniferous rocks on the northwest side of which the coal bed has been prospected. The attitude of the coal bed at loc. 16, while not worked out in detail, must be approximately that represented in Fig. 25. The bed outcrops on the south slope of the main ridge at A and in overturned position on the north slope of the secondary ridge at B. In 1914 Howell visited loc. 17 and measured the following section[1]:

Section of coal bed at loc. 17.

	Ft.	In.
Coal, soft and flaky	1	6
Shale	1±	
Coal, hard	2	0
Shale	1±	
Coal	2	6±
Thickness of bed	8	0±
Thickness of coal	6	0

[1] Since the above description was written this prospect has been reopened and a picked sample of the best coal furnished the following analysis: moisture, .8; volatile matter, 21.6; fixed carbon, 63.1; ash, 14.5; sulphur, 2.1; and B. t. u.'s, 13210.

Just southwest of loc. 17 the overturned limb of the syncline is cut off by the Bland fault, and it seems highly probable that the outcrop on the north limb follows the main ridge, but if so it is well up on the slope and is in such a position that it is doubtful if it could be mined on a commercial scale.

PROSPECTS IN THE LICK CREEK FIELD.

At the Ceres–Burke Garden road where this field is arbitrarily separated from the Bland field, a distinct faulted syncline comes in, which splits Brushy Mountain into two distinct ridges. The place where the ridge splits is locally called the "Doubles." An old prospect (loc. 18) is near the road mentioned above and from its associated rocks it undoubtedly belongs on the southeastern limb of the syncline, though the rocks are so badly crushed that it is difficult to separate one limb from the other.

Howell in 1914 visited two prospects about one mile southwest of the "Doubles"; one on the head of Camp Creek (loc. 19) and the other near the summit of Brushy Mountain (loc. 20). The coal bed at loc. 19 is reported to be 5 feet thick but with considerable shale and pyrite. The prospect is caved so that the coal is not now visible, but from the reports the coal is of doubtful value. The strike at loc. 19 is N. 45° E. and the dip is 26° to the southeast. This coal bed is probably in the northwestern or Lick Creek syncline and if so, it probably does not extend downward very far until it is cut off by the fault which closely follows Camp Creek. The structure at this locality is shown in Fig. 26.

The opening near the summit of Brushy Mountain (loc. 20) is in a coal bed reported to range in thickness from 6 to 8 feet with the following section:

Reported section of coal bed at loc. 20.

	Ft.	In.
Coal	1	6
Shale		1±
Coal	2	0
Shale		1±
Coal	2	6
Thickness of bed	6	2±
Thickness of coal	6	0

If the benches of coal reported in the section given above contain clear coal this would be a most promising coal bed, but from the poor showing in most of the prospect pits of this county it is difficult to believe that such a bed as this will be found here.

The author in 1893 observed 4 feet of coal and shale dipping 60° southeast at loc. 21. The bands of shale are so numerous that the coal bed was regarded as of little value. The steep dip at this prospect (60°) indicates that this outcrop is in the overturned southeastern limb of the Brushy Mountain syncline.

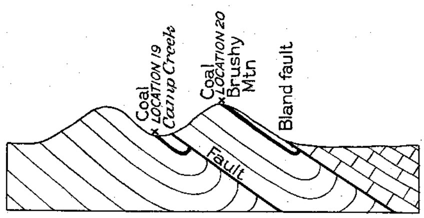


Fig. 26.—Sketch section showing structure at locs. 19 and 20 in the Lick Creek coal field.

The coals on Lick Creek have not been thoroughly prospected and such prospecting as has taken place was done so long ago that there is now little to be seen of even the prospect pits. Coal or old coal prospects were seen at locations 22, 23, 24, 25, 26, and 27, but nothing was seen that would indicate the presence of a coal bed more than 18 inches thick. The coal-bearing rocks are well exposed on the road across the ridge, on which loc. 24 is situated. On this road, which crosses the Brushy Mountain syncline, the rocks are well exposed, including the red shale of the Maccrady formation in the axis of the fold. The structure at this place is shown in Fig. 27. At loc. 24 there are several beds of coal exposed but none of the beds

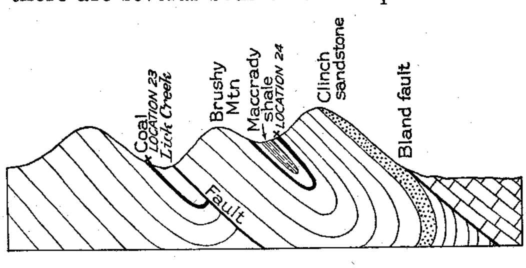


Fig. 27.—Sketch section showing structure at locs. 23 and 25 in the Lick Creek coal field.

has a thickness greater than 10 inches. As there are several of these beds in a group, it is likely that they have been considered as one bed, and if so the bed would have a thickness of at least 5 feet, but about 75 per cent of the bed thus defined consists of shale and is worthless. The dip at this place is 40° S. E.

Similar small benches of coal show in the road at loc. 22, but nothing was seen to indicate a workable coal bed. Howell reports an old prospect in this vicinity which he visited in 1914. Several wagon-loads of coal had been dug here, but the bed is reported to have pinched out in a short distance, showing that the rocks here have been subjected to intense pressure. The rocks strike N. 48° E. and dip 60° SE. At loc. 23, coal has been dug in a prospect pit located near the base of the Maccrady shale, but the pit is caved and only small fragments of coal were seen on the dump.

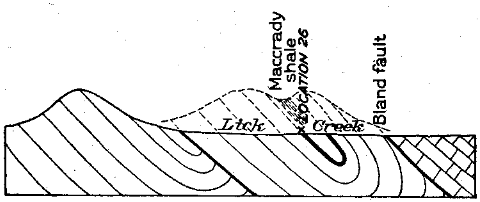


Fig. 28.—Sketch section showing structure on Lick Creek, at loc. 26.

Howell reports a coal bed 6 or 8 inches thick showing at loc. 25, and the author dug up some coal in a ploughed field at loc. 26, but all that was seen could have been in a bed less than 18 inches thick. The structure at loc. 26 is shown in Fig. 28. Coal was also seen at location 27, but here, as elsewhere in this district, the coal occurs in thin layers that can not be considered of workable proportions.

Little is known about the coal beds in Smyth County west of Lick Creek. Coal has been found in Marleys Top which is an isolated area of the Price formation in the westward extension of the Reed Creek field of Wythe County. As the outcrop of the Price formation is very limited in area and as the coal bed appears to be thin and full of shaly partings, the occurrence is not of much importance.

Coal is also reported on Lick Branch, north of Chatham Hill and at a few places farther to the southwest toward Saltville, but the reports are all vague and unsatisfactory. As the coal beds are known to grow thinner and thinner toward the west and as the quality of the coal certainly deteriorates in the same direction, the chance of finding commercially valuable coal in this field seems very remote indeed, so much so that the question will not be pursued further here.

QUALITY OF THE COAL.

With only two analyses of the coals of Bland and Smyth counties at hand, it is rather difficult to pronounce upon the rank and grade of the coal. If the samples which were analyzed consisted of fresh coal, then there would be no excuse for not being able to make a correct statement regarding their quality, for the analyses could be relied upon to express the true composition of the coal. No mines are in operation in either Bland County or Smyth County and the only coal available for analysis was the coal from the old prospect drifts or from natural outcrops. The next important question to decide is whether or not coal under such conditions is weathered and materially changed in its physical and chemical composition.

In coals of lower rank the question can at once be answered in the affirmative for, on exposure at the surface or in such positions that the coal is subject to alternate wetting and drying, it will oxidize quickly and samples of such coal will no longer be representative of the coal in an unweathered condition; higher rank coals oxidize much more slowly and probably are not much affected by exposure to the weather for a year or more, but eventually such coal will yield to the invidious attack of the elements.

During the course of the present work, the author had opportunities to test the effect of weathering of the coal of the Valley fields and he has concluded that the coal on weathering will soon be affected mechanically so that the hard coal will break up into small lumps and the originally jet-black glossy coal will become so friable that it may be crushed in the hand. Even coal that has stood under water for ten or more years will be similarly affected, though water is the best preserver of coal that is known. Several samples of coal that were rendered soft by weathering have been analyzed and found to be unaffected chemically, so that the analysis agrees almost perfectly with that of a sample collected in a near-by mine where there is no question about its fresh and unchanged condition. From several such experiences as this it is concluded that coal, no matter how long it has been exposed at the surface, will remain chemically unchanged, provided it is generally saturated with water either by being submerged or by being covered with an impervious cover, such as a bed of clay, that retains most, if not all, of the moisture in the coal.

Having reached this conclusion, we shall now see if it applies to the two samples collected in the Bland field. Sample 95405 (see page 113) was obtained in an old drift (loc. 4) which was driven into the side of the ravine only a little above the level of the creek. Mr. Thompson states that work was abandoned largely because water stood for most of the year in the lower parts of the drift, but at the time of sampling, owing to an unusual and prolonged drought, the entry was dry. The writer studied the situation carefully before attempting to secure a sample for analysis, and he concluded that the upper parts of the coal bed, where they have been above water level for 15 or 20 years, were too much weathered to furnish a typical sample of the coal, but that the lower bench, which, judging from the water mark on the sides of the drift, had been generally submerged and hence was probably little if any affected. Accordingly, a sample of the lower bench of coal was cut and the cutting revealed the fact that, although the coal was comparatively soft, it still retained its blocky, cubical character, indicating that chemically its composition was little if any changed.

The sample obtained on the farm of Howard Stowers (loc. 9) furnished analysis No. 95406 on page 113. The coal at this location is exposed in a very different manner from that just described. It has been uncovered in the side of a sharply cut ravine by a slight excavation which, when squared up, exposed the entire coal bed on a flat surface. When the coal bed was faced up all of the obviously weathered coal was removed, leaving bright, shining coal at the face and, though the coal was somewhat soft, so that it was easily pulverized to a degree of fineness to enable it to pass through a screen with one-half inch mesh, it still had a fresh and bright appearance. The bank above the coal was composed of a yellow, tenacious clay, which appeared to be nearly impervious, and doubtless had greatly aided in retaining all of the moisture that the coal contained. Under such conditions the writer concludes that the coal was practically fresh and therefore worthy of analysis.

The conclusion reached in regard to each of these samples seems to have been completely verified by the analyses, which are almost identical, despite the different conditions under which the coal had been preserved. As these conditions are so different, it was expected that the analyses would be dissimilar, but being similar proves that the coal in each prospect was in the same condition, and this condition could hardly have been very different from the original condition. It is true that both samples might have been weathered and that in both cases the weathering had been carried to the same point, but such an agreement would have been merely a coincidence and the chances are decidedly against it having occurred. The analyses are therefore regarded as fairly indicative of the unweathered coal of the Bland field.

If analyses 95405 and 95406 are regarded as typical of the coals of the Bland fields, the next point to be considered is the rank of the coal, or, in other words, the degree to which it has been changed by the heat of the earth's crust. Is the Bland coal a semianthracite, as are most of the coals of Montgomery, Pulaski, and Wythe counties, or is it of lower rank? As defined on page 126, a semianthracite is a coal having a fuel ratio—percentage of the fixed carbon divided by the percentage of the volatile matter —of 9.99 to 5, and as the fuel ratio of the coal of the Bland field is only about 3, it is obvious that the Bland coal should not be called a semianthracite, but belongs to a still lower rank, more nearly resembling the Pocahontas and New River coals of the bituminous fields to the west. The next rank below that of semianthracite is semibituminous, and this rank is here tentatively defined as coal having a fuel ratio ranging from 4.99 to 2.5. The lower limit is not yet clearly determined, but, from the evidence at hand, it appears that most of the bituminous coals have a fuel ratio less than 2.5 and most of the semibituminous coals have a fuel ratio of 2.5 or more. Classifying the Bland coal as semibituminous puts it in the same rank as the Pocahontas and New River coals which are the so-called "smokeless" coals, and also among the finest steaming coals of the world.

The greatest drawback to the Bland coal, as shown by the few analyses now available, is the large percentage of ash which it carries. Here again the comparison of the analyses of the two samples is most interesting, for analysis 95405 represents only a single bench of coal, whereas analysis 95406 represents practically the entire bed. It therefore seems reasonable to conclude that the results shown by these analyses are typical of the coals of the field. Sample 95405 contains 49.2 per cent of ash and sample 95406, 46.9 per cent.

The percentage of ash in the Bland coals, if the two analyses given above are typical, is entirely too great for these coals to be sold as a fuel, and even if they could be cleaned by picking and washing so as to reduce the ash content to 10 per cent, it is doubtful if the operation of mining could be made to pay, for with a coal containing 50 per cent of ash, at least 40 per cent is waste material that would have to be mined, loaded into cars, hoisted to the surface, and then thrown away. All of these operations are expensive and they would so add to the cost of operation that the coal could never compete with coal from near-by fields, or at least could not be disposed of at a profit until all of the better coal had been exhausted. Such conditions are too remote to be considered at the present time.

The general conclusion is, therefore, that the coals of the Bland field, as far as they can be judged by the samples collected in this work, contain too much ash to be marketed, at least for a long, long time to come, and if they are ever placed on the market they should be called semibituminous coal and not anthracite or even semianthracite.

No analyses of the Lick Creek coals are available for comparison, but since the fields are practically continuous, and since the field observations, as far as they go, seem to indicate much the same kind of coal, the writer has tentatively concluded that the remarks regarding the coal of the Bland field are equally applicable to the coals of the Lick Creek field, and consequently, this coal will be ranked as a semibituminous coal but with such a large amount of ash that it can hardly be considered as a commercial possibility at the present time or in the near future.

FIELDS OF ROANOKE AND BOTETOURT COUNTIES.

By Marius R. Campbell and Ralph W. Howell

General description.

These fields are the northeastward continuation of the Brushy Mountain coal field of Montgomery County. The outcrop of the Price formation, which is the coal-bearing formation of this region, follows Brushy Mountain northeastward to its termination at Millers Cove, but it comes in again just east of McAfee Gap and follows North Mountain and Caldwell Mountain to the gap northwest of Fincastle, as shown in Fig. 29, where the coal field ends, because of the termination of the outcrop of the Price formation. As North Mountain is the most conspicuous feature in this region, the field will be called the North Mountain coal field.

The field consists of the coal-bearing formation which dips to the southeast and forms the southeastern slope of the mountains mentioned above. Near the foot of the slopes the coal-bearing rocks are concealed by the Shenandoah limestone which has been thrust over and now rests upon and conceals the coal-bearing rocks. This limestone, therefore, as far as surface observations are concerned, limits the coal field in this direction, but in reality the limestone merely rests upon the coal-bearing rocks and it is highly probable that drilling would disclose the presence of the Price formation under the limestone at a considerable distance south of the trace of the fault.

Geologic formations.

Within the limits of the field described above coal was noted at but four localities, but it is probable that thin, irregular beds extend the full length of the outcrop of the Price formation. As shown on Fig. 29, the coal-bearing formation outcrops on the east flank of Brushy Mountain, North Mountain, and the western part of its northeast extension, Caldwell Mountain, in a relatively narrow band of southeastward dipping strata. The red

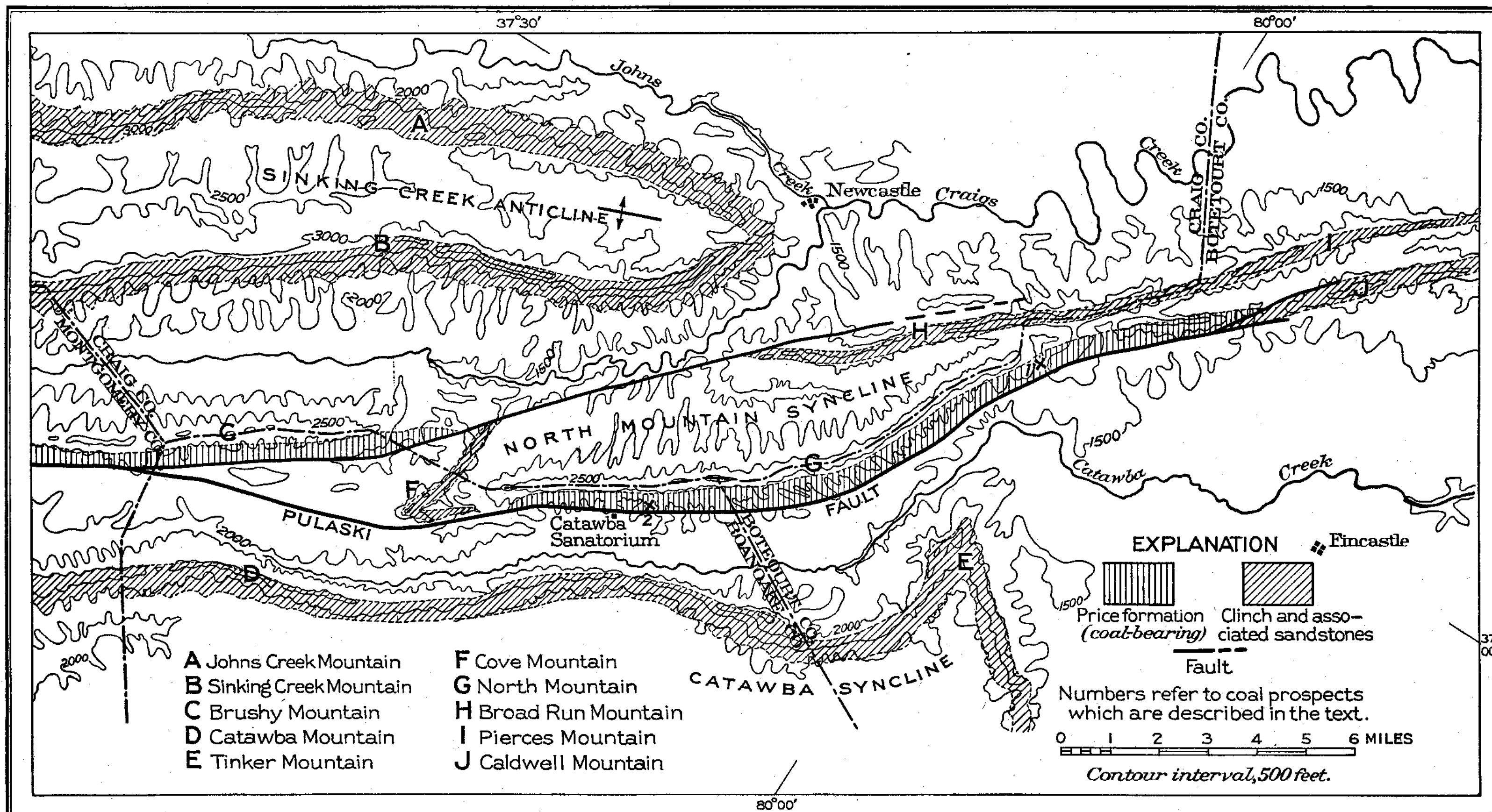


Fig. 29.—Map of the North Mountain coal field in Roanoke and Botetourt counties.

Maccrady shale, which farther toward the southwest overlies the Price sandstone, was not observed in this field, though it may be present. It is altogether probable that the Maccrady shale is concealed by the Shenandoah limestone, which is faulted over and rests upon the Price formation. The fault (Pulaski) which brings the Shenandoah limestone upon the Price is of great displacement and length and it undoubtedly cuts out the coal at some point below the surface, but the exact place can be determined only by a large amount of drilling. On account of the uncertainty regarding the presence of the coal beneath the overthrust limestone mass, it is not advisable, in calculating the area of the field, to include more than that which intervenes between the outcrop of the coal bed and the edge of the overthrust limestone.

Geologic structure.

In the North Mountain field, as in all other fields of Mississippian coals in Virginia, the movements of the containing strata which occurred coincident with the folding and faulting of the rocks, have developed stresses within the coal beds which have broken and shattered the coal and in places fairly ground the less resistant portions to a fine powder. The coal beds in many places consist of an intimate mixture of coaly debris and shattered shale or bone partings. In some places the bed may be pinched out and in other places the coal may have accumulated in a lense of great thickness many times the normal thickness of the coal bed. The simple statement that the coal beds are generally thin and irregular in thickness and that the coal is usually broken, soft, and impure, hardly gives an adequate idea of the unfavorable conditions that may be encountered.

The geologic structure in this field (Fig. 29), as worked out by Professor Holden,[1] is that of a badly crushed syncline which has been thrust northwestward upon the great Sinking Creek anticline in the west and upon a syncline in Devonian rocks near James River. The southwestern end of this crushed syncline is Cove Mountain, just east of Millers Cove. This ridge is formed of the Clinch sandstone and its southern end is the point of the syncline. The north limb of the syncline is outlined by Cove Mountain for a distance of about 2½ miles, but beyond that the Clinch sandstone appears to be lacking for 5 or 6 miles and then comes in forming Broad Run Mountain and is probably continued in Pierces Mountain to within 4 or 5 miles of James River. The mountains are here broken, but it is known that the Clinch sandstone forms Caldwell Mountain, which is

[1] Unpublished data given in a personal communication.

therefore on the southern limb of the syncline. This limb is faulted off at the gap northwest of Fincastle and there abuts almost directly against the end of North Mountain, which is a Devono-Carboniferous ridge, and therefore marks the axis of the syncline. The south limb of the fold is gone from the gap northwest of Fincastle to McAfee Gap where the Clinch sandstone again comes in, but badly crushed and broken, and unites with the Clinch of the other limb at the south end of Cove Mountain.

There is another area of outcrop of the Price formation in Roanoke County which does not show on any of the maps in this report, for the reason that it is not supposed to be coal-bearing, at least in a commercial sense. The outcrop of the Price formation referred to occupies a narrow zone on the south side of Fort Lewis Mountain extending from near La-Fayette on the west toward Salem, but is probably cut off by the Salem fault before reaching a point opposite that town.

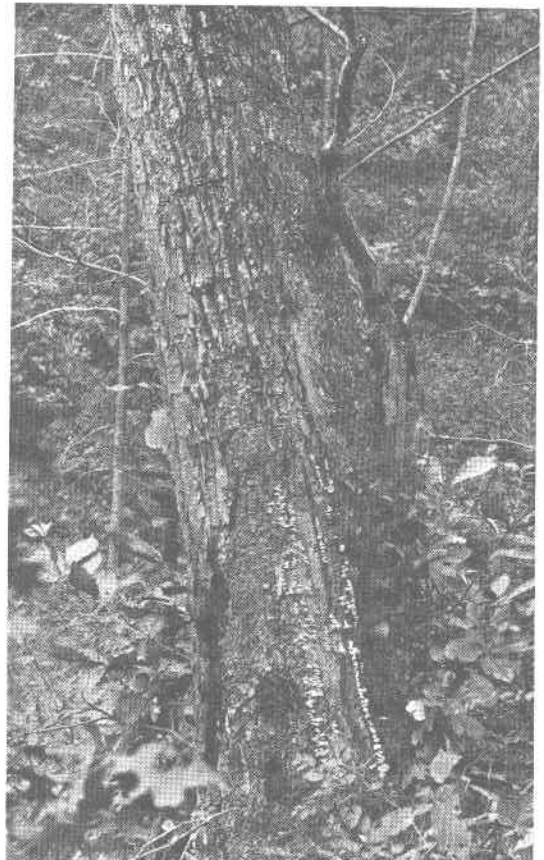
This outcrop of the Price formation occupies nearly the axis of the Catawba syncline, the north limb of which is marked by Paris, Catawba, and Tinker Mountains, shown on Pl. I and Fig. 29. This great syncline is abruptly terminated on the south by a fault which the authors are calling the Salem fault because it passes near, but a little north of that town. This fault has completely obliterated the south limb of the syncline, especially at the west end, bringing the Shenandoah limestone in contact with the Price formation, or where that is absent, with the sandstones and shales of the Devonian.

Description of coal prospects.

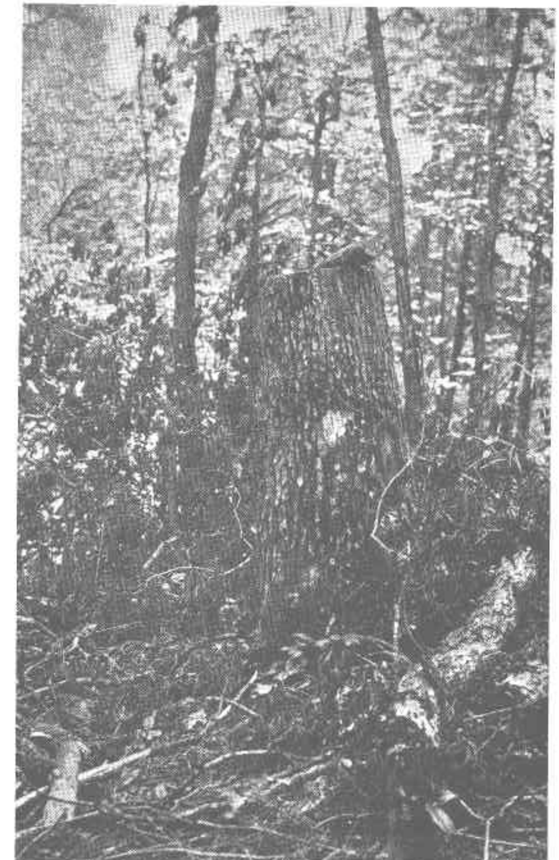
The best known coal prospect in this field is that which was opened many years ago on Stone Coal Run (loc. 1), in the gap directly west of Fincastle. This coal attracted considerable attention during the Civil War, both because of its supposed value as a fuel, and because of its proximity to iron ore and the Catawba iron furnace then in operation. The old numbers of *The Virginias* (Vol. 4, 1883), a newspaper published by Jed Hotchkiss of Staunton and devoted to the exploitation of the natural resources of Virginia, furnish some interesting material regarding the opinions of eminent engineers of that time concerning these coal beds. Mr. Oswald J. Heinrich inspected the mines in these coal beds for the Confederate States authorities and under date of Feb. 13, 1864, submitted the following report:

(A) A chestnut, killed by fire. Wythe County.

(B) Waste in logging in a recent operation in Pulaski County. A sound white oak stump 5 feet high.



(A) A chestnut, killed by fire. Wythe County.



(B) Waste in logging in a recent operation in Pulaski County. A sound white oak stump 5 feet high.

The seam of coal, which has lately been opened, is the upper seam, mentioned in my report of last year as 3 feet thick. An old drift has been reopened since my former visit. The mouth of this drift is at Stone Coal Run, about 25 or 30 feet below the road; it has been driven 40 or 50 feet into the hillside. The seam of coal is 10 feet thick, divided into two benches by about 18 inches of hard shale. The lower bench is from 3 feet to 3 feet 6 inches of solid coal and the upper from 4 to 5 feet of solid coal, making in all from 8 feet to 8 feet 6 inches of coal. The seam is opened immediately upon the creek where water and atmospheric influences have operated most vigorously and have destroyed to a certain extent the character of the coal. Samples which I procured yielded the following:

Volatile matter	12.2
Fixed carbon	78.0
Residue ashes	9.8
Sulphur	a trace

The ash is almost perfectly white. The structure of the coal is slightly laminated, fracture uneven and slightly conchoidal, color pure black, luster sub-metallic. No impurities are perceptible in the coal.

W. G. Atkinson,[1] mining and civil engineer, under date of October 1, 1885, reported to J. R. Anderson & Co., of the Tredegar Iron Works, Richmond, Va., who then owned the Catawba furnace lands, concerning these coals, as follows:

The coal mines and the coal series extend under a considerable part of this property, the coal beds being opened at various points along a line, extending for a distance of from 4 to 6 miles and doubtless farther, as subsequent researches may reasonably be expected to show. There are from five to seven separate and distinct beds, three of these being workable and of value. . . . The thickest bed of coal presents a breast of 5½ to 7½ feet of pure merchantable coal. . . . This main bed is opened at two points by a drift and by a slope. The slope is driven down into and with the coal for 78 feet. . . . It is well timbered and laid with a double track on an inclination of about 35 degrees, coincident with the lay of the coal. . . . Two bands of soft and friable shale occur in the coal, thus dividing the coal into three layers, the two uppermost ones forming the breast described above as 5½ to 7½ feet thick. The roof of the "Big Vein," as it has been termed, consists of a hard black shale, ranging from 5 to 10 feet in thickness and above this is a strongly defined massive sandstone 7 to 10 feet thick. No better roof materials can be found in any coal mine of Virginia. The floor consists of a soft grayish shale

[1] The Virginias, vol. 4, pp. 160, 1883.

> and sandstone passing into a fireclay. . . . At an approximate depth of 25 feet below the "Big Vein" occurs the Two-band coal which measures 22 to 24 inches of coal in two layers, separated by a small band of soft shale averaging 12 or 14 inches in thickness. In the several openings which have been made at points a mile or so apart, the roof consists of a soft grayish shale, 3 to 4 feet thick, on which rests a massive sandstone.

Judging by the condition of the Merrimac of "Big Vein" farther west, where it is now being mined on a commercial scale, it seems obvious that neither Heinrich nor Atkinson was able to distinguish pure coal from that which is badly broken up by bony partings, as the latter condition is characteristic of this bed wherever it is being worked at the present time; therefore, the 5 to 7 feet of "pure coal" reported by them should be taken with considerable allowance, as well as the exceptional purity of the coal, as shown by their analyses. Here again it is obvious that they have taken only picked samples for analysis and the results do not in any way represent the material of which the bed is generally composed.

Search was made by Howell in 1914 to find, if possible, the old mines in the gap cut by Stone Coal Creek. Two caved openings were seen which probably represent attempts to work the upper and the lower beds. The strike is about N. 55° E. and the dip, 34° to the southeast. The smaller of the two beds, as judged from the size of the dump, appears to be the lower bed. The material composing the dump is largely shale and bony coal, but there are a few blocks of apparently good coal, 2 to 3 inches in diameter. There are also fragments of small bright coal of about "buckwheat" size. The larger dump, presumably on the upper bed, contains approximately twice as much material as the smaller one and is composed largely of slack coal or "coal dirt" through which are scattered small lumps of coal that crumble readily between the fingers. It is probable that these are the openings described by Heinrich and Atkinson. The two dumps, by their size and composition, suggest two coal beds, the smaller of which probably contains coal better in quality than any of the benches in the higher and larger bed. This relation of a lower, small bed of fairly solid coal and a higher and larger bed of badly mixed coal and bone is characteristic of the coal beds of the Brushy Mountain field.

About a mile southwest of the Stone Coal Creek mines are several old prospect trenches dug across the strike (here about N. 55° E.) for a distance of about 225 feet. The rocks here dip to the southeast about 35°.

These trenches are on the southeast slope of North Mountain and are in the vicinity of abandoned limonite workings. The lowest opening shows a coal bed 5 or 6 feet thick, overlain by a dark fissile, carbonaceous shale which grades upward into a blue-gray sandstone. Of the 5 or 6 feet of coaly material, only the bottom 2 or 3 feet is reasonably free from shale. The coal in this lower bench is crushed and broken and badly sheared. It is so soft that it can easily be crumbled between the fingers. It breaks into small bright flakes whose surfaces are slickensided by movement which has taken place in the bed. The upper portion of the bed is full of shale which probably occurred originally as partings but which is now much broken and intimately mixed with the coaly material. Approximately 30 feet stratigraphically above this bed, is a bed of carbonaceous shale that pinches down in one place and swells in another place and its intimate structure is distorted and complex. It varies in thickness from 3 to 5 feet and contains a large number of small irregular laminae and lenses of coal in its bottom part. About 40 feet above the bed just described is another layer of carbonaceous shale which is brittle and blue-black in color, due to the inclusion of small flakes of coal. The only coal bed showing any promise is the lowest one in the section, and even in this bed the physical condition of the coal is such as to indicate that the bed as a whole is decidedly poor.

Considerable prospecting has been done by T. G. Chapman at loc. 2, northeast of Catawba Sanatorium. The coal was found a short distance below a relatively resistant sandstone which makes a number of small knobs about half-way up the southeast slope of North Mountain. This prospecting developed several small and irregular beds of coal which are badly shattered and contain many shale partings that were originally interstratified with the more carbonaceous parts, but now are broken and injected erratically through the coal. Most of the coal blooms proved on prospecting to be no more than carbonaceous shale which almost invariably contains scattered flakes and small irregular seams of coal not more than half an inch in thickness.

The largest and best bed developed by Mr. Chapman was visited by Howell in 1914, who reports it as being exposed in a drift about 15 feet long. At the end of the drift the bed, striking N. 48° E. and dipping 70° to the southeast, shows the following section:

Section of lower coal bed at loc. 2.

	Ft.	In.
Sandstone, hard smooth		
Shale		8
Coal, shattered, some hard lumps		9
Sandstone, variable thickness	2	6
Shale, hard		7
Coal		1
Shale		3
Coal		2
Shale		3
Coal, hard, crisp		8
Shale, hard, sandy		
Total thickness	5	11
Total coal	1	8

The 30-inch sandstone parting in the upper part of the bed shows local faults which were not noticed in either the roof or the floor, and although the small layers of shale and coal do not exhibit the usual degree of crushing, the general aspect of the bed indicates that much movement has taken place and that possibly the upper half has been pushed along out of position, between the roof and the lower benches of shale and coal.

A bed about 30 feet higher in the section has also been prospected by a short drift at loc. 2, the section of which, at a point about 10 feet in from the outcrop, is as follows:

Sections of upper coal bed at loc. 2 at mouth of drift.

	Ft.	In.
Sandstone.		
Coal		1
Shale		6
Shale, lenticular, broken and sheared		8
Coal		10
Shale		5
Coal		8
Sandstone.		
Total bed	3	2
Total coal	1	7

Twenty feet from the outcrop.

	Ft.	In.
Sandstone.		
Coal		4
Shale, carbonaceous	1	3
Coal		5
Sandstone.		
Total	2	0
Total coal		9

The strike at this place is N. 53° E. and the dip 78° to the southeast. The gradual thinning of this bed as it was followed into the hill discouraged further operations and the work was abandoned. A few other small beds of coal occur higher in the section, but the two beds of which measurements have just been given are the largest developed at this locality.

The senior author visited the field on the south slope of North Mountain in 1923 for the purpose of studying its geologic structure, and in connection with this work he visited the Chapman prospect near Catawba Sanatorium. As he was quite familiar with conditions in Montgomery County, he was able to make direct comparisons of the two fields, and these direct comparisons resulted in the conclusion that all of the coal beds prospected by Mr. Chapman lie too near the Ingles conglomerate, which is well developed in the mountain slopes above, to be the equivalents of either the Merrimac or the Langhorne coal beds, and that the Shenandoah limestone doubtless covers and conceals the more important beds.

The senior author did not visit Stone Coal Gap, and consequently can not pronounce upon the equivalency of the beds there prospected, but he sees no inherent difficulties in the supposition that along most of the south slope of North Mountain the Pulaski fault cuts so close to the mountain that the uppermost coal beds are either cut out or are concealed, whereas in Stone Coal Gap the fault has receded southward so as to leave the Merrimac coal bed exposed.

Reports are current that coal has been dug in Millers Cove, but no openings could be found and none of the inhabitants could remember coal ever having been mined or prospected here. It seems hardly possible that the rumor is correct, for the geologic formations exposed there are not such as commonly carry coal beds.

The outcrop of the Price formation on the south side of Fort Lewis Mountain was not visited during the course of the present examination, so the authors are not prepared, on first hand information, to say whether there are coal beds exposed here or not. Professor Roy J. Holden [1] informed the authors that he had visited some prospects in that area but the most he found is a highly pyritiferous coal bed about 8 inches thick.

It seems rather strange that this outcrop of the Price formation lying so close to that of Brushy Mountain should be devoid of coal beds, but it must be remembered that these areas are separated by the Pulaski over-

[1] Personal communciation.

thrust fault along the plane of which the Shenandoah limestone has moved northwestward at least 9 miles and possibly very much farther, and that originally the whole Catawba syncline was many miles southeast of its present position. With this great movement in mind it is not difficult to understand why the coal beds are so large in Brushy Mountain and so poorly developed in the area south of Fort Lewis Mountain.

Quality of the coal.

None of the exposures of coal in this field which were examined presented sufficiently fresh surfaces to justify the taking of samples for analysis, hence the only guide to the chemical composition of the coal of this field is that afforded by the analysis of a sample obtained by Mr. Oswald J. Heinrich from a prospect on Stone Coal Run (loc. 1, fig. 29) and published by the late State Geologist, Dr. Thomas L. Watson, in Mineral Resources of Virginia, p. 348, 1907. The small percentage of ash given in the analysis makes it evident that the sample was not obtained by making a cut entirely across the coal bed from roof to floor, as is the custom at the present time, but was made of picked specimens of lump coal. The analysis is as follows:

Analysis of coal from Stone Coal Run (loc. 1).

(Reported.)

	Per cent.
Fixed carbon	78.0
Volatile matter	12.2
Sulphur	trace
Ash	9.8
Fuel ratio	6.39

As this analysis is given in the moisture-free form it should be compared only with the "B" form in the table of analyses, pp. 108-113.

The fuel ratio (fixed carbon divided by the volatile matter) of this coal is 6.39, which compares favorably with the fuel ratio of 6.97 of the sample obtained in the mine of Slusser and Doss, near the east line of Montgomery County (loc. 9, Pl. I). The similarity of the fuel ratios of the coal in these two localities indicates that each had been subjected to about the same stresses when the folding of the rocks took place, and this conclusion seems in general to accord with the structural evidence, as far as that evidence is understood at the present time.

FIELDS OF AUGUSTA AND ROCKINGHAM COUNTIES.

By RALPH W. HOWELL

General description.

For many, many years coal has been known to occur in the first ridge on the northwestern side of the Shenandoah Valley in Augusta and Rockingham counties, and as its outcrop is on the drainage basin of North River it has generally been referred to as the North River coal field. In this field the coal beds crop out on the northwest slope of Narrow Back Mountain from Stokesville in Augusta County to Rawley Springs in Rockingham County.

The coal occurs as thin beds in the upper part of the Pocono formation, which is without much doubt the equivalent of the Price formation, as recognized farther to the southwest. The Pocono formation, as shown by Darton,[1] crops out in the crest and on the northwest slope of Narrow Back Mountain and occupies the trough of an unsymmetrical syncline whose steeply rising eastern limb exposes the hard, conglomeratic basal member of the formation at the crest of the mountain. In places the rocks forming the eastern limb of the syncline are vertical and in others they are slightly overturned, dipping steeply toward the southeast. The west limb dips gently to the southeast and the gentle rise toward the northwest carries the Pocono formation well up on the crests of the ridges that have been left as residual masses by the streams which have cut deep ravines in the mountain mass on the northwest.

Description of coal prospects.

The various old prospects in this field were examined by Howell in 1914. In the vicinity of Rawley Springs he reports two old prospects (loc. 1, fig. 30) which are about 500 feet apart and distant from the hotel about one-quarter of a mile. At neither of these prospects was it possible to see the coal in place, as the pits had caved and even the dump heaps were concealed by growing trees. These dumps contain much shaly material, but there are also a few small fragments of bright, but very fragile coal. These old openings serve little more than to demonstrate, in the absence of other exposures, that the upper, coal-bearing portion of the Pocono form-

[1] Darton, N. H., Geologic Atlas of the United States, Staunton Folio No. 14, 1894, and Franklin Folio No. 32, 1896.

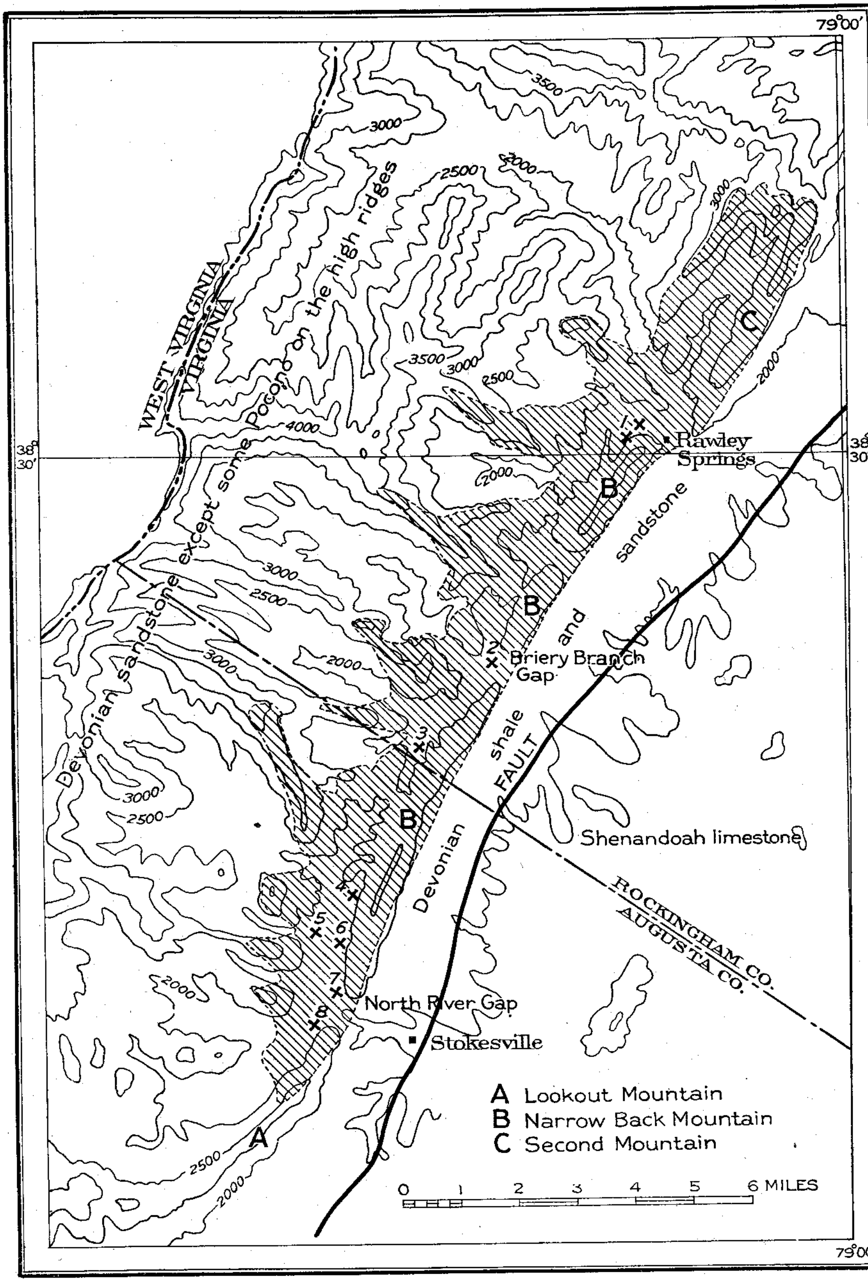


Fig. 30.—Map of the North River coal field in Augusta and Rockingham counties.

ation is here included in the Narrow Back Mountain syncline. No other prospects were found nor were any reports heard of coal having been dug in the neighborhood.

Coal has also been prospected in Briery Branch Gap, 4 miles southwest of Rawley Springs. Here a small drift (loc. 2) had been driven about 30 feet in a coal bed which strikes N. 38° E. and dips 30° to the southeast. As the dip is to the southeast, the drift is probably on the northwest limb of the syncline. A measurement of the bed exposed in this drift is as follows:

Section of coal bed in drift at loc. 2.

	Ft.	In.
Shale, carbonaceous, containing a little coal		3
Shale, hard, blue-gray		1
Shale, carbonaceous		6
Shale, sandy	1	7
Coal, with some shale		4
Shale		2
Coal, with some shale		3
Shale, carbonaceous		5
Coal, impure		3
Shale, black, almost bone		4
Coal		8
Shale, with stringers of coal		6
Coal and shale		4
Thickness of bed	5	8
Thickness of coal (?)	1	10

The benches of coal are all badly crushed and are intimately mixed with shale that formerly existed as partings in the coal. The composition of the bed varies greatly from place to place in the drift, but the section given above appears to be a fair average.

At loc. 3 on Wolf Creek, two openings were made on coal beds at the time of, or shortly after, the Civil War, and it is reported that coal was dug here, put into sacks, and carried down to a small forge that operated near Briery Branch Gap. The old openings are badly caved and overgrown with brush, but the dumps indicate that only a little material was taken out. It is to be expected that, considering the conditions under which these mines must have operated, only the best coal would have been carried away and that the mine dumps would show relatively large amounts of broken and impure coal. As a matter of fact the dumps are composed largely of shale and bone and very little slack coal is present. This would indicate that but little coal was found in the bed, or that all of the coal found was of a grade superior to that found elsewhere in the vicinity. At one place a limited exposure shows a bed of very impure coal, 12 inches in thickness. The roof is sandstone and the floor is a black, bony, carbonaceous shale. The bed strikes N. 23° E. and dips to the southeast 30°. Another badly weathered outcrop of what is supposed to be the same bed, is 3 feet thick. The exposure is too poor to permit of a detailed measurement being made, but it is believed that the coal is soft and very impure.

At a near-by locality a prospect trench across the outcrop of the beds, which strike N. 22° E. and dip 40° SE., exposes a few thin layers of coal and carbonaceous shale. The best bench of coal is only 2 inches thick. The dump of another old mine in the immediate vicinity shows principally bluish and carbonaceous shales. There were a few fragments of bright, hard coal with a maximum size of about one inch. It is reported that a well was drilled a short distance southwest of this locality to test the underlying beds. The log of the well is not available, but it is reported that the drill penetrated no coal bed of value.

The structural relations of the coal occurring at the five localities just mentioned are not clear, but it is believed that all of the prospects are on the northwest limb of the Narrow Back Mountain syncline.

Considerable prospecting and some mining were done many years ago in the vicinity of North River Gap which separates Lookout Mountain on the southwest from Narrow Back Mountain on the northeast. North River and its tributaries drain this area and North River Gap affords a natural outlet for the region back of the mountains to Stokesville and to the lower levels of the Great Valley to the southeast. Several attempts, according to report, have been made to mine coal in this neighborhood, but without success. Darton[1] in 1894 states that:

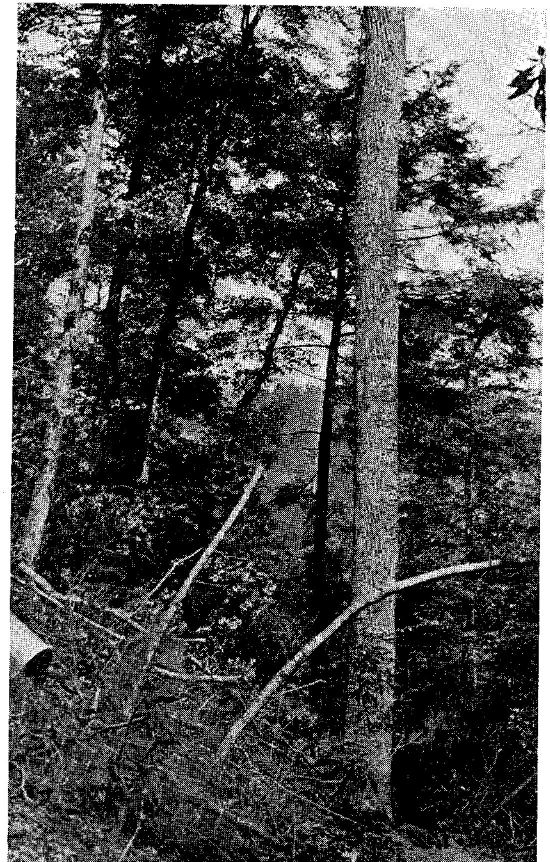
> "A semianthracite coal has been mined to a moderate extent in North River Gap, and the supply is sufficient for local use. The beds are thin and the coal is often much crushed, but it is not difficult to obtain small supplies. Several attempts to find thicker beds have been made by excavations and deep diamond-drill borings, but without success."

Watson[2] makes similar statements concerning the attempted development of this field:

> "Attempts appear to have been made both by diamond drilling near the axis of the syncline and by tunneling across the strike of the

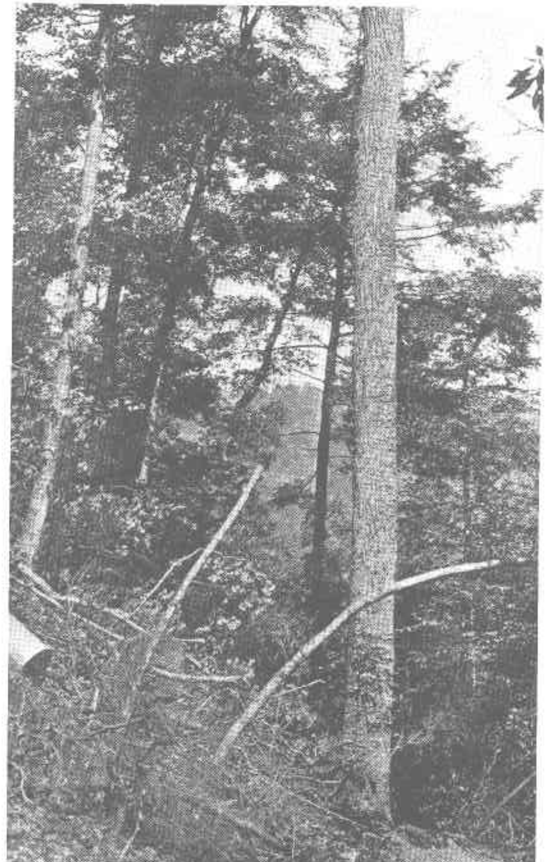
[1] Darton, N. H., Staunton Folio, Geologic Atlas of the United States, No. 14, 1894.

[2] Watson, Thomas L., Mineral Resources of Virginia: Virginia Jamestown Exposition Commission, p, 348, 1907.

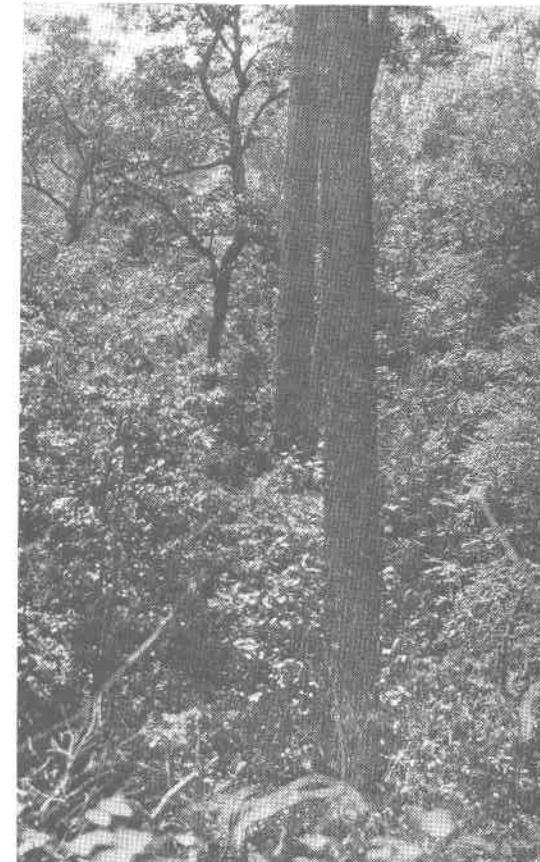


(A) A yellow poplar, 3 feet in diameter, in a cove. In such situations yellow poplar grows rapidly and to large size.

(B) Second-growth white pines, 2½ feet in diameter, in a cove. Such trees will make the upper grades of lumber.



(A) A yellow poplar, 3 feet in diameter, in a cove. In such situations yellow poplar grows rapidly and to large size.



(B) Second-growth white pines, 2½ feet in diameter, in a cove. Such trees will make the upper grades of lumber.

strata, so as to reach the beds in the upturn of Narrow Back Mountain, to develop coal beds of sufficient purity and extent to warrant development, but all such efforts were doubtless unsuccessful. Mining in this field was abandoned long ago and now all the coal that is used in Stokesville and the surrounding region is shipped in by rail."

The following prospects or abandoned mines represent only a few of the attempts that have been made to find coal here, but they presented all of the evidence that was available at the time the examination was made, and, it is believed, they represent the characteristic aspects of the coal beds in this vicinity.

At loc. 4 a tunnel was driven southeastward into Narrow Back Mountain, beginning at a point about 30 feet higher than the water level in Little River. The following section of the coal bed was measured in this prospect:

Section of coal bed at loc. 4.

	Ft.	In.
Coal, impure, soft	1	8
Shale, broken		3
Coal and shale, badly crushed	3	4
Shale, with stringers of coal		7
Coal, with some shale		8
Thickness of bed	6	6
Thickness of coal (?)	5	8

About 20 feet beneath the bed just described, there is another drift, now closed, which is reported to have been driven in a lower coal bed, only a few inches thick. It was hoped that the coal would thicken as the bed was followed into the hill, but, as no such thickening was encountered, the tunnel was abandoned. The rocks here strike about parallel to the mountain and dip to the southeast, showing that they are on the northwest side of the synclinal axis.

At loc. 6 there is an old slope that was driven down a bed of coal which here dips to the southeast into Narrow Back Mountain at an angle of about 20°. It is one of a number of openings in the vicinity, presumably on the same bed as that which was worked in the Dora mine (loc. 7). The prospect is badly caved but it was possible to get a measurement of the coal bed a few feet in from the entrance which is as follows:

Section of coal bed at loc. 6.

	Ft.	In.
Shale, carbonaceous		9
Coal, soft		9
Shale, carbonaceous and bone		5
Shale, sandy, blue	3	0
Coal, reported	1	6±
Thickness of bed	6	5±
Thickness of coal	2	3±

It is reported that, farther down the slope, the dip steepens and the coal bed pinches to almost nothing and again swells to several times its normal thickness. Naturally, under such conditions the coal is soft and badly shattered. A diamond drill-hole is reported to have been sunk to a depth of 900 feet a little north of this slope, but without encountering any coal bed of sufficient thickness to justify development.

The Dora mine (loc. 7), according to report, was the most extensive mine in this district, but it has been abandoned for so long a time that it is completely caved and inaccessible. It is reported that much of the coal taken from this mine was sold locally for the burning of lime, but judging from the size of the dump, it would appear that operations had been rather limited and short-lived. One of the men who formerly worked in the Dora mine claims that the thickness of the coal bed is not more than 5 feet, and that the bottom bench only, about 18 inches in thickness, could be commercially mined. The coal of this bench was soft and impure and it may be questioned whether even this coal could be mined and marketed in competition with better coal from outside fields.

A few old prospects, much higher on the west slope of the mountain than those just described, were visited, but at each place where it was possible to examine the coal, it was found to be so greatly twisted and disturbed that measurements even of total thickness were impossible; and the coal was crushed to a fine dust and intimately mixed with shale, so that individual benches and intervening partings could not be distinguished. The relatively greater distortion of the coal at these higher prospects and the general structural relations suggest that they occur on the steeply dipping or overturned southeast limb of the syncline. It is probable, and the prediction is borne out by such prospecting as has been done, that coal beds so situated are generally bunched and faulted to such a degree that their development is impracticable, and the physical condition of the coal itself will preclude mining on a commercial scale under present market conditions.

At loc. 8 a slope has been driven southwestward into Lookout Mountain on the south side of North River Gap. This slope has long been abandoned and is flooded and badly caved. An examination of the coaly bed showing near the mouth of the slope reveals little more than one foot of coal, which is overlain by a hard black carbonaceous shale, grading upward into sandstone. Conditions did not permit of a detailed examination of the coal, but the dump, which showed excavated material to the extent of 200 or 300 tons, is composed largely of shale. The indications are that no large bench of unbroken coal was encountered, but the occurrence in the limited area of Mississippian rocks on the south side of North River is in itself of considerable interest.

At loc. 5 there are two old prospect drifts on different beds which show that attempts were made to develop coal on Coal Run. These prospects are some distance west of the synclinal axis and the beds are probably lower stratigraphically than any on which the previously described openings were made. It is possible that the prospects on Wolf Creek (loc. 3) and the prospects on the west side of Little River are at about the same horizon. The prospect on the higher of the two beds at loc. 5 was caved at the time it was visited and the coal could not be examined, but the dump showed much shale and bone and only a minor amount of coal. The other prospect is on a bed about 30 feet lower than the one just described, and though the prospect was in poor condition, it afforded an opportunity to examine roughly what is probably the lowest coal bed exposed in this field. At this prospect the rocks strike N. 31° E. and dip 18° or less SE. The entry was driven in the coal bed along the strike which swings more to the north as the coal bed is followed into the hill. At one point on the west side of the entry about 30 feet in from the outcrop the following section was measured:

Section of lower coal bed at loc. 5.

	Ft.	In.
Shale, with some coal	1	0
Coal, soft, impure	1	10
Shale, with some coal	3	0
Thickness of bed	5	10
Thickness of coal	1	10

About 6 feet southwest of the place where the measurements just given were made, the coal is almost pinched out by a sag in the sandstone roof. At a point about 10 feet from the outcrop the bench of coal is only 1 foot 3 inches thick and it is even thinner on the east side of the entry which is here about 20 feet wide.

The Dora mine has attracted attention from a very early date and many glowing accounts of it have been written, but there is a suspicion that many of these were written for the purpose of selling stock rather than for the legitimate purpose of development. The earliest notice of which the writer is aware was published in a book entitled Statistics of Coal, by R. C. Taylor in Philadelphia in 1855. The statement here is as follows:

> At a meeting of the American Association for the Advancement of Science, May 1854, Mr. H. R. Schoolcraft brought forward a paper on the Dora coal formation of Virginia, which was answered by Prof. W. B. Rogers, a brief summary of whose remarks on the subject we beg leave to subjoin:
>
> This Dora bed is no new discovery. Twenty years ago it was explored. It lies some 16 miles from Staunton, Virginia. It is a thin and elusive coal bed. Rumors of its wealth have often stimulated speculators to their ruin. Companies have often been formed with the intention, first of working the stock; and, second, possibly, of working the coal. I have heard of a seam of it fifteen feet thick, but the section I have seen is worthless. The rocks are piled up topsy turvey, the older Silurian rock overlapping the Carboniferous limestone. . . . In one place the coal seam is four inches, in another, four feet thick, and in others you might call it fifteen or twenty feet thick, consisting of shale and coal, according to the direction of your measurement.

This scathing denunciation by Rogers did not settle the question, for it was not based on sufficient evidence; for this Rogers did not have, although his conclusions were doubtless approximately correct. In 1881 another effort was made to exploit this field, but fortunately at this time two diamond drill holes were put down before mining operations were begun. As is usual, however, even the cores of these holes were interpreted to suit the fancy or desires of the one seeking to profit by them. Thus the *Valley Virginian,* of Staunton, Virginia, published in its issue of May 24, 1883, (as quoted in *The Virginias,* Vol. 4, No. 7, pp. 105-106, July, 1883) an article from a correspondent describing the cores referred to above as follows:

> Quite near the surface the drill passed through a vein of excellent fire clay ten feet thick; at 25 feet a vein of 13 inch coal; at 40 feet a vein of 21 inch coal; at 56 feet a vein of 36 inch coal; at 70 feet a vein of coal eight feet thick, and at a depth of 125 feet another vein five feet. Thence down to the depth of 914 feet, when red sandstone was struck; several minor veins were passed through.

In commenting upon this record, the correspondent makes the following statement:

> This practical proof of the richness and quality of the deposits in the Dora field contradicts most emphatically the assertion of self-opinionated surface-guessers and bookworms, and is a decided victory for the opinions of the editors of the *Valley Virginian* and the few persons of this and Augusta counties, who never wavered in their faith of the mineral wealth of the North River Gap.

Fortunately the publication of the article quoted above did not conclude the matter for it shortly appeared that both of the cores mentioned had been examined by Mr. Fred C. Dewey, a thoroughly reliable engineer and chemist who, according to the editor of *The Virginias,* sent the following communication:

> Under date of July 12, 1883, Mr. Dewey writes us: "I enclose a slightly condensed copy of my notes on 'Dora.' You may use my name as freely as you choose, and you had better state that I examined the cores upon the spot, before removal anywhere. The examination was made in the air during a rain, so that the measurements can not be considered to be nearer than one inch, and some of the rocks would be more elaborately and perhaps differently named had there been time and appliances to examine them carefully. However, as you know, the point I was considering was the presence or absence of coal, and that point I think is fully settled by the figures I have given:

Log of drill-hole No. 1 at loc. 7, as interpreted by Fred C. Dewey.

	Ft.	In.
Soil	5	0
Sandstone	32	0
Shale	6	5
Coal, soft, impure		4½
Sandstone	1	8
Coal, soft		11
Shale, broken	2	9
Sandstone	4	10
Shale	3	7
Sandstone	2	10
Shale, dark		5
Coal, soft		10
Shale		3
Coal, soft	2	9
Shale		8
Sandstone and shale	84	0¾
Shale		10
Coal, soft	1	0
Shale, black	1	7
Sandstone	5	5
Coal, lump		1
Shale, with some coal	3	11¼
Sandstone, hard	4	8
Clay, white		9
Sandstone	5	2
Shale	3	5
Shale, with coal		10
	177	0½

"From the last item given above down to a depth of 790 feet, the depth attained at the time of my examination, December, 1881, there is an alternation of shale and sandstone, without the faintest trace of coal."

Log of drill-hole No. 2, loc. 7 as interpreted by Fred C. Dewey.

	Ft.	In.
Sandstone with some shale	24	0
Coal	1	0
Shale	3	0
Coal		2
Shale	9	6
Sandstone	4	0
Coal		4
Shale and some sandstone	10	11
Coal		3
Shale	1	6
Sandstone with a little coal near top	72	0
	126	8

Considered in its general aspect, the North River coal field does not present a promising opportunity for the development of coal mines. So far as could be determined by the field examination and by the log of the drill-hole as given by Mr. Dewey, there are several irregular and thin beds of coal interbedded with shale and sandstone in the upper part of the Pocono formation and these strata are downfolded into a syncline whose southeastern limb is steeply upturned or in places overturned and in consequence of this upturning the coal beds are much broken and squeezed. The coal outcrops on both sides of the syncline, dips toward the axis of the trough where it is under considerable cover and might be mined if it were of sufficient thickness and purity to compete with other coal in the general market.

Quality of the coal.

The data at hand do not permit of a definite statement regarding either grade (that is purity or impurity) of the coal or of its rank in the usually accepted scale of coals. The facts collected seem to indicate that the coal beds are not only thin, but that they are made up, as is generally the case, of coals of this geologic age, of alternating layers of coal and bone, or shale, and that in many places movement within the coal bed itself has crushed the bone and coal and so intimately mixed them that it would be difficult if not impossible to separate them so that the coal might be marketed in a fairly pure condition. It seems reasonable to conclude, therefore, that the coal of Augusta and Rockingham counties is of low grade, because its ash content is probably large and that it might not be economically possible to reduce the ash to what might be regarded as a normal amount.

The coal in the old prospects is so badly weathered that it is not regarded as suitable for sampling and hence no recent analyses are available upon which to base statements regarding the two points specified above. The only analyses of which the writers are aware are some made of coal from the Augusta County field by Booth, Garrett and Blair of Philadelphia, and published in *The Virginias,* as follows:

Analyses of Augusta County coal by Booth, Garrett and Blair.

Constituents	1 Per cent.	2 Per cent.	3 Per cent.	4 Per cent.	5 Per cent.	6 Per cent.	7 Per cent.
Fixed carbon..	89.47	89.02	87.65	86.35	88.09	87.40	85.85
Volatile matter	6.00	6.42	7.58	7.27	6.64	6.10	6.20
Moisture......	.40	.50	.80	.80	0.35	.45	.60
Ash..........	4.13	4.06	3.97	5.58	4.92	6.05	7.35
	100.00	100.00	100.00	100.00	100.00	100.00	100.00
Fuel ratios....	14.91	13.86	11.56	11.88	11.76	14.33	13.85

Nos. 1 and 4.—Opening on Briery Branch about 100 feet above the base of Narrow Back Mountain.

No. 2.—Little Coal Run, from end of 100-foot drift in an 18-inch bed of 5.5 miles southwest of No. 3.

No. 3.—Near Briery Branch at foot of Narrow Back Mountain from a 4-foot bed in a drift 5 or 6 feet long.

No. 5.—Half a mile southwest of No. 2, from a bed 4 to 5 feet thick and 13 feet lower than the one showing at No. 2.

Nos. 6 and 7.—From the Scheffer drift in North River Gap, near Nos. 2 and 5. Sample from a 6-foot bed.

Although it can not be assumed that the analyses given above are strictly comparable with those made to-day in the electric furnace, still from them one may arrive at a fairly definite opinion regarding the rank of this coal. The fuel ratios, as determined from the analyses, are given in the table. They range from 11.56 to 14.91, with an average of 13.16.

In the discussion of the subject of the classification of coals on p. 122 it was stated that all coal having a fuel ratio of 10 or more should be regarded as anthracite; therefore, this coal, with a minimum fuel ratio, as far as present knowledge goes, of 11.56, must be regarded as anthracite and is the only coal in the State of Virginia, known to the writer, which belongs to this rank. It is probably true that were the analyses made in the electric furnace the yield of volatile matter would undoubtedly be increased and hence the fuel ratio be lowered, but it seems hardly likely that such a procedure would lower the fuel ratio of any of the samples noted below 10, and therefore probably would not throw them into the lower rank of semianthracite.

Unfortunately the analyses given above throw little light upon the impurity of the coal, for it is perfectly obvious to one acquainted with the Mississippian coals of the Appalachian region that none of them are of such purity as to reach the market with only from 3.97 to 7.35 per cent of ash. These figures show at once that the samples must have consisted of picked coal, and doubtless in picking the coal for the samples only the very best lumps were selected. For this reason these analyses are worthless and misleading, for they indicate a coal with a very low percentage of ash, whereas all the evidence goes to show that the coal is very impure and when put upon the market would probably contain two, if not three times as much ash as the analyses indicate.

CONCLUSIONS AND SUGGESTIONS

In beginning the study of the coal of the Valley fields of Virginia the writer was of the opinion that they are a valuable resource to the State and particularly to the southwestern part of what is generally known as the Valley of Virginia, and as the work has progressed and as he has become better and better acquainted with the coals, the feeling expressed above has deepened and has now become an abiding conviction. From this it must not be inferred that he has lost sight of the bad points of the coal or of the difficulties that may be encountered in mining it and preparing it for the market. These have all been duly considered and weighed as carefully as it is possible to do, until more information is available, and still the writer finds himself very enthusiastic regarding the future of these fields, provided they are developed in the proper way and the coal is handled in such a manner as to build up a large clientele of satisfied users who will continue to use and to demand this coal as long as it is available.

The questions of the geologic occurrence of these coal beds and their underground extent have been treated as fully in this report as it is possible to do with the information at present available. The writer has, therefore, nothing to add to what has already been said.

The question of mining methods best adapted to the conditions here present is entirely an engineering question which can best be answered by some well trained engineer who enters this field with the intention of making it a study of a number of years' duration. Such a person, however, should be well acquainted with all of the more recent improvements in methods of mining that have been found desirable in the anthracite fields of Pennsylvania, for they are the only fields in this country that have difficulties similar to those which may be encountered in the Valley fields of Virginia.

The writer was recently very much impressed with the manner in which deep mining is being conducted in certain parts of the anthracite fields, and as the possibility of deep mining is liable to become an important question in the Valley fields it is perhaps well to call attention to a method that has solved some of the very serious difficulties that such mining is apt to encounter. In one of the deep mines of the Southern Anthracite field where the workings are 700 or 800 feet below sea level it was found that the pressure was so intense that the gangways could with great difficulty be maintained. The difficulty was finally obviated by sinking the shaft and carrying all of the important gangways in the underlying Mauch Chunk red shale which, as the rocks are folded into a very deep synclinal basin, was easily done. From these main gangways the coal is easily reached by short rock tunnels across the strike to the coal beds, and from each of these tunnels a panel of coal is mined out and then abandoned. This has almost completely eliminated the question of the heaving of the floors of the gangways and in every way has been a great improvement over the old method of driving all of the gangways in the coal bed. Such a procedure as that just described might not be applicable to the deep mines in this field, but it is an expedient that might well be tried if trouble of the kind mentioned above is encountered.

The question of the preparation of the coal for market is one of the most important problems to be considered by the operators in the Valley fields. Picking and washing have long been the procedure by which such coals were cleaned, but the latter, while very satisfactory in a general way, meant that most if not all of the coal must be crushed before successful washing could be accomplished. Recently some improvements have been noted in the manner of washing which may be worthy of trial in the Valley fields.

For a long time float-and-sink tests have been made in liquids of different specific gravities for the purpose of separating the pure (light weight) coal from the impure or dirty coal. Such a separation can be made very successfully, but the great cost of heavy solutions made it prohibitive in a commercial sense. Recently this difficulty has been solved by making a heavy liquid of water and sand. As long as the sand is agitated it is said to act perfectly and the density of the combination can be controlled by the amount of sand added to the water. At present six or seven plants are said to be in operation on a commercial scale using this method, so that it may be considered as beyond the experimental stage. The great advantage of this method over ordinary washing is that the coal can be treated as it comes from the mine without a preliminary crushing. This would be very advantageous in the Valley fields where there are so many streaks of shale or bone mixed with the coal.

The writer would recommend that some up-to-date operator try this method of separation of coal from bone to see if it would not be successful, for it is imperative that these coals be sent to market in only the best condition that it is possible to attain, otherwise customers will be very ready to try other coals or to change their heating apparatus to one that burns oil.

The writer has been severely criticised for stating that the aim of the operators in the Valley fields should be to put on the market a coal whose ash content would not be over 8 per cent. In setting this figure the writer was well aware that it is a very high standard, but he believes thoroughly that the only way to keep the output of the field up to its best is to set a standard even higher than that which can be reached in most cases and then to urge all to come as near this standard as possible. At present there is no Government inspection of coal, but the author firmly believes that such an inspection service is sure to be established in the near future. By this he does not mean that coal will be classified and graded by the Government, but that each car of coal will be tested and the amount of ash in it will be stamped on the car so that the dealer may know exactly what he is receiving. An operator under such a service may send very dirty coal to market, but it will be branded and naturally a car of coal having an ash content of 18 per cent will not sell as readily or for as good a price as coal having an ash content of only 10 per cent. If such a service is established it will be to the interest of all operators to send to market the cleanest coal possible, and if they are equipped in advance with the best washing machinery known the task of shipping acceptable coal will be an easy one compared to what it would be if they were not so equipped.

Unfortunately, up to the present time there has been no attempt to set a limit upon the percentage of ash that an anthracite coal might carry, and there has been almost no information available by which such a standard could be determined. In 1923, however, the Bureau of Mines, in order to assist the State of Massachusetts in administering a new quality law for anthracite, collected a large number of samples of anthracite from stock piles in the yards of the dealers. The ash content of these samples, as stated in an article by O. P. Hood,[1] is as follows:

> The weighted average ash content was: For furnace size, 13.2 per cent; egg, 13.7; stove, 13.7; chestnut, 16.2; pea, 15.6; range, 19; buckwheat No. 1, 18.9 per cent. In the 8 samples of furnace coal the lowest ash was 10.5 per cent and the highest, 14.6 per cent; of twenty-nine samples of egg, the range was from 10.2 to 17.5 per cent; of 20 samples of stove coal, 11.3 to 15.9 per cent; of the 23 samples of chestnut, 10.3 to 46.1 per cent; of 20 samples of pea, 12 to 27.3 per cent; of 4 samples of range, 13.1 to 28 per cent; of 8 samples of No. 1 buckwheat, from 13.6 to 29.5 per cent.
>
> In the chestnut coal the highest six samples ran 46.1, 40.7, 28.3, 25.6, 18, and 16.5 per cent ash. The six cleanest samples ran 10.3, 12.2, 12.9, 13, 13.2, and 13.4 per cent ash.

From the figures just given it is evident that some of the anthracite is reaching the market in a very dirty condition and this should not be imitated by the operators of the Valley field. Such a procedure may succeed for a time, but sooner or later laws will be passed controlling such things and then it will be necessary to reform the practice. A much more reasonable procedure would be to anticipate such action by the State or the Government and to prepare the coal so that it would meet the requirements of any reasonable law before that law is enacted. By proceeding in this manner a clientele could be built up which would be permanent and a great asset in times of stress. The author still maintains that it should be the aim of the operators in the Valley fields to clean their coal so that the ash contained in it would approach 8 per cent and that in no sizes should it exceed 15 per cent.

Another point that should be considered by every operator in these fields and by every one else who contemplates occupying such a position is the question of the utilization of all the coal that is mined without any of it going to waste, for the mining of coal costs money and if the coal is not sold it means so much loss to the operator. Probably every operator hopes to sell all his coal as a domestic fuel, thereby obtaining for it the present high prices in the domestic trade, but no matter how much he may wish to so dispose of his coal, he is seldom able to do so, because much of the output of the mine is too fine to be used for this purpose. The operator in these

[1] How much ash is found in commercial anthracite? Coal Age, February 21, 1924.

fields who is most likely to succeed is the one who is on the lookout for every means of selling his entire output and selling it at a price which will yield a fair return on the money invested.

According to the present practice in the Valley fields a noticeable percentage of the coal from the Merrimac coal bed finds its way to the dump heap or is washed away from the washery as waste coal. What is needed, is some means of utilizing most, if not all, of this waste product, which seemingly is usable only for the production of power. To-day some of this coal is used at almost every plant in operation for the production of power for pumping water, hoisting the coal, and operating the screens and washing. But this is only a small percentage of the work that might be accomplished if better methods of firing were employed and an outlet found for the excess power that might be generated.

The establishment of a super-power zone throughout the northern Atlantic States seems now to be an imminent possibility, and if this should be extended as far to the southwest as the Valley coal fields, it would presumably afford an outlet for all of the electric energy that could be generated. While this may seem somewhat chimerical and like looking far into the future, the writer believes that it may be an accomplished fact before many years, and he who sees it coming and plans to coöperate with the great producing companies is he who will reap the richest harvest for his work.

If we assume that a market for electric power is assured, the next problem is how to convert the waste coal from picking table and washery into electric power. This can not be fully answered at the present time, but certain plants have demonstrated ways and means of utilization that look to the writer very promising, and that certainly can be carried out in these fields when the marketing of the resultant electric current is assured.

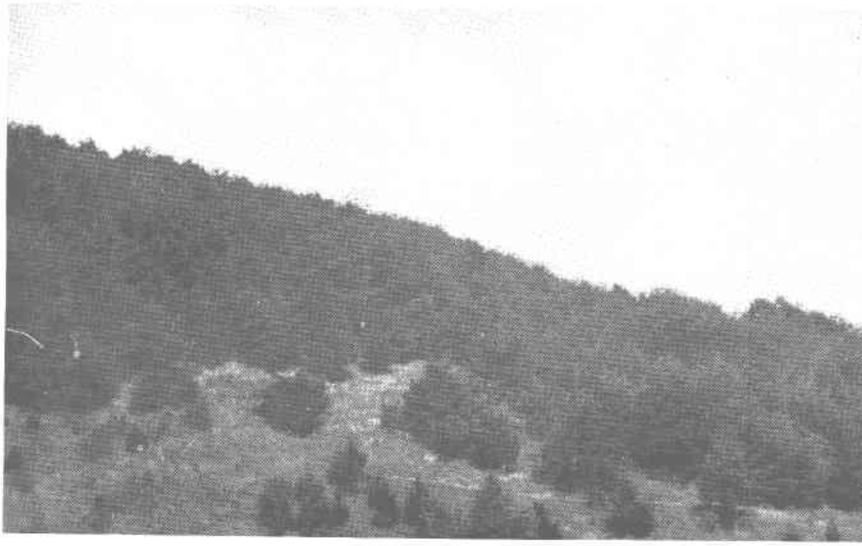
Within the last year or so the Susquehanna Collieries Co. have built at their Short Mountain mine at Lykens, Pennsylvania, a large plant for the production of power, both steam and electric, for the operation of their Short Mountain and Williamstown mines. This plant is using the dried "slush" from the washery, which, as shown by a single sample taken on August 7, 1924, has the following composition:

Analysis of "slush" from the washery of the Short Mountain mine.

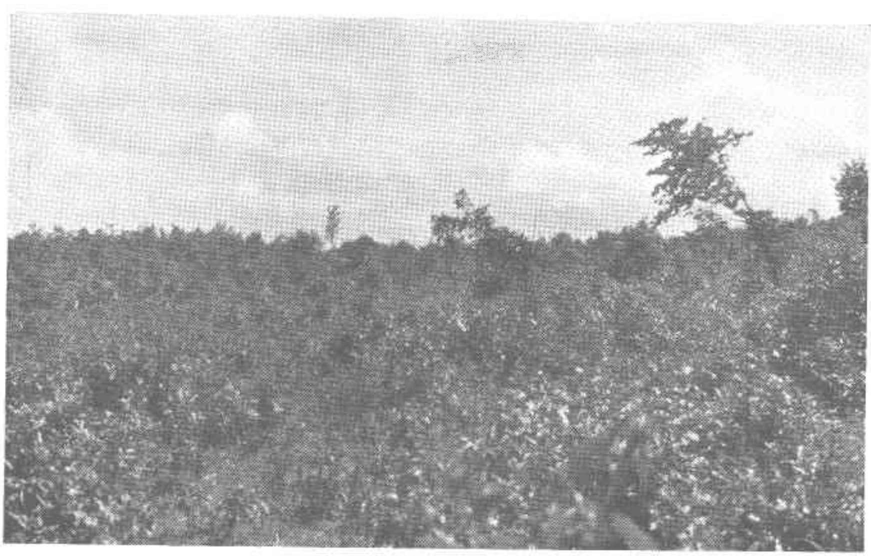
Moisture	.35
Volatile matter	8.20
Fixed carbon	74.90
Ash	16.55

(A) Abandoned field restocking naturally with pines, as is common wherever there are seed-trees nearby.

(B) Clear-cut area with inferior species predominating in the young growth (principally black oak, chinquapin and sourwood).



(A) Abandoned field restocking naturally with pines, as is common wherever there are seed-trees nearby.



(B) Clear-cut area with inferior species predominating in the young growth (principally black oak, chinquapin and sourwood).

The "slush" from the washery is first dried and then pulverized so it will pass through a 40-mesh screen, but in so doing about 82 per cent is reduced so as to pass a 200-mesh screen. The pulverized coal is then piped to the boilers and, after being mixed with air in a specially designed burner, is forced into the combustion chamber which was also specially designed for the use of this coal.

According to a recently published description[1] of this plant the cost of operation is as follows:

> The cost of preparing and handling the coal at the Lykens plant averages about 60 cents a ton over a twelve-month period. This includes operating and maintenance, labor and supplies, including power and superintendence, but not investment charges. The cost of pulverizing alone is about 24 cents a ton.
>
> The cost of preparing and handling the coal here given may at first appear high, but when it is remembered that the plant is being operated considerably below capacity, and that the cost of pulverizing and the maintenance charges on the mills increases rapidly with the degree of fineness of pulverization and the percentage of ash (the coal in this case is pulverized to a fineness of 82 per cent through a 200-mesh screen and contains 20 per cent ash) and that the pulverized coal is conveyed a distance of 500 feet from the preparation plant to the bunkers above the boilers, this cost is not excessive.

This power plant has been running for three years and it is regarded by officials of the company as a great success.

The coal used in the Lykens power plant is of almost the same composition as the coal of the Merrimac bed in the Price Mountain coal field, except that it contains a lower percentage of ash. If the waste coal can be successfully used at Lykens the writer does not see why the same process could not be used in the Valley fields of Virginia, provided a market could be found for the power generated. The one unknown factor in the problem is the fusibility of the ash of the Virginia coal. Does it fuse at such a low temperature that it could not be used in powdered form under a boiler? The writer does not know of any fusibility tests on the ash of this coal, but even granting that it may fuse at a low temperature and thus not be in condition to be used directly under a boiler, it seems possible that other coal of

[1] Susquenanna Collieries Co. burns pulverized anthracite slush at Lykens, Pa. Coal Age, August 21, 1924.

high fusibility might be mixed with it or some other mineral substance be found that, when added, would increase the fusibility so that the coal could be used in powdered form.

The power plant of the United Electric Railway of Providence, Rhode Island, has gone one step further than the Lykens plant for it is burning, in an experimental way, Rhode Island anthracite in powdered form. This anthracite, as shown by analysis Y on page 115, has reached a stage of metamorphism beyond even the highest coals of Pennsylvania, and if this coal can be successfully used in powdered form surely the semianthracites of Virginia can be used in the same manner.

THE FORESTS OF THE VALLEY COAL FIELDS OF VIRGINIA

By Fred C. Pederson,
District Forester, Virginia Forestry Department.

GENERAL DESCRIPTION OF THE FORESTS.

Location and extent of the forests.—The northwestern part of the territory covered by this report consists of long unbroken mountain ranges. The central and southeastern parts are a long fertile valley, but only part of this is level or nearly level land. A large part of it is decidedly rolling, almost too steep for successful cultivation, in addition to which there are a number of small ranges or knobs in the valley section, particularly toward the southeastern part. Both the long, high mountain ranges and most of the smaller isolated ranges or knobs are covered with an almost unbroken forest of some description. The leveler parts of the valley are almost altogether in cultivation or in good pasturage, but even in this section there are numerous small isolated patches of forest ranging up to 25 or 30 acres, particularly on the steeper and rockier soils.

General character and condition of the forests.—The forests as a whole consist of a mixture of hardwood and softwood species, with the hardwoods decidedly predominating except for certain small areas.

The original forests as a whole consisted of a dense stand of large trees of excellent quality, except on the high, exposed ridges, where the trees were necessarily shorter and limbier. But since the settlement of this section, which dates back to before the Revolutionary War period, a large percentage of the area has been cut over once if not several times, with the result that there is practically no timber in this territory now that could be described as virgin growth. Up until about the year 1900, the forests were only lightly or moderately culled of the better species, to meet the smaller timber requirements of those times. The transformation that has taken place in industrial and economic conditions since that period, however, has made competition for accessible standing timber very keen, and as a result, much of the territory has been stripped of most of its merchantable timber, from 10 inches on the stump upward. This statement is particularly true of the western part of the territory, in Smyth and Wythe counties. On the northern slope of Big Walker Mountain as far east as New River the forests have been comparatively lightly culled, due to the greater difficulty of getting timber out from that section, and stands with an estimated volume of four or five thousand board feet to the acre are to be found. These stands are usually only in small patches, however, and are only of sufficient extent to justify portable mill operations. Considerable merchantable timber is also to be found in the northern part of Pulaski County, on the south slope of Big Walker Mountain and on the north slope of Little Walker Mountain, and here there is sufficient timber to make a band mill operation feasible.

The forests of this region as a whole, except for the small isolated patches, have suffered greatly from repeated forest fires in the past. These fires, following the cutting of timber, have to a very large extent turned the forests into scrubby, open stands of inferior quality. In Montgomery County, while the forests have been severely culled in the past, making large sawmill operations impracticable, the stand of young growth and reproduction is relatively dense, and bids fair to have great value in the future. The fact that the forests of Montgomery County are in noticeably better condition than those of Wythe and Pulaski counties can be accounted for only by the fact that the forests of Montgomery County have been systematically protected from forest-fires since 1916.

Another factor that has contributed greatly to the present inferior quality of the forests as a whole is the repeated cutting of the best species, leaving the poorer ones to scatter seed and occupy the ground. The black walnut has been most heavily culled, followed by the yellow poplar and the white pine. More recently white oak, linden, cucumber, ash and the other more valuable species have been cut more heavily than those of less value, leaving the so-called "weed trees" which formerly had little if any value. If this culling and the forest fires and the excessive damage by grazing in certain localities continue, the black walnut, yellow poplar and white pine will almost be exterminated.

THE FOREST TREES OF COMMERCIAL IMPORTANCE.

Common or Local Name.	Scientific Name. (Sargent's Manual, 2d Edition.)
White oak	*Quercus alba L.*
Chestnut	*Castanea dentata Borkh.*
Chestnut oak or rock oak	*Quercus Montana L.* (formerly *Q. prinus)*
Scrub pine or spruce pine	*Pinus virginiana Mill.*
Red oak (northern) or water oak	*Quercus borealis var. maxima Ashe* (formerly *Q. rubra L.)*
Black oak	*Quercus velutina Lam.*
White pine	*Pinus strobus.*
Hemlock	*Tsuga canadensis Carr.*
Shortleaf or "yellow" pine	*Pinus echinata.*
Black locust	*Robinia pseudoacacia L.*
Black gum or tupelo	*Nyssa sylvatica Marsh.*
Yellow poplar	*Liriodendron tulipifera.*
Scarlet oak or Spanish oak	*Quercus coccinia Muench.*
Pitch pine or black pine	*Pinus rigida.*
Shagbark hickory or scalybark or shell-bark hickory	*Carya ovata K. Koch* (formerly *Hicoria ovata Britt.)*
Bitternut hickory	*Carya cordiformis K. Koch* (formerly *Hicoria minima Britt.)*
Buckeye	*Aesculus* (species not determined.)
Cucumber	*Magnolia acuminata L.*
White walnut or butternut	*Juglans cinerea L.*
Black walnut	*Juglans nigra L.*
Pin oak	*Quercus palustris.*
Sycamore	*Platanus occidentalis L.*
Red maple	*Acer rubrum L.*
Linden or lin or basswood	*Tilia* (species not determined).
Hard or sugar maple	*Acer Saccharum Marsh* (perhaps *var. glabrum.)*
Red cedar	*Juniperus virginiana.*
White ash	*Fraxinus americana L.*
White elm	*Ulmus americana.*
Black birch	*Betula lenta L.*
Beech	*Fagus grandiflora Ehrh.* (perhaps *var. caroliniana.)*
Post oak	*Quercus stellata.*

Other species of little if any commercial importance, which are to be found in this region in considerable abundance, are as follows:

Alternate-leaved dogwood	*Cornus alternifolia.*
Sourwood	*Oxydendrum arboreum D C.*
Sassafras	*Sassafras officinale N and E.*
Red bud	*Cercis canadensis L.*
Striped Maple	*Acer pennsylvanicum L.*
Black willow	*Salix nigra Marsh.*
Smooth alder	*Alnus rugosa.*
Chinquapin	*Castanea pumila Mill.*
Scrub oak	*Quercus ilicifolia Wang.*
Ironwood	*Ostrya virginiana K. Koch.*

FOREST TYPES.

Forest types, which are usually based upon the character of the site or upon the dominant species, are the result of the division of the whole forest into stands that differ from each other so greatly that they should be managed differently. But they often merge into one another by gradations that are difficult to distinguish. In general there are four distinct forest types in this region.

Chestnut ridge type.—Chestnut is the most abundant species in this type, but the chestnut oak or rock oak is nearly as abundant. Other less abundant species are black oak, scarlet or Spanish oak, black locust, hickory, northern red oak and white oak. Less common species in this type are black gum, scrub or spruce pine, pitch or black pine, and such underbrush as sassafras, witch hazel, dogwood, scrub oak (especially evident on badly burned areas), and laurel.

This type occurs on the exposed ridges or on the dry upper slopes just below the ridges, particularly on southern and western slopes. The soil in such situations is apt to be thin, with only a small amount of humus and only a light covering of leaf-litter. As a result of these unfavorable factors evaporation is necessarily rapid, resulting in a dry soil, not favorably adapted to the rapid growth of trees. The crown cover is apt to be open, which does not encourage the growth of trees with long, straight, clean boles, so desirable for lumber production. This type is better adapted to the production of mine timbers, chestnut extract wood and chestnut oak tanbark, and should be managed with these objects in view.

Due to the dryness of the site, the fire hazard is greater on the ridges and upper slopes than in the other types. Evidences of these fires are abundant throughout the region, particularly on Little Walker Mountain in Wythe and Pulaski counties. The occurrence of these fires in the past is shown by the fire-scarred bases of the trees and by the dense growth of laurel, scrub oak, and other undesirable shrubs, which the opening of the canopy has made possible. A ground cover of this nature excludes for a time the regeneration of the better species. The simplest and the only feasible remedy for this condition is to protect the forest from fire, which will allow the closure of the crown cover, thus ultimately shading out the undesirable and worthless species.

White oak slope type.—The dominant species of this type is the white oak. Associated with it on the upper slopes (just below the ridge type described above) are chestnut, chestnut oak, black and scarlet oak; on the lower moist slopes, white pine, yellow poplar, cucumber and basswood, while short-leaf pine, pitch pine, locust and northern red oak are found throughout the type. From an economic standpoint, this is the most important of the types, as it covers a much larger area than any of the other types and produces most of the merchantable saw-timber. It produces tall, clear-boled trees.

The best growth is to be found on the lower moist slopes, the quality of the trees decreasing as the dry ridge type is approached. A northern exposure generally produces better timber than a southern exposure. On north slopes white pine reaches a height of 125 feet or more on favorable locations and is exceptionally free from defects.

The small patches of woods on the farms in the limestone section are more apt to be of this type than any other.

Yellow poplar cove type.—While yellow poplar has been severely culled from this type of forest by past logging operations, its growth is so remarkably rapid in the coves that there is enough of it at present to designate the type. Associated with it are white oak, which grows far more vigorously here than in the other types, white pine, linden, cucumber, hard and red maple, beech, buckeye, black and white walnut, hemlock, black gum, black birch, red oak, chestnut oak and black locust. It is the most complex of the types enumerated. The soil is deep and rich, containing a large amount of humus; the leaf-litter is heavy, resulting from an accumulation of leaves blown in from surrounding ridges or washed down the slopes. The site is protected from undue exposure to sun and wind, and hence does not have as great a fire hazard as the slope and ridge types.

It covers a much smaller area than the slope type, but produces the greatest volume per tree of any of the types, and most of the upper grades of lumber are secured in the coves. Yellow poplar grows to remarkably large size in this type. Cucumber and white pine also thrive here.

Hemlock bottomland type.—In some places in the bottomland hemlock occurs almost pure. Associated with it to a greater or less extent are red maple, sycamore, black gum, red cedar, beech, black birch and hickory, and occasionally linden, white pine, yellow poplar and cucumber. This type comprises but a very small percentage of the total area of the forest region, and it could perhaps for practical purposes be thrown with the cove type. It produces valuable grades of lumber and a considerable amount of hemlock bark for tanning purposes.

HISTORY OF PREVIOUS LUMBERING OPERATIONS.

As the fertile valley lands were settled the timber was removed to make way for farms. With the steady increase in the demand for forest products, both for use in the farming sections and for shipping outside, the nearer, more accessible mountain areas were early logged over, only the larger trees of the more valuable species being taken, however. This resulted in what might be called a "selection" system of cutting, since certain trees were selected and the balance left. Such cullings, at first light, later heavier, were gradually extended farther and farther back into the inaccessible parts of the mountains, but there are still to-day a few regions which have been only lightly culled.

This method, while decreasing the percentage of the more valuable species, evidently left a cover of some sort. But the selling price of lumber has advanced so greatly in recent years that the tendency now is to cut almost all trees that are as large as 8 inches in diameter across the stump. As a rule the only exceptions to this are in the case of the most inferior species, such as black gum, red maple, sour wood, butternut and black jack oak.

The writer was not able to ascertain when sawmills made their first appearance in the region, but it is known that mills propelled by water-power were in operation as early as 1875. Steam sawmills appeared in this region about 1890. As far as the writer could ascertain, the only band mill that has ever been in operation in this region is the present one at Atkins, in Smyth County. This mill has been in operation on its present site for the past eight years, but, due to the depletion of the timber within its logging area, it will have closed down before this report is printed.

PRESENT METHODS OF LOGGING.

With the exception of the band mill operation mentioned above, all the cutting of second growth timber in the region is done by small, portable mills, which have a capacity of from 2,000 to 4,500 board feet per day. Due to the increase in the price of lumber, the number of these small mills has been growing yearly, until to-day there are about 85 in continual or seasonal operation in the mountains of this district. Steam is the sole means of power, the fuel consisting of slabs, trimmings from the logs and sawdust. These mills are usually operated by men who do not own any considerable amount of timber, but buy enough to justify a setting.

In the western part of the district, closer utilization is secured by the use of crating machines, which are added to the usual sawmill equipment, and make cabbage crates.

The average cost of lumber "from stump to stick" is about $10 per thousand board feet, of which about $5.50 is chargeable to logging and skidding and about $4.50 is the cost of milling. Hauling is the most variable item in the cost of production. The cost will vary with the length of the haul, the character of the roads, the difference in weight of the various kinds of lumber, and the means of transportation, whether by team or truck. A team cannot usually draw over six or seven hundred board feet to a load, even on good graded mountain roads, and correspondingly less on unimproved roads.

METHODS OF PURCHASING TIMBER.

Timber is bought by the "boundary" (tract), the acre, or on the basis of the log scale or the mill scale. As a rule it works to the advantage of the seller to dispose of his standing timber at a fixed price per thousand board feet, either log scale, as measured in the log by the Scribner-Doyle rule (a combination of the Scribner and Doyle rules, using the highest values from each), or as determined by the actual mill run. The latter method is usually the more equitable, because of its accuracy.

A carefully written contract should govern the sale. Among other things the contract should stipulate the lowest diameter to which trees of the different species may be cut, the log rule, if any, by which the logs are to be scaled, or if the mill scale is to be used this should be specifically stated, the size, number, and character of the trees of any desired species that are to be left for seed trees, the closeness of the utilization that is to be followed through leaving low stumps and preventing waste in the tops, reasonable restrictions about the felling and skidding so that as little damage as possible will be done to the young growth, the exercise of care relative to fires, the operator's liability in case of fire resulting from the operation and the method of payment for the timber.

A written contract of this sort will insure that the buyer and the seller understand each other and thus avoid most of the causes of friction between them.

STUMPAGE VALUES.

Stumpage value is the market price of trees as they stand in the woods, or "on the stump." It is determined by a great number of factors, the most important of which are the distance from the market, the character of the roads, the topography or "logging chance," and the character and quality of the timber. Ten miles and more from a railroad, stumpage prices in this section range from $3.00 to $5.00 per thousand board feet, regardless of species or quality. For more accessible timber the present stumpage prices are approximately as follows (September, 1924):

Species.	*Average value on the stump per M board feet.*
Black walnut	$35
Yellow poplar	10
Cucumber	10
White ash	8 –$10
White oak	5 – 10
White pine	5 – 7
Chestnut oak	4 – 8
Red oak	4 – 8
Black oak	4 – 8
Linden	4 – 8
Scarlet oak	4 – 8
Shortleaf or "yellow" pine	4 – 6
Hemlock	4 – 6
Hickory	4 – 6
Pitch pine	4 – 6
Beech	3 – 5
Sycamore	3 – 5
Scrub pine	3 – 5
Chestnut	3
Black gum	2 – 3

FOREST PRODUCTS.

a. Lumber.—At the present time lumber is the most valuable and probably the most important product of the forests of this region. The forests of this region supply the material for a considerable shipment of lumber to the large manufacturing cities of the north, besides supplying the local demand for lumber of certain sizes and grades. It is likely, however, that after a considerable coal mining business develops in this section all the lumber that can be produced locally, or even more, will be needed in the coal mining business itself. The largest coal mining company in this region at the present time estimates that it is using 30,000 board feet of lumber to mine an acre of coal. The seam on which this company was working at the time these figures were obtained produced 3,500 tons of coal to the acre, on the average, indicating the use of 4.6 board feet of lumber to mine one ton of coal. This ratio is higher than the average, because of the fact that in this case a "double entry" system is in use, and a large proportion of the lumber used is for brattice work. When a "single entry" system is feasible it is said that from 15 to 20 thousand board feet of lumber per acre are necessary for mining the coal. These figures will vary greatly with differences in mining conditions and with the personal element of management, but it is evident that a large amount of lumber is needed in the coal mining operation itself.

b. Ties.—Tie production is second in importance to lumber production in this region. The market for cross ties, bridge ties and switch ties remains active at all times. The railroad companies are the principal purchasers of ties, and information can be obtained directly from them as to specifications, prices and terms of sale. Detailed information on this subject and with regard to lumber markets, etc., which was obtained in the field in connection with this report, is omitted for the sake of brevity.

c. Mine timbers.—The kinds and forms of timbers in demand for mines are many, and while mixed oaks find a more ready market than exists for the other hardwoods, the latter and to a smaller extent the hard pines are usable for this purpose. The principal kinds or forms of timber and lumber used in this section may be listed as follows:

1. Mine props. Mine props may be in the round, sawed, or split; in diameter they vary from a minimum top diameter of 4 inches to 12 or 14 inches, and in length from 3 feet to 12 feet. Most of the props used locally are 8 feet in length, and call for a 6-inch top, although smaller sizes are used. Mixed oak brings the best prices and forms the bulk of the supplies for this purpose.

2. Motor ties and room ties. Material for this purpose is cut in five-foot lengths, with a 4″ x 5″ face, either sawed or hewed. Untreated mixed oak ties are used to a large extent for this purpose.

3. Lagging. Lagging is round timber or poles, about 3 inches in diameter at the small end and 7 feet long, used to fill in behind the props and caps to form the sides and roofing of the tunnels.

4. Mine caps. These are pieces of plank of varying sizes laid across the tops of the props as a support for the roof lagging, and to tighten the props up. A common size used locally is 3 x 8 inches, 18 inches long. Mixed oak and other durable hardwoods are used.

5. Brattice lumber. Brattice lumber (partition boards) is used for building air chambers when a "double entry" system of mining is necessary. It consists of 1″ stock, random widths and lengths, preferably 10 or 12 inches wide, and square edged. Large quantities of No. 3 common lumber

are used for this purpose. The double entry system is employed to secure better ventilation, and the brattice lumber is used to build the air chambers that encircle the rooms.

d. Other products.—Other products of the forests of this region consist of poles, chestnut extract-wood, oak and hemlock tanbark, piling, cordwood and pulpwood. While the revenue derived from these products and by-products is of no small importance, detailed discussion of them will not be included in this report.

FOREST FIRES.

Nature and extent of damage by forest fires.—Forest fires have done an incalculable amount of damage in this region. With the exception of small forest areas surrounded by cleared fields or near the owner's residence, most of the forests have been burned over repeatedly. Of course the ridges and dry slopes suffer more in this respect than the moister slopes or the coves, which do not dry out so readily and hence do not burn so frequently. The damage following cutting is much more severe than before cutting, because of the accumulation of inflammable slash and because of the opening up of the crown cover, which lets the sun and wind strike the ground.

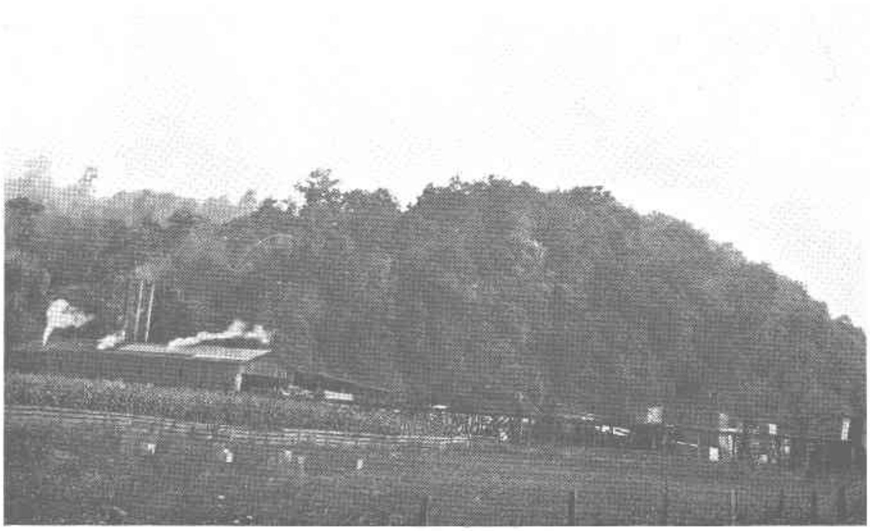
The result of the fires has been great loss to the mature timber from rot and decay, (in many instances even the larger trees being killed outright), the death of the second growth and reproduction, and the failure of these burned-over areas to restock themselves with the more desirable species, or at least a marked delay in this young growth getting established. Furthermore, fires severely injure the soil through chemical and physical changes, open the way to extensive soil erosion, destroy the seeds and seedlings of the more valuable species, reduce the density of the stands, and in time so modify the composition of the stands that they have but very little commercial value.

One of the most harmful results of fires in this region following cutting is that they commonly result in a thick stand of worthless shrubs, such as scrub oak and laurel. These shrubs make it impossible for any timber growth of any value to get a start until the fires are excluded.

Evidences of serious injury by forest fires in the past are general throughout the region, but particularly so in the mountains of Smyth, Wythe and Pulaski counties. In Montgomery and Bland counties, where a system of forest fire protection has been in effect for the past several years, a marked improvement in the condition of the young growth is evi-

(A) The only band mill in this region, that of the Atkins Lumber Co., Atkins. After being in operation eight years it closed down in October, 1924, due to the depletion of its timber supply.

(B) A young stand of pine killed by fire. Wythe County.



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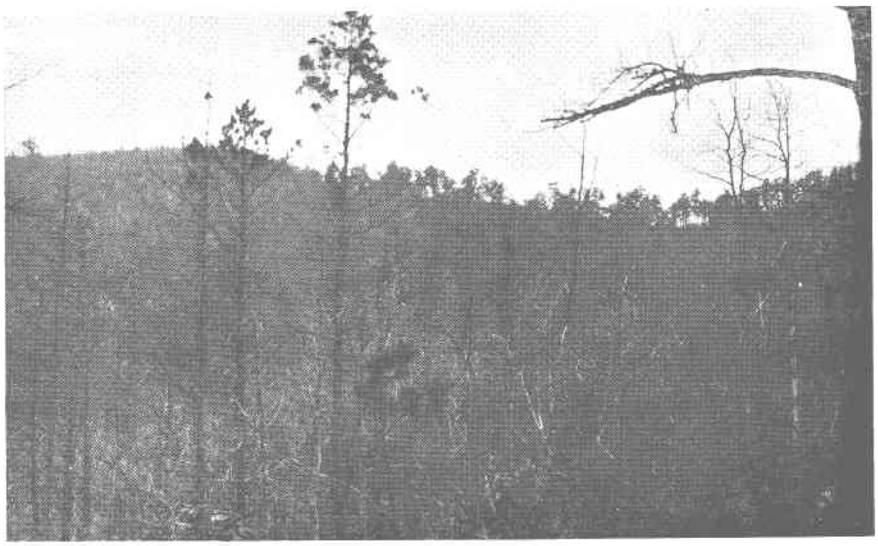

(B) A young stand of pine killed by fire. Wythe County.

dent, even to the casual observer. In these counties reproduction and young growth of valuable trees are making a healthy start and shading out the worthless shrubs which commonly occupy the cut-over areas to the exclusion of any valuable trees in the other parts of the region.

Means of protection against forest fires.—In the case of small isolated tracts of timber the fire problem is not serious, since the owner can protect such properties himself. But the great bulk of the timber in this region is in large contiguous tracts, where each owner's property is exposed to fires originating on the property of every other owner. Under such circumstances organization for fire protection is just as necessary as in a city. The responsibility for organizing such a protective system rests with the State forestry department, under the Virginia laws, but at the present time the forestry department is dependent upon the coöperation of the Boards of Supervisors of the various counties or of groups of owners of adjoining tracts, and is not able to put a protective system into effect without such local coöperation. Information on this point can be secured from the State Forester, University of Virginia, Charlottesville.

DAMAGE BY INSECTS.

There are always a large number of different kinds of insects living in the woods, some of which do more or less serious harm to the trees, while some are indifferent and others beneficial. There are only three kinds of insects doing very serious or striking harm to living trees in this region at this time.

The southern pine beetle.—The most serious harm is done by the southern pine beetle, a small dark beetle which in its larval or grub stage attacks and kills healthy scrub pines, short-leaf pines and pitch pines. There was a serious epidemic of this beetle in this region in about 1890, and there is always danger of another epidemic unless proper remedial measures are taken. There was a fairly serious outbreak in this region within the last two or three years.

The work of the beetle is described and remedial measures are explained in Farmers' Bulletin No. 1188 of the U. S. Dept. of Agriculture, written by A. D. Hopkins, of the Bureau of Entomology, from which the following quotation is taken:

"It attacks the middle and upper portions of the trunks of the healthy pine trees, causing their death by excavating long, winding burrows, or egg galleries, which extend through the inner layers of the living bark and mark the surface of the wood. Eggs are deposited along the sides of these galleries, from which young grubs (larvae) hatch and then feed on the inner bark until they have attained the size of the parent beetles, when they mine into the outer bark and transform to the dormant (pupal) stage, and later to the adult or beetle stage. The beetle then emerges to fly in search of other living trees, in which this process of attack and development is repeated."

The winter is passed in the bark of the living and dying trees in all stages of development. Remedial measures therefore consist of locating infested trees between November 1 and March 1, and destroying the broods by burning the bark of standing or felled trees, or by converting the trunks into fuel wood and using it before the beetles leave the following spring. If the trees are converted into lumber, the slabs and bark should be burned.

Investigations have shown that each patch of dying pine trees resulting from the attack of this beetle is a menace to the living pines within a radius of 3 or 4 miles. Efforts should be made at once, therefore, to destroy the broods of this beetle, according to the suggestions outlined above, as soon as a local outbreak begins. If these suggestions are followed, the danger of wide-spread killing of the pines is not great.

The locust leaf-miner.—The leaf-miner works between the upper and the lower surfaces of black locust leaves, giving the leaves a brown color before the fall frosts occur. While these attacks on leaves rob the tree of much of its vitality, and in isolated cases result in killing the tree, as a rule the attacks do not begin until sometime in the summer, after the trees have had a chance to make a good growth during the spring. The damage from this source is not expected to be very serious.

The locust borer.—The locust borer bores in and out through the wood of black locust trees, particularly at the bases of the trees. In this region it practically confines its attacks to the older trees, usually those over 30 years old, hence, the locust being a rapid growing tree and valuable while very small, it is feasible to utilize the locusts while small and before they become seriously susceptible to attack. In other states pure plantations of locust have been ruined by the borer while very small, but the borers are not abundant enough to do this in this region, and in any case it is believed that such damage can be obviated by growing locust trees in mixed stands instead of in pure stands.

FUNGOUS DISEASES.

There are always a great number of different kinds of fungi that work in the woods, some of them doing more or less severe damage, but most of them confine their attacks to dead trees, which they cause to decay. Serious damage is done in the case of living trees where fungi gain entrance at places near the ground where the bark has been killed by a fire, and decay extends upward. This kind of injury occurs wherever fires are allowed to burn in the woods. The only fungous disease which can be considered an epidemic in this region at this time is the chestnut blight or chestnut bark disease.

Chestnut bark disease or chestnut blight.—This disease attacks living healthy chestnut trees, causing their death usually within four years after the time of the first attack. The disease does not attack any other trees except chestnut. This epidemic originated in this country in New York City in 1905, and it has been spreading in all directions where chestnut occurs since that time. Already the bulk of the chestnut trees in the northern half of Virginia are dead or dying from this disease, but it has only reached the region covered by this report in the case of a few isolated spot infections in a very few places.

So far as anyone can tell at the present time there is nothing to stop the progress of this disease. In all probability it will become more and more severe in this region and will probably result in the almost complete extermination of the chestnut in this region. The problem in the case of chestnut is how to utilize the present stands to the best advantage and to try to get a satisfactory stand of other valuable species to take the place of the chestnuts which are killed.

INJURY DONE BY GRAZING.

A small number of horses or cattle ranging over a large area of woods do very little damage, but if the number of head of stock is large in proportion to the area of the range the damage may be quite serious. Under such circumstances the cattle and horses nibble and kill the young seedlings and trample a large proportion of what they don't eat. Their tramping, particularly at times when the soil is wet, makes the soil hard and compact, which makes the germination of seeds difficult or impossible and makes the rainfall run off the surface instead of soaking into the ground.

The damage is particularly severe in the case of seedlings of yellow poplar, which stock are particularly fond of and which is from the standpoint of lumber and pulpwood production the most valuable tree to grow in the coves and on the moist slopes. Hence it is often desirable to keep stock out of such areas at a time when the stand is being reproduced, whereas the grazing may do no harm a little later, when a thrifty young stand has got beyond the reach of the cattle. It is often desirable to fence off a small portion of the woods for shade for the cattle and keep them out of the balance of the forest.

NECESSITY OF MORE CONSERVATIVE CUTTING.

Cutting has almost always been done in this region in the way that the operator supposed would give him the most immediate profit, entirely disregarding the condition in which the woods were left and whether another cut would ever be possible or not. Of course this has resulted in the steady deterioration of the woods. Even in the counties where a fire protection system has been established, the young growth is not as dense or of as valuable species as it would have been if the cutting had been done always in accordance with the scientific principles of forestry. The determination of the right method of cutting in each case is the work of a professional forester, and a careful examination of the forest in any given case is needed in order to enable the forester to determine how to apply the principles of forestry to the given situation. Only a general outline of the methods that will usually be most applicable in this region will be attempted here.

Care in logging.—A principle that should be applied in every case without exception is that greater care should be used by the workmen in logging. In felling trees, care should be taken not to throw them into the midst of clumps of young trees, which may be seriously injured or totally destroyed. By the exercise of a little care in skidding the logs out of the woods, much breakage, bending, trampling and skinning of young growth can be avoided. It should always be kept in mind that this young growth, often spoken of as "brush," represents the first stage of tree growth, and has great possible value.

Closer supervision by timberland owners of operations on their property will pay them well.

Diameter limits.—In certain types of forest and conditions of operation it is considered desirable not to clear-cut any given stand in one operation but to cut over a given stand a number of times at intervals of a few years, each time taking out only the larger trees, thus leaving a stand of medium sized and small trees to occupy the ground and to grow to larger size before they are cut. Such a forest is called in forestry a "selection" forest and such a cutting is known as a "selection" cutting. It is rather generally recognized that under certain conditions cutting in this way is desirable and many timberland owners have tried to keep their land more or less productive by adopting this method instead of allowing the purchaser to cut every tree that he thought he could make any profit out of.

This method is sometimes spoken of as the "diameter limit" method, since under it trees are usually sold down to a certain diameter limit. But in actual practice, selling in this way has seldom accomplished what it was intended to or could accomplish, because the diameter limits have been placed far too low. The diameter limits have usually been 10 or even 8 inches measured across the stump, which obviously results in the cutting of all except extremely small trees. The limits should vary with the species primarily, the most valuable tree species, such as yellow poplar, black walnut, white pine, cucumber, linden and white oak being sold only down to a diameter of 16 inches or preferably 18. On the other hand the least valuable species, particularly red maple, black gum, beech and scrub pine should be cut down to as small sizes as can be marketed without loss. This would result in a larger proportion of the more valuable species in the next cut and would also result in a much larger amount of the more valuable species in the next cut, because trees between 16 and 8 inches in diameter are too small to yield a great amount of lumber but are just at the period of their most rapid growth, a time at which it is wasteful to cut them.

Such diameter limits for the different species should not be rigid, but should be flexible, and the trees should be selected for cutting by a forester, who would mark for cutting some of the inferior individual specimens that are slightly below the normal diameter limit and would save for future growth some of the better individual specimens that are slightly above the diameter limit.

Seed trees.—The other method of cutting with provision for future growth which will be most applicable in this region is the method of clear-cutting the bulk of the stand, leaving certain trees to scatter seed for a new crop. Obviously the trees selected to bear seed after the cutting of the balance of the stand should be of the species that are most desired in the succeeding crop, whether from the standpoint of high quality of their wood, their rapid growth, their particular adaptability to the use for which they will be wanted, or their ability to thrive under the existing conditions, such as the quality of the soil, the amount of moisture, and the insects and diseases with which they will have to contend. The number of trees that need to be left for this purpose will vary considerably, but in general it is probable that one or two trees to the acre, well distributed, will be enough in the case of species that have light seeds that are blown considerable distances by the wind. Such trees include yellow poplar, the pines, black locust, and white ash. In the case of trees with heavy seed, which are not blown far by the wind, probably three or four trees to the acre, well distributed, will be needed. Such trees include all the oaks, the hickories, and the chestnut (which, however, should not be selected as a seed tree, because of the probability that the chestnut trees will be killed by the blight).

Seed trees should have reasonably large crowns, to enable them to bear and scatter fairly large crops of seeds, and they should be healthy enough to live for a number of years and scatter several crops as insurance in case the early seedlings should be killed by fire, but otherwise the seed trees need not be the largest or finest individual specimens. Forked or limby trees which would have little value for lumber may be made to serve perfectly well as seed trees. The selection of the seed trees is the work of a forester.

SUMMARY.

If fires are excluded from the forests of this region and cutting is done conservatively, in accordance with the principles briefly outlined above, the woods of this region will be immensely productive, yielding a great variety of materials, but particularly the wood which will be needed in the mining industry itself as soon as the coal in this region is operated on a large scale. Otherwise the woods will degenerate into waste lands, practically worthless for any purpose.

INDEX

GEOLOGIC MAP
OF THE
COAL FIELDS OF MONTGOMERY, PULASKI, & WYTHE COUNTIES, VIRGINIA
PREPARED BY
VIRGINIA GEOLOGICAL SURVEY
THOMAS LEONARD WATSON, DIRECTOR
IN COOPERATION WITH
UNITED STATES GEOLOGICAL SURVEY
GEORGE OTIS SMITH, DIRECTOR
SURVEYED IN 1914-18-1921-23-24
BASE MAP BY
U. S. GEOLOGICAL SURVEY
AND ARMY AIR SERVICE
GEOLOGY BY
MARIUS R. CAMPBELL, RALPH W. HOWELL, ROY J. HOLDEN
AND KENT K. KIMBALL
1924
Scale 1/62500
4 Miles
WALKER MOUNTAIN
LITTLE WALKER MOUNTAIN
BRUSHY MOUNTAIN
GAP MOUNTAIN
SINKING CREEK MTN
PARIS MOUNTAIN
COVE MOUNTAIN
DRAPER MOUNTAIN
PULASKI FAULT
SALEM FAULT
WYTHEVILLE
PULASKI
Dublin
Blacksburg
Christiansburg
Radford
Rural Retreat
Crocketts
Max Meadows
NEW RIVER
COLUMN
REPRESENTING THE ROCK FORMATIONS IN THEIR NATURAL ORDER
CARBONIFEROUS
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Mississippian
DEVONIAN
SILURIAN
ORDOVICIAN
CAMBRIAN
Shenandoah limestone
Coal measures of the bituminous fields 3000'+
Lee formation (sandstone and conglomerate) 500'
Pennington shale 1000'
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Maccrady shale 700'+
Price formation including group of coal beds
Ingles conglomerate member 1700'
Devonian sandstone and shale 3650'
Clinch and associate sandstones and overlying Helderberg limestone 600'
Sevier shale and underlying sandstone and shale 1400'
Chickamauga limestone 200'
Knox dolomite (Sandy layer 0' to 40') 3600'
Nolichucky shale 300'
Honaker limestone 800'
Watauga shale (shale and limestone) 1000'
Shady dolomite 800'
Erwin quartzite 500'
EXPLANATION
Fault.
Outcrop of coal group.
Mine and prospect. Numbers used in text description.
Dip and strike symbol. Strike indicated by long line; dip, by short line; degree of dip, by figures.
Road, hard surfaced accurately mapped.
Road, dirt, accurately mapped.
Roads, not accurately mapped.
Note: In some parts of the area no data regarding roads are available, hence roads are omitted.
SECTION H-H'
SECTION I-I'
SECTION F-F'
SECTION G-G'
SECTION E-E'
SECTION J-J'
SECTION C-C'
SECTION D-D'
SECTION A-A'
SECTION B-B'