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GEOLOGY OF THE BIG STONE GAP COAL FIELD
OF VIRGINIA AND KENTUCKY

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J. W. POWELL, DIRECTOR

GEOLOGY

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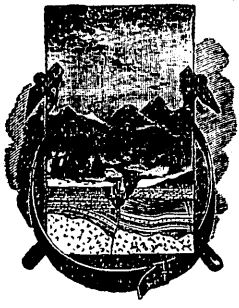
BY

MARIUS R. CAMPBELL



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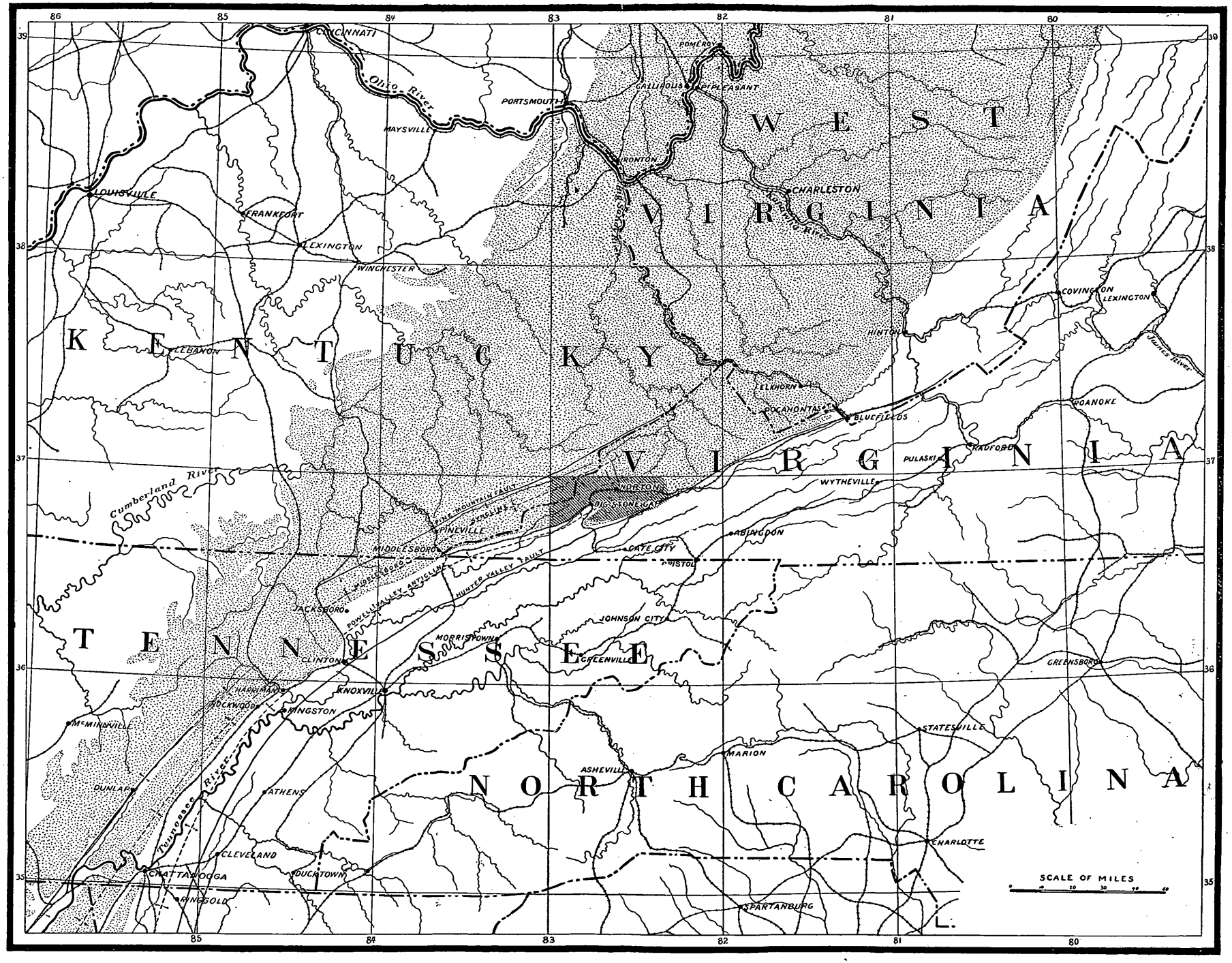
APPALACHIAN DIVISION,
Washington, D. C., June 13, 1893.

SIR: I herewith respectfully transmit and recommend for publication as a bulletin of the Survey the manuscript, maps, and sections relating to the Big Stone Gap coal field, prepared by Mr. M. R. Campbell, assistant geologist of the Appalachian Division, as a result of the field work of 1891. Mr. Campbell's work in this field has been done with care, and the result of his investigation will be of much practical value, not only to the development of the local field, but also to an understanding of the geology of the Coal-measures of southwestern Virginia and Kentucky.

Very respectfully,

BAILEY WILLIS,
Geologist in charge.

Hon. J. W. POWELL,
Director U. S. Geological Survey.



MAP SHOWING THE RELATION OF THE BIG STONE GAP COAL FIELD TO THE CENTRAL PORTION OF THE APPALACHIAN BASIN.

GEOLOGY OF THE BIG STONE GAP COAL FIELD OF VIRGINIA AND KENTUCKY.

By Marius R. Campbell.

INTRODUCTION.

The central portion of the Appalachian coal basin is an unknown region so far as the details of its stratigraphy are concerned. This territory is mainly restricted to the southeastern side of the basin, and extends from the Flat Top field of Pocahontas, Virginia, to central Tennessee. Its undeveloped condition results not from the barrenness of its strata, for it carries fine bodies of workable coal, excellent in character and well disposed for mining, but arises from its remote position. The country is rough and broken, its population thin and scattered, and its poverty proverbial. These have been the principal elements in preventing the development of its mineral resources, for development is dependent entirely upon transportation facilities, and such a country offers little inducement for railroad building. Until within a few years the more available mines in other portions of the Appalachian basin have been adequate fully to supply the demand for coal and coke, and the stores of fuel locked up in these barren hills have been allowed to lie undisturbed.

While the supply of coal could be met by other portions of the field, there was little demand for extensive and systematic geologic work. The work was usually done by private enterprise and was necessarily limited to the examination of specific coal seams throughout a small extent of territory, without opportunity to examine the adjacent country for a comprehensive view of the field. Even where the work was well done the lack of an adequate topographic base upon which to delineate the geologic facts observed detracted materially from its value. In general, the results obtained from this scattering, desultory work are totally inadequate to determine either the structure or stratigraphy of the field.

In the last few years this condition has changed; the consumption of fuel has rapidly increased, and the increased demand has stimulated prospecting and development in this region. At present there is an

urgent need of geologic information regarding the structure and stratigraphy of the field, upon which to base future operations.

In 1891 the U. S. Geological Survey undertook to meet this want by mapping in considerable detail the areal geology of the region and by making a careful study of the various members of the Coal-measure series. Accordingly the writer was instructed to map the Estillville atlas sheet and make a special study of the coal territory north of Stone mountain.

Previous to this, all geologic research had been confined to the measurement of a special section of the Coal-measure series, and reports had been made only on the practicability of mining and transporting the products of the mines, with descriptions of the coals from various seams. No attempt had been made to group the measures, or to map the outcrops of the important members. Necessarily, from this method of work, the detailed structure of the field had been overlooked, and many errors in correlation occurred.

With these facts in view it was decided to confine the work of the U. S. Geological Survey mainly to areal geology; construction of a correct stratigraphic column; division of the series into groups, recognizable throughout the field; and the determination of the details of structure. In pursuing this plan of work no attention was paid to the composition, commercial value, and coking qualities of the coals.[1]

As the principal coals occur in a mountain range, rising at its highest point 4,200 feet above sea level and 2,800 feet above Big Stone gap, the altitude of a coal outcrop is most important in determining its stratigraphic position. The Norfolk and Western and the Louisville and Nashville railroads afforded base levels from which altitudes were obtained. Lines of levels had been run by the Virginia Coal and Iron Company from the railroad surveys to all their openings on Callahan and Looney creeks, and these were very kindly placed at our disposal. In other portions of the field the aneroid barometer was the only instrument employed in determining altitudes. These readings were checked repeatedly, but it is altogether probable that appreciable errors exist in the altitudes of the observed outcrops. These errors are undoubtedly greater in the mountains, for the range of altitudes is greater, and during the field work in the heights the weather was extremely unfavorable; but where this error is greatest the coals are fortunately of least value and most inaccessible.

Meander lines were run, connecting all exposures of coal and forming a complete network over the field; this gave the correct relative

[1]For information concerning these important points the reader is referred to the following papers: J. J. Stevenson, Notes on Geology of Wise, Lee, and Scott Counties, Virginia; Am. Phil. Soc. Proc. 1880–'81, vol. XIX, pp. 88–107. C. R. Boyd, The Economic Geology of the Bristol and Big Gap Section of Tennessee and Virginia, Pursuing the General Course of the South Atlantic and Ohio railroad; Am. Inst. Min. Eng. Trans. 1886–'87, vol. 15, pp. 114–121. McCreath and d'Invilliers, Mineral Resources of the Upper Cumberland Valley in Southeastern Kentucky and Southwestern Virginia, 1888. McCreath and d'Invilliers, report on a Portion of the Virginia and Tennessee Coal and Iron Company's Property, Wise County, Virginia, 1892.

location which, when adjusted to the topographic base, determined the outlines of the geologic map.

The mode of correlation and determination of structure employed in the final preparation of the field notes is novel, and, as it gave excellent results, a slight description of it will be given. All the observations on coals and other characteristic horizons were platted on a large-scale map (2 inches to 1 mile), and then numerous cross sections were made in various directions connecting the outcrops. The great key rocks, the Harlan and Gladeville sandstones, gave the clue to the general structure, making it possible to correlate the principal coals across wide intervals that would otherwise have been exceedingly difficult to span. This method of establishing numerous cross sections has the essential qualities of a model, and when the sections were so adjusted as to agree at their intersection it was found that they brought out details of structure which could hardly be detected by any other method.

In presenting this paper the writer has two objects in view. The first is to add to the general knowledge respecting the geology of this central district. The groups determined in this region will be carried over the adjoining territory if they can be distinguished and they afford a type-section of the Coal-measures where they are probably best developed. The results are not put forth as final, but as representing the most probable conclusions from the observed facts.

The paper is also intended as a guide for practical operators in the field. It is meant to present a detailed description of the stratigraphy with the thicknesses of its prominent members, but especial stress is laid upon the structure, the details of which are given as far as determined. As will be shown in detail, prospectors are frequently at a loss to account for the change in elevation and attitude of a coal seam; or, failing to realize the influence of a change of structure, they make an erroneous correlation and mistake the outcrops of a single bed for distinct seams. By the aid of the key rocks described in the body of this paper, the writer was enabled to recognize and map many of the minor folds that are the principal cause of trouble in the field, and by the same criteria the practical worker can do the same and shape his work accordingly.

GENERAL DESCRIPTION.

LOCATION OF THE FIELD.

The Big Stone gap coal field is located in southwestern Virginia and southeastern Kentucky and includes portions of the counties of Wise, Scott, and Lee in the former state and Harlan and Letcher in the latter. Its northern boundary is the parallel of 37° north latitude and its western the eighty-third meridian; its southern and eastern boundaries are irregular, being mainly the southern margin of the Coal-measures. The map comprises a territory varying from 12 to 15 miles wide and 36

miles long; it is a part of a long, narrow basin extending northeast and southwest, bounded on either side by sharp, rocky ridges that render it quite difficult of access. The few water gaps in these barriers are of great importance, as they are the gateways through which all lines of transportation must enter in order to reach the coal fields within.

In the area mapped there is one such natural gateway, Big Stone gap, and it is from this important topographic feature that the field has been named. This passageway is already utilized by two lines of railroad, and is destined to become one of the principal outlets for the products of the field.

TOPOGRAPHIC FEATURES.

Within this territory there are two widely different types of topographic forms that may be designated as the coal basin type and the valley type.

Type of topographic forms in the coal basin.—The plateau or "mesa" type of surface relief is characteristic of the interior of the coal basin in West Virginia, southeastern Ohio, Kentucky, and northern Tennessee. Eastern Kentucky is, perhaps, the typical locality, as it exhibits this phase of topography in most pronounced form. In that state the territory of the Coal-measures is an elevated base-leveled plain that has been dissected by streams. As the rocks are nearly homogeneous and practically horizontal, erosion has been guided by chance; the streams wind and the drainage basins are irregular in outline; the divides, being determined entirely by the cutting of the streams, are extremely irregular both in plan and section.

In the Big Stone gap field this type occupies the entire region except Pine and Stone mountains. The portion in Kentucky consists of the Big Black mountains, a zig-zag ridge with long branching spurs that are simply the divides left by the side streams as they cut their deep and narrow valleys between them. The valleys are carved in nearly horizontal strata, with but few hard beds to affect the rounded contours of the slopes. On the Virginia side the topography is very different, there being but two prominent ridges, the Bluff spur and Nine-mile spur, both in Wise county. In Lee county there are no marked elevations, the surface at the foot of the Little Black mountain being nearly flat at a general altitude of 2,000 feet above sea level. This appears to be an old base level and the region is quite thickly settled. On its southern side, near Stone mountain, the north fork of the Powell river has cut a deep gorge, and the small streams are actively engaged in deepening their channels, cutting into this old plain along numerous cross valleys. In the Pigeon creek region, just across the line in Wise county, the topography is rough and broken and there are few inhabitants. Further east, on Looney and Callahan creeks, the broader valleys afford easier access to the country, but the hill slopes continue to be steep and are generally covered by the original growth of timber. East of the Roaring fork the country becomes more open, the hills,

though high and steep, are quite generally cleared and farmed on top, the creeks still wind through bottoms, and the hill slopes are more round than in the region further west. East of Guest river this phase disappears and the topography assumes the character of a plateau; the valleys are sharply cut, the slopes rising from 200 to 900 feet to a stratum of hard sandstone that has preserved this district from erosion. Toms creek has cut deeply into this table-land, which nevertheless extends to the eastern extremity of the field and forms the prominent sandy ridge that limits the Tennessee river basin on the north.

Type of topographic forms of the valley.—This type is characteristic of the Appalachian valley from Alabama to New York, and consists of ridges formed by upturned hard strata that have resisted erosion more successfully than the adjoining beds. These ridges are generally straight for long distances, remarkably even crested, and sharp in section.

In the Big Stone gap field there are two excellent examples of this type, in Stone and Pine mountain, both formed by the upturned Lee conglomerate. Pine mountain is remarkably straight and even crested; the Lee conglomerate forming it dips southward about 30° and is composed of three or four heavy sandstones with interbedded shales. The sandstones weather very slowly, while the shales are rapidly worn away; thus the main ridge is made up of three or four subordinate ridges, each composed of a massive sandstone. These are generally bare of vegetation, extremely rough and rocky. On its northern face Pine mountain presents a fault scarp and is so steep that it is difficult to cross.

Stone mountain is equally rough, but the attitude of the beds varies and gives rise to a variety of forms. Near the western edge of this field the conglomerate has a nearly vertical dip and its upper bed, the "Bee rock," stands against the mountain slope with bare rock faces 600 or 700 feet high. On each spur this bed forms a "tooth" of sandstone projecting above the ridge. It makes the mountain almost impassable. In the vicinity of Ohriger gap the dip flattens to 20° or 30° and the mountain changes character accordingly; east of this the dip increases and the mountain grows rougher. Opposite the mouth of Roaring fork the conglomerate dips about 70° north and its outcrop presents a curious spectacle. The "Bee rock," here about 100 feet thick, stands out as a bare rocky wall for almost half a mile and varies in height from 50 to 200 feet; the curious feature is that the shale has been cut away behind this by a small branch, leaving a solid wall of sandstone which overhangs its base. East of Norton, at the junction of Powell and Stone mountains, is probably the roughest portion of the mountain. Here the conglomerate forms an anticlinal arch, but the streams have all cut deep canyons, leaving high cliffs. These are wild and picturesque but almost inaccessible. East of this the

arch dies out and the mountain loses its rough character; the streams flowing south into the Clinch river, having the advantage of lower and shorter outlets, have cut gorges, but these are not so picturesque.

Pine and Stone mountains constitute the barriers that inclose this field. Pine mountain effectually prevents access to the field from the northwest; it has no low gaps from the Breaks of Sandy to Pineville, a distance of 85 miles. Stone mountain, on the southeastern side of the field, offers less obstruction to traffic, though it also presents a barrier to the economic development of the inclosed basin. This mountain extends from Norton, Virginia, to Jacksboro, Tennessee, but in that distance it is broken by three water gaps—Big Stone, Pennington and Big creek gaps; there is also Cumberland gap, which has long been noted as a highway between the east and west. This is at present only a low wind gap, but doubtless, in not very remote geologic times, it was a water gap, occupied by a branch of the Cumberland river that has since been diverted from its original course and is now a tributary of the Clinch river.

Two of these gaps are of great importance to the Big Stone gap field. Big Stone gap, as already noted, is the principal outlet for the rich coal basin drained by the main Powell river, or the western portion of Wise county, north of Stone mountain. Pennington gap is the natural outlet for the basin west of this area. The coals are not so important, but there are several workable seams on the head waters of the north fork of Powell river, in Lee county. No railroad has been built through this gap, but in case of the development of valuable coals in this basin a line could easily be constructed from the Louisville and Nashville railroad at Pennington gap station to reach any portion of the field.

Another important outlet for the coal of this field is around the eastern end of Stone mountain, and this route is already followed by the Clinch valley division of the Norfolk and Western railroad. So, for the Virginia portion of this field, there are three open gateways. In the Kentucky portion there are but two avenues of approach, either by a road up the Poor fork of the Cumberland from Pineville or up the Russell fork of the Sandy in Kentucky to above the Breaks, and then up the Pound river, connecting with the Poor fork through a low divide 2,000 feet above sea level.

As the stream valleys of these approaches are generally narrow and tortuous it will probably be some time before the demand for new sources of supply is sufficient to make the building of such lines profitable. The coals visible on these streams seem to warrant the construction of such lines, but the demand is certainly not in the immediate future.

Drainage.—The Black mountain in this field forms the general water-shed between the Big Sandy flowing north, the Cumberland flowing west, and the Tennessee flowing southwest. Although the water from this region diverges on such different lines and pursues such widely different courses, it is all united again in the lower Ohio.

The Tennessee river drains by far the largest portion of the field, practically all of the Virginia territory. The Clinch river is the principal outlet for this portion, and the territory is divided between its two branches, Powell and Guest rivers. At present they share it about equally, but this relation has not always been maintained. In remote ages the stream draining this portion of the country probably had its source on Sandy ridge, where Big Tom's creek at present heads, flowed west along the present channel of Guest river and discharged its waters into the Powell river through the low gap at Norton. A tributary of the Clinch has cut away the divide to the east and the drainage from Norton east has been reversed. Though this change occurred long ago, the marks of the old stream are well preserved and unmistakable, and the deserted channel at Norton affords the railroads a comparatively easy passage way across a divide that otherwise would have been a serious obstacle.

In the Kentucky portion of the field the drainage is entirely through the Poor fork of the Cumberland river. This stream with its large tributaries, Clover lick, Clover fork, and Looney creek, has cut deep gorges in the soft Coal-measure rocks; these gorges are important chiefly because they afford geologic sections and routes for transportation.

Development of the country.—From the mountainous character of the country, its value for agricultural pursuits is small, especially so where its mountains are composed of Coal-measure rocks that generally yield a light, poor soil. The bottoms along the streams are valuable, but these are of small extent and of rare occurrence. The greater part of the country is still forest-covered, but it has been robbed of its best timber.

The development of the mineral resources of this region should raise it from the low rank it has hitherto held into one of the wealth-producing portions of the country.

STRUCTURE.

GENERAL DESCRIPTION.

Along the eastern margin of the Appalachian coal field there is a belt of slightly disturbed strata that forms the transition from the nearly horizontal rocks of the Cumberland plateau to the highly contorted strata of the great Appalachian valley. In the practical development of coal in the interior of the basin the question of the attitude of the rocks is rarely considered, but in the transition belt their dips are important. The strata, besides being bent into many large folds, are frequently traversed by numerous minor undulations that have a decided effect upon the elevation and attitude of the coal. These, on account of their apparent insignificance, are generally disregarded and are the most frequent cause of error in correlating coal outcrops. The practical operator, in order to understand the full effect of these minor disturbances upon the seam of coal, must be familiar with the general structural features of the field and their interrelations.

As the Big Stone gap coal field is situated upon the eastern margin of the coal basin, a brief description will be given of the prominent structural features that characterize the transition belt throughout most of the central portion of the Appalachians.

STRUCTURAL FEATURES.

The principal faults and folds are indicated on Pl. I, and they may be described as follows:

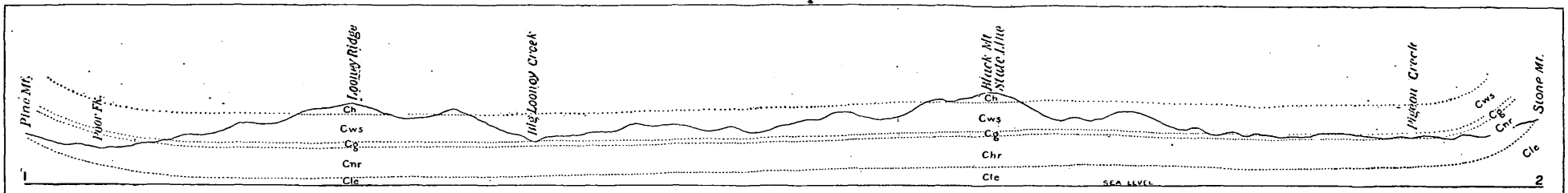
1. A profound break—the Hunter valley fault—stretches from near Rome, Georgia, to the New river, Virginia, and forms the southeastern limit of all known Coal-measures. This is one of the most extensive faults in the Appalachian province, having a length of 370 miles and a stratigraphic throw of 11,000 feet. This fault, like others throughout the province, has developed from an anticlinal fold, which, owing to the extent of the thrust, has entirely disappeared except at the extremities of the fault; there the anticline still exists.

2. West of the Hunter valley fault, throughout most of its extent, there are remnants of a syncline originally accompanying the now faulted anticline. The syncline has been nearly buried by the overthrust mass, and is only visible in such remnants as White Oak mountain, Tennessee, and Wallen ridge and Powell mountain, Virginia.

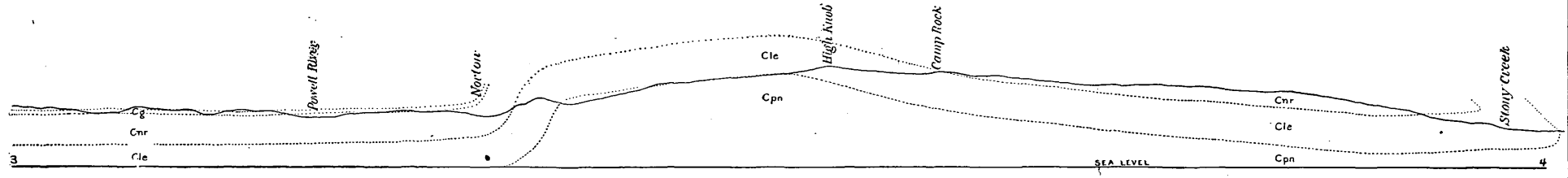
3. Northwest of the syncline is one of the most pronounced structural features in the region, the Powell valley anticline. This great fold has its northern termination in the Big Stone gap field, and extends thence south as far as Gadsden, Alabama; it is generally a single, broad fold, but in places it is composed of several smaller anticlines or narrow faulted strips developed therefrom; in width it varies from 5 to 12 miles, with an average of 7 or 8 miles.

4. On the northwest side of this arch is a correspondingly wide trough or synclinal fold, which is here designated the Middlesboro syncline. The Big Stone gap coal field covers part of this great trough, which rapidly widens to the northeast as the Powell valley anticline flattens out, and at no great distance is merged in the flat, unbroken Coal-measures of West Virginia. To the southwest the trough holds its normal width of 12 or 13 miles to the line of the Knoxville and Ohio railroad, where it abuts directly against the horizontal rocks of the upper Coal-measures of Cross mountain. The exact nature of its termination is not known, but it is probably cut off by a cross fault along the line of the railroad. Southwestward from this cross fault the strata are flat and undisturbed for about 25 miles, but opposite Harriman, Tennessee, a syncline develops of about the same width and in the same relative position; this extends far southwest, and is locally known as Walden ridge and Sand mountain, and in central Alabama is merged in the basin of the Black Warrior.

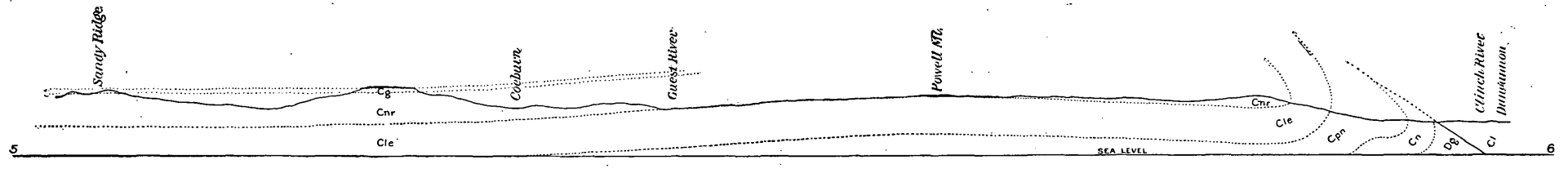
5. The last conspicuous structural feature toward the northwest was originally a sharp anticlinal fold, which, upon the continuation of the



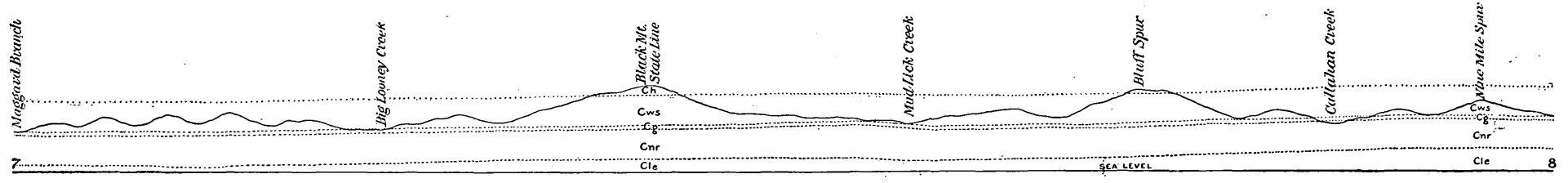
SECTION FROM THE MOUTH OF LEWIS CREEK KY. TO THE HEAD OF PIGEON CREEK VA.



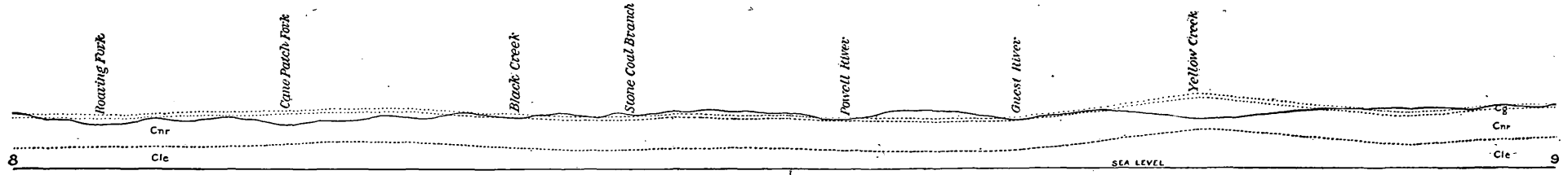
SECTION THROUGH NORTON, HIGH KNOB AND STONY CREEK.



SECTION THROUGH COEBURN AND DUNGANNON.



SECTION ALONG AN EAST AND WEST LINE FROM MAGGARD BRANCH TO NINE MILE SPUR.



SECTION ALONG AN EAST AND WEST LINE FROM NINE MILE SPUR TO YELLOW CREEK.

Ch HARLAN SANDSTONE Cg GLADEVILLE SANDSTONE
Cws WISE FORMATION Cnr NORTON FORMATION

STRUCTURE SECTIONS ACROSS THE BIG STONE GAP COAL FIELD.

SCALE OF MILES

Cle LEE CONGLOMERATE Cn NEWMAN LIMESTONE
Cpn PENNINGTON SHALE Dg GRAINGER SHALE.
Cl CAMBRIAN LIMESTONES

thrust, developed into a fault throughout most of its length. Between the Tug fork and Russell fork of the Big Sandy river it is described as a simple anticline[1], growing in magnitude toward the southwest; in the vicinity of Russell fork the fault develops and continues southwest for a long distance. The overthrust limb of the anticline forms the present monoclinal ridge of Pine mountain, faulted along its northern base and thrust upon the nearly horizontal rocks of the upper Coal-measures. The course of the fault is southwest, parallel with the axis of the Middlesboro syncline, and it is terminated by the same cross fault. An interruption occurs here similar to the one mentioned in connection with the syncline. As the syncline develops again southwestward, so does the anticline, in the form of a gentle fold which increases in magnitude to the southwest and forms the noted Sequatchie valley and its southwestward extension, Brown's valley. This arch is faulted throughout most of its length, but the thrust has not been so great as in Pine mountain, and the anticline is not destroyed.

When it is considered that each of these great structural features passes through the small territory of the Big Stone gap coal field, it will be seen that a knowledge of the characteristics of each one is of the greatest importance, as they all have an influence on the practical value of the field. They are accordingly described together with the minor folds that accompany them.

STRUCTURE OF BIG STONE GAP FIELD.

The axis of the Powell valley anticline enters this field from the west 2½ miles south of Stone mountain, striking N. 55° E.; the height of the fold is such that the Knox dolomite, which is 7,200 feet below sea level in the syncline north of Stone mountain, is here brought to the surface at an elevation of 1,500 feet, making a rise in the arch of 8,700 feet. From this point the axis holds about the same course, N. 55° E., to a point just south of Little Stone gap, where its height has diminished to 5,800 feet above the syncline on the north. From Little Stone gap its direction is changed to due east and its downward pitch is so rapid that at the state road south of Coeburn it is only 1,200 feet high, diminishing to almost nothing at the Clinch river.

Like most folds in the Appalachian region, this anticline is unsymmetrical; its northwestern side is almost vertical, while its southeastern limb dips gently away from the axis and gradually merges into the shallow syncline on the south. From Clinch river to High knob the Carboniferous strata are not eroded from the fold, the Lee conglomerate serving as its protecting shield; further west erosion has cut deeply into the arch, down even to the Silurian limestones, but the character of the fold is the same. The vertical northern limb is shown in the sharply upturned Lee conglomerate of Stone mountain; the

[1]Geological Survey of Kentucky. Preliminary report on the Southeastern Kentucky Coal Field, by A. R. Crandall and G. M. Hodge, Frankfort, Kentucky, 1887, p. 7.

crown of the arch, in the flat-lying limestones in the center of the valley; and the light southern dips in Wallen ridge and Powell mountain.

In Powell mountain, east of Slemp gap, the remnant of the syncline between the Powell valley anticline and the Hunter valley fault is comparatively unimportant, both as a feature of the structure of the field and its mineral resources. The Coal-measure rocks in this basin lie so high in the mountain that erosion has removed almost all of them except the heavy Lee conglomerate.

The character of the fold in Powell mountain is shown in Pl. II. Section 3–4 exhibits the structure along a line from Norton through High knob to Stony creek, and shows the conglomerate in a vertical position just south of Norton, the crown of the arch north of High knob, and the gentle syncline on the southern side of the mountain sharply overturned along the Hunter valley fault. Section 5–6 is along the state road south of Coeburn, and shows the very gentle anticline of Powell mountain, with a slight trace of the syncline on its southern side; a little farther east the fault has completely obliterated the trough, and the arch itself is lost in the slight irregularities of the strata in the vicinity of the fault.

The Middlesboro syncline is the true coal basin of the Big Stone gap field, and from an economic standpoint is decidedly the most important structural feature in the region. This basin has suffered a large amount of minor, irregular deformation, that probably owes its origin to the unknown forces which folded the rocks of the great Appalachian valley. The flexures assumed by the rocks under this great pressure are of various forms, but for practical purposes they may be divided into two general classes:

1. Folds affecting an indefinite number of strata, of relatively deep-seated origin, and differing from the great plications of the valley only in degree.

2. Folds generally of less magnitude than the preceding class and limited entirely to the stratum in which they originate.

Folds of the first class are doubtless due to the fact that the strata were not rigid enough to transmit the pressure without bending. Local conditions probably determined their positions and the direction of the pressure determined the strike of the fold.

Folds of the second class are due simply to the contortions of a single weak stratum in adjusting itself to a new position determined by the differential movement of the two adjacent rigid beds; this folding is frequently carried to such an extent that faulting occurs and the result is a long series of regular dips in the same direction, but as these are limited to the single formation they give no indication of the general structure of the region.

This class almost always accompanies great plications and is a common cause of variability in the thickness of coal seams.

Pl. III is a contour map of the top of the Gladeville sandstone. The object of the map is to bring out the details of structure that can not

be shown in sections unless the vertical scale is greatly exaggerated. In constructing this map, the Gladeville sandstone was chosen simply because it is the stratum which is most easily recognized throughout the field, and the structure of this formation resembles that of any bed above or below it. In tracing coal the prospector can use this map to determine the elevation at which any coal bed occurs; given the distance of a coal bed above or below the sandstone, this figure should be added to or subtracted from the elevation of the sandstone in the given locality. The data at hand were not sufficient to determine all details, but the main features are fairly well ascertained. The axes are indicated by broken lines, and the character of the fold by arrows pointing in the direction of the dip. This map illustrates the complexities of this field, in which the rocks are supposed to be nearly horizontal; in fact, they are nowhere horizontal, and rarely maintain regular dips for any great distance.

The main axis of the Middlesboro syncline is near the northwestern edge of the basin, as shown on Pl. v at A A′, passing through the highest points on Benham spur and Looney ridge; it is approximately parallel to Pine mountain and about 2¾ miles distant from it.

This syncline is traversed by a low, broad anticline, B B′ C, that toward the western edge of the field is parallel with the main axis; at B′ its direction changes and its volume increases, so that the axis B′ C has a nearly due north and south direction. Its height above the syncline axis at A is 800 feet and at C 350 feet. From B′ there are indications of the southward continuation of the axis C′ D to its junction with the main fold near Olinger gap.

This arch is called the State line anticline, for its axis corresponds very closely with the state line across this field. As a rule it is located east of the crest of the mountain and separates an area of slightly disturbed, regularly-dipping rocks in Kentucky from an area of much minor folding in Virginia. On the Kentucky side the strata descend at an average rate of about 90 feet per mile; the dip is steeper near the anticlinal axis, B B′ C, and flattens out as it approaches the synclinal axis A A′. On the eastern side the descent is neither so great nor so regular. The slight effect of gentle dips in the strata appears in the topography of this district. Southeast of this axis B B′ C, the disturbed strata are deeply eroded, but in the Kentucky region, even though the dip is considerable, the slope is regular and erosion has apparently been no more active than where the strata are horizontal.

Northward from Isom Rock spur the State line anticline diminishes rapidly in altitude, and near the northern edge of the map merges into a northwestward dipping monocline. The data are insufficient for an accurate determination of the form and elevation of the arch near the margins of the field, but it appears to diminish in both directions as it passes off the territory.

Almost parallel with this arch and comparatively near it a number of

oval basins lie along a common axis. This axis is marked D D′ on Pl. V, and will be styled the Crab Orchard syncline, from Crab Orchard post-office, in Lee county, Virginia. It enters the field three-fourths of a mile above Cynthia post-office, at quite a distance from the State Line anticline, and about 200 feet below it. Thence eastward it rises somewhat faster than the anticline, and at the county line it is but 100 feet below it; it rapidly deepens in the distance of 1 mile beyond that line to 250 feet below the anticline; again it rises as it crosses Little Looney creek, but deepens again to a basin north of Mud Lick creek. Beyond that its course is uncertain, but it seems to disappear at about the same place as the State line anticline, in the monoclinal dip to the northwest.

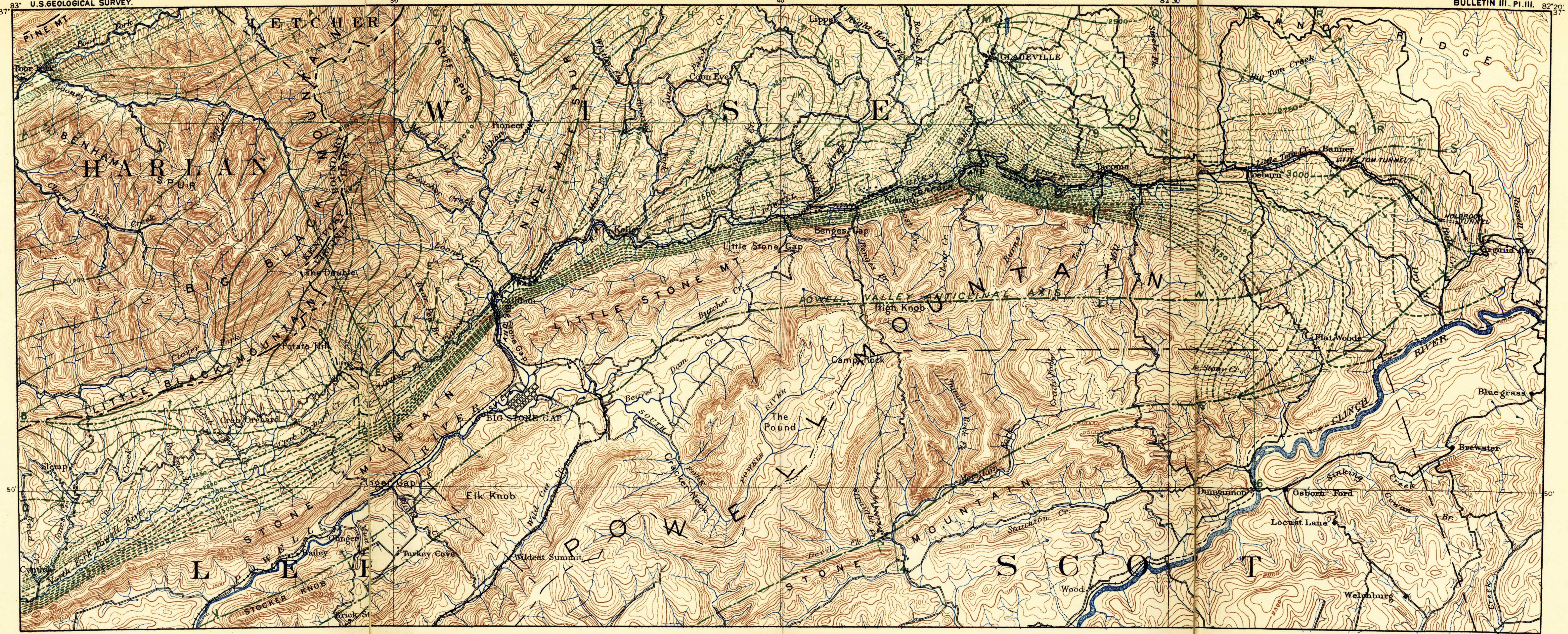
As these folds approach the divide along the county line, their axes come closer together, and the dip of the strata between them is about 6°. This steep dip, together with the acute angle at which they cross the divide, gives the structure a very complicated appearance. It is apparent from a consideration of the structure that a coal which shows on one side of this ridge at a certain elevation may range from 100 feet higher to as many feet lower on the other side, so the correlation is uncertain unless a coal can be traced continuously in outcrop. This is difficult, as coals seldom show on dry ridges. This divide has proved a barrier across which no one has been able positively to identify coal seams, but no one, so far as the writer is aware, has ever offered an explanation of the difficulty.

East of the Crab Orchard syncline are two slight wrinkles, E E′ and F F′, of small extent and but a few feet above or below the normal elevation. These are insignificant in a general view of the field, and the data at hand are not adequate to describe them, but they would be very important in any mining enterprise undertaken in this portion of the field, and should be carefully studied in regard to their effect upon the workable seams of coal.

The details of the next two axes are almost unknown; their presence was hardly manifest in the field, and the observations failed to cover the ground. The anticlinal axis G G′ is called the Pioneer anticline and the synclinal axis H H′ the Mill creek syncline.

On both sides of Nine-mile spur the Imboden coal lies at approximately the same altitude, and the rocks have no visible dip; but at Pioneer, where an entry has been driven in on the Imboden seam, the slope is a few feet per mile toward the west, while on the Roaring fork the strata rise to the east in a large anticlinal fold. As these dips are in the same direction and at the same level, they necessarily involve a compound flexture, the form and extent of which are unknown. The northern extension of these small folds is uncertain, but before reaching the state line they probably disappear in the gentle and regularly dipping monocline to the northwest.

East of the Roaring fork the strata rise quite rapidly in an anticlinal arch, whose axis is I I′ J on the map; it will be called Coonseye anticline,



Axes of Folds
Contours below the surface
" above "

Contour Map of the Upper Surface of the Gladeville Sandstone.

By

Marius R. Campbell.

Scale $\frac{1}{125,000}$

0 1 2 3 4 5 6 Miles

Contour Interval 50 feet

from Coonseye post-office. This peculiar axis forms a complete loop, inclosing a basin 100 feet deeper than the lowest point in the encircling rim. There can be no question about this interpretation of the structure from the Roaring fork through Coonseye, and as far around as the abrupt bend in Powell river; beyond that there is some uncertainty, as the notes were found to be inadequate to determine the details, though the general structure is probably that shown on the map.

This fold is an important one for miners and prospectors, for over considerable territory the arching of the strata has lifted the coals so high that all are eroded except the Imboden seam, which here attains an unusual thickness, varying from 4 to 16 feet, and is raised from an elevation of 1,900 feet above sea level on the Roaring fork to 2,275 feet just south of Coonseye. From this axis the strata descend into the interior basin K K′, on a dip of about 10°, which is probably the steepest dip in the field.

Lying between the Coonseye anticline and the great Gladeville anticline is an irregular syncline, or a succession of basins, arranged along a common axis and named Guest river syncline, LL′. From Stone Coal branch northeast this basin is quite well defined, but southwest from that branch the structure is uncertain. All along the northern base of Stone mountain, from Norton to the western edge of the territory, there exists a belt of greatly contorted strata that are well exposed in the numerous cuts along the Louisville and Nashville railroad. The soft shale, with numerous small seams of coal, is highly plicated and frequently, as at Big Stone gap, the folding has involved heavy beds of hard sandstone; locally the strain has been so severe as to cause faulting. All this folding is classed in the second division, as given on page 22. From the sharpness of the flexures and the fact that they are generally found in the soft shale, it does not seem probable that the cause was deep seated or that the massive conglomerate, lying immediately below the shale, took part in the folding. From present knowledge there are no important coals in this belt, and the study of it is unprofitable as involving details of structure that are of no consequence.

East of this is the sharpest anticlinal fold in the region, the formation of which has had probably more influence than any other in modifying the surrounding structure. This is the Gladeville anticline MM′ and its apparent continuation M′ N. The arch is so pronounced that it has raised the conglomerate to the surface considerably north of its normal boundary, as is well shown in the Guest river valley, 2½ miles below Norton. The river has preserved its channel around this projecting point only with great difficulty, and by following the great bend that is such a marked feature of the topography.

The axis of this fold crosses the Norton and Gladeville road 1 mile west of town, where the crown of the arch is formed by the Gladeville sandstone. This bed is 485 feet higher here than it is on Guest river at the crossing of the Norton and Gladeville road; from

this summit it descends eastward to an elevation of 2,470 feet at Gladeville, or 100 feet below the summit altitude. This anticline, just after crossing the Gladeville and Pound gap road, 1 mile northwest of the town, passes into a monocline with relatively steep dips to the west, while to the eastward the strata extend in a high table-land or mesa with very gentle undulations.

Commencing just north of Gladeville and swinging in a crescent with the convex side toward the mountain is a synclinal axis OO′, that passes near the edge of the escarpment just above Tacoma and dies out near the head of Steeles fork of Cranes Nest creek, 2½ miles west of Coeburn; from its location this is called the Gladeville syncline. Immediately north of the Gladeville syncline is a short and insignificant fold, the Bear creek anticline NN′, which is crescent-shaped and parallel to the syncline.

East of Banner another fold, Little Tom anticline, SS′, has its origin on the flanks of the Powell valley arch, crosses the railroad in the vicinity of Little Tom tunnel, and, swinging gently to the north, passes out of this territory with a general course of N. 70° E. This arch is small, but it has a marked influence on the position of the coal seams. McCreath and d'Invilliers[1] traced this fold as far as Lick creek, holding an average course of N. 72° E.; they consider it the continuation of the Powell valley anticline, but this is manifestly an error, as the latter fold trends due east and west and is cut off by the Hunter valley fault.

Near Little Tom tunnel the anticlinal axis appears to divide, throwing off a small spur to the north RR′, but for lack of data its position is uncertain.

The last structural feature in this territory is a synclinal basin, whose axis TT′ trends northwest and southeast, but in all probability it turns northeast near Virginia city between the Little Tom anticline and the overturned conglomerate along the northern side of the Hunter valley fault. This is called the Virginia city syncline, from a station by that name on Russell creek.

There is a marked relation between the most of these slight undulations and the Powell valley anticline. In the western portion of the field, where the large anticline is developed in full force, the minor folds are only two in number and small in size. East of Olinger gap the Powell valley anticline diminishes in magnitude and the small folds increase in number and size. It would appear that the pressure was exerted in forming many small folds instead of one large one. A line drawn east and west through Big Stone gap marks a change in direction of the axis of the Powell valley anticline and a corresponding change, though in an opposite direction, in the axes of the minor folds. This new direction, approximately north and south,

[1] Report on a portion of the Virginia and Tennesse Coal and Iron Company's property, Wise county, Virginia, 1892. By A. S. McCreath and E. V. d'Invilliers.

is maintained by the small folds until near the northern limit of this territory, where they again resume their normal, northeast-southwest, direction.

GENERAL GEOLOGY.

DIFFICULTIES OF CLASSIFICATION.

In the Coal-measures of this field there are no beds of limestone to serve as keys to the structure and stratigraphy, consequently the geologist is deprived of one of the best guides to correlation; he is limited entirely to the shales, coals, and sandstones which here constitute the Coal-measures. These three elements are very variable both in thickness and in physical characteristics. Coal seams, as every operator knows from practical experience, are subject to a great many changes. Some of these, as changes of thickness, of chemical composition, and of physical appearance, as well as of the character of floor and roof, are largely due to conditions affecting the deposition of the material; others are due to movements of the strata by which the soft coal was crushed—in places squeezed to a feather-edge and elsewhere collected into masses many times thicker than the normal seam.

The probability of change makes it extremely difficult to trace a seam of coal even under the most favorable conditions. Ordinarily the conditions are unfavorable, and the prospector, depending upon the coal alone as his guide, is very liable to err in his correlations.

Sandstones and shales are the product of sedimentation under unstable conditions, and the geologist accepts them with caution as guides to stratigraphy. True, some beds of sandstone are very regular and hold over large areas, but as a rule this will not apply to the sandstones of the Coal-measures, for it is exceptional to find any bed sufficiently well marked to be recognizable throughout even as small a field as that of Big Stone gap.

Altogether the task of subdivision and classification of such a mass of rapidly alternating and changing sediments is a most difficult one, and especially so where the field is traversed by numerous small folds or undulations. The policy of the U. S. Geological Survey in regard to subdivision of the rocks is to make such a classification as is best calculated to express the facts in the given territory regardless of subdivisions that have been made in other portions of the field. The geologist, by recognizing these local features, puts his work in such a shape that others working in the same field will be able to trace his groups without being obliged to attempt an extremely uncertain correlation with the various groups as determined by the Pennsylvania or New York geologists. So in the present work no effort has been made to divide the Coal-measures into the classic divisions of Lower Productive, Lower Barren, Upper Productive, and Upper Barren measures.

TABLE OF FORMATIONS.

The following table shows the formations recognized in the present work, the names being local geographic names taken from the imme-

diate field, and the thicknesses being the mean of the most reliable measures made on the southern side of the field:

	Formation.	Symbol.	Mean thickness.	Character.
			Feet.	
Carboniferous:	Harlan sandstone	Ch	880	Mainly coarse, white sandstone with sandy shale or thin coals.
	Wise formation	Cws	1,270	Shales, sands, clays and coals.
	Gladeville sandstone	Cg	100	Heavy, coarse white sandstone.
	Norton formation	Cnr	1,280	Shales, sandstones, clays and coals.
	Lee conglomerate	Cl	1,500	Conglomerate, shales and coals.
	Pennington shale	Cpn	1,100	Red and green shale with beds of sandstone.
	Newman limestone	Cn	930	Limestone and calcareous shale.

REVIEW OF PREVIOUS WORK.

Before this work was undertaken very little had been done to classify these sediments, and determine their thickness. The first mention of any of these formations is an account of a reconnoissance made by J. P. Lesley from Coeburn eastward.[1] He observed the Gladeville sandstone capping the hill (Robert's butt) back of Coeburn, and gave it the local name of "Sheep Rock" conglomerate, but in attempting to follow it to the east he confused it with the Lee conglomerate, and consequently misinterpreted the structure. He described the overturned edge of the Lee conglomerate along the great fault line as the dipping down of the "Sheep Rock" conglomerate, and was necessarily led to an erroneous correlation of the coals in that district. South from Coeburn he made the same mistake in correlating the "Sheep Rock" conglomerate with the Lee conglomerate of Powell mountain, giving him a syncline where the Powell valley anticline is located.

In 1880 Mr. J. J. Stevenson made a careful study of the section from Big Stone gap to the crest of the Big Black mountain, probably in the vicinity of Isom Rock spur.[2] He did not classify the measures into groups, but his section may be stated as follows, by assuming the base of the Harlan sandstone to be 400 feet beneath the crest of the mountain, and the base of the Gladeville sandstone 190 feet above the Imboden seam, as shown on Callahan creek:

	Feet.
Harlan sandstone	400
Wise formation	630
Gladeville sandstone	120
Norton formation	601
Lee conglomerate	
Total thickness	1,751

The measure of the lowest formation is only roughly approximate, as his last distance was estimated. He remeasured and revised this sec-

[1] The Geological Structure of Tazewell, Russell, and Wise counties, Virginia. Am. Phil. Soc., Proc., vol. VII, 1871-'72. pp. 492-494.

[2] Notes on the Geology of Wise, Lee, and Scott Counties, Virginia. Am. Phil. Soc., Proc., vol. XIX, 1880, 1881; p. 91.

tion in 1881,[1] and the result, subdivided in the same manner, yields the following section:

	Feet.
Harlan sandstone	400
Wise formation	1,155
Gladeville sandstone	120
Norton formation	755
Lee conglomerate.	
Total thickness	2,430

Mr. Stevenson did not measure to the highest point in the mountain, which is at the triangulation station west of the Double, 4 miles from the line of his section. The altitude at the station is 4,150 feet, and that at the crest, where his section crosses it, is only 3,900 feet; the difference would add 250 feet to the top of his column, if the rocks are horizontal, making the Harlan sandstone 650 feet. As the rocks dip slightly toward the triangulation station, 280 feet more must be added to the thickness of the upper member. In his second measurement he increased the thickness of the Wise formation 525 feet, or almost doubled it; the result approaches the measure as given on p. 28. The difference, 115 feet, can easily be accounted for by inaccuracies in measurement and the uncertainty of aneroid readings.

The Gladeville sandstone has a greater thickness than that stated in the general section, but the table is mean thickness for the field and is therefore not strictly comparable. A section on Callahan creek gives the same as Stevenson's section.

The Norton formation shows the great difference in measurement. Mr. Stevenson in his later measurement changed his figures 154 feet, giving him 755 feet instead of 601 feet as determined by his first work. Neither of these figures is worth much, for Mr. Stevenson distinctly states that they were estimates merely and anyone familiar with the problem will readily understand how unreliable estimates are on this formation. The discrepancies between the various estimates of the thickness of this formation are due to the absence of any well marked stratum from which to measure and the great amount of disturbance that it has suffered in the uprising of the Powell valley anticline.

Mr. C. R. Boyd also measured the same section,[2] as follows:

	Feet.
Harlan sandstone in part Wise formation	828
Gladeville sandstone	120
Norton formation	570
Lee conglomerate.	
Total thickness	1,518

[1] Op. cit., pp. 237, 238.

[2] The Economic Geology of the Bristol and Big Stone Gap section of Tennessee and Virginia, pursuing the general course of the South Atlantic and Ohio Railroad. Am. Inst. Min. Eng., Trans. Vol. 15, 1886, 1887, pp. 119, 120.

Messrs. Andrew S. McCreath and E. V. d'Invilliers studied the region south of the Big Black mountains and west of Big Stone gap,[1] and first called attention to the Gladeville sandstone as a key rock. They thus describe it[2] on the north fork of Powell river, west of this territory:

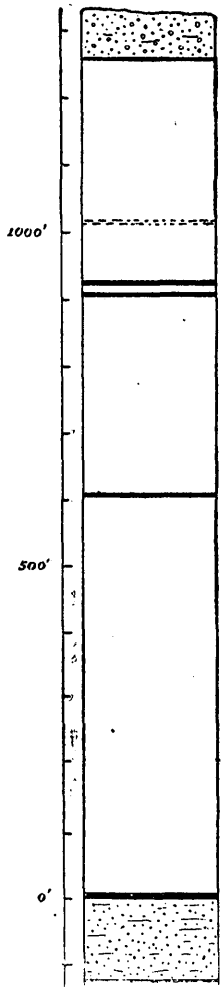


Fig. 1.—Section on Childs creek, Ky.

There is, however, a very conspicuous ledge of sandstone outcropping along the southeastern base of this mountain for some distance along the Roaring fork toward Penningtons gap. This rock is largely honey-combed, though otherwise massive, and from 30 to 50 feet thick. Its presence here is only important as bearing upon the horizon of some of the coals to be presently mentioned along the Kentucky portion of the Cumberland field, where this rock, if indeed it be correctly identified, outcrops nearly the whole length of the Cumberland river from the head of Clover fork nearly to Pineville. It is the important rock of that section, causing conspicuous cliffs along the river bank, and the only possible guide to the geology of the Cumberland river. Here, along the north fork of Powell river, its position would seem to occur about 250 to 300 feet above the top of the conglomerate measures No. XII, although it is by no means certain that a fault does not exist along the north base of the Stone mountain, which, of course, would materially affect the correctness of this calculation. In any event, upon the Cumberland waters a rock of similar constitution occurs, as already stated, but evidently at a considerably greater interval above the conglomerate measures outcropping in Pine mountain.

This estimated distance above the conglomerate on Powell river is certainly too small, and it seems that the very steep dips near Stone mountain were not taken into account. These dips are so nearly vertical that all the measures between the conglomerate and the Gladeville sandstone might rise to the surface in a quarter of a mile without the intervention of a fault, which is hardly probable, although the soft shales are considerably folded and crushed. They write further:[3]

The most conspicuous feature of the river geology west of Huffs creek is the appearance above the water for the first time of a prominent and massive honey-combed sandstone, which, from a point above Trace branch, or about 2½ miles above Rockhouse branch, becomes a conspicuous feature of the river cliff to and beyond Harlan Court-House. * * * Along both Clover fork and the Cumberland river itself this prominent sandstone rock is rarely absent. * * * The thickness of these sandstone measures is certainly greater than in Virginia, although nowhere apparently over 100 to 125 feet thick, including its shale members. * * * Its identity at Rockhouse branch, Childs creek, and Harlan Court-House, if maintained, would be of the greatest importance, for it would at once give the key to the structure of this coal field and would render a correlation of its various coal beds a much more simple and easy task.

They give a section[4] on Childs creek, a small tributary of Clover

[1]Mineral Resources of the Upper Cumberland Valley of Southeastern Kentucky and Southwestern Virginia, 1888. [2]Op. cit., p. 41. [3]Op. cit., pp. 55,56. [4]Op. cit., p. 62.

fork entering from the south 4 or 5 miles below Rockhouse branch, and it shows that they recognized the two key rocks, the Harlan and Gladeville sandstones. This interval between these two members agrees remarkably well with the average for the field.

In 1892 these gentlemen made an examination of the territory east of Tacoma. Their investigations were limited mainly to an examination of coal outcrops, and from these alone the structure of the field was determined. They failed to recognize any key rocks, but their interpretation of the structure agrees essentially with that shown on Pl. III.

At the Montreal meeting of the American Institute of Mining Engineers held February, 1893, Mr. J. M. Hodge presented a paper on this field, in which he recognizes the base of the Harlan sandstone and gives a measured section from Big Stone gap to the crest of the Big Black mountain. He attempts no subdivision of the series, and his sections are incomplete at both ends, as he regards the mountain summit as 4,000 feet above tide, whereas it is 4,150 feet at its highest point, and at the base he has not measured to the "Bee rock." His section is drawn from barometric elevations, without correction for the dip of the strata, so it is vague. Mr. Hodge estimates that the upper two-thirds may be 300 feet too thick. The section as it stands, applying the classification herein employed, would be as follows:

	Feet.
Harlan sandstone	385
Wise formation, Gladeville sandstone	1,660
Norton formation	355
Total	2,400

The thickness of the upper member should be increased, making it agree with the figures as given for the field, 880 feet. The other figures show for themselves, the greatest difference being in the lower or Norton formation.

THE FORMATIONS.

Harlan sandstone, the most conspicuous rock to be seen in crossing the Big Black mountains, occurs 400 to 600 feet below their crest, and produces, under favorable conditions, cliffs and ledges—the so-called "rock houses" of the mountaineers. Its base, 30 or 40 feet in thickness, is the cliff-making member, and is a massive sandstone composed of well-rounded grains of white quartz, varying from the size of ordinary clean beach sand to pebbles of the size of a pea. This heavy stratum grades upward into thinner bedded sandstone, in all forming a single bed about 100 feet thick. The Isom rock, on the spur bearing the same name, at the head of Little Looney creek, is probably the best exposure of this stratum in its typical form, and it is widely known. In a study of the upper measures the recognition of this sandstone is very important, and for that purpose a brief description of the observed outcrops is here given.

It probably caps the Little Black mountain, at the head of Rockhouse branch, at an altitude of 3,000 feet, but the identification is not certain. It was positively identified on Potato hill, at 3,530 feet, and the Butt, at 3,560 feet. At the angle in the mountain northeast of the Butt its elevation is 3,580 feet, its highest occurrence in this region. At the extreme point of Middle ridge it is well exposed in heavy cliffs at an altitude of 3,400 feet. The same phase appears on Hall spur in higher and less accessible cliffs, which give the ridge a rugged, picturesque appearance. Above the head of Clover Lick creek the sandstone was seen on the two trails; on the south side its altitude is about 3,200 feet, and on the north side, below the house of Joshua Gilliam, it is 3,060 feet. On Gap creek, directly east of Gilliam's, it is 3,190 feet. On the Maggard branch trail it forms cliffs at 2,950 feet, and in the extreme western end of Benhams spur, and on its northern side, its elevation is 2,900 feet. At the head of Big Looney creek, just beneath the Double, it is 3,400 feet, and on the trail from the head of Big Looney to the Isom Rock spur it is 3,450 feet. Across the mountain, on the latter spur, it is 3,500 feet. From this point it descends rapidly toward the north, for on Road spur it is only 3,370 feet, and on a spur above Henry fork of Mud Lick creek it is 3,170 feet. On the extreme high point of Looney ridge, just above the mouth of Lewis creek, it shows as a heavy ledge at 3,000 feet. On the high Bluff spur above Shepard's mill it is 3,220 feet, and on the new-cut county road, just below Dan Richmond's house, it is 3,270 feet. The last exposure seen is on a high point of Nine Mile spur at 3,400 feet, but the stratum was not certainly identified.

This massive stratum, at the base of the Harlan sandstone, was found to be recognizable throughout the field, and became important as a key rock, which afforded a means of correlation of the various coals and recognizable sandstones on the Virginia side with those on the Kentucky side of the mountains.

By platting all of the elevations observed on the base of this sandstone and constructing a model of its under surface, the structure north of the state line was quite accurately determined. The thickness of the rocks from the base of this sandstone to the highest point in the mountain is 880 feet, and its members are so much alike throughout that it is regarded as a single formation, to which the name Harlan sandstone is applied, from its typical development in Harlan county, Kentucky. It should not be understood from the name that the strata are all sandstone, but the prevailing character is that of a sandstone like the one at the base. There are a number of beds of sandy shale carrying coals, but so far as known none of the latter are of workable thickness, except possibly one seam near the base, which will be described on another page. There is no place where a good continuous section could be measured, but on ascending to the triangulation station from Big Stone gap by way of the Isom Rock spur and the Double, a fair knowledge of the formation may be obtained.

The base of the Harlan sandstone on Isom Rock spur will be recognized by even the most casual observer, for the massive sandstone forming the lowest member is here well exposed in a heavy ledge that is about 100 feet thick. Above it are sandy shales and thin-bedded sandstones to the crest of the mountain, from 350 to 375 feet above the base of the formation. These sandstones are quite fossiliferous, being full of plant remains that weather out and lie scattered about upon the ground. From this point the trail passes along the summit of the mountain to the south, crossing sandstones, shales, and thin coals, that are successively higher in the series, until at the Double a second heavy ledge of sandstone appears just at the turn in the mountain crest. The trail to the triangulation station follows a narrow summit composed of this sandstone, or in lower places winds about among the heavy blocks of its débris. This heavy bed is about 550 feet above the bottom of the formation. After leaving this the trail passes gradually up over higher rocks to Creech's fields, where within about three-quarters of a mile of the station another heavy ledge of coarse, white sandstone is seen that is about 780 feet above the base of the formation and 60 feet thick. Above the sandstone there is a stratum of shale that outcrops just below the upper cabin; a seep here shows the presence of a coal seam in the shale, but it is probably of no consequence. Above this is a heavy sandstone 40 or 50 feet thick that is well shown at the triangulation station and constitutes the highest rock of the series in this region. No evidence of variation in the thickness or character of this formation could be determined, for the observations were confined to an area which is too limited to show any changes in sedimentation.

Gladeville sandstone.—The other key rock is the Gladeville sandstone, named from the county seat of Wise county, Virginia, where it is well exposed.

This sandstone was traced continuously throughout the field on both sides of the mountain, and without doubt is the best guide to the structure and stratigraphy that can be found. According to the report of McCreath and d'Invilliers it retains its distinctive character as far west as Harlan. To the east it probably extends far beyond the limits of this field, as it shows no indications of diminishing in that direction. In thickness it varies from 75 to 120 feet in different parts of the field. There is some doubt as to the correctness of the measure obtained on Clover fork. The base is well marked near water level at the mouth of Rockhouse branch, and the 4-inch coal, 75 feet above, was taken as its top. At present the writer is inclined to the belief that the heavy sandstone lying above the 4-inch coal should be included in the measure, making it about 120 feet, for on Lewis creek 40 feet of the top is sandy shale and the total thickness is from 100 to 120 feet.

In the eastern portion of the field the conditions of deposition were reversed, for here the massive sandstone or conglomerate is at the top

and the sandy shales below. It is this massive ledge at the top that makes such a showing in the vicinity of Gladeville and Lipps. Above Tacoma the sandstone is well exposed near the top of the hills, 120 feet thick. It is massive in its upper portions and becomes thin-bedded toward the bottom, but it carries no shale. The massive layer at the top is the cap that has protected the hills from erosion and gives them their mesa-like character.

Wise formation.—Having established the value of the Gladeville sandstone as a key rock and its continuity throughout the field, the next step was to determine the thickness of the measures lying below the Harlan sandstone and above the Gladeville. This is a heterogeneous mass of sediments—sandstones, shales, and coals. Many of the latter are of good size and quality, but no individual stratum is well enough marked to make its separation possible. So the mass was regarded as a group and named the Wise formation, from Wise county, Virginia, where it forms the principal part of the mountain slope. To prevent errors, eight clear, direct sections were measured across the outcrop of this formation. Besides these main sections a large number of independent observations were made at different points on the Gladeville sandstone and from these a model was constructed and found to agree almost exactly with the one made for the base of the Harlan sandstone, with a constant difference between them of 1,270 feet, the thickness of the Wise formation. Variations in the thickness of this formation were not recognized; if they exist, as they probably do, they are well within the limit of error of barometric readings. The remarkable agreement of this average measure with the thickness of the same formation on Childs creek as determined by McCreath and d'Invilliers has been referred to and confirms the result beyond question.

Norton formation.—Lowest in the series, above the great Conglomerate, lies the Norton formation, named from the principal railroad town in this section. This formation is at once the most important and the least understood of any formation in the field—important because the great bulk of the workable coals belong to it, and least understood on account of the great difficulty every geologist has experienced in determining what strata belong to it, their thickness and their representatives in other portions of the field. The formation outcrops in two principal lines, one along the northern side of Stone mountain, and the other along the southern side of Pine mountain.

The disturbed condition of the rocks along Stone mountain has been the cause of the discrepancies in the published accounts of the thickness of this formation; no two geologists agree in their figures. The writer stands alone in his excessive measure of 1,280 feet, and were it not for his determination of the Gladeville sandstone as a constant horizon the figures would be but a rude estimate. As it is, they are given with full confidence that they will be found correct within a small limit of error.

In view of the uncertainty regarding the thickness of this member considerable time was spent in efforts to determine it closely. The recognition of the Gladeville sandstone on the Kentucky side of the mountains afforded a better means of approaching the question than a direct section from Big Stone gap. Accordingly a section was measured from the top of the conglomerate opposite and a little below the mouth of Lewis creek up that stream three-fourths of a mile to the crossing of the Gladeville sandstone, and from that point was carried up to the base of the Harlan sandstone on Looney spur. This gave an excellent section with regularly decreasing dips and fair exposures, and a measure not only of the Norton formation, but one of the Wise formation above as a check. The thickness of the former so determined is 1,310 feet.

A section was measured at Poor Fork post-office, but the result was not so satisfactory, as the recorded dips are contradictory. When the section was constructed it appeared to be 200 to 300 feet thicker than the Lewis creek section. As this measure was not substantiated by any other measured section it is regarded as of doubtful value.

Again a section was carefully measured at Coeburn, Virginia, where the conglomerate had a very light dip (about 10°) and the strata above it are free from minor folds. This gave 1,260 feet for the Norton formation.

Finally a careful survey was made through Big Stone gap and up Little Looney creek to the mine on the Imboden coal. This was not a single line of observation, but the whole country was carefully mapped to get the exact structure, if possible.

Pl. IV shows the result. As may be seen in the section the conglomerate is folded, forming a well marked syncline in the center of the gap, from which the rocks rise to the north in a sharp fold which is well shown on the eastern side of the creek; from the crest of this anticline they dip very steeply to the north, and at the last exposure of conglomerate, the Bee rock, on the Louisville and Nashville railroad, the dip is 70° N. This same dip continues for 1,000 feet along the line of the railroad, approximately at right angles to the strike. It is a zone of great disturbance, west of which the rocks are nearly horizontal.

Immediately above the Bee rock are 450 feet of shale, in which are four thin seams of coal, the largest being 18 inches thick. Above this is a heavy, bluish white, coarse sandstone 280 feet thick; then more shales, coals, and sandstones, greatly folded and crushed. Beyond these, just opposite the Louisville and Nashville bridge, appears the top of a very heavy sandstone that shows also at the east end of the double tunnel. This sandstone very much resembles the one standing nearly vertically, before described, and is probably the same. If so, a slight fault occurs between them, resulting from the sharp flexure at the bridge. On the west side of the old channel, 4 or 5 rods above the mouth of Pigeon creek, this local fault can plainly be seen, where

the heavy sandstone dipping 30° N. is faulted against the edge of a stratum which is apparently the same, dipping 60° N. Above the sandstone the interval was measured in nearly horizontal rocks and the result is a thickness of 1,275 feet. Thus at three quite widely separated points in the territory the measurements on this formation are 1,310, 1,275 and 1,260 feet. There is an element of uncertainty in each of these, but it is hardly probable that it exceeds 5 per cent.

Lee conglomerate.—This is the most prominent formation in the field, being the mountain-making member of the Carboniferous formations. It underlies the entire basin, but appears at the surface only in the two ridges bounding the basin, Pine and Stone mountains. Its equivalent north or south not being positively determined, the name "Lee" is applied to it here, from Lee county, Virginia, as it constitutes the northwestern line of that county from near Pennington gap to Cumberland gap, a distance of 35 miles.

It is a complex formation, varying in thickness from 1,200 feet at Hurricane gap, in Pine mountain, to 1,600 feet at Norton. It is best exposed at Big Stone gap, where it exhibits the following section and the structure shown in Pl. IV:

	Feet.	In.
Massive sandstone (Bee Rock)	95	0
Black carbonaceous shale	31	0
Dark sandy shale	14	0
Brown and green shale	10	0
Not exposed, probably shale	85	0
Dark shale	210	0
Sandstone with few thin beds of shale	566	0
Coal	4	10
Shale with few beds of sandstone	112	0
Coal	3	0
Shale	150	0
Conglomerate	250	0
Total	1,530	10

This is the first of the above described formations which shows a change in thickness within the limits of the field. This change is in harmony with the general increase in thickness of the various formations of the Coal-measures toward the southeast, as observed in the northern portion of the Appalachian basin. How the complex formation 1,500 feet thick at Big Stone gap changes to a single bed 20 to 100 feet thick in Menifee county, Kentucky,[1] is unknown, and probably will remain so until the drill of the prospector reaches its horizon in many places between Pine mountain and Menifee county. It seems altogether probable that the upper formations share in this thickening toward the southeast, but as yet no data are at hand from which to draw conclusions. The base of the conglomerate marks the base of the Coal-measures.

[1] Kentucky Geological Survey, vol. II, new series, pp. 353–357.

Below the Coal-measures there is a large series belonging to the Carboniferous period that has lately received from Prof. H. S. Williams[1] the name Mississippian series. This series is well developed in the Big Stone gap field and consists of two members, shale and limestone.

Pennington shale.—The shale member has a great development in this region and has been named Pennington shale, from the gap of the same name in Lee county, Virginia. It is quite well exposed in Big Stone gap, where the following section was measured:

Lookout conglomerate, very coarse at the base.

Pennington shale:	Ft.	In.
Green calcareous shale	5	7
Green and red sandstone	1	11
Blue shale	6	2
Coal	1	4
Bluish shale	10	4
Green sandstone	2	10
Olive green shale	7	4
Soft, nonfissile, variegated shale	10	6
Sandstone	3	7
Soft red shale	8	0
Sandy shale	4	0
Bluish sandstone	19	0
Concealed, probably shale	506	10
White sandstone, cross-bedded	49	0
Conglomerate, white quartz pebbles	7	8
Bluish yellow calcareous shale	27	0
Blue sandy shale	10	5
Limestone, very impure and fossiliferous	4	1
Calcareous and argillaceous sandstones	7	10
Calcareous shale, very fossiliferous	6	0
Blue sandstone, cross-bedded	12	0
Purple and green shale	9	5
Shale, slightly sandy	4	3
Green and purple shale	4	7
Argillaceous sandstone	8	4
Fine-grained sandstone	13	5
Sandstone, regularly bedded	80	0
Sandstone, much cross-bedded	107	0
Dark blue calcareous shale	9	0
Sandy shale	7	7
Argillaceous shale	3	0
Heavy sandstone (South Atlantic and Ohio tunnel)	67	0
Total	1,025	0

Newman limestone, shaly at top.

This is supposed to be the equivalent of the Mauch Chunk red shale of Pennsylvania and the Chester group of Kentucky. It varies in thickness as the conglomerate does, being 1,025 feet at Big Stone gap, the same at Pennington gap, and but 890 feet at Hurricane gap, in Pine mountain.

[1] U. S. Geological Survey, Bulletin 80, 1891.

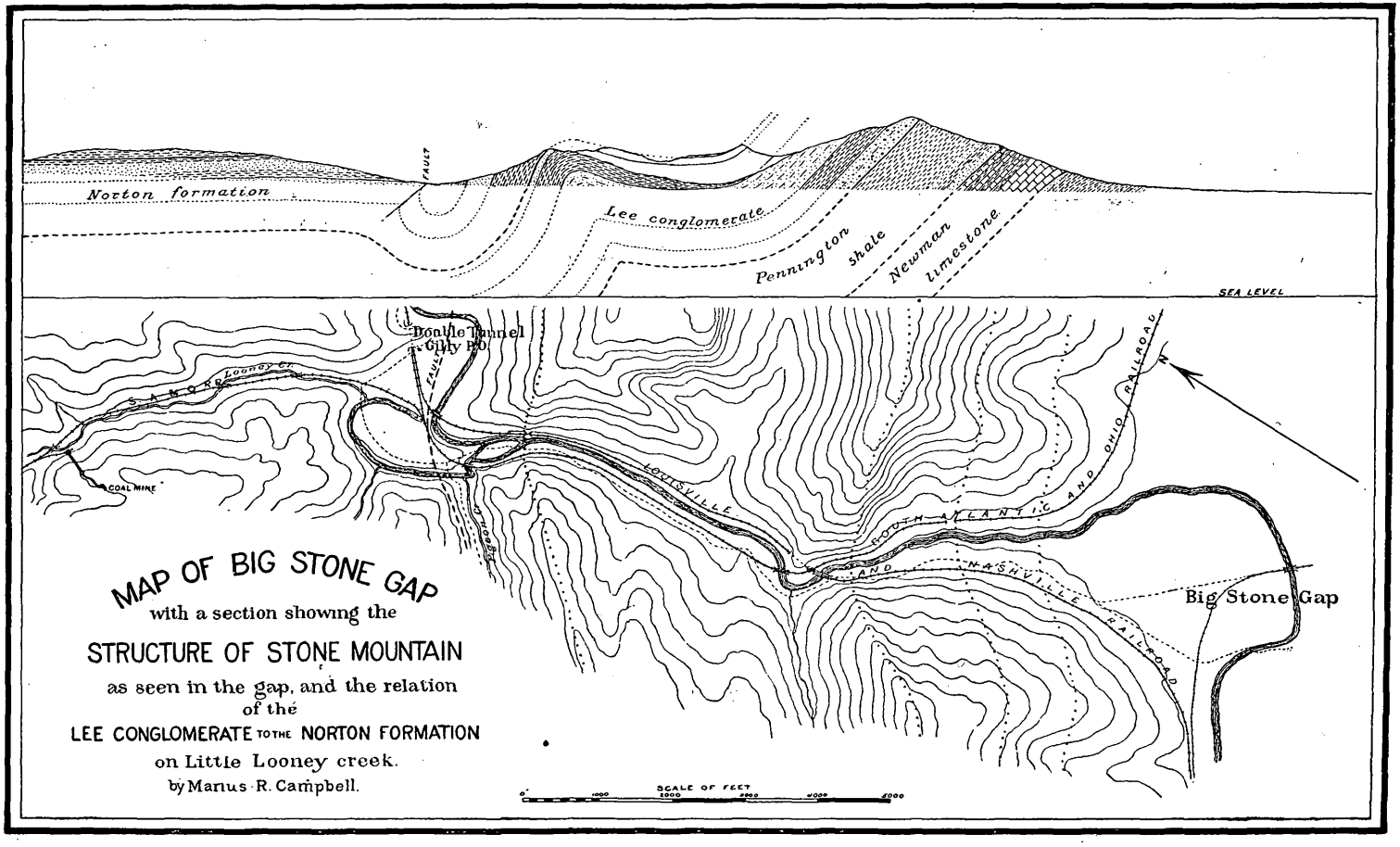
Newman limestone.—This is a widespread formation covering the entire Appalachian basin, except in Pennsylvania and Ohio. In the vicinity of Big Stone gap it is well exposed in a fine line of cliffs around the head of the valley east of the town. In the gap, where it is shown on the eastern side of the stream in all its detail, the following section was measured:

Pennington shale.

Newman limestone:	Ft.	In.
Dark blue calcareous shale	4	2
Dark sandstone	3	3
Black shale	5	8
Blue calcareous sandstones	5	4
Dark blue shale	18	4
Calcareous shales with beds of limestone	8	0
Dark shale	5	6
Green sandstone	6	5
Green shale	12	0
Sandy shale	19	0
Dark blue calcareous sandstones and shales	28	6
Limestone, dark, very impure	16	6
Blue shale	22	5
Impure limestone	26	5
Blue, purple, and black shale	88	0
Calcareous shale	34	0
Heavy, earthy limestones	17	3
Green shale	3	8
Impure limestone	2	2
Green shale	2	8
Impure limestone	22	6
Green and brown shale	23	0
Blue shale with beds of limestone	9	8
Calcareous shale	10	6
Blue, seamy limestone	17	0
Argillaceous limestone	38	6
Heavy, blue limestone, becoming cherty towards base	578	9
Total	829	2

Red, calcareous sandstones.

Grainger shale.—Below the Newman limestone at Big Stone gap is a shale bed about 410 feet thick, which varies from red calcareous sandtones at the top to ash-colored micaceous shales below, and finally merges into the Chattanooga black shale that underlies it. The age of this mass of sandy shales has never been determined; they have somewhat the appearance of a transition bed between the Devonian below and the Mississippian above, but in this paper they are regarded, provisionally, as of Devonian age. This formation thins rapidly southwestward, and probably disappears about Cumberland gap.



MAP OF BIG STONE GAP

with a section showing the

STRUCTURE OF STONE MOUNTAIN

as seen in the gap, and the relation of the

LEE CONGLOMERATE TO THE NORTON FORMATION

on Little Looney creek.

by Marius R. Campbell.

DESCRIPTION OF COAL OUTCROPS.

COALS IN THE MISSISSIPPIAN SERIES.

In the Big Stone gap field there are no coals of commercial importance in the Mississippian series. The Pocono formation, which carries the semi-anthracite coals of Bland, Pulaski, and Montgomery counties, Virginia, probably disappears before reaching this field, or, if it be present, it has changed character and contains no coal. The Pennington shale above the limestone carries a small seam, as shown in the section at Big Stone gap.

In the valley of McGee creek, on the south side of Powell mountain, a coal seam occurs at about the same horizon. It is opened on the east side of the ravine N 2, probably 100 feet above the creek and about 20 or 30 feet below the conglomerate, and dips 45° N. under the mountain. It is a fine-looking cannel, but its thickness could not be determined on account of its distorted condition; the exposure varied from 4 to 6 feet in thickness in a length of 40 feet.

These are the only places where coal was seen in the Pennington shale, and only the latter is thick enough to be of value. The possibility of mining the cannel seam with profit could be determined only by tracing its outcrop to some more favorable place than that on McGee creek, since the rocks are there too much disturbed to admit of economic mining.

COALS IN THE LEE CONGLOMERATE.

Mr. Stevenson reported six coal seams in his section at Pennington gap,[1] three of which were seen by him and three reported, but none exceeded 3 feet in thickness, and all were greatly crushed. One of the most important horizons is immediately beneath the top bed of conglomerate, where an entry was driven in on the seam some distance, but this is now abandoned.

Between Pennington and Big Stone gaps no traces of coal were observed, but this does not preclude their existence, for no good exposures of the strata occur between these points.

At Big Stone gap, Pl. IV, immediately beneath the "Bee rock," or upper conglomerate, there is a mass of black carbonaceous shales exposed in the railroad cut, just below the tunnel of the Louisville and Nashville railroad; they are probably the only representatives of the coal in Pennington gap at the same horizon. Just above the heavy conglomerate at the base of the series there is a coal 28 inches to 3 feet thick, showing in the southern end of the Louisville and Nashville tunnel, just above the bridge, K 38. At the northern end of the same tunnel, K 37, a coal shows 4 feet 10 inches thick; but both these coals are so crushed and distorted that it is impossible to estimate their normal thickness.

[1] Loc. cit.

At Little Stone gap the stain of two small seams of coal shows in the road below the middle of this formation, E 63 and 64. They appear to be about 3 feet thick and 6 inches thick respectively, with sandstone between them.

A coal in this formation is reported in the Cracker neck, on the South fork of Powell river, on the north face of Powell mountain, but it was not seen. It is probably near the same horizon as the heavy coal in Big Stone gap.

In the road over High knob, just above Stony creek, a small coal shows, which is probably not over 18 inches thick and about 250 feet below the top of the conglomerate; but this measure is uncertain, as the exact top was not determined here.

The next place toward the east where a conglomerate coal was seen is at William Osborn's, on Powell mountain, at the head of McGee creek trail, N 1. A coal shows at Osborn's house and it is said to be 4 feet thick, though only 18 inches were seen. This is immediately below the top conglomerate or Bee rock, and is in the same stratigraphic position as the bed noted by Mr. Stevenson at Pennington gap.

On the state road, just above Little Stony creek, two or three small seams show by their stain in the road, O 1, 2, and 3, one of which is reported to have been opened on Little Stony one-half mile above the road, but it was not visited.

On Guest river, near where the line between Wise and Scott counties leaves the river, fragments of coal were seen 220 feet below the top of the conglomerate, but the outcrop could not be found and nothing is known about its thickness.

On Pine mountain no coals were seen in this formation, although two sections were measured across the mountain, but exposures are not good and a coal seam might easily have been overlooked.

There can be but one conclusion in regard to the economic importance of the conglomerate coals in this field, and that is, that the seams are usually too thin for profitable working, and even if they were of workable thickness they are too much squeezed and contorted to warrant investing much capital in their development.

There are a few places along the southern slope of Powell mountain and the lower course of Guest river that may not be so much disturbed, and, if so, they are the places where prospecting should be done to determine the presence of workable seams.

COALS IN THE MEASURES ABOVE THE LEE CONGLOMERATE.

In describing the exposures of coal in these measures it is impossible to treat each formation separately, as in most cases each ravine showed coals belonging to different members and the observations were so connected as to be of but little value if treated separately; consequently, the subdivisions for description will be geographic rather than strati-

graphic. For this description of outcrops the territory will be divided into several fields or basins, as follows:

1. Kentucky basin, embracing all that part of Kentucky lying within the boundaries of this field except the territory drained by the Clover fork of the Cumberland river.

2. Crab Orchard basin, including all the territory in Lee county, Virginia, lying north of Stone mountain, and generally known as the Crab Orchard; also the area drained by the Clover fork in Kentucky.

3. Imboden basin, including the territory drained by the Powell river through Big Stone gap. The name is applied to this region because the famous Imboden seam of coal has its greatest development here.

4. Guest River basin, comprising all of the region east of Norton, and so named because the Guest river is its principal stream.

KENTUCKY BASIN.

The first coal of noticeable thickness above the conglomerate is exposed on the north side of the Poor fork in the bank of the stream just below the mouth of Big Looney creek, A 2, where it has been opened, but the pit is so closed that but 12 inches of coal is now visible. Between this and the conglomerate is a mass of shales and thin beds of sandstone, with an aggregate thickness of 375 feet. Above the coal is a massive bedded sandstone that forms a marked feature in the topography of the valley. So far there is a close correspondence between this section and the one at the head of Big Stone gap, but above the sandstone the resemblance disappears.

In a small ravine opposite the mouth of Lewis creek a coal is exposed about 20 inches thick; this is apparently the same seam as the one noted above, as it is about the same distance above the conglomerate, and has the same heavy sandstone overlying it. Above this coal horizon is a mass of sediments about 350 feet thick, in which no coal was seen; at its summit, at the southern bank of the Poor fork, above Poor Fork post-office, a small coal, A 3, is visible, that corresponds closely in position with the coal in the bottom of the double tunnel at Gilly, K 20, 21, and 22. A careful search for some representative of the Imboden coal revealed only an 18-inch seam, A 4, near its horizon. From the results obtained, it seems quite certain that in the Kentucky basin the workable coals lie entirely above the Imboden horizon, and that search for that seam is hopeless. As far as could be ascertained, there is but one coal of any consequence below the Gladeville sandstone, and that lies just beneath it, but no exposure could be found on Clover Lick creek.

Through the Kentucky basin the Gladeville sandstone is well shown, and was observed on every stream traversed. It does not often appear as ledges along the hillsides, but is a very conspicuous object in the bottom of the valleys. The streams have cut narrow canyons in it from 5 to 15 feet deep, or are flowing on its upper surface, in which case it appears in their channels as a hard smooth floor. There are along these streams other heavy sandstones of the same general char-

acter as the Gladeville, which can with difficulty be separated from it by physical characteristics; but the presence of an important coal seam above and below the Gladeville makes its identification quite easy. Again, in this Kentucky field there is another check that will be found useful in doubtful cases, and that is the interval between the sandstone and the base of the Harlan sandstone, 1,270 feet above it. This check can almost always be applied, as the Harlan is easily found in the high spurs projecting into the valleys. On Clover Lick creek the Gladeville is very massive at the mouth of Pound Mill branch; above this it is near water level, sometimes rising a little above the creek and again nearly disappearing beneath it, until in the distance of 1½ miles it passes entirely below water level.

Within 200 feet of the top of this sandstone three quite heavy seams of coal occur, making it the most important coal horizon to be found in the Kentucky basin.

The lowest of these seams occurs but little above the sandstone, and on Clover Lick creek exhibits the unusual thickness of 16 feet. Unfortunately, this great development does not extend far in any direction. On Rockhouse branch of Clover fork it seems to be represented by 4 inches of coal and 18 inches of slaty coal; but it may occur higher up in the sandy shales and may have been overlooked, or it may be absent.

In a small ravine below Childs creek a coal is reported by McCreath and d'Invilliers near this horizon, with the following section[1]:

Shale roof.	Ft.	In.
Coal	0	8
Shale	0	1
Coal	0	2
Shale	1	3
Coal	0	11½
Shale	1	6
Coal	2	8
Shale	0	2
Coal	0	7
Total	8	0½

Fire clay and shale floor.

This is called by them the Bailey coal, and is described as thinning eastward rapidly.

In a small ravine on the east side of Clover Lick creek and about a quarter of a mile above the school house, the most remarkable development of this coal occurs, A 28, where it shows 13 feet of coal without a parting. There are fine exposures of coal in this ravine, as the following section shows:

Sandstone.	Ft.	In.
Coal (A 30)	3	9
Sandstone	18	0
Shale	3	0
Coal (A 29)	5	3
Interval	100	0
Coal (A 28)	16	0

Sandstone (Gladeville) to creek.

[1] Op. cit., p. 58.

The lowest coal, A 28, has been opened in the hill across the creek, A 24; the pit had so fallen in that the coal was not visible, but it is evidently a heavy seam.

On Pound Mill branch, a short distance from Clover Lick creek and about 70 feet above it, there are indications of a thick seam of coal, A 26, that must be the same bed, but no section could be obtained. About 1¼ miles above Pound Mill branch, and just above the mouth of a branch entering from the southeast, a coal, A 32, shows at about this horizon, with the following section:

	Ft.	In.
Sandy shale.		
Black shale	4	0
Coal	1	11
Knife-edge parting:		
Coal	0	3
Total coal	2	2
Blue shale.		
Sandstone.		

Two miles above Pound Mill branch this coal goes under water level (A 34), but its full thickness is not exposed, only 3 feet of coal being visible.

A mile above this a heavy coal, 42 inches thick, shows just above water level on the south side of the creek (A 36). There was difficulty in identifying this bed, but a section carefully constructed along the creek made it quite evident that this is the same coal as the heavy seam in Pound Mill branch. It disappears beneath the bed of the stream at A 34, but probably does not descend far below, and at A 36 simply rises, and the stream has removed its covering for a short distance.

Above this heavy seam two other important coals were noted in the valley of Clover Lick creek. On Pound Mill branch one of these coals is reported as 4 feet thick, but only a foot or so could be seen (A 25).

By barometer this is 145 feet above the heavy coal, and if the identification is correct shows a thickening of the interval between these two coals from 126 feet near the schoolhouse to 145 feet on this branch. In a small ravine on the south side of Pound Mill branch signs of coal were seen at an elevation of 130 feet above the heavy coal (A 27). At first this was taken to be the coal noted above, and it was thought that there was a southerly dip which would account for the difference of 15 feet in altitude; but on reviewing all the data accessible, it seemed more probable that the strata are horizontal or dip slightly to the northwest, and the two outcrops are the same as the two upper coals in the ravine near the schoolhouse (A 29 and 30). This determination is quite important as fixing approximately the position of the axis of the Middlesboro syncline near the mouth of Pound Mill branch.

Two miles above this, on a branch from the north, a natural outcrop of a 37-inch coal (A 33), was seen, which is about 90 feet above the large coal. Half a mile farther up a seam 18 inches thick, (A 35)

occurs on the northern side of the creek, 40 feet above water, and is probably one of the coals observed lower down. The dip, as calculated for the sandstone, would bring the coal on the lower branch from 15 to 18 feet above this, which would correspond well with the interval observed below near the schoolhouse. That makes this 37-inch coal the upper and the 18-inch seam the lower of these coals.

Less than a quarter of a mile above Hayes run a coal seam 12 inches thick shows in the bank of the stream (A 37), but it soon disappears beneath its surface. This is supposed to lie about 200 feet above the Gladeville sandstone.

Above this 12-inch seam no other coal was seen on either route traversed, but that does not preclude the possibility that there are a number of coals in that interval, and indeed some are reported, of workable thickness. On the trail leading across the Big Black mountain, two miles west of the triangulation station, a heavy coal is reported, and as nearly as could be determined is near the base of the Harlan sandstone. It is said to be 7 feet thick and corresponds with the coal at the head of Big Looney creek of the same thickness and position.

As before mentioned, there is probably but one coal below the Gladeville sandstone of any importance. This has been opened on a little branch a quarter of a mile back of the house of William Gilliam (A 6), on Big Looney creek, and shows the following section:

	Ft.	In.
Coal	0	6
Shale	0	8
Coal	4	3
Total	5	5

An opening (A 5), in the next branch west of this is probably on the same coal, though it is 85 feet higher and differs somewhat in section, as follows:

	Ft.	In.
Shale with many thin seams of coal	3	6
Coal	2	0
Shale	0	6
Coal	0	4
Total	6	4

The difference in elevation is compatible with the identity of these two seams, for the most western exposure (A 5), is farther from the axis of the syncline and naturally at a greater elevation; in this vicinity there is evidence of a local disturbance giving slight easterly dips. As these dips occur about on the line of A 5, they would tend to carry the coal considerably lower on the next branch at A 6. These two causes would account for the difference of 85 feet in elevation. In the next branch to the east the Gladeville sandstone is exposed in the bed of the branch from its mouth to a coal that outcrops a quarter of a mile back from the main stream and about 100 feet above it (A 7).

This coal is quite different from the last, clearly belonging above the sandstone, and is the representative of the heavy seam on Clover Lick (A 28). Its section is as follows:

	Ft.	In.
Sandy shale roof.		
Coal	0	6
Shaly coal	0	6
Coal	1	6
Shale	0	6
Coal	0	8
Shale	1	8
Coal	0	3
Shale	0	4
Coal	0	4
Shale	0	2
Coal	0	10
Total	7	3

This is a good illustration of the extreme variability of this seam, which in the distance of 1½ miles changes from a body of clear coal 13 feet thick on Clover Lick creek to a bed 7 feet 3 inches thick, with so many shale partings as to be worthless.

A coal shows in natural outcrop in a small ravine east of Clover Lick creek, A 31, 350 feet above Poor Fork post office, and about 240 feet above the Gladeville sandstone. This probably corresponds to an important seam farther east, B 25 and C 2.

On the trail leading across the point of Looney spur, from Looney creek to Poor fork, some exposures of coal are visible; one on the summit, A 8, and another in the ravine above the trail on the southern side, A 9. These are probably the seams exposed on Clover Lick 20 feet apart, A 29 and 30.

On Big Looney creek, opposite and a little above the house of John Creech, a coal is exposed just above the cliff of Gladeville sandstone, A 10, 80 feet above the stream. It is not well exposed, only about 3 feet being visible. Still farther east a seam has been opened on the north side of the creek 230 feet above water level, A 11. It shows 65 inches of coal, and, referred to the sandstone, corresponds to the coal, A 30, on Clover Lick creek.

About a quarter of a mile above the house of John Creech, in a small ravine from the south, a coal, A 12, is exposed, which was reported to be 7 feet thick, but its thickness could not be seen. The outcrop is a natural exposure under an overhanging ledge of sandstone, with 3 feet of the top of the seam exposed; this has been dug into and used for local purposes. The stratigraphic position of this coal is somewhat uncertain. At first it was considered equivalent to the heavy seam immediately above the sandstone, but the notes show no indications of a heavy sandstone below it, in fact the smooth, rounded surface of the hills would indicate either shale or soft, thin bedded sandstone. It therefore has been correlated with the second coal above the sandstone, A 29, on Clover Lick creek.

In the next ravine to the east a comparatively good section was obtained. The first coal observed was about 150 feet above Big Looney creek, A 13. This seam has the appearance of being a heavy one, but only 16 inches is exposed. Below this coal the stream wanders over a sloping surface thickly strewn with blocks of heavy sandstone, which probably were derived from the immediate vicinity and mark the horizon of the Gladeville sandstone. This would make the above coal A 13, equivalent to the heavy seam, A 28, on Clover Lick creek. Above this coal is an interval of about 50 feet of thin-bedded sandstone and sandy shale, following which is a second coal, A 14, that also has the appearance of being a heavy seam, but only shows 2 feet of coal in natural outcrop in the bed of the branch. Above this is an interval of about 65 feet, and then another coal, A 15, showing a complete section of only 18 inches.

The representatives of these coals on Clover Lick creek are quite uncertain. The intervals and character of seams are so different that correlation is difficult and unsatisfactory. The three consecutive coals, A 13, 14, and 15, are probably equivalent to the three coals, A 28, 29, and 30, but the intervals are somewhat different, as will be seen by the following:

Clover Lick creek.	Ft.	In.	*Big Looney creek.*	Ft.	In.
Coal (A 30)	3	9	Coal (A 15)	1	6
Interval	21	0	Interval	65	0
Coal (A 29)	5	3	Coal (A 14)	2	0+
Interval	100	0	Interval	50	0
Coal (A 28)	16	0	Coal (A 13)	1	0
Total	146	0	Total	119	6
Gladeville sandstone.			Sandstone.		

This shows a thickening eastward of the upper interval and a thining of the lower, but the two sections have nearly the same total thickness.

On Maggard branch, at the base of the Gladeville sandstone, indications of an outcrop were seen (A 16). Above this the very heavy sandstone shows in the bed of the stream up to about three-quarters of a mile from Big Looney creek, where the top is exposed with its accompanying coal, A 18, but no measure could be obtained here of the thickness of the coal. Above this on Maggard branch no exposures were seen until the Harlan sandstone was reached; above this coal stains are of frequent occurrence, but they give no indication of workable seams.

On Big Looney creek, just above the mouth of Maggard branch, the coal lying below the Gladeville shows in the north bank of the creek, A 17, 28 inches thick, but poorly exposed. Above this the dip of the rocks corresponds so nearly with the fall of the stream that the heavy Gladeville sandstone is at or near water level for a long distance.

About one-half mile below the mouth of Gap branch there is a fine

showing of coal in natural outcrop in the bed of the stream, B 9, with the following section:

Sandstone roof.	Ft.	In.
Coal	5	0
Shale	0	2
Coal	0	6
Total	5	8

That this coal is equivalent to the one seen just above the mouth of Maggard branch, A 17, seems somewhat doubtful, as it occurs in different strata: at Gap branch the prevailing rock is sandstone, whereas at Maggard branch it is shale. Nevertheless the two coals occupy the same stratigraphic position beneath the Gladeville sandstone. On this latter consideration this coal, B 9, has been considered as the equivalent of A 17, and it is assumed that in the interval the character of the surrounding sediments changes from shale to sandstone.

About half a mile above the mouth of Maggard branch, in a small ravine from the south, coal indications were observed about 100 feet above the creek, A 19. No exposure was seen, but the bed is probably the seam above the Gladeville sandstone.

At the mouth of Gap branch the Gladeville makes a heavy showing in the bed of the creek, and affords an excellent exposure for the study of this important stratum. Up the Gap branch a few hundred yards, and 40 feet above Big Looney creek, the coal above the sandstone shows 3 feet thick, with two thin partings, B 10. Still farther up this branch, and 60 feet vertically above the last outcrop, another coal, 2 feet thick, shows in the shales, B 11. Sixty-five feet above this the stain of another coal was seen, B 12. These three coals, B 10, 11, and 12, correspond with the three coals west of Maggard branch, A 13, 14, and 15, and presumably with the three on Clover Lick creek, A 28, 29, and 30. The uppermost of these occupies the same position as regards the underlying coals and the Gladeville sandstone as does the so-called "Cannel" seam on Preacher (B 37) and Mud Lick (C 3) creeks in Virginia. The intervals correspond closely, so there is not much doubt about the correctness of the correlation. This "Cannel" seam appears to be remarkably persistent, and was provisionally identified throughout the entire field.

On Big Looney creek above the mouth of Gap branch the coal above the Gladeville sandstone disappears beneath the creek at the distance of about one-half mile, B 13, and a mile above this the next coal, B 11, shows at water level as an 18-inch seam, B 14. This disappears in a short distance and no exposure was seen until the next large branch from the south was reached. Just a little below the mouth of this branch and on the other side of the creek in a small ravine a coal, B 24, shows 20 inches thick, and is correlated with B 12, or the "Cannel" seam.

About half a mile above this last exposure, on the main creek, a coal has been faced up in the bank of the creek just back of the blacksmith

shop of Mr. Jenkins, and shows 4 feet 1 inch of coal without a parting, B 25. Stratigraphically this is about 80 or 90 feet above the "Cannel" seam, and is an important coal over quite a large area. It is probably the coal which outcrops near Clover Lick creek, A 31, and shows on Mud Lick creek, Virginia, C 2, where it is 4 feet thick. Above this, on the main creek, a number of coals were seen, but none of them appeared to be of any economic importance, although Mr. C. Ballard Thruston, of the Kentucky geological survey, discovered several good beds.

On Gap branch a coal, B 16, 630 feet above the sandstone, is exposed, and the same coal was probably identified on Big Looney creek, B 29 and 30, and also on Lewis creek, B 6, and on a small branch west of Lewis creek, B 2. At the latter exposure it shows as follows:

	Ft.	In.
Coal	1	6
Dark shale	35	0
Coal	0	10

The following is the section at B 30 on Looney creek:

	Ft.	In.
Coal	1	4
Shale and sandstone	16	0
Coal	1	6

On Gap branch a coal, B 17, shows about 300 feet above the last-mentioned one, and is 3 feet 8 inches thick. This coal is about 300 feet below the Harlan sandstone, and was probably seen on Big Looney Creek at J 3, but no measure of its thickness could be obtained.

The extreme top of the Wise formation is a heavy coal which was reported in a number of places, but only seen in one or two. On the trail from the head of Big Looney creek across the Big Black mountain to the Isom Rock spur it is well shown. Here on the north side of the mountain, B 31, Mr. Thruston opened this seam several years ago and reported its thickness as 7 feet. This could not be verified, as the opening had become partly filled with mud and water, but at least 6 feet of fine coal still remains visible. Mr. Thruston's section at the head of Big Looney creek is as follows:[1]

	Ft.	In.
Coal	0	9
Shale	0	4
Coal	1	0
Shale	0	1
Coal	0	4
Shale	0	1
Coal	0	1
Shale	0	1
Coal	0	10
Shale	0	5
Coal	0	3
Shale	0	7
Coal	0	7½
Total (B 32)	5	5½

[1] Resources of the Upper Cumberland river, p. 50.

	Ft.	In.
Interval	75	0
Coal (B 31)	7	3
Interval	40	0
Coal	2	5
Interval	30	0
Coal	0	8
Shale	1	8
Coal	5	0
Total	7	4

The coal given as 7 feet 3 inches is the one referred to, B 31, and the interval immediately above it of 75 feet is the heavy base of the Harlan sandstone. Thruston's openings on the two seams were found, but the interval between them, measured barometrically, is 100 feet instead of 75 feet, as given. The coal, B 32, above this sandstone was seen directly above the opening at B 31, but no thickness could be obtained. The two lower coals in the section were not seen at all.

The stain of the coal immediately underneath the Harlan sandstone was seen in two places on Gap branch, B 18 and 19; it is reported as showing in the ravine east of the Big fork ridge B 23, but it could not be found.

On Lewis creek no coals of any importance were seen below the Gladeville sandstone; the latter is well exposed in the creek bed from a point a little more than a quarter of a mile above the schoolhouse up to the coal opening on the eastern fork of the creek, B 3. Its base is very heavy, but near its top it carries about 40 feet of sandy shale. The thickness of the coal seam above the sands could not be determined at the opening, B 3, as its base is not exposed; only 24 inches of coal are now visible. This coal also shows in a small ravine west of Lewis creek, B 1, with the following section:

	Ft.	In.
Sandstone roof.		
Coal	3	2
Heavy sandstone.		

A few higher coals were seen on Lewis creek, but simply as stains on the mountain side, and no data were obtained as to their thickness and character.

No detailed examination was made of the country along the southern side of the Poor fork between Lewis creek and Big Looney. Several of the inhabitants state that there are no coals known in that region, but this kind of evidence is not conclusive. Doubtless all the coals of Looney ridge on the southern side occur on the northern side, but they must, necessarily, lie at higher levels near the edge of the syncline, and will be found by future prospectors high up on the ridge. At present there is too much good coal to be seen at water level in other valleys to make these coals of much importance.

It is an assured fact that within the territory drained by the Poor

fork there are a number of workable coal seams, whose attitude is such that they can be easily and profitably mined, and the quality of whose coal is sufficiently good to warrant their development. The question of transportation is the all-important problem; the outlet for the field is naturally down the Poor fork to Pineville, where a line of railroad would connect with the Louisville and Nashville system. As stated on a preceding page, the present demand for fuel does not appear to be great enough to warrant the opening of this field, and many years may elapse before transportation can be secured.

CRAB ORCHARD BASIN.

In this portion of the field, owing to the disturbance along the northwestern side of Stone mountain, the thickness above the Lee conglomerate cannot be determined, so the Gladeville and Harlan sandstones must be the datum planes from which to measure. These two are well exposed, and are easily identified by their characteristics.

The Gladeville sandstone forms the floor of the Clover fork valley throughout most of its extent; at intervals it lifts sufficiently to allow a small coal lying immediately below it to appear in the bed of the stream, but it rarely rises higher than this, and soon dips below water level again. At the mouth of Rockhouse branch this coal is probably 10 feet above the creek, I 9, with the sandstone as a heavy ledge resting directly upon it; in the next 2 miles upstream, the coal shows at water level in four places, I 16, 17, 19, and 20; above this, it sinks beneath the stream and does not reappear in the valley.

On the Virginia side the lower coals are better exposed and were seen in a number of places. The Gladeville sandstone first makes its appearance at Robnet's chapel, lying about horizontally, and is at or near the surface over a large area south and west of the village. The road leading south from the chapel down Jones creek valley is on this sandstone for some distance and then passes below it. One and a quarter miles south of the chapel a coal, P 7, has been opened in a small ravine on the east side of the creek 60 feet above the road; it is poorly exposed and much contorted, only 20 or 30 inches being visible. This coal is supposed to lie immediately under the Gladeville sandstone, for though the latter was not seen in place, the blocks of its débris are very heavy and indicate that the ledge is but a short distance above. This is probably the opening referred to by McCreath and d'Invilliers in which they obtained a complete section of the seam, described by them as follows:[1]

A. J. Bailey's coal is opened on a small branch entering Jones creek from the east, a short distance north of Jake branch, and about 2¼ miles from the river. The open-

[1] Resources of the upper Cumberland valley of southeastern Kentucky and southwestern Virginia, pp. 34–38.

ing is 150 yards from the creek and about 100 feet vertically above it. The dip northwest is quite severe (15°) * * *. Its section and analysis are as follows:

Section.

Gray and blue slate roof.	Ft.	in.
Coal	4	7
Slate	0	1
Coal	0	4
Total	5	0

Analysis.

Water	1.206
Volatile matter	41.539
Fixed carbon	48.274
Sulphur	3.527
Ash	5.460
	100.006

Color of ash, pink.

The Carroll coal is opened in the bed of Jones Creek 1 mile north of Bailey's, and by barometer 75 feet lower than this latter coal. Geologically it is of course a much higher bed, owing to the still north dip of the measures along this creek. Massive yellow sandstone outcrops in the creek just above the coal outcrop, forming a natural barrier and falls, and at the same time the true roof of the coal. About 14 inches of blue slate rock intervenes between this sandstone and the top of the coal. The opening had partially filled with water from the creek, making the exposure imperfect to either measure or sample. The dip is still severely NNW. 15° to 20°.

* The bed section and analysis will therefore show as follows:

Section.

Sandstone. Blue slate roof.	ft.	in.
Coal	3	5½

Analysis.

Water	1.508
Volatile matter	38.602
Fixed carbon	48.393
Sulphur	3.077
Ash	8.420
	100.000

Color of ash, red.

Again they refer to the northwest dip of the measures along Jones Creek.[1]

The feature of Jones creek territory is the marked dip in the measures north from the river. The result of this structure is to carry the thicker beds of the lower measures quickly under water level, bringing in a great thickness of barren measures above the Carroll coal, whose character suggests a correlation with the rocks outcropping in the Black mountain in the vicinity of Morris gap.

These quotations are made to correct the impression they convey as to the structure of this region. The work done by McCreath and d'Invilliers was limited to isolated observations on various coal outcrops and they failed to comprehend the structure, which could only be understood upon careful mapping of the whole country.

[1] Op. cit., p. 39.

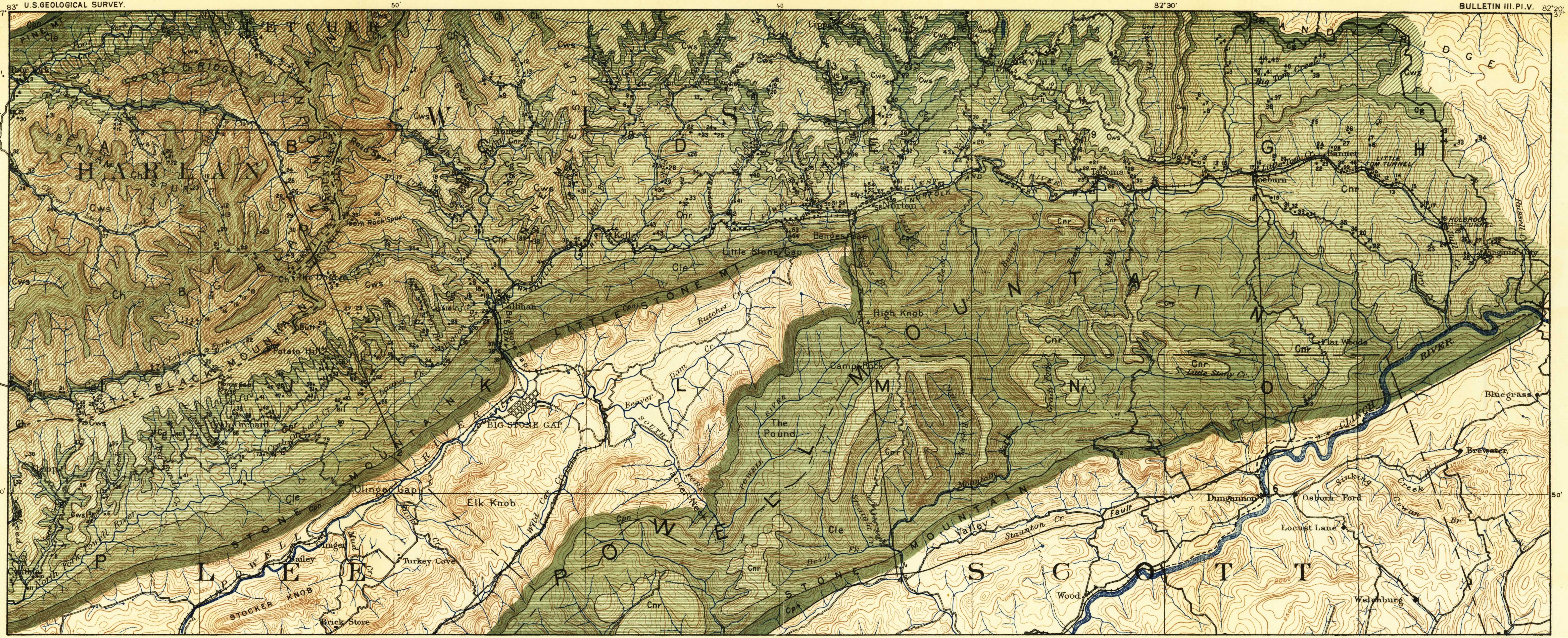
A continuous northwest dip from the river to Robnet's Chapel is simply impossible, as this would bring the Harlan sandstone down to within a few hundred feet of the chapel, supposing the dip to be 15°. The structure is very evident when the outcrop of the heavy Gladeville sandstone is followed south from the chapel; for a mile the road down Jones creek is either on the outcrop of this stratum or just above or below it, so in that distance the dip can not be very much. Below this for nearly another mile the debris of this bed is very heavy in the road and plainly shows that it caps the hills to about this point. Although no measure was made on it here, judging from the topography, the rise or fall in these 2 miles could not have exceeded 100 feet. The quoted passages themselves furnish evidence pointing the same way; the two analyses are strikingly similar. They are placed side by side for comparison:

	Bailey coal.	Carroll coal.
Water	1.206	1.508
Volatile matter	41.539	38.602
Fixed carbon	48.274	48.393
Sulphur	3.527	3.077
Ash	5.460	8.420
Color of ash	Pink.	Red.

In this paper chemical analysis has not been used as a means of correlation, but the above shows that as far as chemical composition is concerned these coals may be one and the same. The physical character of these seams, as far as seen, is similar in that both have the blue shale roof and the same heavy bench of coal at the top.

The Carroll coal as described by McCreath and d'Invilliers is directly beneath the Gladeville sandstone, while the Bailey coal, without much question, occupies the same relative position. Everything observed points to their being the same seam, excepting the northwest dips along the creek. It is very certain that the Gladeville sandstone does not dip in this direction at the rate given, and the only explanation is that the softer shales, coals and sandstones below this heavy stratum have been crumpled in taking up the horizontal motion. This phenomenon is frequently observed on a small scale in the folded rocks of the valley, and it is highly probable that it has occurred here on a large scale, giving rise to these apparently continuous northwest dips.

On the Jones creek road, about half a mile above the point where Reed creek joins it, there is a belt of greatly disturbed rocks that appear to be compressed into close folds. This greatly disturbed condition makes it very difficult to correlate the coals exposed south of this belt with those exposed north of it. Just below this a coal in two



The area of the map is divided into squares lettered A. B. C. D. &c. and the coal outcrops are numbered in each square.

GEOLOGIC MAP OF THE BIG STONE GAP COAL FIELD.

BY

MARIUS R. CAMPBELL.

1893.

Scale 1/125,000

0 1 2 3 4 5 6 Miles

Contour Interval 100 feet

HARLAN SANDSTONE.	WISE FORMATION.	GLADEVILLE SANDSTONE.	NORTON FORMATION.	LEE CONGLOMERATE.	PENNINGTON SHALE.
Ch	Cws	Cg	Cnr	Cle	Cpn

benches shows in the road, P 10, and is here regarded as the equivalent of the famous Imboden seam farther east, but the evidence for this is not conclusive. At the point where the main road crosses Jones creek a coal is exposed in the creek bank, P 11, dipping north 10°, and 2 feet 6 inches thick; this, from the dip, would be about 100 feet below the last mentioned coal. A coal at this horizon, or about 100 feet below the Imboden, was seen on the Roaring fork, D 22, and one 18 inches thick was noted by Stevenson[1] on Little Looney creek at 110 feet below the Imboden.

In the hillside opposite Cynthia post-office and 170 feet above the creek a coal has been opened, but its thickness could not be determined. Assuming the correlation before mentioned to be correct, this coal would occur just beneath the Gladeville sandstone. The topography above the coal outcrop indicates the presence of a hard bed, but at the time the work was done in this region the importance of the Gladeville sandstone as a key rock was not appreciated and its location was not determined in many places where it otherwise would have been. The absence of these data now makes correlation uncertain.

East of Robnet's chapel the Gladeville sandstone rises rapidly, and the main road to Crab Orchard crosses its outcrop at the divide between Jones and Cox creeks.

On the latter creek, below this road, there are several exposures, I 36, 37 and P 3, 4, 5 and 6, which probably belong to one seam that is divided into two benches with a parting of 20 feet between them. That these seams are beneath the Gladeville is quite apparent, but how much below is uncertain. The seam, being divided in two benches, would most nearly resemble the coal on Jones creek, correlated with the Imboden, but the data at hand are not sufficient to settle the question. The upper one of these coals is reported to be 7 feet thick and the lower one 4 feet 6 inches, but the openings were so filled by debris that a complete measure was impossible. Two feet 3 inches of coal was seen in the upper and 3 feet in the lower.

In this territory there are a number of coals above the Gladeville sandstone, but it is doubtful if there are any of importance, as they are either too thin to mine or too much broken up by partings to be of commercial value.

As the Gladeville sandstone is well exposed both north and south of the Little Black mountain, correlation of the various coals on the Virginia side with those on the Kentucky side of the mountain is not very difficult. The coal bed immediately above the sandstone, although it outcrops at a number of places, is of no value, as the seam is very variable. As before noted, it shows on Rockhouse branch as 1 foot 10 inches of shaly coal, I 10, above which is a considerable thickness of black carbonaceous shale. This coal shows in the valley of the Clover fork in four places, above the mouth of Rockhouse branch, I 18, 21, 6

[1]Op. cit., p. 238.

and 7, but near the mouth of Razor fork the grade of the valley rises more rapidly and the coal disappears beneath the bed of the stream. On Reed creek, on the Virginia side, it shows in a number of places, I 32, P 1 and 2, where it lies nearly horizontal but with sufficient roll to bring it alternately above and below water level. On Jones creek it is 16 inches thick at I 31; above Robnet's chapel it appears considerably thicker, for here a thickness of 18 inches was seen, I 34, and the bottom not exposed.

On Cox creek, about a mile above the main road, a seam, I 35, shows in outcrop with 30 inches of coal exposed; it is thought to be the same seam, as it occurs just above a heavy sandstone that is correlated with the Gladeville.

The coal beds above the base of the Gladeville sandstone show in a good section on Rockhouse branch, as follows:

Sandstone.	Ft.	In.
Coal	0	4
Sandy shale	5	0
Coal (I 42)	3	0
Shale and sandstone	60	0
Coal (I 15)	1	2
Sandstone	15	0
Coal (I 14)	0	4
Shale (I 14)	0	6
Coal (I 14)	1	2
Dirty coal (I 14)	0	2
Coal (I 14)	1	6
Dirty coal (I 14)	0	2
Coal (I 14)	0	8
Interval	4	6
	60	0
Coal (I 13)	1	0
Shale (I 13)	1	2
Coal (I 13)	0	1
Shale (I 13)	0	6
Coal (I 13)	0	8
Blue shale (I 13)	1	6
Coal (I 13)	0	3
	5	2
Interval	14	0
Coal	0	4
Interval	15	0
Coal	0	1
Interval mainly shale	300	0
Coal (I 12)	1	0
Sandy shale	50	0
Coal (I 11)	3+0	
Interval shale and sandstone with probably some coal	150	0

	Ft.	In.
Coal (I 10)	0	4
Shaly coal (I 10)	1	6
	1	10
Heavy sandstone, Gladeville	90	0
Coal (I 9)	?	

The coal I 11 is at about the same horizon and probably corresponds with the "Cannel" seam on Callahan creek. This same coal is faced up on a small branch of Jones creek on the south side of the mountain, I 30, and exhibits the following structure:

	Ft.	In.
Coal	1	6
Shale	2	2
Dirty coal	1	4
Shale	2	6
Coal	4	0
	11	6

On the road across the Little Black mountain from Slemp post-office, a coal stain shows in two benches, I 33, which is probably the same coal. On the same road but on the northern side of the mountain the following section was measured:

Summit.	Ft.	In.
Interval	70	0
Coal (I 24)	1+	0
Interval	220	0
Coal (I 23)	1	3
Shales and thin bedded sandstones	70	0
Coal (I 22)	2+	0
Sandstone	90	0
Coal?		
Sandstone (Gladeville) to creek	10	0

In the above section I 23 is probably equivalent to I 11 in the Rockhouse branch section.

About half a mile farther up the Clover fork, in a ravine coming in from the south, the following section was measured:

Black impure limestone.	Ft.	In.
Blue shale	50	0
Coal	00	2
Blue shale	25	0
Coal (I 29)	3	0
Interval mostly shale	100	0
Coal (I 28)	2	2
Sandstone	60	0
Coal	0	4
Sandy shale	30	0
Coal (I 17)	1	0
Sandstone	70	0
Coal, probably heavy seam (I 26)	(?)	
Interval to creek, mainly sandstone	125	0

In this section the last interval probably contains the small coal 90 feet below I 26, and below that the sandstone is of the Gladeville formation. This is not entirely certain, for in this field the upper portion of the sandstone is without definite characteristics by which to identify it.

A little above Lauder creek, and on the south side, a coal was seen 125 feet above water level, I 8, which is probably the same as I 26 of the above section, and which becomes a very important coal in the vicinity of Morris gap. Just below the main forks of the creek it shows on the north side, I 5, about 25 feet above water level; it consists of 5 feet of solid coal, with heavy sandstone above and below. Above the forks, on the south side, J 19, the bed is 50 feet above the stream and is composed of 5 feet of coal with 18 inches of blue shale above; in both places, I 5 and J 19, it has been dug into for local use. About half a mile up the main branch of the creek it has been opened by an entry driven in on the seam, J 21, and shows the following section:

Black shale roof.	Ft.	In.
Coal	3	8
Shale	0	2
Coal	0	10
Total	4	8

It was opened not long since in a little branch called Sang Trace, on the Morris gap road, J 20. Its thickness here is reported as 7 feet, but the opening was so filled with water and mud from the creek that but 4 feet of coal was visible. At this opening it is 195 feet above the creek and shows a strong northerly dip of about 2° or 180 feet per mile; this dip probably does not hold for any distance but rapidly diminishes to the gradual dip of about 80 feet to the mile observed in all the sections in the Kentucky basin. On the Razor fork of Clover fork a large number of coal outcrops were observed, but like the coals in the upper portion of the Rockhouse branch section, they are so split up with shale partings as to be almost worthless. The elevation of these exposures was not determined with sufficient accuracy to make it possible to correlate them with other portions of the field.

On the main stream, above the mouth of Razor fork, a few outcrops were located, but there were none of any value. One and one-quarter miles above Razor fork in a small ravine on the south side of the valley, at J 22, the following section was measured:

Shale.	Ft.	In.
Coal	2	6
Shale	10	0
Coal, dirty	1	6
Shale	2	6
Coal	0	8
Shale to creek	15	0

This probably corresponds with a coal noted on the Morris gap road on the northern side of the mountain, J 33, showing in the hillside in

two benches. On the trail that crosses the Little Black mountain from the head of Clover fork signs of coal were seen, J 23; this, from its position and altitude, is about 630 feet above the Gladeville sandstone, and would correspond with coals noted on Big Looney and Lewis creeks, B 16, 30, 29, 6, and 2.

The dip as shown at Morris gap brings the strata at much higher levels on the southern side of the mountain; the Gladeville sandstone, whose base is about 1,860 feet above sea level at the mouth of Razor fork, is 2,100 feet on the road south of Morris gap, and shows as a heavy white standstone, forming rocky spurs and ledges along the mountain slope. The coal just beneath this sandstone shows in the Morris gap road at an elevation of about 2,080 feet, J 37; this rises and becomes more important eastward, where it has been opened in several places, showing a fine body of coal. Its best development is about a mile and a quarter east of the Morris gap road and three-quarters of mile above the main valley road, J 45, and its section is as follows:

	Ft.	in.
Coal	1	8
Knife edge of slate.		
Coal	3	8
Knife edge of slate.		
Coal	1	4
	6	8

One-half mile farther east this seam has been opened at J 48, but not with so good a showing; it could not be measured, but is reported as 6 feet thick with several partings. McCreath and d'Invillers[1] report several coal seams on Little Crab Orchard creek that were not seen by the writer, but from their section and interval they would agree with the coals already described. One large seam has the following section:

	Ft.	in.
Shale roof.		
Coal	1	8
Shale	0	½
Coal	3	9
Slate knife edge.		
Coal	0	2
Slate	1	0
Coal	1	7
	8	2½

This is undoubtedly the same coal as that described above, belonging directly under the Gladeville sandstone. About 150 feet above this they noted an opening with this section:

Slate roof:	Ft.	In.
Coal	2	0
Clay slate	0	1
Bone coal	0	6
Splint and bony coal	0	6
Coal	2	8
	5	9

[1] Op. cit., pp. 31-33.

If the above correlation is correct this bed would correspond to the main seam on the Clover fork, I 11, 23, 26, 8, 5, and J 19, 20, and 21.

As stated by McCreath and d'Invilliers,[1] these two are in all probability the only coals of commercial importance in this region, and as our investigations verify this statement we will omit the consideration of a great number of coal outcrops visited in the region between Cox creek and the county line. The structure in this part of the field is probably a very gentle, almost flat, synclinal trough, but the basin is traversed by so many minor undulations that the strata have light dips in various directions; this renders it all but impossible to correlate the various coal outcrops.

There has been a large amount of speculation as to the representative of the Imboden seam in Lee county. This coal has become so prominent and the name Imboden is so generally recognized in this region as a synonym of a heavy seam of fine coking coal that any man who wishes to advertise his property claims that his coal is the undoubted representative of the famous seam of Wise county. As a matter of fact the western continuation of that seam is unimportant. If it extends into Lee county it has lost its specific character and can not be distinguished among the numerous seams outcropping along the southern side of the Little Black mountain. The writer is inclined to correlate with the Imboden, mainly on the strength of structural evidence, a coal showing in several places in the head waters of the North fork of Powell river. This coal was first seen in a small branch near the county line, J 83, and on following the branch down two more openings, J 82 and 81, were found, but in no place could a section of the seam be obtained, as the coal dips lightly northward and the openings were in the bed of the creek and filled with water. At J 81 the thickness is reported as 4 feet. The dip on this seam flattens out toward the west and the coal is nearly horizontal, giving an irregular line of outcrop. From the last described exposure it probably swings to the south and was next identified on the Olinger gap road, which it follows for about a mile, showing at J 78, 77, 76, 75, and 74; at the latter point it leaves the road and was next reported on the Big Crab Orchard creek, J 73, but was not seen. The next exposure of this coal is on a branch of Little Crab Orchard creek, J 70, but its thickness was not obtainable. From this point its outcrop is uncertain; it is provisionally correlated with a coal on Big Bundy creek that makes a heavy showing in the bluff, I 41, but slides have so obscured its outcrop that it was impossible to obtain any idea of its thickness. This series of outcrops is directly in line with the exposures of lower coals already described on Cox creek and also on Jones creek, and their position is the principal reason for correlating them with the Imboden.

Altogether the coals in this basin are rather unreliable, and, although two or three seams present a fine appearance locally, careful prospect-

[1] Loc. cit.

ing should be done to determine the extent of workable coal before development is begun on a commercial scale.

IMBODEN BASIN.

This is separated from the basin previously mentioned by the county line ridge—the divide between the waters of the North fork of Powell river flowing through Pennington gap, and the streams flowing east into the main Powell river at Big Stone gap.

So far as known no coals of commercial value cross this ridge, though quite a number, varying from 1 inch to 3 feet thick, can be identified. The coal seam correlated with the Imboden crosses the ridge with a light northward dip from J 83 and shows on the east side of the divide in a small ravine, J 84, 60 feet above the road and 36 inches thick; it crosses Pigeon creek where the main road first crosses that stream, J 59, where the coal is 26 inches thick. East of this point it follows the creek, closely skirting the base of the hill on the east side and showing at J 60 and 61. It was next seen in a small ravine, J 63, 1½ miles from the county line, with 30 inches of coal. In the next branch to the east and about 300 yards north of the main road, J 64, the bluff shows the following section:

	Ft.	In.
Coal (J 64)	4	6
Shale to creek	40	0

On the small branch entering Pigeon creek above the mouth of Bearpen branch it shows in a small ravine, K 26, about three-quarters of a mile from the main road, with the following section:

	Ft.	In.
Coal	1	0
Shale	5	8
Coal	2	0
Shale	0	6
Coal	3	6
Total	12	8

This section shows a much greater thickness than the exposures already described, and this increase in size appears to be due rather to number and size of partings than to a thickening of the coal itself.

On Bearpen branch there is a peculiar showing of coal 70 feet above water level on the west side of the creek, K 33, about half a mile above the road. On the steep slope of the hill there are two old openings, but their present condition is such that it is impossible to obtain a section of the coals; these openings are about 100 feet apart in a northeast-southwest direction, and the southeastern opening is 45 feet vertically above the other one. Both show contortion of the strata, and from the facts observed it is impossible to say whether they are openings on the same or on different seams. The upper opening shows a coal 4 or 5 feet thick, while the lower opening is almost filled with débris, and only 18 inches of coal is now visible. The interval of 45 feet between the openings corresponds with that

between the Imboden and Kelly seams. If this identification is correct, the Kelly or upper seam is here the prominent one and the Imboden may be insignificant. But on account of the proximity of these exposures to the disturbed area along Stone mountain, and indeed of the disturbance shown in the coals themselves, the correlation is extremely unreliable. On the next branch to the east, K 29, there is also a phenomenal development. The pit had so fallen in that it could not be measured, but J. J. Stevenson gives the following section of the coal in this opening:[1]

	Ft.	In.
Coal	6	10
Shale	0	10
Coal	2	5
Shale, averaging	0	3
Coal	4	6
Total	14	10

Mr. Stevenson considers this the Kelly seam, although he made no effort to find the Imboden under it and so to verify his conclusions. About a quarter of a mile above this opening a heavy coal was seen at water level, K 14; this is probably the same coal as K 29, but no section of it could be obtained. There are more and better exposures of coal on Bearpen branch than on any other stream in this vicinity, and the identification of the various coals is very important in determining the structure in the triangle formed by Pigeon and Looney creeks and the crest of the mountain. For the sake of uniformity we will assume the lower of the two openings at K 33 to be on the Imboden seam. Its elevation is 1,845 feet above tide, but at the mouth of the next branch above, K 28, it has descended to 1,810 feet, and in the next, K 27, to 1,800 feet. From this point it rises about as the creek bed ascends to K 10, where it shows at water level 5 feet 6 inches thick. This is without much doubt the Imboden, for about a quarter of a mile down stream the Kelly seam, K 11, is exposed in the bluff 40 feet above the stream. Its complete thickness could not be measured, but 2 feet 6 inches of coal were seen. At K 10 the Imboden disappears beneath the stream, and about a quarter of a mile farther up the Kelly is seen at water level, K 6. Not even here could its full thickness be obtained as only 2 feet 6 inches of coal is visible.

This shows clearly the structure on Bearpen branch. From the mouth of the branch the strata dip to the north in a gentle syncline, whose axis is three-quarters of a mile above the mouth of the branch; from this syncline they rise to the anticline, whose axis is at K 10, or 1½ miles from the mouth of the creek; then they descend gently to the north again to Little Looney creek.

East of Bearpen branch the outcrop of the Imboden seam has been traced continuously as far as Nine-mile spur. The various openings

[1] Op. cit., p. 94.

are numbered in the map K 17, 16, 15, 19, 18, 7, 1, 2, and 3; C 35, 33, 19, 16, and 27.

At K 7 this coal is mined by the South Atlantic and Ohio Railroad Company. The seam is opened from a small ravine that enters Looney creek from the west; the main entry is driven nearly due south up the dip, which is just sufficient to provide perfect drainage. The mouth of the mine is 240 feet above Looney creek, and the coal is delivered to the cars down an incline. In the mine the coal varies in thickness from 5 feet 6 inches to 9 feet 7 inches; where it shows 5½ feet it is solid coal without a parting, but where the bed begins to thicken it does so by splitting into two benches. A mass of dirty coal enters like a wedge, swelling the thickness of the seam to 9 feet. At the mine the Kelly coal is reported 50 feet higher up in the hillside, K 8, 4 feet thick.

The Imboden has also been opened half a mile above this mine and on the opposite side of the creek, K 2, where it is about 6 feet thick and 90 feet above the water. The last exposure of this coal on Little Looney creek occurs in a small ravine, K 1, just opposite the foot of the trail leading to the Isom rock, where it shows 6 feet 6 inches thick.

There is only one other coal of any importance in this district, and this is of more value from a stratigraphic point of view than in a commercial sense, as the seam is not large enough to mine but is an important guide to the structure. This seam is about 440 feet above the Imboden and about the horizon of the "cannel" seam farther east. It is well shown on the extreme head of Pigeon creek, just beneath the butt, J 26, at an altitude of 2,465 feet; it shows an outcrop 2 feet 6 inches thick under a ledge of sandstone, which makes a marked fall in the creek. A coal was reported as showing in the branch farther up, but it was not visited; it may be the heavy coal lying about 100 feet above the cannel.

On a small branch of Pigeon creek just east of this a coal was seen, J 27 and 28, that is here correlated with the cannel, and shows the following:

	Ft.
Coal	4
Interval	15
Coal	4

The entire thickness of this lower bench could not be obtained, but is probably not much more than the amount given.

These openings are at considerably lower levels than the one on Pigeon creek. This is easily explained by the structure of the region. The outcrop on Pigeon creek is on an anticlinal arch, while the last opening mentioned is in the synclinal basin lying just east of this arch, and the strata descend quite rapidly from the butt eastward. These seams were next observed on the head of Little Looney creek, just across Looney ridge from this last-named outcrop, but higher up on the anticlinal arch, J 6, 7, 8, and 9. These are good exposures; the

upper seam is the larger, measuring 3 feet 3 inches thick and capped by a sandstone that produces a fall in the creek similar to the outcrop on Pigeon creek; 20 feet below this the other coal shows with a thickness of 18 inches.

This cannel seam is next opened on Preacher creek, a tributary of Callahan creek, B 37; this is its type exposure, for here it shows its character of a cannel coal, and from this circumstance received its name. Its section here is as follows:

	Ft.	in.
Sandstone	0	0
Cannel shale	0	4
Cannel coal	2	0
Shale	0	4
Shaly coal	0	4
Shale	0	5
Coal	0	5
Shale	0	4
Coal	3	4
Total	7	6

It is here in its greatest development, and appears to thin in either direction.

On Callahan creek the coals have been well prospected and located. At the mouth of Preacher creek the Imboden has been opened in the bluff on the west side 200 feet above the creek, C 35, at an altitude of 1,852 feet above sea level. About a mile up Preacher creek it shows in three places, C 33, in natural outcrop as it disappears beneath the creek, in an old prospect hole on the west side of the creek, and in an entry that has been driven in on the seam lately, just below the natural outcrop and on the eastern side of the creek. These three exposures, in close proximity, offered an excellent measure of the dip of the strata which is to the northwest and about 130 feet per mile. The opening recently made exhibits a wonderful thickness of the seam, as is shown by the following section measured where the coal had been faced up 20 feet from the mouth of the drift.

Sandstone roof.	Ft.	In.
Coal	11	0
Bony coal	0	3
Coal	1	8
Clay	0	2
Total	13	1

Sandstone floor.

Just across the road spur, on Mud Lick creek, is a fine exposure of the Imboden seam, C 19, where an entry has been driven in some distance and considerable coal mined, and at this place an oven has been

built to test its cooking qualities. Its section at this opening is as follows:

Sandstone.	Ft.	In.
Shale	10	0
Coal	1	10
Knife-edge parting.		
Coal	1	4
Bony coal	0	1
Coal	0	6
Bony coal	0	6
Coal	2	4
Total	16	7

From the descriptions given it will be seen that the main coals in this portion of the field, occur in a group of rocks 400 or 500 feet thick, whose lower limit is the shale and sandstone underlying the Imboden seam. The best type section of this belt of coal-bearing strata was obtained on Mud Lick creek near its junction with Callahan creek. Here the hill on the west side of the creek has been trenched from its summit to the Kelly coal, which is about 80 feet above the creek. A section was carefully measured here with a Locke hand level, but unfortunately the trench had become so filled that it was impossible to get the thickness and character of the coals, but their position and the character of the interval is well shown. The thickness of the coals is given as reported, or, in round numbers, as they occur in neighboring localities:

Summit of hill.			Ft.	In.
Sandstone			45	6
Coal (Cannel seam) (C 25)			6	6
Sandstone, thin bedded			29	0
Coal (upper splint)[1] (C 24)			1	6
Interval, no exposure			58	6
Shale			16	6
Sandy shale			13	6
Coal (lower splint)[2] (C 23)			2	0
Shale	Gladeville		25	0
Heavy sandstone	Gladeville		71	0
Sandy shales	Gladeville		26	0
Coal (C 22)			2	0
Interval, no exposure			45	0
Shale			13	0
Interval, no exposure			24	0
Shale			29	0
Coal (Kelly seam) (C 21)			1	6
Interval			75	0
Coal, Imboden (C 19, 20)			6	7

[1] This coal, though covered in the trench, did not appear to be more than 18 inches thick, but is reported as 3 feet 6 inches, and is so given by Mr. Stevenson. Op. cit., p. 238.

[2] This coal appears to be 2 feet in the ditch, but is certainly heavier, as the surface creep tends to reduce the apparent size. Mr. Stevenson gives it as 3 feet 6 inches to 4 feet 6 inches, and within a few miles the seam shows a thickness of 6 or 8 feet, with many heavy shale partings.

Summarized, the preceding section is as follows:

	Ft.	In.
Coal, Cannel.		
Interval	29	0
Coal, upper splint.		
Interval	88	6
Coal, lower splint.		
Interval, Gladeville sandstone	122	6
Coal.		
Interval	111	0
Coal, Kelly seam.		
Interval	75	0
Coal, Imboden.		

This section, while not showing the Gladeville sandstone in what we may consider its type form—a heavy ledge-making sandstone—still shows an interval of 71 feet of heavy sandstone, with 26 feet of sandy shales beneath. This appears to be the reverse of the section on Clover fork, for there the hardest, heaviest stratum is at the base. The formation shown on Mud Lick creek is characteristic of it throughout the entire territory east of Callahan creek.

The Cannel seam has been opened on the Road spur, less than half a mile from the head of this trench, at the point where the trail from Preacher creek first reaches the summit of the spur, C. 18, with the floor of the seam at an altitude of 2,202 feet above sea level. Here the coal shows 6 feet 6 inches thick, but it appears to thin a little to the north it shows on Mud Lick creek, C 3, $3\frac{3}{4}$ miles from its mouth, at water level, with a thickness of 5 feet of solid coal.

About 100 feet stratigraphically above this there is another heavy coal, C 2, that outcrops on Mud Lick creek about three-quarters of a mile above the Cannel seam and shows in section as follows:

	Ft.
Sandstone.	
Coal	4
Shale.	

This coal appears to be identical with the coal of Big Looney, B 25, exposed in the creek opposite the blacksmith shop of Mr. Jenkins, both being about 100 feet above the Cannel seam and of the same character and thickness, viz, 49 inches on Looney creek and 48 inches on Mud Lick creek.

But one higher coal was seen on Mud Lick, C 1, and it is too small to be of any commercial importance. It is east of Gibson gap and shows in the creek 24 inches thick. This is about the horizon of a heavy and persistent coal as observed on Big Looney, B 16, 29, and 30, and on Lewis creek, B 6 and 2.

On Callahan creek the Imboden is well shown at Pioneer, C 16, where the Virginia Coal and Iron Company are making preparations to mine it; they already have a double entry driven in on the bed 500 feet that reveals a general thickness of 6 feet. The entry rises on a very slight upgrade toward the southeast with its mouth about 30 feet above

the stream, affording an ideal location for a mine. A quarter of a mile upstream, the coal goes under the level of the creek and does not appear again. The Kelly seam shows at water level a short distance above Pioneer, C 15 and 14, and is here but a thin, insignificant coal 9 inches thick. The Gladeville sandstone is the next marked stratum that is noticeable on ascending the creek; it is seen but a short distance below the forks of the creek at Shepard's mill, and is indicated mainly by the large amount of coarse, sandy debris in the creek valley; on careful examination heavy ledges may be seen in the point of the hill on the east side of the creek.

At Shepard's mill a coal shows in the bank of the creek, C 10, just above the forks. This seam is 3 feet thick in a heavy bed of shale, and from its position, with reference to the Gladeville sandstone, would correspond to the Lower Splint coal as shown on Mud Lick creek.

On the new-cut country road above the mill a small coal, C 8, 11 inches thick, is exposed in the bed of the creek and is probably 70 or 80 feet above the coal showing at the mill. This interval corresponds with the interval above the Lower Splint coal on Mud Lick creek and would place this coal at about the horizon of the Upper Splint seam. On the Meadow fork this seam shows three-quarters of a mile above the mill, C 13, as a 10-inch seam. Its outcrop here is 50 feet higher than the outcrop of the Lower Splint seam at Shepard's mill, but the strata probably dip northward here by an amount sufficient to bring this to the same geologic horizon as the coal on the county road. There is also a coal showing just north of this, C 12, and about 80 feet above it, and if this interpretation of the structure is correct, it would represent the Cannel seam. The section at this exposure is as follows:

	Ft.	In.
Sandstone roof.		
Coal	1	0
Shale	3	9
Coal	3	3
Total	8	0

On this fork of the creek indications of coal were seen above this, but there were no valuable beds.

On the new-cut county road a number of small seams were observed and coal indications were quite plentiful, but the barometric observations on these coals are so contradictory that they cannot be correlated with well determined beds.

On the same road there is a good showing of the heavy sandstone at the base of the Harlan, both in ledges and débris. The maximum thickness of the Harlan formation in this portion of the field is about 600 feet, and this is found on the bluff spur. A coal 6 feet thick is reported on this spur, but its location is unknown; from the description it would appear to be about 300 feet above the base of the Harlan sandstone.

South of Pioneer, on Kelly branch, the Imboden coal is exposed at an elevation of 1,852 feet above tide, C 27; it shows here 6 feet of coal, with 4 feet of shale above it. About 200 feet above this, in a branch, C 26, a small coal 2 feet thick was seen, overlaid by sandstone (Gladeville).

The next exposure of the Imboden occurs on Church House run, C 36 and 38, about 1¼ miles above its mouth at an altitude of 2,075 feet. It is exposed in two places in natural outcrop and probably has a northerly dip of 180 feet per mile; it makes a heavy showing, but no measure of thickness could be obtained. Seventy or 80 feet above it were found indications of another coal, C 37, that may be the Kelly seam.

There is some diversity of opinion regarding the above correlations. McCreath and d'Invilliers[1] describe a coal on Church House run, 300 feet below this, as the Imboden. This latter coal is also referred to by J. J. Stevenson,[2] who gives the following section:

	Ft.	In.
Coal	3	10
Shale	0	5
Coal	3	6
Total	7	9

This opening was not seen by the writer, but from the description quoted, it probably occurs directly above a heavy sandstone that is well shown in the branch.

The writer's reason for the above correlation is that the Imboden seam, on the Fork spur between Little Looney and Callahan creeks, within three-quarters of a mile of the double tunnel, is at an altitude of 2,070 feet, K 3, while on Mill creek, C 31, across the point of Nine-mile spur, it is at 1,990 feet, both of which are higher than the lower coal on Church House run; consequently if the lower coal is the Imboden, there must be a synclinal trough with its axis near the mouth of Church House run. The outcrops of the coal north of here show no indication of such a basin; it can not pass west of Pioneer, as the Imboden seam has been followed throughout this region almost continuously, and it is equally certain that it does not pass east of Pioneer, for the entry at that place is driven southeast up a very gentle dip for 500 feet. The anticline that is shown to exist east of Pioneer is much more likely to have its axis in this vicinity than a syncline; the indications seem to point to a connection between this anticline and the folding just south of the double tunnel; in fact, the region about the mouth of Callahan creek is one of considerable uplift and probably is directly connected with the anticline east of Pioneer. The interval of 300 feet between the two coals noted is not conclusive either way, as there are coals both above and below the Imboden seam at that distance. The

[1] Op. cit., p. 28. [2] Op. cit., p. 95.

coal on Little Looney, K 9, at about that interval below the Imboden, shows the following section:

	Ft.	In.
Coal	1	0
Shale	2	0
Coal	1	8
Total	4	8

This coal occurs just at the top of a heavy sandstone, and is well shown in an old opening on the west side of the creek a mile above the double tunnel. Its location above the heavy sandstone gives additional weight to the view that it is equivalent to the lower coal on Church House run. From a careful consideration of all available data, it would seem that all previous determinations on this lower bed have been in error in correlating it with the Imboden.

On Mill creek there are two seams of coal, 60 or 70 feet apart, that have been opened in a number of places. An opening on the lower seam in a small branch 1¼ miles above the railroad shows 7 feet of coal, C 32. No detailed section of the seam was measured, but if it has any partings they are insignificant.

Further up, on the main branch, C 31, the same coal is 54 inches thick, and again at C 30, a little higher, it shows the following:

	Ft.	In.
Coal	2	3
Shale	0	2
Coal	4	6
Total	6	11

The upper coal is exposed in two places near the head of the branch C 28 and 29, as follows:

Shale roof.	Ft.	In.
Coal	1	4
Clay	1	2
Coal	1	5
Shale	1	5
Coal	2	5
Total	6	21

One of the great surprises of the region is the absence of this coal on the Roaring fork, below the mouth of Cane Patch fork. The Imboden doubtless exists in the extreme hilltops between Mill creek and Roaring fork, but as our lines of search always followed the streams, we have no data for that part of the territory. The Imboden was first seen on the west side of the Roaring fork, a quarter of a mile below Frank Sturgill's, where it outcrops in two places, D 8 and 9, but no measure could be obtained of its thickness. The only complete sec-

tion was obtained at an opening close to Sturgill's house, D 10, where it shows as follows:

Sandstone roof.	Ft.	In.
Coal	1	6
Shale	1	4
Coal	2	2½
Dirty coal	1	1
Coal	1	1½
Shale, carrying sulphur	0	5
Coal	3	2½
Shale	10	5½
Coal	0	9½
Total	10	10½

About 1½ miles above this, on the stream which enters from the west, a coal is exposed in two places, D 5 and 6, about 8 feet thick. No detailed section was made of it nor was its elevation determined, but it is not far from the same altitude as the opening at Sturgill's, and is probably the same seam.

Above Sturgill's, half a mile on the main stream, a coal is exposed, D 4, that is apparently the Kelly seam; again, at the distance of a mile, the same coal is seen (D 1) three feet thick. This indicates that the strata are nearly or quite horizontal. This is well sustained by the broad, open character of the valley.

On the road from Sturgill's to the Cane Patch fork, across the ridge, a heavy coal is seen in natural outcrop by the roadside, D 11. It is about a quarter of a mile above the forks of the road at the school house, on Cane Patch fork, and about 100 feet above it. This is without doubt the Imboden at an altitude of 2,050 feet above tide, while at Sturgill's it is only 1,960 feet; this gives a rise of 90 feet in this distance or 135 feet per mile on an east and west line. This rise of the strata eastward to the Coonseye anticline has been described on p. 25. It is of great economic importance, as the arch in the strata is sufficient to carry the main coal horizons high above what is now drainage level, and erosion has removed all of the coals except the lowest or Imboden seam. This just caps the hills, supported by a very heavy sandstone that occurs a short distance below it.

As the axis of this anticline passes about through Coonseye post-office, the Imboden seam continues to rise to that point and there attains an altitude of about 2,125 feet. No outcrop was seen there, but coal signs were very abundant at this altitude on the side of the hill, D 13, southwest of Coonseye. The axis of this fold pitches down to the north and the Imboden seam probably dips beneath Cane Patch within three-quarters of a mile of the main road.

On Cane Patch fork, a little more than a mile above the main road, a coal, D 2, occurs at an altitude of 2,140 feet; no measure could be obtained of its thickness and but little is known as to its equivalency. It outcrops beneath a heavy ledge of sandstone, which suggests the

conclusion that it is probably the seam just beneath the Gladeville sandstone and about 160 feet above the Imboden.

A few hundred yards north of the main road, a coal, D 12, was seen at an altitude of 2,025 feet; it is a small seam and its horizon is probably 80 or 90 feet beneath the Imboden.

About a mile south of Coonseye, on a small branch that joins the Cane Patch fork from the east, 2 coals have been opened at altitudes of 2,275 and 2,335 feet above tide. The lower coal, D 24, the Imboden, has 49 inches of solid coal with a shale roof, while the upper, or Kelly seam, D 25, has:

	Ft.	in.
Shaly coal	1	3
Coal	6	0
Total	7	3

This shows a remarkable thinning of the Imboden, for three-quarters of a mile directly west of this, this seam has been opened on the hill top, D 23, at an altitude of 2,195 feet, and shows the following section:

	Ft.	in.
Coal	2	0
Clay	3	0
Coal	1	0
Shale and clay	3	0
Splint coal	1	0
Coal	3	1¼
Total	13	1¼

The prospector was very uncertain whether this 13-foot seam was the Imboden or some higher coal, so these hillsides were very thoroughly searched to find lower coals, but without success. The following fine section was exposed in a trench from the base of the Imboden to the level of the Cane Patch creek:

	Ft.	in.
Imboden coal (D 23)	13	1¼
Not seen, probably sandstone	70	0
Heavy sandstone	20	0
Coal (D 22)	1	0
Clay (D 22)	3	0
Coal (D 22)	0	8
	4	8
Shale	10	0
Sandstone	105	0
Sandy shale, argillaceous at base	110	0
Coal (D 21)	0	8
Sandstone to Cane Patch fork	10	0
Total	348	1¼

South along the Roaring fork the Imboden has been opened in the extreme hilltops bordering the stream. In a ravine just east of the junction of Cane Patch with Roaring fork it shows, D 26, at an alti-

tude of 2,140 feet; a half mile further south it has been opened, D 28, and it reported as 16 feet thick, but it had fallen in so that it could not be measured.

Nothing was seen of the coal 90 feet beneath the Imboden. The sandstones are heavier and possibly replace this coal altogether. The lower coal, on the other hand, seems to come in thicker, for along the lower course of the Roaring fork a seam, which has the appearance of being at this horizon, is exposed at several points with a thickness of from 26 to 32 inches. This coal appears to be about 320 feet below the great Imboden coal, and shows just below the ford on Roaring fork 32 inches thick, D 30, besides showing in one place above this, at D 27. This may probably be equivalent to the 8-inch coal seen on Cane Patch, D 21, or possibly another seam at a slightly lower level. The southern continuation of these lower coals is uncertain. Three-quarters of a mile above the mouth of Roaring fork, D 43, a coal shows at water level 26 inches thick under a 10-foot ledge of sandstone, and this may possibly be the same coal as the last mentioned bed.

The structure in this portion of the field is quite uncertain, but the Coonseye anticline probably turns southeast, crossing the Roaring fork above this opening, and continues to Kelly station, where it is lost in the numerous minor wrinkles that accompany Stone mountain. South of this anticline the strata dip again into a slight synclinal basin in which the outcrop, D 43, on Roaring fork is situated; they then rise rapidly to the south, carrying this coal from water level on Roaring fork to an altitude of 180 feet above Powell river at a point three-quarters of a mile above the mouth of Roaring fork. This bed is correlated with the coal on Roaring fork and also with the coal exposed in the railroad cut at Kelly station, where, being closely folded upon itself, it has the appearance of a 6-foot seam.

The finest showing of coal in this field is on the headwaters of a small stream flowing south into Powell river, between Roaring fork and Bearpen creek, D 33. Here the Imboden seam shows a bottom bench of coal 13 feet thick without a parting, and an upper division of coal spoiled slightly by dirty streaks, making a total of 16 feet. The elevation of this opening is 2,235 feet; 50 feet above this a coal is reported, D 32, 4 feet thick, which is the Kelly seam, but it was not seen.

The correlation of these beds with the ones showing on Black creek farther east is one of the perplexing questions of the region.

As noted above, the heavy Imboden occurs on the divide between Roaring fork and Black creek at an elevation of from 2,235 to 2,275 feet, and, as seen by the section on Cane Patch creek, no coal for at least 330 feet below this is of any importance. On Black creek, less than a mile from the divide, two important seams of coal have been opened at several points; the lower about water level, at an altitude of 2,080 feet, and the upper 60 feet above it.

Fig. 2 is a map of the territory lying between Roaring fork and

Black creek, north of the main Powell river. It shows on a larger scale than the general map the relative positions and altitudes of the observed outcrops. The Imboden seam occurs on the hilltops at several points already described, D 24, 23, 26, 28, and 33, and coal indications were seen at two other points, D 34 and 31, that apparently belong to the same horizon. The Kelly, or upper coal, appears to be present over all the territory, although its actual outcrop was seen in but two places, D 25 and 32. The hilltops extend but little above this and carry

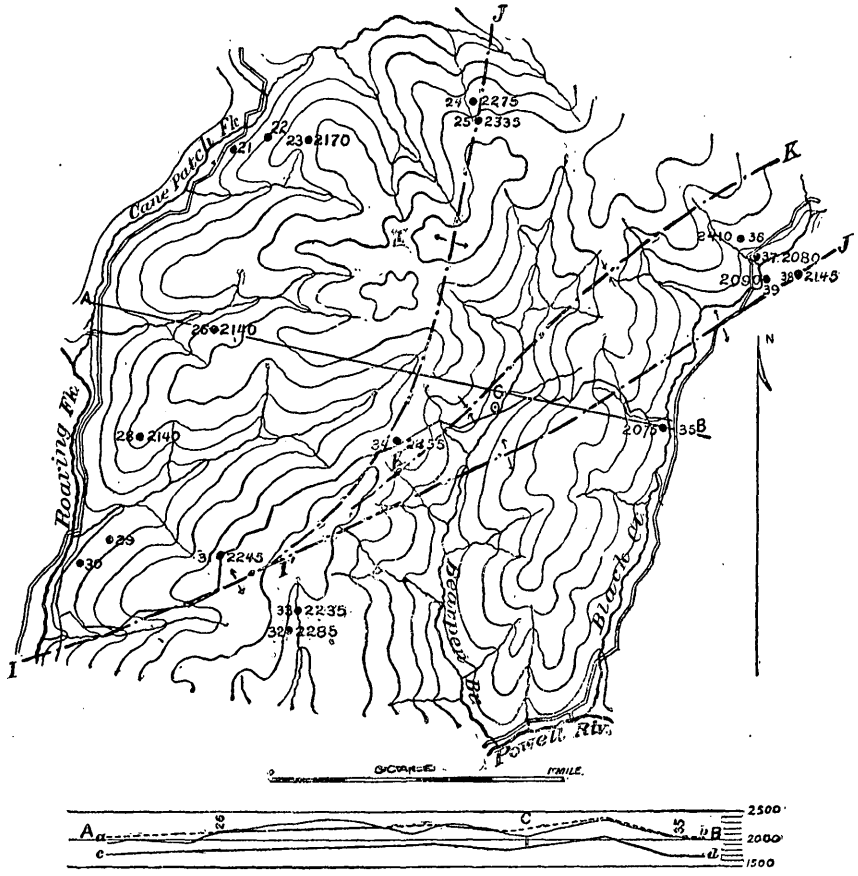


FIG. 2.—Map and section showing the structure between Roaring fork and Black creek.

few, if any, of the higher coals. On Black creek the lower coal has been opened at D 35, 37, 38, and 39, and the upper seam at D 36.

The most of this territory was thoroughly prospected by D. J. and E. T. Lewis, and they early determined the outcrops, but for a long time they were uncertain as to whether the coals showing on Black creek could possibly be the same as the heavy coal in the hill tops near Roaring fork. The seam might rise from 2,080 feet at D 37 to 2,275 feet at D 24, or from 2,075 feet at D 35 to 2,255 feet at D 34, but there are some conflicting facts that made this seem improbable, viz:

1. The coal seam at D 37 had a light northwest dip, showing on an exposure of 20 feet or more, at right angles to the strike, a dip of 5°, which would, if held, carry D 37 about 600 feet beneath D 24.

2. If D 35 rose on a regular dip to the altitude of D 34, it would of necessity be cut through by the Bearpen branch and show somewhere on the trail that crosses from Black creek to Roaring fork. But such is not the case, and the prospectors in endeavoring to solve the problem trenched the hill from summit to base on the east side of Bearpen, just north of this trail, and found nothing but sandy shales. Then in order to make assurance doubly sure a diamond drill was put down at C on the map, through coarse, extremely hard white sandstone, until 220 feet below the surface the drilling became so difficult and the prospect of coal so poor that the drill was stopped, but without penetrating this bed of sandstone.

There is only one sandstone known in this region that bears any resemblance to this heavy bed revealed by the drill, and it occurs in the hilltops facing Roaring fork and beneath the Imboden coal. On Black creek the only sandstone answering this description occurs in the bottom of the valley between the openings D 35 and D 39 and shows in heavy ledges below the schoolhouse; this is unquestionably below the Black creek coals and sustains the same position relative to these coals that the sandstone on the Roaring fork does to the Imboden and Kelly seams. Assuming that this sandstone is one bed throughout, the lower of the Black creek coals may be correlated with the Imboden seam and the upper with the Kelly, but when that is done it is still necessary to explain how the Imboden coal can dip from the hilltop at D 34 to the creek at D 35 without showing in the ravine at Bearpen branch.

The idea that it is faulted down immediately suggests itself, but on close examination this hypothesis fails to answer the question, because the rocks in all this region show no trace of faulting. Moreover the relations of the beds in this and the adjoining territory could hardly have been produced by faulting and may be much more easily explained on another hypothesis.

To understand the structure here it is essential to know something of it in the surrounding country, and then the problem becomes comparatively simple. By reference to Plate III it will be seen that the Coonseye anticline crosses this territory and is the dominating structural element. The principal or northern axis I I′ J is a broad rounded arch, while the southern I′ J′ is a small sharp fold; both pitch downward to the east and unite near Powell river. This loop incloses a synclinal basin K K′, which dies out southwestward in this field, and the two anticlines merge into one. In Fig. 2 the section at the base along the line A B illustrates the structure. In this section the line *a b* represents the Imboden coal; at *a* its altitude is about 2,060 feet above sea level or 250 feet above the Roaring fork, and it

rises gently toward the east as the main limb of the Coonseye anticline; it cuts the hill first at the point indicated as D 26, still continuing to rise eastward until the axis of the arch I 'J, is reached where it is at an altitude of about 2,250 feet; from this point the coal descends slightly to the east, to the synclinal axis K K', at or near the drill hole on Bearpen branch; the bottom of the valley is here composed of the heavy sandstone in which the prospect hole was drilled; above this sandstone there are normally 50 or 60 feet of shale, and above it the coal. This would bring the coal on Bearpen at an elevation of about 2,160 feet. From this point the strata rise rapidly to the east or southeast in the anticlinal fold I' J', and the point where the trail crosses the ridge east of Bearpen branch coincides exactly with the axis of this anticline. On account of this peculiar structure the strata on the west side of this ridge rise at about the same rate as the slope of the hill, and the shale that shows near the creek forms the whole slope from the creek to the summit of the ridge; this is well shown in the road and also in a trench cut by Mr. Lewis in search of the heavy coals which he thought must necessarily outcrop on this hillside. The rock exposed is shale from top to bottom, with no trace of coal. This shale bed ends a few rods east of the summit and gives place on the surface to a sandstone that covers the whole eastern side of the hill with heavy debris. This sandstone is supposed to be the same as the one on Bearpen, and simply comes to the surface a few rods east of the summit and descends about with the slope of the hill, until lower down it disappears beneath the surface and is replaced by the shale already noticed. The line of greatest elevation of the beds marks the axis I' J' of the anticline and is but a little east of the summit of the ridge where this trail crosses. At the foot of the ridge the sandstone and shale have both disappeared from the surface and the Imboden coal belonging above them comes to the surface in the outcrop at D 35.

It may be urged against this hypothesis concerning the structure that the outcrop at D 35 shows no evidence of a southeasterly dip, as the anticline just northeast of it would seem to require. It is well to bear in mind that the maximum dips in such a structure would only be 8°, and but few of that amount. The outcrop D 35 does not show dip, but it is not extensive enough to judge from; besides the coal is faced up along the strike of the bed and consequently would not show a dip of even 8°. The dip at this point is probably lightly to the southeast, as the next exposure of this coal on Stone Coal branch is lower than that on Black creek and there is no known evidence of a disturbance in the strata between them.

The anticlinal axis I' J' continues northeast nearly parallel with the road from Black creek across the head of Stone Coal branch and down a small stream to the Powell river. It crosses Stone Coal branch about a quarter of a mile below this road, and the next stream is crossed at about the point where the road first comes down to the stream after crossing the divide from Stone Coal branch.

On the northwestern side of this arch the dips are comparatively steep for the field—5° as shown in the exposure at D 37 on Black creek and 7° as shown in the road on Stone Coal branch. These dips hold only a short distance, carrying the strata down about 150 feet.

South of this arch on Stone Coal branch there is a slight trough, very nearly horizontal, but which deepens to the northeast into a marked syncline. This flat trough or terrace keeps the coals at about the same level from Black creek to near the mouth of Stone Coal branch. The Imboden seam rises on the 5° dip mentioned from an altitude of 2,080 feet at D 37 to 2,145 feet at D 38; here the seam appears horizontal as it is about on the axis I′ J′. From D 38 the coal descends to an altitude of 2,000 feet on Stone Coal branch, where it is exposed in the bed of the creek (E 34), three-quarters of a mile from West Norton, but its thickness could not be ascertained.

At the mouth of a small branch above this and at an elevation of 2,025 feet a partial section of a higher coal (E 35) was measured as follows:

	Ft.	In.
Coal	1	0
Shale	0	2
Coal	2	2
Total	3	4

Base of the lower bench was not seen.

As the dip at the latter exposure is northeast it would tend to make the interval between these seams greater than their difference of altitude; thus it would closely approximate the interval between the Imboden and Kelly seams.

Above the outcrop of the Imboden seam on the hillside west of the creek there are two higher coals exposed, and, assuming the Kelly seam to be 60 feet above the Imboden, as on Black creek, the section would be as follows:

	Feet.
Coal, heavy (thickness reported) (E 31)	5
Interval (Gladeville sandstone?)	115
Coal (E 32)	?
Interval	110
Coal, Kelly seam (E 33)	4
Interval	60
Coal, Imboden (E 34)	?
Water level in creek.	

These figures agree very closely with the type section on Mud Lick creek as given on p. 63. The Gladeville sandstone noted in the section as doubtful was not seen in outcrop, but some sandstone debris shows at this horizon that may represent it. This section might be extended below the Imboden to a coal outcropping in the road near the mouth of Stone Coal branch (E 47 and 48). It is here 30 inches thick and about 300 feet geologically below the Imboden. The interval

between them is occupied by a heavy sandstone that corresponds to the very heavy sandstone occurring beneath the Imboden on Roaring fork and Black creek.

In the streets of West Norton a coal has been opened in at least half a dozen places (E 49, 50, 51, and 52). This is probably the same coal as that observed at the mouth of Stone Coal branch, brought down at this point by some of the minor folds that occur in this line adjacent to Stone mountain. This coal shows considerable thickening eastward, as the following section of the seam at D 52 indicates:

Shale roof.	Ft.	In.
Coal	0	8
Shale	1	2
Coal	0	8
Shale	0	2
Coal	1	2
Shale	0	4
Coal	0	6
Total	4	8

The section shows but an increase in the number and size of the partings rather than in the actual amount of coal.

The eastward continuation of this coal seam is very uncertain, as it is in a region of much minor disturbance. When the railroad yards were first graded at Norton a seam was visible in the yards at several points (E 58 and 59) and considerable coal was exposed, but no large seam was seen, and it is quite probable that this is the same coal as the one in West Norton.

The Imboden is well shown at the Cooper opening on Powell river 1¼ miles above Stone Coal branch (E 37), where the following section was measured:

Shale roof.	Ft.	In.
Coal	4	0
Shale	0	2
Coal	4	0
Total	8	2

This entry has since been reopened and is said to show 10 feet of coal further in.

West of the Cooper opening (E 37) a coal shows on the slopes of a small ravine at E 36 at an elevation of 50 feet above E 37, but the coal was so covered that no thickness could be determined. These are regarded as the Imboden and Kelly seams with the normal interval of 50 feet between them.

About a mile above the Cooper opening a small coal 18 inches thick (E 25) shows in the road up Powell river and is probably the coal underneath the Gladeville sandstone, as this is the next formation cut by the river in ascending order.

Above this, near the foot of the trail that crosses the divide to Guest river, in shales that immediately overlie the sandstone, is a very small but quite persistent coal (E 26) that appears for a considerable distance up Powell and Guest rivers.

Following up Powell river the Gladeville sandstone is again crossed as it rises above the river and the coal beneath the sandstone is well exposed in the great bend of Powell river (E 19, 18, 17, 16, and 15). Its best exposure is at E 16, where it shows in the creek bank with the following section:

	Ft.	In.
Coal	2	6
Shaly coal	0	6
Total	3	0

Above this the river again cuts through the Gladeville sandstone where it is nearly horizontal and gives a fine exposure of the heavy ledges that occur at its top. The last outcrop of this sandstone is seen a little above the schoolhouse or near where the road turns to the west toward Coonseye.

The small coal immediately overlying the sandstone shows in a number of places in this vicinity at E 4, 3, 2, and 1; at the last point the stream runs above it and the next coal is one that occurs in the west bluff 2 miles above the schoolhouse and 120 feet above the stream bed, D 3. No section was obtained, but half a mile farther up the stream on the eastern side the following measurements were made upon the same seam:

	Ft.	In.
Coal	0	6
Interval	20	0
Coal	3	0
Interval	5	0
Coal	0	6

Above the upper coal in the section a heavy sandstone was noted that forms cliffs along the valley, and above the sandstone another coal seam is reported. The main seam given in the section is without much doubt equivalent to the cannel seam, and the coal reported above the sandstone may possibly represent the heavy seam on Mud Lick creek, about 100 feet above the cannel.

In the country about Coonseye but few coals were seen, except as stains in the road, for the country is high and the road follows the divide. Coonseye post-office is situated on the Gladeville sandstone at about the summit of the Coonseye anticline. This heavy sandstone was not observed in place, but the ground is almost covered with great blocks of coarse, white sandstone that revealed the position of the Gladeville as definitely as though its actual outcrop was seen. The road east from Coonseye passes above this sandstone, and at the bend of the road on the summit, the Lower Splint coal, lying just above the

Gladeville, shows in natural outcrop, D 17, on the west side and just below the road. One hundred feet above this coal or at the Cannel horizon, another coal shows in the road, D 16, simply as a stain.

On the head waters of Black creek there are several outcrops of coal that are hard to identify. They were seen on a branch entering from the east at a point about due east from Coonseye. The first, D 20, is about 20 inches thick and is exposed in the bed of the creek one-quarter of a mile above the main stream. A short distance from the first and 45 feet above it the second, D 19, is exposed 6 inches thick. Farther up the same branch, about half a mile from the main stream and 80 feet above the first seam occurs the largest showing of coal (D 18). This last coal is about 3 feet thick and is provisionally but doubtfully correlated with the Cannel seam.

This completes the consideration of the Imboden basin, the country drained by the main branch of Powell river, which is one of the important coal fields of the Appalachians. Throughout its whole extent, except where erosion has removed the lower beds, it has a very fine seam of bituminous coal, and when the field shall have become thoroughly developed, it will afford a large amount of first-class fuel for the industries of the middle South.

In almost all parts of the basin the altitude of the principal seam is such that its coal can be mined and transported at a small expense. The bed is generally above water level and has such gentle inclinations that an entry can be readily located so as to follow in on the seam with a slight up grade; this gives a descent toward the mouth of the entry for drainage and easy transportation. The valleys are remarkably level for such a rough country, affording excellent facilities for the construction of branch lines of railroad with which to place its coal and coke upon the market.

GUEST RIVER BASIN.

This is much less extensive than the Imboden basin and its geological formations are fewer in number. Its rocks are all included between the Lee conglomerate at its base and strata which lie one or two hundred feet above the top of the Gladeville sandstone.

The basin is mainly drained by Guest river which has cut a deep, narrow valley throughout its entire length from west to east. On the northern side of the valley bold bluffs rise from near the water's edge to the Gladeville sandstone that caps them 800 or 900 feet above the stream. On the southern side the valley is bounded by the great arch of the Lee conglomerate known as Powell mountain, which, in the western portion, rises abruptly from the stream and is extremely rough and rugged. Farther east the conglomerate has a gentler dip and the mountain, descending to a low, flat swell, disappears entirely at the Clinch river.

The relation that the strata in this basin bear to those in the Imboden district is well shown on the road that crosses the dividing ridge between Powell and Guest rivers, near the northern edge of the map. The level of this road, leaving Powell valley at the schoolhouse west of Lipps, is just on the top of the Gladeville sandstone, or at the Lower Splint coal horizon. This coal is seen as a slight stain in the road but a few rods south of the schoolhouse, E 4, at an altitude of 2,325 feet. From this point to the summit of the ridge at 2,410 feet no rocks are seen in place, but some sandstone débris occurs on the slope. Descending on the eastern side the Lower Splint coal shows in a small ravine on the right of the road, E 5, at the same altitude as at the schoolhouse 2,325 feet, showing that in this direction the strata are about horizontal. From this coal exposure the road follows a small ravine, cut through the Gladeville sandstone, and Guest river is reached at an altitude of 2,160 feet, or 165 feet below the Lower Splint coal. The rough road through this ravine impresses the observer with a distinct idea of the hardness of the Gladeville sandstone.

A short distance up the river the coal underlying the sandstone is seen in a ravine 10 feet above the road at E 6 and 135 feet below the Lower Splint coal. This gives a good measure of the sandstone, for the strata are horizontal and the difference in altitude is the thickness of the Gladeville. This is the maximum thickness measured in the field. In descending Guest river no outcrops are seen for about a mile, heavy sandstone débris covering everything. In this interval the sandstone sinks beneath the river, and the coal and shales seen at the junction of the Rocky fork lie on top of the sandstone. The rocks along Guest river form a flat syncline, and this small coal is visible in a great many places along the main stream and the Rocky fork. The points where it was observed are numbered on the map E 7, 8, 9, 23, 22, 21, 20, and 28.

From near Lipps to the crossing of the Norton and Gladeville road the river flows on or near the top of the Gladeville sandstone. The stream has but little fall, and a tortuous, winding course on the horizontal sandstone; but at the road crossing it cuts through the sandstone, which here rises rapidly to the southeast toward the Gladeville anticline.

On the Norton and Gladeville road, below the crossing, several coals are exposed, but none appear to be of workable thickness except those in the vicinity of Norton. In grading the streets and in excavating for the foundations of buildings in the main town north of the principal street coal was found in abundance. It appeared to extend horizontally, but with many undulations that rendered it almost impossible satisfactorily to determine what seam or seams it represents. The observed outcrops are E 53, 54, 55, 56, and 57, and have the appearance of belonging to two distinct seams, 20 or 30 feet apart.

One of these beds, apparently the lower, is exposed in the main street at the turn near Guest river, E 60, and has the following section:

Argillaceous sandstone.	Ft.	In.
Coal	3	0
Shale	0	5
Coal	1	8
Total	5	1

This exposure is 60 feet above the river, but the strata have such a pronounced northward dip that this seam probably passes below water level within 500 feet of this turn in the road. At E 61 a heavy coal has been opened just below the road and but little above water level. It has been faced up and shows the following section:

Shale roof.	Ft.	In.
Coal	2	8
Clay	0	8
Coal	0	2
Clay	0	4
Coal	1	6
Dirty coal	0	2
Coal	0	5
Shale	0	6
Coal	2	8
Shale	0	1
Coal	0	4
Total	9	6

No lower coal could be seen at this point, but one appears in an exposure a quarter of mile farther north in a small ravine that enters from the west, E 39.

The section measured at this point is as follows:

Shale roof.	Ft.	In.
Coal	2	10
Clay	1	0
Coal	0	3
Clay	0	6
Coal	1	10
Clay	0	8
Coal	1	10
Total	8	11

Shale, 20 feet.

Coal not measured, 2 or 3 feet visible.

The above section corresponds so closely with that for E 61 that the identity of the upper bed in the two openings can scarcely be questioned. The total thickness of the seam increases southward, but the change occurs mainly in the bottom.

The exact equivalence of these two coal beds is quite uncertain. All the structural evidence indicates that they are at the horizon of the Kelly or the Imboden seam, and may represent either one or both of them.

The upper coal corresponds well in general thickness with the Imboden as seen on Powell river, except that here it is much more broken up by partings that materially detract from its value. But it may be the Kelly seam and the lower bed may be the Imboden. In that case the two coals have changed in character and the interval between them has diminished.

A comparison of the sections, as shown at the openings E 37, 39, and 61, is very interesting, and shows the change that may possibly have occurred in the Imboden seam southeast from the Cooper opening on Powell river:

E 37.

	Ft.	In.
Coal	4	0
Shale	0	2
Coal	4	0
Total	8	2

E 39.

Coal	2	10
Clay	1	0
Coal	0	3
Clay	0	6
Coal	1	10
Clay	0	8
Coal	1	10
Total	8	11
Interval	20	0
Coal	?	

E 61.

Coal	2	8
Clay	0	8
Coal	0	2
Clay	0	4
Coal	1	6
Dirty coal	0	2
Coal	0	5
Shale	0	6
Coal	2	8
Shale	0	1
Coal	0	4
Total	9	6
Interval	?	
Coal	3	0
Shale	0	5
Coal	1	8

E 61 contains five partings of clay and shale, while E 39, unquestionably an opening on the same seam, contains only three partings; this change, when continued to E 37, could easily give a seam with but one parting.

The maximum development of the Imboden seam is near the Roaring fork, and it gradually diminishes in all directions. This statement

will be seriously questioned in the district, but future development will, we feel confident, verify our conclusions that the upper coals die out toward the east and the lower coals increase in number and thickness.

The error in correlating these lower coals of the eastern district with the Imboden farther west seems to be due to failure to appreciate the change in structure. In the vicinity of Big Stone gap the strata are very sharply upturned along Stone mountain, and, as a consequence, a stratum 1,000 feet above the conglomerate appears at the surface very near the mountain. East of Norton the conglomerate dips very gently under the coal basin, and the same stratum, 1,000 feet above it, occurs high up in the hilltops or at quite a distance from the mountain. The prospector expects to find the Imboden coal in the valley bordering the mountain at Tacoma as it is found on Pigeon creek, and any coal occurring in this position is called the Imboden.

The outcrops along the Norton and Gladeville road from the point where it crosses the river to near the summit, where the road turns south to Yellow creek, might be perplexing. The ascent in that distance is 300 feet, and from the river to within a few rods of the corner the road is upon a coarse white sandstone that is either horizontal or dips lightly toward Guest river. This is evidently the Gladeville sandstone, as the exposures are almost continuous from the river to the corner. The peculiar attitude of the bed is due to the eastward rise of the strata in passing over the Gladeville anticline. At the forks of the road the shale underlying the sandstone appears, and extends in the direction of Gladeville until near the summit, where the sandstone reappears at the top of the arch. The dip of this stratum forms the slope to Gladeville. There are on this slope but a few feet of shale, the road generally being on the bare sandstone, and Gladeville is built directly upon this solid foundation, the rock itself showing in many places.

The road from Rocky fork to the Gladeville and Pound gap turnpike follows a small stream called Wheatley branch across an anticline which is very similar to that on the Norton and Gladeville road. On this branch, the arch being lower, the sandstone is not cut through, but forms the foundation of the road the entire distance from Rocky fork to the Pound gap road. About a mile from Rocky fork the Lower Splint coal is exposed in several places, E 11, 12, and 13; no complete section could be obtained, but 18 inches of coal was seen at one place. The summit of the arch is not reached until the road unites with the Gladeville and Pound gap road about three-quarters of a mile from Gladeville.

The Pound gap road northwest from Gladeville rises gradually with the sandstone until at the junction of the Wheatley branch road it crosses the axis of the fold; from this point north to the edge of the territory it still follows the top of the sandstone down a monoclinal

dip to the north, descending in that distance about 200 feet. The road is almost continually at the horizon of the Lower Splint coal, which shows in about a dozen places. The bed does not appear to be thick enough to be of importance.

On the road north from Gladeville the same coal shows, F 2 and 3, and the road for the most part runs on the heavy sandstone. In the eastern portion of the town of Gladeville the Lower Splint coal has been opened a little, F 4, but the opening was so filled with water that only 18 inches of coal could be seen.

The road from Gladeville northeast to Cranes Nest creek has more numerous natural exposures upon it than any other road traveled, but they are confined to a narrow vertical range, probably from the Lower Splint to the Cannel seam. In a distance of 3 miles at least twenty outcrops were seen in the road, but only one was of any consequence, and that is probably the lowest one of the series. About a mile and a half from the forks of the road east of Gladeville is an old opening, F 7, on this coal, which indicated a considerable thickness, but no measurements could be made. The high lands that lie west of this road may hold some higher coals, but no examination was made to ascertain the fact.

Southeast from Gladeville, along the Coeburn or Stage road, there are numerous exposures of coal. After crossing the creek just east of town the road rises gently to the southeast on the dip of the Gladeville syncline, and the small coals that occur just above the sandstone make a considerable showing along the road. The rise is quite rapid for three-quarters of a mile, carrying the sandstone 100 feet higher than at the creek crossing. On this arch, named the Bear creek anticline, the Gladeville sandstone reaches an altitude of about 2,500 feet; then it gradually dips down to Bear creek to 2,475 feet above sea level, whence it rises to the mesa north of Tacoma. Just west of Bear creek crossing a heavy seam of coal shows in the road above the sandstone, F 10. No opening has been made on the seam, but it appears to have the following section:

	Ft.	In.
Coal	?	
Shale	5	0
Coal	1	4
Shale	1	3
Coal	1+	

A short distance south of the road on Bear creek a coal seam, F 11, is exposed in the creek bank underlying the sandstone, showing the following:

Shaly sandstone.	Ft.	In.
Coal	0	4½
Shale	1	3
Coal	1	10+
Total	3	5½+

Shaly sandstone.

Along the road from Bear creek to the edge of the escarpment, above Toms creek, where the road passes below the Gladeville sandstone, no important coals show, but stains in the road are numerous.

It is well at this point to go back to the consideration of the Yellow creek region, for the coals of that valley form a transition between the unimportant lower coals west of Norton and the same seams in increased thickness in the Tacoma-Coeburn territory.

On Yellow creek the Imboden seam was not discovered. Its place is doubtless quite high, and this would account for the fact that it was not seen, as no prospecting has been done above the main valley. It may be absent, but since it is so heavy at Norton, and again at Tacoma, the probabilities are in favor of its being present here.

The correlation of the coals in the Yellow creek valley is very uncertain, as data are scarce and the dips on the anticline are extremely variable. The best determination made from all available data identifies the most prominent coal here with the Widow Kennedy seam farther east, at about 475 feet above the conglomerate and 760 feet below the Gladeville sandstone. This coal shows at several points, E 43, 44, 45, and F 18, 19, and 20. In thickness it ranges from 25 to 38 inches. At a point about 200 feet below this is a small coal, E 46, which shows as a small stain in the road.

Above the Kennedy seam are two small coals, E 30, in a ravine above the road, where it leaves the creek and commences the ascent toward Gladeville. The upper is 14 inches and the lower about 2 inches thick; they are 770 and 720 feet, respectively, above the conglomerate—about the horizon of the Upper Banner seam farther east.

Between Yellow creek and Tacoma but one coal was seen. It shows in the railroad cut nearly opposite the mouth of Burns creek, and is probably within 100 or 200 feet of the conglomerate.

In the vicinity of Tacoma quite a number of coals appear, but as there is considerable evidence of folding in the mountain side north of town, identifications of these coals with those further east, where the strata are more regular, have a doubtful value.

The lowest coal exposed at Tacoma is in the bend of the river, F. 26, southeast of the depot. This is supposed to be the Imboden, though there is little evidence of identity. It outcrops here on a dip of 10° northwest and shows the following section:

	Ft.	In.
Shale roof.		
Coal	0	2
Shale	0	3
Coal	0	7
Knife edge parting		
Coal	1	8
	Ft.	In.
Dirty coal	0	8
Coal	1	6
Total	4	10
Shale floor.		

According to a carefully measured section this coal is about 200 feet above the conglomerate. McCreath and d'Invilliers give a section of this seam measured by them in 1892 as it was exposed in an opening a mile east of Tacoma[1], F 31, that is as follows:

Shale roof.	Ft.	In.
Coal	0	2
Slate	0	2[2]
Coal	2	8
Slate, with seam of mineral charcoal	1	0
Coal	1	4
Total	5	5

They have accepted the name commonly applied to this seam, Imboden, without giving their reason for the correlation. East of this, in a railroad cut, F 32, the coal shows again as follows:

Shale roof.	Ft.	In.
Coal	2	2
Clay	1	6
Shale	3	6
Coal	1	0
Total	8	2

Shale floor.

At Tacoma, southwest of the depot, F 25, a small seam is exposed about 330 feet above the conglomerate. This is also exposed a mile east of town at F 31, where it is about the same distance above the conglomerate. Its full thickness could not be obtained at either place, only 12 inches of coal being visible at F 30 and 18 inches at Tacoma.

About 425 feet above the conglomerate lies an important seam that has been traced throughout all of the territory east of Tacoma. It bears the local name of Widow Kennedy seam. At Tacoma the position of its outcrop is a little doubtful, but it is probably the coal which shows northeast of the depot, F 24, and also in the creek west of town, F 23; in neither case could its thickness be determined. One mile east of Tacoma this seam has been worked by the Greeno-Bodine Coal company, F 29. Their slope is driven in on the seam N. 9° W., and on a downward dip of 13 feet in 100, or 7° 30′. At the mouth of the mine the section of the seam is as follows:

Sandstone roof.	Ft.	In.
Coal	4	1
Clay	0	6

Sandstone.

McCreath and d'Invilliers[1] report that the thickness is 5 feet 3½ inches measured 500 feet down the slope, with the same roof and floor,

[1] Report on a portion of the Virginia and Tennessee Coal and Iron Company's property, Wise County, Virginia, 1892, p. 35.

[2] To 4 inches.

but at 600 feet the coal pinched out in all directions. They attribute this to some of the accidents of deposition which they assert have affected this coal bed throughout the field. While this may be correct, the writer is inclined to attribute some of it in the vicinity of Tacoma to the disturbance of the rocks. The sharp dips (10° to 15°) around Tacoma show that the rocks are thrown into folds, and this folding is very apt to squeeze the soft beds on the haunches of the arch. As the coal is the most yielding member of the rock series it suffers most, and in such localities is frequently too much crushed and contorted to mine. The structure about Tacoma makes it quite possible for such distortion of the coals to occur, and if so, all the seams are liable to be affected by it.

In such a region as this, though the extent and position of the coals can be quite accurately determined by study of the surface indications, the liberal use of the drill in advance of mining operations may frequently save many times the cost of drilling and enable the operator so to locate his entries and arrange his work as to avoid, to a great extent, the irregularities that affect the seam.

At the Greeno-Bodine works, east of Tacoma, the Lower Banner seam has been opened, F 28, and, according to McCreath and d'Invilliers,[2] varies in thickness from 4 feet to 4 feet 10 inches.

The Upper Banner seam has also been opened, F 27, and according to the same authority[3] shows the following section:

	Ft.	In.
Slate roof.		
Coal, 2 feet 8 inches to	2	10
Slate parting, some coal, 2 feet 6 inches to	3	3
Coal	2	5
Sandstone parting	0	1
Coal	2	0
Total	10	7

At Tacoma, 370 feet above the Kennedy seam, a small coal, probably equivalent to the Upper Banner seam, is exposed, F 22, but not in such manner that a section could be obtained. The most prominent coal observed in the vicinity of Tacoma outcrops in a ravine above the town, at an altitude of about 2,210 feet, F 21, and shows a thickness of 3 feet 11 inches. The structure would indicate that this is equivalent to the Imboden seam, but the character of the coal itself would lead to its correlation with the Upper Banner seam, as shown at the Greeno-Bodine opening east of town. In this paper it is considered as the Imboden, but the structure here is not simple enough to make this certain.

The Gladeville sandstone is exposed in the road from Tacoma to Gladeville, about a mile from the depot in Tacoma; the point where it is crossed is on the southern limb of the Gladeville syncline, and it

[1] Op. cit., pp. 33–34. [2] Op. cit., pp. 29–30. [3] Op. cit., p. 31.

shows a northwest dip of 15°. Just beneath it the coal, which was described on Bear creek, F 11 and 12, is seen in two benches; F 17, its lower bench is here 3 feet thick, but the size of the upper bench is unknown.

After passing across the upturned edge of the Gladeville sandstone, the coal lying just above it is seen outcropping in two places, F 15 and 16. These exposures are located on the northern limb of the syncline, which accounts for their difference in elevation. From this point to the Stage road the sandstone is at or near the surface—the protecting cap of the plateau. It holds this position along the Stage road for a distance of 2½ miles, rising gradually from an altitude of 2,525 feet at the junction of the Tacoma road to about 2,900 feet at Coeburn.

On the road running north from the Stage road, along the divide between Bear creek and Steele's fork of Crane's Nest creek, the Gladeville was probably seen in a small branch flowing into Steele's fork, 1¾ miles north of the Stage road, and at an altitude of 2,580 feet, showing a decided northerly dip; the small coal just above it shows in a number of places.

West of Coeburn the Stage road, after leaving the outcrop of the Gladeville sandstone at the divide, descends rapidly in the series, and a number of seams are exposed along it in the side of the mountain. The seam immediately beneath the sandstone was not observed, nor was the Imboden, although the stain of a small coal was seen that may represent the latter. The finest showing of coal is at about the horizon of the Upper Banner seam; it outcrops a mile west of Tom's creek about 2,365 feet above tide, G 9. It is poorly exposed, but has the following section.

	Ft.	In.
Shale roof.		
Coal	0	1
Shale	0	3
Coal, base not seen	2	9
Total	3	1
Sandstone	20	0
Coal	?	
Shale floor.		

About 100 feet below this, at the lower Banner horizon, indications of coal were observed, G 12, but no section of the seam could be obtained. Still lower, and half a mile west of Toms creek, at an altitude of 2,120 feet, the Kennedy seam shows only as a stain, G 13.

The field east of Toms creek was worked hurriedly and more in the form of a reconnoissance than of a final survey; hence the results are less satisfactory. The writer has availed himself of the lately published report of McCreath and d'Invilliers on this region, as they describe many outcrops not seen by him and developments that have taken place since his field work was done.

The section through Coeburn on a north and south line has been referred to as one of the principal sections for determining the thickness of the Norton formation. The section extends from the crest of Powell mountain on the south to that of Sandy ridge on the north and is a plain, simple section. The Lee conglomerate of Powell mountain dips northward about 7°, and on the road south of Coeburn, disappears beneath the surface a quarter of a mile south of the Guest river crossing. The light northerly dip continues to Coeburn, as is shown by the coal outcrops at G 19 and 18. These are 60 feet apart, vertically, though they are outcrops of the same seam, the so-called Imboden at Tacoma, 225 feet above the conglomerate. Stratigraphically 100 feet above this is a coal that has been described as showing at Tacoma and in the mine below town. This coal outcrops in the streets of Coeburn, G 17, but is of no consequence. Back of Coeburn, at a normal distance of 475 feet above the conglomerate, is found the Kennedy seam, G 16, at an altitude of 2,060 feet; the northward dip of the strata carries this under water level a short distance up Big Toms creek.

The upper coals are well exposed on this creek, and for a description of them the writer is indebted to McCreath and d'Invilliers.

The lower Banner seam has been opened on Banner branch of Big Toms creek, G 6[1], at an altitude of 2,078 feet, showing the following section:

	Ft.	In.
Slate roof.		
Coal	3	2
Fireclay floor.		

This seam also shows on Fullers branch, G 5[2], at an altitude of 2,082 feet, 3 feet thick, and also at G 41[3], 3 feet 3 inches thick. Again it was recognized on the south side of Big Toms creek at an altitude of 2,095 feet at G 37[4], 3 feet 10 inches thick.

Preparations are being made for the extensive development of the upper Banner seam, in the valley of Big Toms creek, and, in view of this development, the seam has been carefully traced throughout the valley, and opened in a number of places. McCreath and d'Invilliers give numerous sections on this creek, which will be presented here in order to present a clear view of the field.

On Banner branch, at G 8, they give this section:[5]

	Ft.	In.
Slate roof.		
Coal	2	0
Sandstone	0	1½
Coal	2	2
Slate	0	0½
Coal	0	10
Total	5	2

[1] Op. cit., p. 15. [2] Op. cit., p. 17. [3] Op. cit., p. 20. [4] Loc. cit. [5] Op. cit., p. 12.

On Fullers branch, at G 4, an exposure shows a considerably greater thickness than on Banner branch; their section is as follows:[1]

Slate roof:	Ft.	In.
Coal	2	6
Sandstone	0	1½
Coal	1	9
Slate	0	1
Coal	0	6
Slate parting	0	4
Coal	3	1
Total	8	4½

South of Big Toms creek, at G 38, this coal has been opened and shows the following section:[2]

Slate roof.	Ft.	In.
Coal	2	9
Sandstone	0	1
Coal	1	8
Slate	0	2
Coal	1	1
Total	5	9

Higher up on Toms creek, at G 39, they give the following section:[3]

Slate roof.	Ft.	In.
Coal	1	9
Sandstone	0	1
Coal	2	0
Slate	0	2
Coal	0	5
Slate	0	7
Coal	0	7
Shale	0	1
Coal	3	5
Total	9	1

At G 50 the following is the section:[4]

	Ft.	In.
Coal	3	1
Sandstone	0	2
Coal	1	11
Parting, some coal	1	8½
Coal	2	11
Total	9	9½

They report an interesting outcrop from the west side of Tom's Creek above the Banner branch.[5]

It is called the Edwards seam and is reported to be 250 feet above the Upper Banner seam and 4 feet 5 inches thick. This in all probability corresponds with the Imboden coal, which is normally 190 feet above the Upper Banner seam and occurs at Laconia.

East of Coeburn, on Little Tom's creek, the Kennedy seamout crops

[1] Op. cit., p. 16. [2] Op. cit., p. 21. [3] Op. cit., p. 23. [4] Op. cit., p. 25. [5] Op. cit., pp. 28-29.

near the level of the valley almost to the head of the stream. It has been opened at G 21, 22, and 23, but it could not be measured at any of these openings.

At Banner, G 24, the Virginia Gas Coal Company has endeavored to develop the Kennedy seam, but without success, as the coal varies from a feather edge to 8 or 9 feet in thickness. This irregularity may be due to accidents of deposition or in part to deformation after the beds became consolidated. The mine is located on a line of disturbance that is shown by the opposing dips in the two entries. It is probable that this disturbance is quite local, but its effect upon the soft coals may have been considerable. At G 30 where this same seam disappears McCreath and d'Invilliers report its thickness as 3 feet 6 inches.[1]

According to the same authority the Virginia Gas Coal Company have opened the Lower Banner coal at G 25, 140 feet above their opening on the Kennedy seam,[2] with a thickness of 3 feet 8 inches to 3 feet 10 inches of coal with slate roof. The difference in altitude between these two openings on the Kennedy and the Lower Banner seams is probably not the thickness of strata between them, for the distance between the openings is sufficient, with the observed northwest dip, to make this interval, 260 feet, the normal thickness. This is all the more probable because on the next branch to the east the interval is practically the same and is described by McCreath and d'Invilliers as follows:[3]

> The Kennedy seam has been dug out of the creek bed at this point (G 27) for the use of the contractors on the Little Tom tunnel, showing 5 feet thick at 2018 A. T. Prospecting had been carried on above this along the hillside north of the creek and a bed of coal, thought to be the Lower Banner, opened at an interval of 266 feet above the Kennedy at 2,284 A. T. (G 26). This section showed only 3 feet 6 inches thick, capped with a hard gray slate roof, the bed carrying 8 inches of slate parting 8 inches from the top. This abnormal bed section, no less than the great interval between it and the Kennedy, throws doubt upon the correctness of its identification, and it would appear more like a split of the Upper Banner seam.

The above conclusions are hardly warranted by the fact; the section of the coal bed is not abnormal, for when compared with the nearest known exposure of the Lower Banner seam, G 25, it shows almost exactly the same aggregate thickness; the only difference is the occurrence of a slate parting in the latter exposure, which is by no means rare in coal seams. The interval of 266 feet is not greater than that observed in all of the sections measured by the writer, when due allowance has been made for the dips of the strata.

At the eastern end of the Little Tom tunnel, at an altitude of 1,990 feet above tide, a small coal shows about 100 feet below the Kennedy seam. The section at G 46, in the approach to the tunnel is as follows:

Sandstone:	Ft.	In.
Shale	4	0
Coal	2	2
Blue shale		

[1] Op. cit., p. 37. [2] Op. cit., p. 38. [3] Op. cit., pp. 38-39.

In the small ravine coming in from the north, the head of Dollarhide creek, McCreath and d'Invilliers report several openings;[1] they recognized the Kennedy seam at an altitude of 2,060 feet at H 8, carrying from 4 feet to 4 feet 6 inches of coal. Again 240 feet above this there is another seam, H 6, which they mistake for the Upper Banner, and of which they give two sections:

	Ft.	In.
Coal	0	8
Slate	0	7½
Coal	3	6
Total	4	9½
Slate roof:	0	0
Coal	1	3½
Slate	0	3½
Coal	3	2
Total	4	9

The first section coincides almost exactly with that on p. 89, showing the same slate parting, in a little thicker seam.

East of Little Tom tunnel the road descends more rapidly than the strata, and at the junction of Dollarhide and Bull creeks it reaches the next lower coal, locally known as the Imboden, but only about 225 feet above the conglomerate. This has been opened on the west side of Bull creek, H 13, beneath the western end of the trestle, 60 feet below the railroad grade and 60 feet above the stream, showing 3 feet 4 inches of coal. Half a mile below this a coal rises above the railroad, but it bears no resemblance to H 12, being in every case much broken up by partings. It shows at H 15, 16, and 17 in the railroad cuts. At H 17 its section is as follows:

	Ft.	In.
Shale.		
Coal	1	4
Shale	3	4
Coal	0	7
Shale	5	0
Coal	3	0
Shale.		
Total	13	3

From the exposures in the ravine at the west portal of the Holbrook tunnel, H 18, there are two seams separated by an interval of about 25 feet; the lower consists of one bench of workable thickness, while the upper one is too much cut up by heavy shale partings to be of any value.

From Little Tom tunnel to the Holbrook tunnel a fine section is exposed and can be measured with considerable accuracy; it is as follows:

[1] Op. cit., p. 39.

		Ft.	In.		Ft.	In.
1.	Sandstone.					
2.	Shale				4	0
3.	Coal (G 46)				2	2
4.	Shale, dark blue				25	0
5.	Coal				0	4
6.	Shale, dark blue				20	0
7.	Heavy sandstone				40	0
8.	Shale				45	0
9.	Coal	1	7			
	Shale	3	4			
	Coal	0	7	H 17	13	13
	Sandy shale	5	0			
	Coal	3	0			
10.	Shale and sandstone				25	0
11.	Coal (H 13)				3	4
12.	Sandstone to creek				60	0

In the above section the heavy sandstone, No. 7, forms the west portal of the Holbrook tunnel, dipping gently toward the east for a short distance and then rising. In this way it forms the roof and walls of the tunnel for a distance of 1,000 or 1,200 feet and then rises above it so that the broken seam, H 17, forms the wall for above 500 feet of the eastern end. This rises above grade at the eastern portal, and the lower coal is exposed below the level of the grade and on the west side of the branch, at H 25. An entry has been driven in a short distance on this seam, but it had so fallen in that it was impossible to obtain the thickness of the coal; it appeared to be 3 or 4 feet.

The seam at the base of H 17 is well shown along the railroad from this point to Virginia city. At the western end of the little curved tunnel, H 26, it has the following section:

	Ft.	In.	Ft.	In.
Shale			18	0
Coal	0	6		
Dirty coal	0	5	3	3
Coal	2	4		
Argillaceous sandstone			8	0
Coal	1	0		
Shale	1	2	2	9
Coal	0	7		
Shale			1	7

At the eastern end of Big Bull tunnel it shows as follows, H 32:

	Ft.	In.	Ft.	In.
Coal			3	0
Soft sandstone			8	0
Coal	0	8		
Shale	1	8	3	2
Coal	0	10		
Shale			4	4
Coal			0	8

This coal can be traced by its peculiar structure beyond Virginia city, though in that interval the rocks are considerably contorted;

beyond this along the line of the railroad the strata rise rapidly so that the conglomerate is brought to the surface just south of Russell creek.

The coal noted at H 25, 18, and 13 occurs 20 to 40 feet below this seam and appears to be a split from it. It is locally known as the Jawbone seam and has a remarkable development in the vicinity of Dwina. It was first seen on the east side of Bull creek one-half mile south of the west portal of Holbrook tunnel, H 24; it is here greatly crushed and contorted and not fully exposed, but it was estimated as 10 feet thick. McCreath and d'Invilliers give a section of this coal as it is exposed in a ravine directly west of H 23, as follows:[1]

	Ft.	In.
Slate roof.		
Coal	1	3
Knife-edge parting.		
Coal	2	8
Knife-edge parting.		
Coal	1	8½
Slate parting	0	2½
Coal	1	3
Total	7	1

This coal shows on the branch above Dwina, H 28, but slides have concealed the outcrop so that only 4 feet of coal is now visible.

On Bull creek, about three-quarters of a mile from the river, the Lee conglomerate is exposed as a massive sandstone, in which the creek has cut quite a gorge to the river; it is nearly horizontal, with a light northerly dip, and is the best guide to the stratigraphy in this portion of the field. On Dry fork of Bull creek the conglomerate is exposed for a mile above Bull creek as a coarse, heavily bedded sandstone. Above this on the Coeburn road but two coals are visible, and they are the lowest coals in the field. At H 22 a coal has been dug into, but the opening has partly fallen in, so that it was impossible to obtain an accurate measure, but it appeared to be 4 or 5 feet thick. Again at H 21 the same coal is seen in the road as a stain; it consists of a heavy bench, at the bottom 3 to 5 feet thick, with another coal 8 feet above it.

These are regarded as the equivalents of Nos. 9 and 11 of the section between Little Tom tunnel and Holbrook tunnel. The interval between them, which is 8 feet here, is 25 feet there, and 30 or 40 feet in the neighborhood of Holbrook tunnel. They are also the equivalents of the so-called Imboden seam of Tacoma. On this road, at the summit, is a higher coal, H 20, which is correlated with G 46. Numerous stains of coal were seen between this summit and Coeburn, but all are at about this same horizon.

The territory described in this paper is bounded on the east by the Sandy ridge road, on which two coals of importance were seen. In order to correlate these seams it is necessary to consider some openings

[1] Op. cit., p. 42.

on the left fork of Russell creek. McCreath and d'Invilliers recognized the Kennedy seam on this fork two and one-half miles north of Big Bull tunnel, H 34, at an altitude of 2,070 feet, and state its thickness at 2 to 5 feet.[1]

They also give the section of a coal opened in the hillside, H 33; 6 feet 11 inches[2] thick, 295 feet above the Kennedy seam, or 2,365 feet above tide; this they describe as the Upper Banner, but, as has been shown, it is more likely to be the Lower Banner.

This view is verified by the fact that the Edwards seam, which the present writer correlates with the Imboden, outcrops at H 3, at an altitude of 2,650 feet, or 270 feet above H 33. This corresponds with the normal interval of 290 feet between the Imboden and the Lower Banner. The Edwards coal, according to the same authority, has the following section:

	Ft.	In.
Slate roof.		
Coal	0	10
Clay parting	0	1
Coal	3	5
Total	4	4

Half a mile south of this outcrop an old opening was seen at 2,440 feet above tide, H 4; this shows a coal about 4 feet thick and, allowing for the light dip of the rocks to the south, is 180 feet beneath the Edwards or Imboden coal. The normal interval is regarded as 190 feet in this portion of the field. Thus the facts sustain the correlation of these outcrops with the Imboden and Lower Banner.

This basin, as a whole, contains some of the best coal territory in the field. It has several seams of excellent quality and of workable thickness. Occuring in the territory far enough from Powell mountain to be free from its disturbance, they are well disposed for mining. This is especially true of the Sandy ridge region, where the strata are nearly horizontal and where Big Toms creek has exposed them in its long and deeply cut valley.

But two more coal openings need to be described. They are located on Stock creek, on the south side of Powell mountain. On a little branch entering this creek three quarters of a mile above the Hunter valley road a seam has been opened and considerable coal taken out for local use. The seam is 3 feet thick and appears to be about 90 feet above the Lee conglomerate. One and three-quarters miles above the opening on the old road leading across the mountain to Cracker neck a coal is exposed which is 30 inches thick and about 60 feet above the conglomerate. These two openings are probably on the same seam, though the interval above the conglomerate is not constant. Near the summit of the mountain a coal is reported, but it could not be found; it also is probably the same seam. The

[1] Op. cit., p. 46. [2] Op. cit., p 27.

Norton shale on Powell mountain is but the remnant of a once continuous formation that extended across this great arch; erosion has been so active that nothing but scattering remnants are left and these are generally too thin to carry valuable coals. There is a possibility that at some point in the syncline the shale may be thick enough to carry some of the heavy coals, but the chances are decidedly against it. The valuable coal territory lies north and west of Powell and Stone mountains, and it is exceedingly doubtful if these mountains will ever furnish coal for commercial mining.

STRATIGRAPHIC DISTRIBUTION OF THE COAL HORIZONS.

In conclusion, the writer wishes to call attention to the stratigraphic and geographic distribution of the coal in this field. For this purpose three generalized sections are given (see Pl. VI), representing the stratigraphic distribution in the western, middle, and eastern portions of the field. These sections show four well marked coal horizons:

(1) The upper and least important one occurs at the base of the Harlan sandstone; it carries one heavy seam of coal, but from its location near the summits of the mountains is of but little commercial value.

(2) The second productive formation, in descending order, is directly above the Gladeville sandstone, and is the important horizon in the Kentucky portion of this field; its thickness is about 200 feet, and it carries at least three important seams of coal.

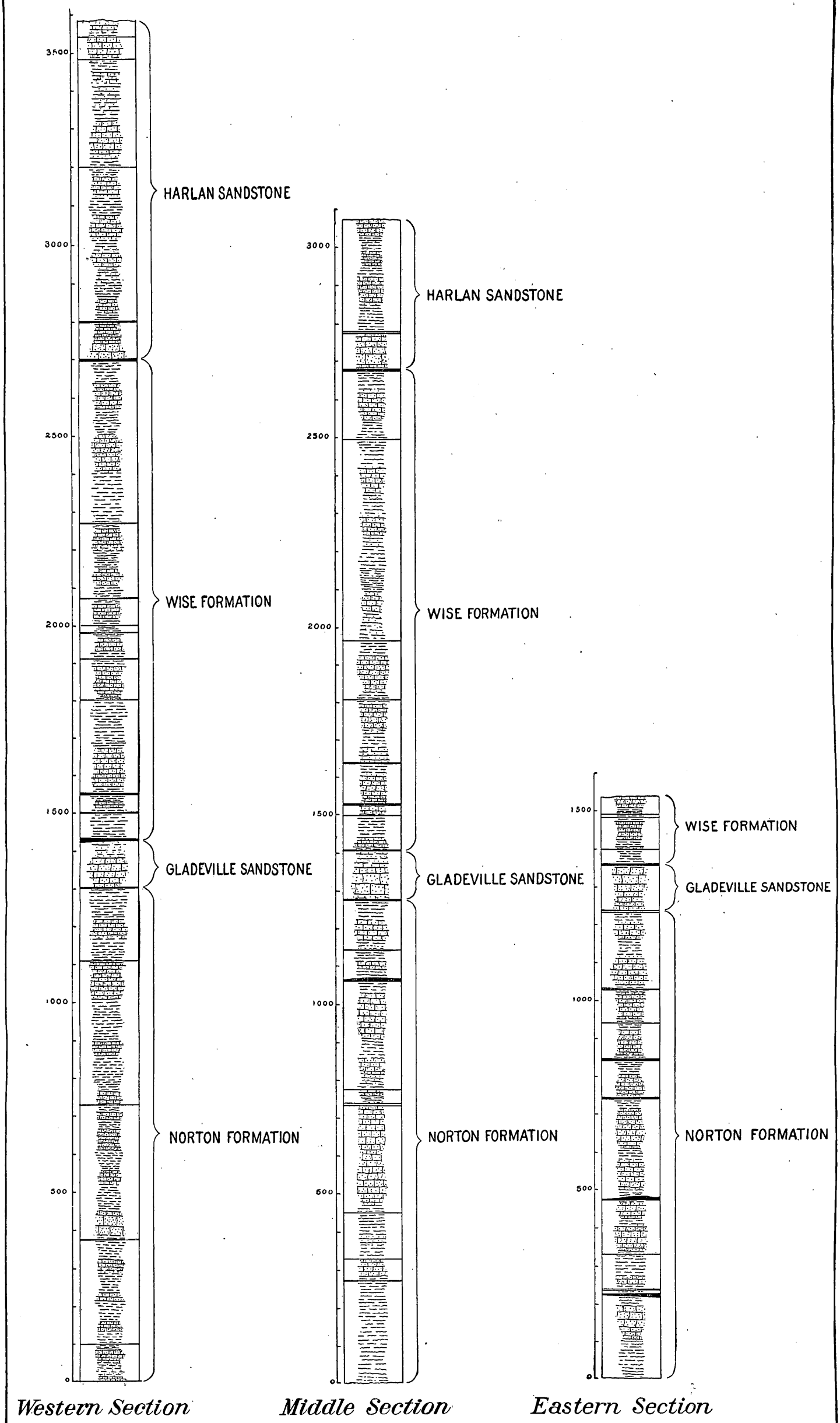
(3) In the Imboden and Crab Orchard basins the prominent coal horizon is somewhat lower. The formation is thicker, but the coal of greatest importance is at its base. It extends from the Imboden seam at the bottom to the Cannel seam at the top, an interval of about 550 feet. The important seams in the Crab Orchard are above and below the Gladeville sandstone, while in the Imboden basin, although a number of coals in this interval are workable, they are generally overshadowed by the more prominent Imboden seam.

(4) Lastly, in the Guest river basin the productive formation is almost entirely below the Imboden, extending from that seam to within 200 feet of the base of the Norton formation. Even within this basin a noticeable change occurs from west to east. In that direction the upper coals diminish in importance and the lower coals thicken.

The bearing which these facts have on the broader questions of sedimentation in Carboniferous times can only be determined when all of the adjoining territory shall have been mapped and its stratigraphy carefully studied.

CORRELATION.

Our present knowledge of the Coal-measures of the Appalachian basin will not permit any definite correlation of the coals of the Big Stone gap field with those of other portions of the basin. While this is obviously true of individual coal seams, it is not necessarily so of the larger groups of strata. No systematic attempt has been made hitherto



GENERALIZED SECTIONS FROM DIFFERENT PORTIONS OF THE FIELD, SHOWING IMPORTANT COAL HORIZONS.

toward any general correlation south of the Great Kanawha river, but some correlations that are probable may be stated. The main points of disagreement between the sections measured by various geologists in the different fields may be brought out, and the work which is necessary to bring harmony out of the present discordant statements may be suggested.

CORRELATION WITH WEST VIRGINIA.

The Big Stone gap field is an almost detached synclinal block of the Coal-measures, so that it is cut off from the main Kentucky-West Virginia field on all sides except the northeastern; in that direction little if any connected work has been done. The nearest point where systematic tracing of coal has been carried on is to the west and northwest in Kentucky, but that is beyond the Pine mountain fault, across which correlation is extremely difficult, as this fault has thrust Devonian rocks upon upper Coal-measures of quite uncertain stratigraphic position. The question is far from a simple one and demands the most careful work before any identification can be regarded as conclusive.

The only attempt at correlation between these two fields of which the writer is aware is that of the Imboden coal of Big Stone gap with the Elkhorn coal showing on Elkhorn creek, Kentucky. Mr. John R. Proctor states the correlation as follows:[1]

> This coal (Imboden), which has been identified as the third workable bed above the conglomerate, has been named by the Kentucky Geological Survey the "Elkhorn bed," from the Elkhorn fork of the Chatterawah or Big Sandy river, where it was first discovered and identified by the survey as a coking coal of great excellence.

The means by which the identity of the two seams was established is unknown to the writer, but it appears that the Imboden seam in the vicinity of Big Stone gap, being the first workable seam of prominence above the conglomerate, agrees with the Elkhorn, which is also the first important seam above the conglomerate on the Big Sandy river. Chemical analysis and the fact that both are good coking coals also seems to have been part of the evidence of correlation. But there is other evidence which makes the identity of the two appear decidedly improbable. According to the writer's determination, the Imboden on Little Looney creek is 1,060 feet above the top of the conglomerate, the interval being occupied by shale, sandstone, and coal beds. The interval between the Elkhorn coal and the top of the conglomerate is about 450 feet.[2] This necessitates an increase in thickness of the strata below the coal from 450 feet on the Elkhorn to 1,060 feet at Big Stone gap, which seems doubtful. It has been shown that the Imboden is either absent on the Poor fork or is represented by a thin, insignificant seam. This indicates that the Imboden is the local development of an otherwise unimportant coal and that its extension toward the northwest is very doubtful.

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[1] Big Stone Gap, Virginia. By John R. Proctor, p. 10.

[2] Geol. Survey of Ky. Preliminary Report on the Southeastern Kentucky Coal Field. By A. R. Crandall and J. M. Hodge, Frankfort, Ky., 1887. p. 19.

Toward the northeast the possibilities of identification are much better, and it is quite possible to correlate large groups of strata with considerable certainty. For this purpose the correlation recently made by Prof. I. C. White[1] of the coals of Pennsylvania, Ohio, and West Virginia may be used.

The following section is compiled from various measures given by Prof. White, that are selected either because they are considered the type sections or because of their proximity to the Big Stone gap field.

	Feet.
Permo-Carboniferous[2]	1,162
Upper Coal-measures[3]	292
Barren measures[4]	800
Lower productive measures[5]	1,006
Pottsville conglomerate[6]	1,400
Total thickness of Coal-measures	4,660

The following is a general section of the Coal-measures as determined in the Big Stone gap field:

	Feet.
Harlan sandstone	880
Wise formation	1,270
Gladeville sandstone	100
Norton formation	1,280
Lee conglomerate	1,500
Total Coal-measures	5,030

Above the great conglomerate series no definite correlations have been made. Thruston[7] suggests that the coal at the top of the Wise formation may be equivalent to the Pittsburg seam; if this be so, the base of the Harlan sandstone must correspond with the Pittsburg sandstone

Mr. J. M. Hodge[8] correlates the entire series above the conglomerate with the Lower Productive measures of Pennsylvania.

These correlations are assumptions which have no direct evidence to support them beyond a general resemblance of the measures.

These general sections show considerable agreement in their total thickness, the difference of 370 feet, by which the latter exceeds the former, being in line with the thickening observed throughout the northern portion of the Appalachian basin. The lowest or conglomerate members are doubtless equivalent, as this formation has too marked a character to be confused with the Productive measures

[1] Bull. U. S. Geological Survey, No. 65.

[2] Op. cit. Section on Dunkard Creek, Pa. p. 22.

[3] Op. cit. Section near Raymond City, W. Va. p. 56.

[4] Op. cit. Section near Charleston, W. Va. p. 85.

[5] Op. cit. Section at mouth of Armstrong creek on the Great Kanawha River, West Virginia. p. 140.

[6] Op. cit. Section at Nuttallburg, W. Va. p. 197.

[7] Resources of the Upper Cumberland Valley in southwestern Kentucky and southwestern Virginia, p. 50. McCreath and d'Invilliers.

[8] The Big Stone Gap Coal Field. A paper read before the American Institute of Mining Engineers at the Montreal meeting, February, 1893.

above. The enormous increase in thickness of this formation toward the south or southeast is its marked characteristic and is stated by Prof. White as follows:[1]

In the bituminous regions in Pennsylvania, and everywhere in Ohio, they (Pottsville series) rarely exceed 300 feet and seldom go below 150; but southwestward through West Virginia they begin to swell out, reaching 700 feet at the head of Black Water, in Tucker county; 1,400 on the New river in Fayette, * * *

This rate of change is quite regular and if continued would make the thickness about 1,530 feet as measured in Big Stone gap. According to Prof. White the Pottsville conglomerate holds its threefold character throughout the region studied by him; in Big Stone gap the three heavy plates of sandstone are well shown and they probably correspond to the Homewood, Connoquenessing, and Sharon conglomerates or sandstones of Pennsylvania.

Above the Pottsville conglomerate Prof. White has traced out and identified three well-marked sandstone horizons, as follows:

1. Waynesburg sandstone.
2. Pittsburg sandstone.
3. Mahoning sandstone.

He describes the Mahoning sandstone as follows:[2]

The lowest sandstone deposit of the Barren measures; and although at times consisting of one solid rock, yet it is generally complex. The usual rule is for the mass to divide into two sandstones, an Upper and Lower Mahoning, each 40 to 50 feet thick, with a shale interval between containing a coal bed and limestone or iron ore. * * * the whole series being 100 to 150 feet thick. In Wyoming county, West Virginia, they cap the summits of Guyandotte mountain at an elevation of 3,000 feet above the sea. In the Great Kanawha region this rock is extremely hard and silicious, and at many points a mere bed of pebbles, some of which are as large as an egg.

Prof. White traces the sandstone spoken of above from central Pennsylvania to Wyoming county, West Virginia, which is within 40 or 50 miles of the Big Stone gap territory.

The Pittsburg sandstone he describes as follows:[3]

It varies in thickness from 25 up to 70 feet, and is usually coarse, friable, and often pebbly * * *. This rock is especially massive in the vicinity of Hartford City, Pomeroy, and other contiguous regions, and the same may be said of the eastern line of its outcrop from Pennsylvania clear across West Virginia to the Kentucky border. In the George's Creek, Salisbury, and Ligonier basins, however, this rock makes but little show in the topography, its place being occupied by soft shales.

The uppermost sandstone, the Waynesburg, at the base of the Dunkard Creek series, is thus described:[4]

This stratum is the only one in the series that is generally conglomeratic or contains quartz pebbles larger than coarse sand grains * * *. When at its greatest development the thickness of this stratum approaches 75 or even 100 feet * * *. From Blennerhasset Island, below Parkersburg, this rock is almost constantly visible either in bed or bluffs of the Ohio on down to 25 miles below the mouth of the Great Kanawha. It is the emergence of this stratum from the bed of the stream which makes Letart Falls in the Ohio river.

[1] Op. cit., p. 181. [2] Op. cit., p. 95. [3] Op. cit., p. 63. [4] Op. cit., p. 40.

The position of these sandstones in the general column is shown in Fig. 3, in comparison with the heavy sandstones of the Big Stone gap field.

These sections show the probable equivalency of these sandstones, and although the correlation is at too long range to be of much value,

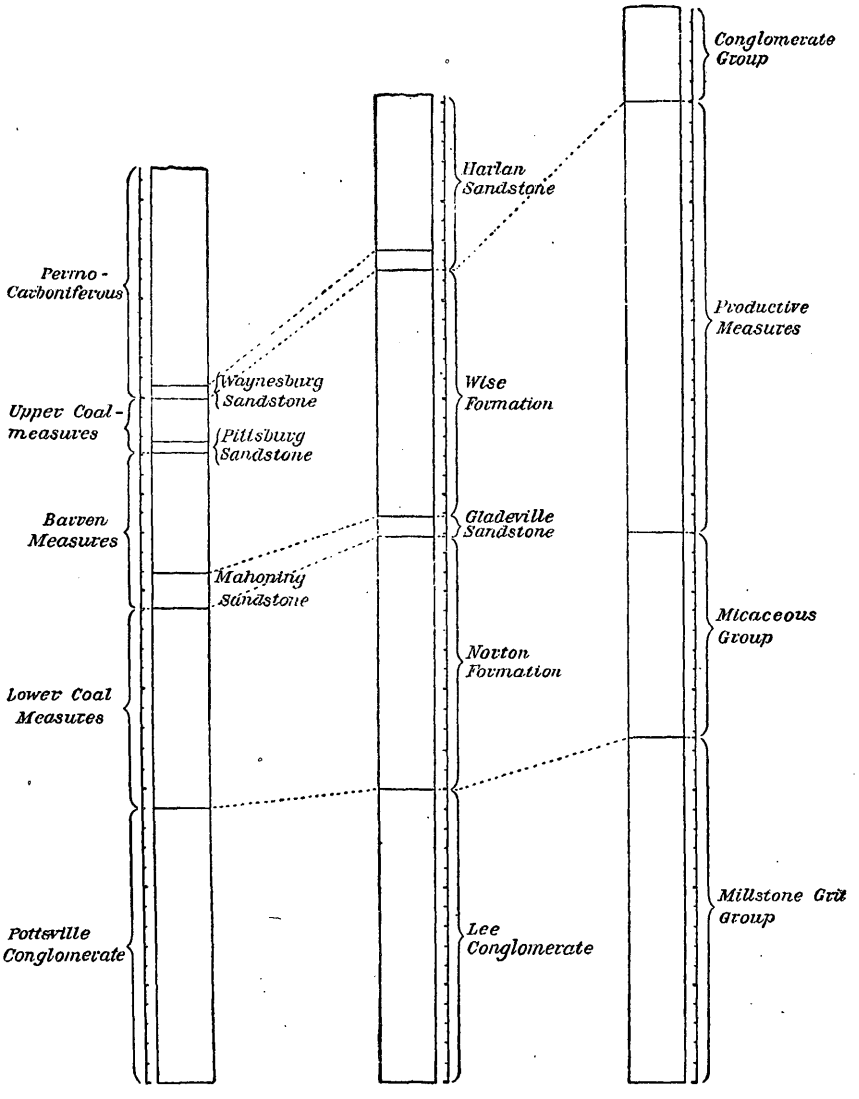

FIG. 3.—Sections showing thickness and position of various groups and their supposed equivalence.

it is presented in the hope of encouraging further study in the intermediate territory.

The Mahoning sandstone has been found by Prof. White to be a constant element throughout his field as far southwest as Oceana, West Virginia, and it does not appear to thin out or change character in

this direction. In the Big Stone gap territory the Gladeville sandstone shows a similar persistency and in every respect bears a striking resemblance to the Mahoning sandstone. Assuming this correlation to be correct, the Norton formation would be equivalent to the Lower Coal-measures.

Above the Mahoning, Prof. White describes two other coarse sandstones, or conglomerates, which seem persistent as far as his observations extend. Only one was noted in the Big Stone gap region. The Pittsburg sandstone differs from the Harlan sandstone, as the latter is very hard and resists degradation to such an extent that it almost invariably forms cliffs; and the Pittsburg sandstone is replaced by shales on the eastern side of the basin in Pennsylvania and northern West Virginia. It is therefore probable that in the Big Stone gap field, which is on this eastern line, this sandstone is thin or is represented by shale. Hence it seems likely that the Harlan sandstone is the equivalent of the Waynesburg sandstone. If this correlation should prove correct the Harlan sandstone corresponds to Prof. White's Permo-Carboniferous or Dunkard Creek series.

These correlations are only provisional, requiring more field work in the intermediate region to justify positive statements.

CORRELATION WITH REGION SOUTHWEST OF BIG STONE GAP.

In the opposite direction, or southwest from Big Stone gap, the comparison of sections is even more difficult; for the intermediate, unknown territory is of much greater extent, and the next region carefully studied shows a marked disagreement in its stratigraphic column from the Big Stone gap field.

The Lee conglomerate holds a thickness of over 1,000 feet as far south as the northern line of Tennessee. Mr. A. R. Crandall, of the Kentucky Geological Survey, gives a roughly measured section through Pine mountain, in the Narrows of Clear creek, on the Tennessee state line,[1] in which the thickness is given as over 1,000 feet. Mr. Arthur Keith, of the U. S. Geological Survey, in surveying the Maynardsville atlas sheet, measured a section of the conglomerate in Wilson gap, Claiborne county, Tennessee; this gap is in the Cumberland mountains, directly southeast of the Narrows in Pine mountain, and shows the following section:

	Feet.
Coal-measures	
Lee conglomerate	1,250
Pennington shale	800
Newman limestone	

This agrees with the general section for the Big Stone gap field, except that both the Lee conglomerate and the Pennington shale are thinner. By these measures we know that the conglomerate formation holds its own, as a complex formation of great thickness along the eastern side of the basin from the Kanawha river to Wilson gap, Tennes-

[1] Geol. Survey of Ky. Report on the Geology of Whitley county and a part of Pulaski. P. 110.

see; beyond this the formation can not be traced satisfactorily, as only partial sections are available. Prof. J. M. Safford gives a section of Pine mountain in Tennessee in which the thicknesses are estimated and consequently are not very reliable: [1]

	Feet.
Conglomerate, summit of Pine mountain.	
Flaggy, micaceous sandstone on top; slate and shales below	220
Compact grit on top; slate and shale below	120
Coarse sandstone on top; clay, slate and shale	100
Mountain limestone.	

The formation below the conglomerate in this section appears to correspond with the Pennington shale further northeast, but on the other hand it seems to be equivalent to the lower coal measures of southern Tennessee as described by Safford.

Mr. C. W. Hayes, in mapping the Kingston atlas sheet, lying between the parallels 35° 30′ and 36°, makes the following classification of the coal measures:[2]

	Feet.
Walden sandstone	1,300
Lookout sandstone	260 to 550
Bangor limestone.	

In this classification the Lookout includes everything from the top of the Bangor (sub-Carboniferous) limestone to the top of the first heavy conglomerate; the conglomerate itself varies from 25 to 60 feet in thickness and forms the edge of the escarpment; below the conglomerate is a mass of sandstones, shales, and coals that graduate downwards from the coarse conglomerate into the shales immediately overlying the Bangor limestone. This division corresponds with the Lower Coal-measures of Safford and appears to occupy the same stratigraphic horizon as the Pennington shale, but the connection has never been traced. The prevailing opinion has been that these lower measures are the representatives of the lower portion of the Lee conglomerate of Big Stone gap. Mr. J. J. Stevenson makes the following statement,[3] in speaking of the Quinnemont (Pottsville) conglomerate as shown in Pennington gap:

> The coal beds in the greater part of the Tennessee coal field belong to this group, and without doubt much of the section obtained in the northeastern district of that coal field should be referred to the same horizon, as Prof. Safford has done. The coal beds there are somewhat variable. A noteworthy feature of this group in Tennessee is that the bottom plate of conglomerate is absent, and the coal group passes directly into the Lower Carboniferous.

The published data upon which to base such a statement seem to be entirely inadequate. This is one of the important problems to be solved in the near future, and only the careful mapping of the intervening territory will settle the question. The writer would suggest that it is altogether possible that the conglomerate group instead of losing its basal

[1] Geology of Tennessee, Nashville, 1869, p. 404.
[2] U. S. Geological Survey, Geologic Atlas of the United States, Kingston Sheet.
[3] Am. Phil. Soc. Proc., 1880–81., vol. XIX, p. 230.

member in Tennessee retains that member in full force, and that it is the upper member that is either absent or unrecognizable. Mr. Hayes estimates the thickness of the measures above the Lookout, on the Kingston sheet, to be 1,300 feet, but these measures have never been studied in detail and are practically unknown; no conglomerate was observed above the heavy bed at the edge of the escarpment, but for at least 1,000 feet (estimated) heavy sandstones predominate that may easily be the representatives of the beds of conglomerate at Big Stone gap. This group of rock seems to occupy the entire basin in this territory except the northeastern part, where the syncline apparently deepens and the character of the rocks change, shale and soft sandstone becoming the predominant elements. No accurate measures were made on these beds, but the writer, who assisted Mr. Hayes in this work, is of the opinion that they may be the equivalent of the Norton formation at Big Stone gap.

The sequence is about the same on the western edge of the plateau, except that the measures below the conglomerate are thinner, as is shown by the following section, measured in Fentress county, Tennessee: [1]

		Feet.
Upper Coal Measures:	Conglomerate (40 feet) Shale, sandstone, and coal (174 feet)	214
Conglomerate		90
Lower Coal-measures		35
Mountain limestone.		

In the vicinity of Chattanooga the section is about the same as shown by Safford's section measured at Tracy City, Tennessee: [2] [3]

		Feet.
Upper Coal-measures:	Conglomerate (50 feet) Shale and coal (240 feet)	290
Conglomerate		70
Lower Coal-measures		228
Mountain limestone.		

[1] J. M. Safford: op. cit., p. 396.

[2] Op. cit., pp. 369–370.

[3] *Condensed section of Coal-measures at Tracy city, Tenn.*

[C. W. Hayes, September, 1893.]

Walden sandstone:	Feet.
Coarse cross bedded sandstone with pebbles at the top and bottom	70
Cross bedded sandstone with some beds of shale	90
Thin bedded sandstone	65
Coal, main Sewanee seam	5±
Sandstone and shale	44
Coal, "Little Sewanee"	1±
Sandy blue shale	25
	300
Lookout sandstone:	
Conglomerate and sandstone	65
Sandstone, shale and coal	195
Limestone	..
	260

Mr. Hayes gives the following generalized section for this region:[1]

	Feet.
Walden sandstone	1,000
Lookout sandstone	400 to 500
Bangor limestone.	

His classification is the same as for the Kingston sheet, and the heavy bed of conglomerate at the top of the Lookout varies from 25 to 70 feet.

South of this the measures of the Alabama survey are the basis for correlation. On the western border of the field, in the Warrior basin, the beds below the conglomerate, corresponding to the Lower Coal-measures of Safford, are thin. The writer measured a section west of Guntersville, Alabama, in which the bed of shale between the limestone and the conglomerate is only 60 feet. It appears to thicken southeast and south, for on the eastern face of Blount mountain a section was measured by Gen. A. M. Gibson and given by Mr. Henry McCally,[2] in which the shale, thin-bedded sandstones, and coals underneath the conglomerate measured 620 feet in thickness. The writer feels full confidence in this figure, as he measured a section on the eastern face of this mountain in Greasy cove, and, though exposures were poor, the thickness of these measures is probably between 600 and 800 feet. According to the Alabama geologists this formation becomes barren of coals southwest of Blount mountain, and is apparently confused with the Oxmoor or sub-Carboniferous shales in the Cahaba basin, as the conglomerate is reported as resting directly upon the Oxmoor sandstones and shales.[3]

In the various fields we have considered, the rocks below the conglomerate vary greatly; in the Cahaba basin they are classed as the upper portion of the sub-Carboniferous; in northern Alabama and southern Tennessee they are classed as the Lower Coal measures; in Virginia and further north they are considered as sub-Carboniferous. This outlines the question, and it is hoped that more work can be devoted to it, both stratigraphic and paleontologic, in order to obtain the correct correlation.

The Conglomerate apparently varies greatly south of Chattanooga. In Alabama, outside of the Cahaba basin, the classification of Safford has been followed, and the Conglomerate group recognized as carrying but two beds of conglomerate; but in his reports on the various counties in the Warrior field, Mr. McCally has brought out some additional facts.

In the report on Marion county, Alabama,[4] McCally gives the thickness of the Coal-measures as 1,283 feet, and in that interval he notes five beds of conglomerate occurring at irregular intervals. Again, in Winston county,[5] he gives the thickness of the measures as 1,233 feet,

[1] U. S. Geological Survey, Geologic Atlas of the United States, Chattannooga Sheet.

[2] Geological Survey of Alabama. Report on the Coal-measures of the Plateau Region of Alabama. Montgomery, Alabama 1891, pp. 114–116.

[3] Geological Survey of Alabama, Cahaba Coal Field, Joseph Squire, 1890.

[4] Geol. Surv. of Ala.: On the Warrior Coal Field, 1886, pp. 30, 31.

[5] Op. cit., pp. 64, 75.

and notes four conglomerates. These counties are on the northern border of the Warrior field and hold only the lowest measures; in the next tier of counties to the south the higher measures are found, and a good section was measured in Walker county,[1] but no conglomerates are noted above the horizon of the Winston county beds.

In Jefferson county the most complete section is given:[2] Its base up to a thickness of 1,700 feet contains four quite well marked conglomerates; above this, other beds of conglomerate are noted, but all are quite thin, being less than 15 feet in thickness and appearing to be but local features. This upper portion of the section is 1,300 feet thick.

Gen. Gibson, in his Blount mountain section,[3] gives the measures a thickness of 1,340 feet, and includes four conglomerates.

Lastly Mr. Squire gives for the Cahaba basin[3] the most complete section of the Coal-measures south of Virginia yet published. His section is as follows:

	Feet.
Conglomerate group	480
Productive group	2,200
Micaceous group	1,040
Millstone grit group	1,765
Total Coal-measures	5,485

The following section is an attempt to represent by figures the character of the millstone grit as shown by Squire in his sections, but unfortunately he only indicates in a general way where the beds of conglomerate are, without giving their thickness or the thickness of the interval of sandstones, shales, and coals that occur between them:

	Feet.
Conglomerate	75
Interval	500
Conglomerate	175
Interval	560
Conglomerate	185
Interval	70
Conglomerate	200
Total	1,765

Considering the conglomerate group alone, there appears to be a mass of sediments characterized by four or five well marked beds of conglomerate that can be identified across the basin in Alabama; as shown in the sections, it is 1,765 feet thick in the Cahaba basin, 1,700 feet in Jefferson county, 1,340 feet in Blount mountain, and about 1,250 feet in Marion and Winston counties. This group bears such a resemblance to the Lee conglomerate of Big Stone gap and the Pottsville conglomerate of the Kanawha that it at once suggests their equivalence. In the intermediate Chattanooga region, if that correlation be correct, nothing but the base of the series is preserved, or the top has lost its distinctive character and is not recognized. Fig. 3 shows the entire

[1] Op. cit., pp. 131–134. [2] Op. cit., pp. 272–274 and 416–417 [3] Loc. cit.

section of the Cahaba basin compared with the generalized section of the Big Stone gap fields and the type section from West Virginia. The agreement in the aggregate thickness of the strata is striking, showing a regular increase from 4,660 feet in West Virginia to 5,030 feet in the Big Stone gap field and 5,485 feet in the Cahaba basin. Above the Millstone grit group in the Cahaba section no resemblance is found between this and the other sections until the topmost member is reached; this Conglomerate group of Squire bears a strong resemblance to the Harlan sandstone as described by the writer. If this correlation be correct the three type sections would show as follows:

	West Virginia.	Big Stone gap.	Cahaba basin.
Permo-Carboniferous	1,162	880	480
Intermediate measures	2,098	3,650	3,240
Conglomerate	1,400	1,500	1,765

These show a marked gradation that is suggestive of some connection in genesis, but present knowledge is not sufficient to determine the question. Careful stratigraphic work is needed in the northern half of Tennessee—in the Briceville region—where the upper measures may be found; they may give the key to the stratigraphy in the Chattanooga region. Besides stratigraphic work, thorough paleontologic work is needed at many points, but especially to determine the age and equivalence of the highest beds in the southern region, for in that territory the upper measures exist only in isolated remnants and can not be correlated without the evidence of fossils.

If the work in view by the U. S. Geological Survey is successfully completed it will doubtless in the near future settle many of these questions of correlation that at present we can see only vaguely through the mist of uncertainty that surrounds them.

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