BULLETIN OF THE GEOLOGICAL SOCIETY OF AMERICA
VOL. 18, PP. 29-178 APRIL 9, 1907

CARBONIFEROUS OF THE APPALACHIAN BASIN *

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(Presented by title before the Society, December 29, 1906)

CONTENTS

* The earlier papers of this series, now closed, are in this Bulletin, volume 14, pages 15-96; volume 15, pages 37-210; volume 17, pages 65-228. The writer desires to acknowledge his obligations to Doctor I. C. White and Mr David White, who throughout the whole period of his study have been unreserved in giving information and criticism. At the same time it must be understood that these observers are committed in no wise to conclusions offered by the writer.

Manuscript received by the Secretary of the Society January 5, 1907.

The Monongahela Formation

CORRELATION

The practically continuous area of Monongahela is confined to the southwest four counties of Pennsylvania, a narrow strip in eastern Ohio, and central West Virginia. Small outlying patches remain east from the Alleghenies, in the First and Second basins of Pennsylvania, and, at the south, beyond the Kanawha river in West Virginia. The area in which this formation remains is far within that of the Conemaugh, except at the east.

The formation, as limited by Doctor I. C. White, has the Pittsburg coal bed as the lowest and the Waynesburg coal bed as the highest stratum. The thickness varies from somewhat more than 400 feet in central West Virginia to about 140 feet at the most northerly exposure in Jefferson county of Ohio. This formation is characterized by notable variation in thickness of intervals and in composition of the rocks, as well as by local irregularities of deposit, whereby every student in the several parts of the area has been led into serious errors of correlation. These have made study of the Monongahela more perplexing than that of any earlier Carboniferous formation.

In ascending order, the important members of the formation are:

Pittsburg coal bed.
Pittsburg sandstone.
Redstone limestone.
Redstone coal bed.
Fishpot limestone.
Lower Sewickley coal bed.
Sewickley sandstone.
Upper Sewickley coal bed.
Benwood limestone.
Tyler red beds.
Ritchie red beds.
Uniontown limestone.
Uniontown coal bed.
Uniontown sandstone.
Waynesburg limestone.
Little Waynesburg coal bed.
Waynesburg coal bed.

The Pittsburg coal bed.....Maryland: Cumberland, Elkgarden, Great vein, Pittsburg. Pennsylvania: Pittsburg, Connellsville, I. Ohio: Federal creek, Pomeroy, Lower Barnesville, VIII, Pittsburg. West Virginia: Pittsburg.
H. D. Rogers, 1839.

At one time this bed was thought to be a practically continuous sheet underlying the whole remaining area of Monongahela, somewhat less than 20,000 square miles; but studies by Professor E. B. Andrews during the Second Geological Survey of Ohio proved its absence from a considerable part of the field in that state and Doctor White's study of oil well records in West Virginia, almost 20 years later, led to a similar conclusion for much of that state. The northern boundary of this barren area is in Guernsey county of Ohio and the coal is to all intents wanting in Noble, Monroe, east Morgan, and most of Washington in Ohio, most of Wetzel, Tyler, Pleasants, Wood, Ritchie, Doddridge, Gilmer, Roane, Calhoun, Jackson, Clay, Kanawha, Putnam, and Mason counties of West Virginia, all within the area in which formerly the bed was supposed to exist. Yet, even when thus restricted, the coal underlies a vast area, 7,000 or 8,000 square miles, in which it exhibits for the most part such regularity in variation as to both quantity and quality as to render it, from an economic point of view, the most important member of the formation and probably of the whole bituminous coal measures. Within the barren area itself it is represented frequently by black shale and occasionally it reappears abruptly as a bed of workable thickness.

The Pittsburg coal bed in the ordinary condition, as seen in most of Pennsylvania and Ohio, is double, showing a "roof" division separated by an "over-clay" from the "Main" coal below. The "roof," varying in thickness from a few inches to 10 or 12 feet, is composed sometimes of laminations of coal and clay; at others, the coal and clay are segregated into beds, each 6 inches to a foot, while again it is almost wholly coal or almost wholly carbonaceous shale. At the best the coal is inferior and is not mined. This division is wanting in the Salisbury basin of Somerset county, Pennsylvania, and is seen rarely along the eastern outcrop in West Virginia; but it reappears suddenly on the Kanawha, where at one locality it attains to almost the extreme thickness.

The "over-clay," varying from a few inches to 2 feet, is thoroughly persistent, though sometimes so carbonaceous as to be almost a bony coal; even in West Virginia it seems to be present always, though the "roof" is wanting.

The "Main" coal may be regarded as in three benches—"Breast," "Bearing-in," and "Bottom"—but in a great part of the field the "Breast" as well as the "Bottom" is divided by a thin parting, so that five benches are distinct. The parting slates are ordinarily very thin, rarely exceeding half an inch, often much less, and in considerable areas

some of them contain much mineral charcoal. The persistence of these filmy layers throughout thousands of square miles is not the least remarkable feature of this bed. The "Bearing-in," known in some localities as the "Bands," is not persistent in West Virginia, where along the eastern outcrop the bed is often only double, with a mere parting, there being no deposit between the benches. The coal is not the same throughout the bed, and each bench is apt to show its own type, distinguishing it as sharply from the others as though the partings were many feet thick. The coal differs in volatile, in ash, in coking qualities, and in sulphur; that from one bench is "brick;" from another, prismatic; from a third, hard, with more or less of semicannel. Like other beds, the Pittsburg occasionally carries some cannel; but this is unusual, occurring only on the border of the field.

The proportion of volatile shows variation geographically, as was indicated long ago by Professor H. D. Rogers. Along a line passing westnorthwest from Maryland to Ohio, the ratios between volatile and fixed carbon in the several basins are:

Maryland	4.47 to 4.78
Salisbury	3.18 to 3.38
Connellsville	1.81 to 2.07
Lisbon	1.38 to 1.83
Washington county	1.03 to 1.79

These ratios are taken from Mr A. S. McCreath's analyses. This decrease is most marked along the westnorthwest line, but there is in a general way a decrease northwardly in several of the basins. The volatile is high throughout Ohio. In West Virginia, as shown by Professor Hite's analyses, the volatile increases, there being as much in the continuation of the Connellsville as in the southern Lisbon of Pennsylvania; still farther south, on the line of the Salisbury basin, the ratio is 1.4, while in Mason County, on the central line of the trough the ratio varies from 1.04 to 1.33.

The Pittsburg coal bed has its greatest thickness at the southeast, in the Potomac areas of Maryland and West Virginia, where the Main coal is 12 to 14 feet. Along a westnorthwest line in Pennsylvania the thickness decreases, becoming 8 to 10 feet in the Salisbury, 8 to 9 in the Connellsville, 7 to 8 in the Lisbon, 6 to 7 in the Waynesburg, and 5 to 6 in basins farther west. It retains the latter thickness into Ohio, but more frequently approaching the lower figure. On the western outcrop, in Belmont and Guernsey counties of Ohio, the thickness falls to 4 feet, and at last to 3 feet 6 inches, the several divisions of the bed being still distinct. North from this line the bed grows thinner, slowly in the

Ligonier, Connellsville, and Lisbon, in which it retains a good thickness to the last exposure, but farther west the diminution is more marked, for in northern Allegheny the bed rarely exceeds 4 feet 6 inches, while in Beaver county it falls to 3 feet 6 inches; but in Jefferson of Ohio it is 4 feet at the most northerly exposure. The conditions along the northwestern and western outcrop are suggestive. The greater thickness in Jefferson and the marked increase to 6 feet southwest in Harrison county makes the greatly increased thickness, 8 to 9 feet, in western Morgan and Athens not at all surprising. It is clear that the thin coal of Guernsey is only evidence of approach toward the barren area, which begins in the southern part of that county. The western limit of the bed must have been considerably west from the present outcrop in Harrison, Guernsey, and Muskingum; it is probable that a great area of thick coal has been removed, and that the thick coal of Morgan at one time covered most of Muskingum and Carroll counties, west from Guernsey and Harrison. The great thickness at the extreme northern exposures within the Ligonier, Connellsville, and Lisbon basins leads to the belief that Professor J. P. Lesley was not far wrong when he suggested that the Pittsburg at one time reached almost to lake Erie.

While the bed loses thickness from all sides toward the central area, where it is wanting or so insignificant as to be unimportant, it is equally true, as already stated, that even within that area one finds patches in which the bed is of commercial importance. One of them, with Pomeroy, Ohio, as its chief shipping point, has an area of not far from 100 square miles; those along the Kanawha in West Virginia are smaller, but there the bed shows at times its complex "roof," "over-clay" and "Main" coal, with the latter exhibiting close structural resemblance to typical localities near the Pennsylvania line. Such occurrences are of great interest from the theoretical standpoint.

In some portions of the field the Pittsburg coal bed shows a tendency to wide separation of parts, somewhat like that observed in the anthracite beds and in the Pottsville beds of the Kanawha region. In the Potomac basins of Maryland and West Virginia the several portions of the bed are separated by shales and clays, so as to occupy a vertical space of 40 to 63 feet; in the Salisbury basin of Pennsylvania the bed and its partings are in a vertical space of 46 feet at the southern end, but this increases to about 160 feet at the northern end, with shales, sandstones, and limestones in the intervals; in the Connellsville basin one finds at a few miles south from Uniontown, in Fayette county, the Pittsburg in all about 14 feet thick and 30 feet below the Redstone coal bed; but northward the Pittsburg interval quickly increases to 58, 66,

and 68 feet, the interval to the Redstone coal bed decreasing to 25 feet. The upper coal layers of the Pittsburg disappear northward, but the interval from the "Main" coal to the Redstone decreases very slowly and becomes normal only as one approaches the north end of the basin. A similar condition exists in southern Fayette within the Lisbon basin, but the divergence as well as the area in which it occurs is not so great; farther west in Pennsylvania and Ohio the tendency to local irregularity of deposit is shown by the presence of "rider" coal beds at many localities.

The Pittsburg sandstone (H. D. Rogers, 1858) is a variable rock overlying the Pittsburg coal on the borders of the basin, but it is far from being persistent, the interval being filled with shale very frequently. A thin deposit of shale usually intervenes between the coal and the sandstone. This coarse deposit is present commonly along the northern outcrop in Pennsylvania as well as in the Connellsville basin and southward in the exposed area of West Virginia; it is important along the southern edge of the field in that state into Ohio, where it is almost constant in Gallia, Meigs, and Morgan counties on the south and west border; but northward from Morgan, on the western border, it is wanting until one comes to western Belmont, Guernsey, and Harrison. Its distribution in Ohio lends probability to the suggestion already offered respecting the western extent to the Pittsburg coal bed. This sandstone is confined practically to the borders of the field, and within the interior portions one finds shale with only occasional sandstone in the interval.

The Redstone limestone (J. J. Stevenson, 1877) is confined to the north central part of the field, being absent along the northern outcrop in Pennsylvania as well as in nearly the whole of West Virginia and Ohio. Like the other limestones of this formation, it is non-fossiliferous or at the most contains minute forms which may be of fresh-water types. It persists in Pennsylvania between Chestnut ridge and the Ohio river and is present in eastern Belmont of Ohio; it disappears quickly south from the Pennsylvania line in West Virginia. Perhaps it may be the "limestone group" of Andrews in southeastern Ohio, but that can be no more than a mere suggestion; for, as indicated by Professor Andrews more than 30 years ago, these limestones appear to be irregular deposits of calcareous mud and are given to sudden variations. Within Pennsylvania and the immediately adjacent part of West Virginia the correlation is exact.

The Redstone coal bed (H. D. Rogers, 1858) is very persistent in the northern part of the basin, though rarely attaining sufficient thickness

to be of local importance. It is from 30 to 80 feet above the "Main" coal of the Pittsburg and its place is almost invariably marked by coal or by richly carbonaceous shale. In many localities where it is wanting its absence is due to erosion during deposition of an overlying sandstone, continuous downward with the Pittsburg. Sometimes it is of workable thickness in southern Pennsylvania and adjacent part of West Virginia near the Monongahela river. The identification of the bed is very clear in Pennsylvania, West Virginia, and Belmont county of Ohio, but the reference of isolated bits of coal in southern Ohio is tentative to the last degree. They may be only "rider" coals to the Pittsburg. A feature of the Redstone in much of Pennsylvania is the occurrence of broad clay veins in localities where the underlying Pittsburg coal bed is undisturbed. The bed is roofed ordinarily by shale or sandstone and is often only an inch or two above its limestone. At one place in Washington county, Pennsylvania, it has a limestone roof.

The Fishpot limestone (J. J. Stevenson, 1876) has been regarded as equivalent to the Sewickley limestone (F. and W. G. Platt, 1877), but the relations of the latter limestone are very uncertain and in all probability it is not the same with the Fishpot. This limestone is separated at most by 5 or 6 feet from the Lower Sewickley coal bed, and occasionally the two deposits are apparently in contact. It seems to be wanting east from the Alleghenies as well as in the eastern basins and along the northern outcrop in Pennsylvania; but it seems to be persistent, though extremely variable, in most of the area west from Chestnut ridge across Pennsylvania into northern Ohio as well as southward for 30 miles in West Virginia. It is thick in some of the Pennsylvania basins and thin or uncertain in others. It becomes very thick in the basins of Fayette and Westmoreland as well as in the adjacent portions of Washington and Greene, sometimes 30 feet, and it is equally important on the Ohio river. This deposit is confined to the northern part of the basin and, like most of the other limestones in the formation, seems to be wholly wanting in the interior part. Its interval rarely carries any limestone in Ohio south from northern Monroe county.

The Sewickley coal bed (H. D. Rogers, 1858) includes two coal beds; the lower bed rests on the Fishpot limestone or is separated from it by thin clay, while the upper bed overlies the Sewickley sandstone and is almost directly under the great Benwood limestone. One seldom sees both beds well defined in a single section. The type sections obtained by the geologists of the First survey as well as by those of the Second survey were obtained in southern Fayette and Greene counties near the West Virginia line, where the Sewickley sandstone is unusually

variable; there was supposed to be only one bed and the conditions there observed were applied throughout the Pennsylvania areas. Later studies, supplemented by records of shafts and borings, make it possible to correct the writer's error of 30 years ago.

The Lower Sewickley coal bed is the Sewickley of most of Greene, Washington, and Allegheny counties, Pennsylvania, as described in volume K of the Pennsylvania reports. It is the persistent bed of Fayette and Westmoreland counties within the Connellsville basin, but it is very indefinite in the Lisbon. The horizon is well marked by the Fishpot limestone below and the Sewickley sandstone above, between which one usually finds either coal or black shale. The bed is of workable thickness at some localities in Fayette and Greene counties of Pennsylvania and it is a well marked coal horizon in West Virginia, being noted in very many oil-well records at 25 miles south from the Pennsylvania line. In northern Ohio it is present in Belmont and perhaps Monroe county as coal, but very thin. Its extent is much less than that of the Pittsburg, the interior area in which it is wanting being much greater.

The Sewickley sandstone (I. C. White, 1891) is a remarkably persistent deposit, 5 to 40 feet thick, recognized throughout Pennsylvania and northern Ohio and very distinct in West Virginia to at least 40 miles south from the Pennsylvania line. It is present in many oil-well records, even into the central area of West Virginia. Near Uniontown, in Fayette county of Pennsylvania, it is wanting in a shaft where the Sewickley coals have united, the resulting bed separating the Fishpot and Benwood limestones. In the southwest part of that county the sandstone gradually decreases and the Upper Sewickley coal bed is let down almost to the Fishpot limestone.

The Upper Sewickley coal bed. Maryland: Gas, Tyson. Pennsylvania: Sewickley. West Virginia: Sewickley. Ohio: VIIIc, X, Cumberland, Meigs creek, Macksburg, Upper Barnesville.

This is an important coal bed near Frostburg, in Maryland; it is unimportant in the Connellsville basin, where one finds at its horizon only black shale, but in western Fayette and Westmoreland it is persistent as coal, almost directly underlying the Benwood limestone; and there, as in the adjacent portions of Washington county, it is occasionally thick enough to be mined. In much of Washington and Allegheny counties it is little more than black shale, but when it comes up again on the westerly side, in the West Virginia panhandle, it is coal in two or three

divisions with varying intervals. There, as in Jefferson and eastern Belmont of Ohio, it is unimportant; but in western Belmont and Harrison it becomes more important than the Pittsburg. In much of Ohio it is the chief source of supply, although its coal usually contains more ash than that of the Pittsburg. Where best developed it is a triple bed, the middle bench being thick, the other, separated from it by thick clay partings, being too thin to be worked. It extends much farther eastward into the barren area than the Pittsburg does; it is the important Macksburg coal of southern Noble and northern Washington at 25 miles southeast from the disappearance of the Pittsburg; but it becomes irregular and of little value further toward the middle of the trough. It is insignificant in West Virginia, but a trace of it was seen on the Baltimore and Ohio railroad west from Clarksburg, in Harrison county, and it may be the coal reported in some records termed the Sewickley in the following pages. While the horizon is well marked in much of Pennsylvania and occasionally carries workable coal in small areas there, as in Maryland, it is most thoroughly characteristic of the westerly side of the trough, where within its present area it has more coal than the Pittsburg. Judging from conditions shown by the latter bed, which reaches 9 feet on the western outcrop in Morgan county, one should expect the Upper Sewickley to increase greatly toward its western outcrop; but the contrary is true, as, accordingly to Professor Brown, the Upper Sewickley "is thin and unsteady and of little economic value" in western Morgan, whereas it is important in eastern Morgan as in Noble, southeast Muskingum and southern Guernsey. But is a coal bed to the western outcrop.

The Sewickley horizon was characterized by local irregularity of deposit. Reference has been made to the disappearance of the Sewickley sandstone and its rapid reappearance in southern Fayette of Pennsylvania. In southern Greene county, Doctor White found the Lower Sewickley, 4 feet 10 inches thick and in several benches; but at half a mile away these benches are distributed in a vertical space of 33 feet 6 inches. On Wheeling creek, 3 miles east from Wheeling, West Virginia, the section is:

Upper Sewickley coal bed:

	Feet	Inches	Feet	Inches
Coal	1	2		
Fireclay, sandstone	6	4	8	6
Coal and shale	1	0		
Clay and Sewickley sandstone			14	0
Lower Sewickley coal bed			1	8

in all 24 feet 2 inches. A section in Wheeling shows the Upper Sewickley 3 feet thick and 17 feet above the Lower Sewickley, also 3 feet, a vertical space of 23 feet; but at another place in Wheeling, Doctor White found the three beds once more and in a vertical space of 43 feet. At 12 or 14 miles below Wheeling, on the Ohio, Doctor White's section shows the Upper Sewickley 2 feet thick and separated by 12 feet of Sewickley sandstone from 10 feet of coal and shale apparently representing the Lower Sewickley. The varying interval between Upper Sewickley and Pittsburg along the western outcrop suggests similar irregularities in that region.

The Great limestone (H. D. Rogers, 1858) included all of the limestone bed in the Monongahela formation. In 1876 J. J. Stevenson restricted this term to the deposits between the Upper Sewickley and the Uniontown coal beds, and divided it into Lower and Upper; in 1877 he applied the term Uniontown to the upper division, and in 1903 Doctor White designated the lower division as the Benwood.

The Benwood limestone (I. C. White, 1903) is almost directly above the Upper Sewickley coal bed. It seems to be wanting east from the Alleghenies and is very thin along the northern outcrop in Pennsylvania, though some trace remains in the Ligonier, Connellsville, and Lisbon basins almost to the last exposure. Farther west in Allegheny and northwest Washington it is either wanting or very thin. Southward it comes into the section rather abruptly, attaining great thickness almost at once. It is not always continuous limestone, but sometimes is very largely calcareous shale, and at others is broken by shale or sandstone beds. It reaches its maximum thickness in Fayette and Westmoreland within the Lisbon basin, and retains it along the Monongahela river in much of Greene and southern Washington. It is from 60 to 90 feet thick in that area and in some places is continuous with the Uniontown limestone above. This great thickness continues for a little way into West Virginia, but it quickly becomes insignificant, and in less than 40 miles there is barely as much as 7 feet in this interval. It seems probable that the mass persists under Greene county of Pennsylvania, for where the rocks come up again near the Ohio river it is very thick and so prominent that the name is given from Benwood 4 miles below Wheeling.

In Ohio this limestone is wanting within northern Jefferson, Harrison, and northern Guernsey counties; it is thick in eastern Belmont and southern Jefferson, but in the western part of the former county it is broken into many layers, varying in thickness and separated by shales or sandstones. The Benwood interval contains limestone beds along

much of the western outcrop, and, as in Pennsylvania, some of the more persistent beds are magnesian, being referred to by Andrews as "cement beds." Southwardly it is replaced by sandstone, sometimes 60 feet thick and often very coarse, so that the Upper Sewickley is known as the "Sandstone coal" to distinguish it from the Pittsburg or "Limestone coal."

The interval of 20 to 40 feet between the Benwood and Uniontown limestones is occupied usually by sandstone or sandy shale.

The Uniontown limestone (J. J. Stevenson, 1877) is one of the more persistent members of the section. It is wanting east from the Alleghenies, but is present throughout the Connellsville basin, is apparently one of the upper limestones near Greensburg, is everywhere in the Lisbon basin south from the Pennsylvania railroad, extends to the most northerly outcrop of its place in Allegheny county, and seems to be present everywhere in Washington and Greene where its place is exposed. It is present in northern West Virginia toward the eastern outcrop, but diamond-drill cores do not show it toward the west. It evidently disappears southwardly at no considerable distance from the state line. It is present in the northern panhandle of the state, and in Ohio one finds limestone at this horizon in by far the greater part of the area when the place is exposed. In much of Pennsylvania it has a characteristic yellow color on the weathered surface, wholly unlike that of any other limestone in the formation. The thickness varies from 2 to 12 feet.

The Uniontown coal bed.....**Maryland and Pennsylvania: Uniontown. West Virginia: Waynesburg, Macksburg, Uniontown. Ohio: Hobson, Cumberland, Waynesburg, Clarington.**
H. D. Rogers, 1858.

This bed is rarely of interest or importance on the northeasterly side of the great basin, where it was first studied and named. Its insignificance in that region caused failure to recognize it in other regions. Doctor White's suggestion, that the West Virginia bed, usually referred to the Waynesburg, might prove to be the Uniontown, proves to be correct. The bed is present as coal, but very thin, in Maryland; its place is marked by shale or coal almost everywhere in the Connellsville basin, but it is not a workable bed anywhere, for, though thick enough near Uniontown, its coal is very bad. In the Lisbon basin it is present to the most northerly exposure, but for the most part is very thin, except in some places within Fayette and Greene counties, where it is opened occasionally by farmers, but yields miserable coals. Farther west the coal does not extend northward into Allegheny or northwestern

Washington, but it is shown frequently south from the line of the Pennsylvania railroad in the latter county, though never more than about 2 feet thick and always apparently very inferior. It is seldom more than 2 or 3 feet above its bright yellow limestone and at times the coal and limestone are separated by a mere parting shale. The bed is present in the northern panhandle of West Virginia and is distinct in western Belmont of Ohio, though wanting in Jefferson, Harrison, and apparently in northern Guernsey. It does not seem to reach the northern outcrop in Ohio, reaching northward there hardly any farther than in Washington county of Pennsylvania; but southward it is persistent as shale or coal along the western outcrop, where it is known as the Hobson coal bed and is occasionally workable. It is of considerable local importance in northern Monroe, where it has a somewhat complex structure. It is certainly present under the Cowrun anticline in Washington county and northward along the Ohio river, but southward it evidently disappears. It is insignificant in the exposed area within the eastern part of the West Virginia field, but it is distinctly a coal bed in Harrison, Doddridge, Gilmer, Lewis, and Wirt, in all of which it is exposed and at times shows a structure recalling that seen in Monroe of Ohio. The records of oil borings show that it is present in all counties north from the Little Kanawha river except possibly Wood, where every trace of coal seems to have disappeared in this formation. Its occurrence farther south is very doubtful and it is not reported in any record.

The distribution of the Uniontown contrasts notably with that of the lower beds. The Pittsburg is practically absent from the great interior area, though its horizon is marked often by thin coal or by carbonaceous shale; it is a thick bed on the borders of the field, thinning from all sides toward the middle. The Upper Sewickley is insignificant for the most part on the east side, though its place is rarely without shale or some coal, but on the west side it is important, extending southward to many miles beyond the Pittsburg's disappearance, though, like that bed, marked only by black shale or wholly wanting in the central buried area. The Uniontown, however, always thin and never attaining more than purely local importance, is a well marked coal horizon west from Chestnut ridge, and even from farther east in West Virginia, across the whole basin. It is a distinct coal horizon in the central part of the field, where the lower beds have become indefinite, and does not disappear southwardly until one approaches the region where the Pittsburg reappears. Though a coal bed in a so great area, it shows no regular variations in thickness such as those of the Pittsburg, but is a thin sheet, usually

double, sometimes still further divided. Its peculiarities possess much interest, considered in reference to the origin and accumulation of coal beds. The carbonaceous shale at this horizon usually contains fragmentary remains of fish, with small lamellibranchs and other forms of undetermined relations. In Monroe of Ohio and Doddridge of West Virginia it is associated with plant-bearing shales. Near Uniontown, Pennsylvania, it underlies an impure limestone containing lamellibranch shells.

The interval between the Uniontown and Waynesburg coal beds is the most variable in the formation. In Marion county of West Virginia the Waynesburg coal bed is somewhat more than 100 feet above the Uniontown limestone, but this interval decreases northward until, in Allegheny and northern Washington of Pennsylvania, the coal and limestone are practically in contact.

The Uniontown sandstone (I. C. White, 1891) is a rather persistent deposit occupying much of the interval, though, like other sandstones, it is apt to be replaced rather abruptly by shales. One finds it very frequently in southern Pennsylvania, at times tenacious enough to form cliffs, but only moderately coarse in grain and very seldom containing pebbles. It shows the same features in much of the exposed area in West Virginia as well as across the northern portion of the state, as appears from oil-well records; but farther south, in Lewis, Gilmer, Doddridge, Tyler, and Pleasants counties, a broad band crossing the state from east to west, the sandstone is massive, coarse, and even conglomerate, exposed in many places and recorded elsewhere in oil wells. It is one of the "Carroll" sands in Ritchie county. In Washington, Morgan, and Athens of Ohio the band continues and the rock is the 200-foot conglomerate of Professor Andrews. Northward and apparently southward from this strip the conglomerate is wanting, the sandstone, where present, is fine grained, and in broad areas the interval is filled by shales. This conglomerate, much resembling that above the Waynesburg coal bed, proved a stumbling block in correlation. It geographical distribution is puzzling.

The Waynesburg limestone (J. J. Stevenson, 1877) is in the upper part of the interval between the coal beds and is of wide extent. It is from 10 to 40 feet below the Waynesburg coal bed. It is present in Maryland and it may be part of the thick limestone in Broad Top; it seems to be present throughout Fayette and Westmoreland counties wherever its horizon is reached, but is wanting in Allegheny and northern Washington, where the Waynesburg coal bed approaches closely to the Uniontown limestone; yet it was seen farther south in Washington,

and in that county as well as Greene it is absent from few sections in which its place is exposed. It disappears quickly southward in West Virginia, where it is without representative almost everywhere in the exposed area. It persists across the northern panhandle into Belmont county of Ohio, but thence there is little information respecting it, as few detailed sections extend above the Uniontown (Hobson) horizon. An impure limestone is reported occasionally at 30 to 40 feet above the Uniontown coal bed.

A sandstone sometimes appears between this limestone and the Waynesburg coal bed, but it is unimportant except in western Marion and northern Harrison of West Virginia, where it is massive and extends downward below the place of the limestone. This was termed the Gilboy sandstone by Doctor White.

The Little Waynesburg coal bed (J. J. Stevenson, 1876) is an unimportant horizon, economically, as the coal rarely attains workable thickness. Like the Uniontown, its areas of moderately thick coal are far away from the borders of the field, as marked by the Pittsburg and Waynesburg coal beds. It is found commonly as a thin coal, one foot or less, at very many places in southwest Pennsylvania and immediately adjacent parts of West Virginia, but it seems to be wanting in Maryland, Ohio, and practically all of West Virginia. It is separated by a variable interval from the limestone below.

The Waynesburg coal bed.....Maryland: Koontz, Waynesburg. Pennsylvania and West Virginia: Waynesburg. Ohio: Tunnel, XI.
H. D. Rogers, 1858.

This bed, at the top of the formation, is a notable deposit in the northern part of the field and is apparently present wherever its horizon is reached in Maryland, Pennsylvania, northern Ohio, and northern West Virginia. Measurements in Pennsylvania are almost as numerous as are those of the Pittsburg, and it is the principal source of domestic supply in considerable areas, though its coal is so inferior that the bed rarely attains commercial importance. It is thin, 2 to 4 feet, including partings, along the northern border in Pennsylvania and in Ohio. In the latter state it is usually very thin and it seldom appears in sections south from Belmont county. Traces of it are reported occasionally in Morgan, Monroe, and Noble counties, while in Meigs and western Washington a thin coal bed sometimes appears under the upper conglomerate of Andrews. The bed is present at Wheeling on the Ohio, but farther south becomes thin and apparently disappears within 30 miles.

In its full development the bed is double, triple, quadruple, or even

more divided and the parting clays show abrupt variations in thickness. This subdivision is characteristic not only in southwest Pennsylvania, but also in Maryland, where the coal is mined on commercial scale. The extreme subdivision was seen in northern Greene county of Pennsylvania, where the measurement is:

	Feet	Inches
Coal	1	0
Clay	1	0
Bone	0	6
Coal	1	3
Clay	0	6
Coal	2	2
Clay	3	0
Coal	0	3
Clay	0	4
Coal	0	5
Shale	10	0
Coal	0	8

in all, 21 feet; but the lowest parting quickly decreases to 2 feet and soon disappears, as do most of the others; so that within 3 miles the bed is double, averages 6 feet in thickness, and shows these variations:

	Inches
Coal	12 to 18
Clay	12 to 48
Coal	12 to 42

The Waynesburg coal bed is persistent in Monongalia, Marion, eastern Wetzel, northern Doddrige, and northern Harrison of West Virginia, with its chief thickness at the east in the first two counties, where it at times reaches to almost 12 feet, inclusive of the moderately thick partings. Southwardly it disapepars or is so thin that drillers of oil wells thought it not worth recording. It is wanting along the southeastern and southern outcrop, except perhaps at Arbuckle, in Mason county, where Doctor White found a multiple coal bed 268 feet above the Pittsburg and underlying a pebbly sandstone. This overlying rock resembles very closely that seen 240 to 250 feet above the Pittsburg at Antiquity, on the Ohio river, 20 miles north from Arbuckle. That is the Waynesburg sandstone of the Dunkard. The sandstone observed at Arbuckle seems to be persistent on the southern outcrop, but the underlying coal bed is not.

Red beds are unimportant in by far the greater part of the Monongahela area; they appear to be wholly absent from Maryland, Pennsylvania, northern Ohio, and insignificant along the northern border of

West Virginia. The important locality is in the central region, within West Virginia and Ohio, where are the great reds of the Conemaugh, some of them extending downward into the Allegheny.

Red beds appear in the Pittsburg-Upper Sewickley interval within the south central counties of Ohio, Monroe, Washington, Morgan, Athens, and Gallia, as well as in Wood, Ritchie, Gilmer, Calhoun, and more southern counties of West Virginia. Farther north the only occurrence of red is in Wetzel, where 5 feet are on the Pittsburg coal bed. The greatest thickness is in Calhoun, Mason, Wood, and Ritchie of West Virginia, where the mass beginning at or below the place of the Pittsburg is at times more than 100 feet thick.

A widespread deposit is in Ohio at 18 to 46 feet above the Upper Sewickley and varies from 52 to 14 feet in thickness. It appears in many sections from southern Guernsey through Monroe, Morgan, Washington, and Meigs, and it is thicker in Tyler, Ritchie, and Wood counties of West Virginia. For convenience of reference, this may be designated as the Tyler reds. Another deposit, equally well marked, underlies the Uniontown coal bed or its place and is reported from southern Marshall, Marion, Wetzel, Doddridge, Tyler, Ritchie, Jackson, southwest Harrison, and northeast Gilmer of West Virginia, as well as in Washington, Monroe, Meigs, and Guernsey of Ohio. Its place is concealed in most of the published sections from Ohio. It is rather thin in that state, seldom more than 20 feet, but in Ritchie, Gilmer, and elsewhere in West Virginia it is very thick and at times continuous with the Tyler reds below. Reds occur at this horizon in counties south from those mentioned, but they are not differentiated in the records. This mass, which may be termed the Ritchie reds, has much greater extent than the Washington reds of the Conemaugh, but much less than the Pittsburg reds. The chief area of reds is in Wood and Ritchie of West Virginia, where there is hardly a foot of the Monongahela section which is not occupied in some well or other by red shale.

The variation in thickness of the Monongahela—that is, of the interval between the Pittsburg and Waynesburg coal beds—is greater than that of the Conemaugh, the interval between the Upper Freeport and Pittsburg beds. The variations in these two formations do not coincide geographically. The greatest thickness of the Conemaugh is in Allegheny county of Pennsylvania, at the most northerly exposures of the Pittsburg, and that thickness decreases very slowly southward, losing barely 50 feet by the time the southern line of the state has been reached. Eastwardly the decrease is small, the interval being practically as large in Maryland as in southern Pennsylvania. Along the eastern border

in West Virginia the change is slight, but the decrease is notable toward the west, for in Ohio the interval becomes little more than half that north from Pittsburg.

In the Monongahela the greatest thickness, somewhat more than 400 feet, is in Marion and northern Harrison of West Virginia. Northwardly this decreases gradually, until in northern Washington of Pennsylvania it is but 166 feet at least 20 miles south from the line of the last exposure in Allegheny county. There is a similar decrease eastwardly, for it quickly becomes 350 feet, while in Maryland it is barely 250 feet. Westwardly the decrease is slow for 25 or 30 miles, but thence more rapid, so that in Ohio the interval is barely 240 feet. In that state there is a decrease northwardly, and at the last exposure in Jefferson county it is but 140 feet, this locality being northwest from the last measurement in Pennsylvania. Toward the south, southeast, and southwest the story is the same. The area of deepest deposit is in southern Greene and Fayette of Pennsylvania, Monongalia, Marion, eastern Wetzel, northern Harrison, Doddridge, and eastern Tyler of West Virginia.

EAST FROM THE ALLEGHENIES

Broad Top.—Fifty years ago Professor J. P. Lesley recognized the Pittsburg coal bed in the Broad Top area of Bedford county, where it remains in a tract of somewhat more than a square mile. Stevenson says that it is reported 5 feet thick, but the coal has never been utilized and the thickness as given is probably excessive. A limestone 12 feet thick is at 200 feet above the coal, and at somewhat less than 275 feet is another coal bed, belonging probably in the Dunkard formation.*

Maryland.—Some small areas of great commercial importance remain in Allegany and Garrett counties of Maryland, showing the full section; others in Mineral county of West Virginia are very small and retain only the lower part of the formation. The rocks throughout are tender and disintegrate readily, while the sandstones are rarely thick enough to affect the topography, so that sections in detail are obtained only in shafts or borings. Messrs O'Harra and Martin give this succession from a shaft near Frostburg, in Allegany county:

	Feet	Inches
1. Koontz [Waynesburg] coal bed	1	10
2. Concealed	20	0
3. Waynesburg limestone	5	7
4. Sandstone and shale	31	3
5. Uniontown coal bed	0	5
6. Sandstone and shale	57	10

* J. J. Stevenson: Bedford and Fulton counties (T 2), pp. 59, 60, 249.

	Feet	Inches
7. Sewickley [Tyson] coal bed	5	6
8. Shale and some sandstone	46	0
9. Coal bed [Redstone]	2	6
10. Shale, sandstone, and shale	28	4
11. Limestone	5	6
12. Shale	7	8
13. [Pittsburg] coal bed	40	4

	Feet	Inches
Coal and shale	7	4
Shale	19	11
Coal and shale	3	7
Main coal	9	6

The Waynesburg or Koontz bed is 8 feet 5 inches at Koontz, in Garrett, and 6 feet at Lonaconing, in Allegany. As at the west, it is triple to quadruple, with, at one locality, broad clay veins. It is from 90 to 115 feet above the Sewickley or Tyson coal bed. The thin streak referred to the Uniontown coal bed was observed only in this shaft, its place being concealed elsewhere. The Sewickley is an important coal bed, single, double, or even more divided, with at times nearly 5 feet of coal and thicker toward the southern end of the area. The coal bed, Number 9, thought by the Maryland geologists to be possibly the Lower Sewickley seems rather to be the Redstone. The assignment of the lower part of the section to the Pittsburg horizon is in accord with Doctor White's original suggestion respecting the section in Mineral county of West Virginia and it is rendered the more probable by conditions farther west. The following measurements show the variations in the bed:

	Feet	Inches	Feet	Inches
Coal and shale	7	4	8	3
Shale	19	11	22	6
Coal and shale	3	7	12	6
Coal	9	6		
Total	40	4	43	3
Coal	4	6	2	0
Shale	2	0	6	0
Coal	1	0	9	6
Shale	4	9	16	0
Coal	0	10	4	6
Shale and S. S.	6	11	18	0
Coal	14	0	7	0
Total	34	0	63	0

The measurements are from the Consolidated shaft, the Borden shaft, Lonaconing and Mineral county of West Virginia, arranged in the order from north to south. At Lonaconing one finds about 20 feet of coal in a total of 34 feet; at the Borden shaft the carbonaceous matter is distributed throughout 22 feet of black shale between the highest portion and the Main coal. The lowest division is known throughout as the "Big vein." The interval from the Waynesburg to the Pittsburg as here described is 205 to 211 feet.*

WEST FROM THE ALLEGHENY MOUNTAINS, IN PENNSYLVANIA

The First and Second bituminous basins.—A small area of Monongahela, known as the Salisbury basin, remains within the First basin in Somerset county at about 50 miles southwest from Broad top and 20 miles northwest from Cumberland, in Maryland. It embraces about 20 square miles and extends from near Meyersdale southward almost to the Maryland line. Its great coal bed was identified with the Pittsburg by Professor J. P. Lesley in 1839. The area was examined in 1876 by F. and W. G. Platt and J. J. Stevenson, who, while agreeing as to the measurements, by no means agreed respecting the relations of the beds.† The section at the north end of the area, as given by the Messrs Platt, is:

	Feet
1. Coal bed, Uniontown	2
2. Clay	1 to 6
3. Limestone	10
4. Slates	42
5. Black slate	3
6. Coal bed	1
7. Clay	1
8. Black slate	15
9. Coal bed	Blossom
10. Limestone	5
11. Concealed	52
12. Coal bed. Redstone	Blossom
13. Concealed	15
14. Black shale	10
15. Pittsburg coal bed	10

This section is distinct for three miles southwardly to near Salisbury,

* P. T. Tyson: Second rept. Agric. Chemist, 1862, pp. 46, 47.
C. C. O'Harra: Allegany county, pp. 125, 126, 127, 177, 180.
G. C. Martin: Garrett county, pp. 141, 142.
I. C. White: U. S. Geol. Survey Bulletin, no. 65, pp. 56, 63.

† But Stevenson in his report on the Fayette and Westmoreland district accepted the conclusions of his colleagues, as they had been adopted by the Director of the Survey.

beyond which the sudden southward rise of the measures and decrease in height of the hills prevent direct tracing of the higher beds. To increase the difficulty, the continuity is broken by a broad valley, cut down to the Pittsburg coal bed, whose decayed outcrop is on the surface.

The highest coal bed is double, 2 feet 2 inches at the most northerly exposure and 2 feet 9 inches at 2½ miles from Meyersdale. The underlying limestone, 152 to 160 feet above the Pittsburg coal bed, the 160-foot limestone of the Platts, is 10 to 12 feet thick and continuous at the northern exposure, but at the most southerly exposure of the full section it is divided, with 2 feet of coal above the middle. It is quarried at several places and always yields lime of great purity. The limestone, No. 10, from 72 to 87 feet above the Pittsburg, the 90-foot limestone of the Platts, is 5 feet thick at the northern exposure, but increases to 10 feet at 2 miles northwest from Salisbury. It has been opened at a few places, but it is very impure everywhere, contrasting in this respect with the upper limestone.

The "Redstone," or 44-foot coal of the Platts, is 25 feet above the Pittsburg in one section and 35 feet above that bed in three other sections, of which the most southerly is about 3 miles southwest from Meyersdale. The material filling the interval in these sections is the same throughout—sandstone, 15 feet; black shale, 20 feet. The compiled section for Salisbury given in the Somerset County report is erroneous, as it shows a limestone below the "Redstone," which, as may be seen by reference to the text, does not exist there—or, as for that matter anywhere else. There is no coal between the Pittsburg and the "Redstone," and the latter coal at the last exposure of the typical section shows:

	Feet	Inches
Coal	2	0
Parting	—	—
Coal	1	3
Clay	0	1
Coal	1	3

but at half a mile away it is 5 feet 6 inches thick, with the bottom bench 4 feet. Here one reaches the broad deep valley, beyond which the section is:

	Feet	Inches
Limestone	Not measured	
Interval	65	0
Coal bed	4	6
Black shale	11	0
Pittsburg coal bed	Not measured	

but at a mile west from Salisbury this limestone is only 55 feet above the coal bed, which is 13 and at another exposure 18 feet above the Pittsburg. The coal bed is triple, 6 feet 1 inch thick and with the thick bottom bench seen at the last exposure of the "Redstone." Black shale seems to fill the interval to the Pittsburg. No trace of coal appears at 35 to 40 feet above the Pittsburg, nor is any coal found at that horizon anywhere south from a line passing east and west at 3½ miles southwest from Meyersdale. The coal bed, 11 to 18 feet above the Pittsburg, is evidently the "Redstone" and the decreased interval is due to disappearance of the sandstone. Followed southward, this bed, termed the "rider" in the Somerset county report, constantly approaches the Pittsburg, the interval becoming 6, 4, and 1 foot. Very near the southern end of the area, Mr W. G. Platt measured:

	Feet
1. Concealed	15
2. Ferruginous sandstone	9
3. Concealed	11
4. Coal bed	Blossom
5. Clay	6
6. Limestone	10
7. Concealed	12
8. Coal bed	4
9. Slate	4
10. Pittsburg coal bed	10

and the coal bed, Number 4, exposed near by, is very like the "Uniontown" of the northern section. It is taken to be the "Redstone" in the Somerset County report. The underlying limestone is almost exactly the same in composition with the 160-foot limestone at the north, the variation being barely one per cent in any constituent. It disappears quickly southward and the Ferruginous sandstone is very near the Pittsburg at the most southern exposure.

Stevenson's conclusion was that this limestone at the southern end is the 160-foot limestone of the northern end; that the coal overlying it is the "Uniontown," and that the "rider" of the southern is the "Redstone" of the northern portion. He regarded all the higher beds as splits from the Pittsburg, but he was unable to correlate them with beds farther west.

The Pittsburg coal bed shows unusually abrupt variations in structure and quality. At the north it is divided into many benches and the section at one pit cannot be duplicated at another. Southward from Salisbury it is apparently solid coal in the 8 feet above, but the foreign mat-

ter seems to be distributed throughout so as to increase the ash. The thickness varies from 8 feet 6 inches to 9 feet.*

Some small patches remain within the Second basin north from Ligonier, in Westmoreland county, at about 40 miles northwest from the Salisbury basin. The measurements are:

	Feet	Inches
1. Limestone	6	0
2. Concealed and thin limestones	111	0
3. Coal or coaly shale	0	6
4. Clay	3	0
5. Limestone	8	0
6. Shale and sandstone	28	0
7. Clay	2	0
8. Limestone	4 to 10	0
9. Coal bed	2	9
10. Shale	17 to 37	0
11. Pittsburg coal bed	8	0

It is difficult—indeed, impossible—to make positive correlation of the beds above the Pittsburg. The interval, Number 10, decreases northward, the measurements being 3 miles apart. This locality is far north for Monongahela and, compared with the Blairsville-Connellsville basin a few miles west, the limestone is in great excess. It is quite possible that the highest limestone belongs within the Dunkard. The Pittsburg shows traces of a roof division, apparently wanting in the Salisbury basin, there being on top at most of the pits from 8 to 12 inches of coal and slate interleaved. The main coal is usually 8 feet thick and is in five benches, in which the character of the coal differs. The "bottom," about 8 inches, is very poor, but the second, 2 feet thick, is very good; the third, ordinarily less than 1 foot, is broken by many binders of clay and mineral charcoal; the fourth, about 2 feet, is prismatic, tender, and very pure, while the top bench is hard coal, often containing some cannel.†

The Blairsville-Connellsville basin.—This following the westerly foot of Chestnut ridge, the last great fold of the Appalachian in Pennsylvania, may be regarded as practically continuous from the Kiskiminetis river at the north across Fayette and Westmoreland counties to within a few miles of the West Virginia line at the south. The section rarely extends much above the Waynesburg coal bed, the rocks yield readily to

* F. & W. G. Platt: Somerset county (H 3), pp. 78, 83, 85, 86, 89, 93, 94, pl. vi, figs. 29, 30, 31, 32, 33, 39.
J. J. Stevenson: Fayette and Westmoreland (K 2), pp. 40, 41, 53, 54.

† J. J. Stevenson: Fayette and Westmoreland, pt. II (K 3), pp. 14, 152, 153, 167, 168, 169.

the weather, and the surface for the most part is gently rolling, so that natural exposures are comparatively rare.

On the Pennsylvania railroad, about 8 miles south from the Kiskiminetis river, some cuts give opportunity for approximate measurement; two imperfect sections were obtained, one at a mile and a half, the other at 5½ miles north from the railroad, and Mr Platt gives a measurement in Indiana county at a short distance north from the river. These may be compared.

	Feet	Inches	Feet	Feet	Inches	Feet
1. Sandstone				Not measured		Not measured
2. Coal bed				Blossom		Blossom
3. Sandy shale				15	0	15
4. Limestone				5	0	Fragments
5. Interval						
6. Coal bed			Blossom			
7. Shales	30	0	30	75	0	60
8. Limestone	1	6	Fragments			
9. Clay, concealed, and sandstone	40	0				
10. Coal	0	8		Blossom		Blossom
11. Shale	7	0	70	5	0	
12. Coal	0	10				
13. Limestone	1	6		1	6	
14. Shales	35	0				44
15. Coal bed	0	8	Blossom			
16. Clay, calcareous shale	4	6	50	60	0	
17. Interval	80	0				
18. Pittsburg coal	9	0	Blossom	Blossom		7

There is an error in the first measurement, and the interval from Number 8 to the Pittsburg is 161 feet; in the second it is 120; in the third the Lower Sewickley coal bed is but 66, and in the fourth only 44 feet above the Pittsburg. The highest coal bed, shown nowhere in the vicinity of the first two measurements, underlies a massive sandstone and seems to be at the Waynesburg horizon; so that the Monongahela appears to lose about 100 feet of thickness in 10 miles. This is in accord with conditions farther west along the northern outcrop.

Six miles south from the Pennsylvania railroad the interval, Waynesburg to Pittsburg, by barometer without regard to the dip, is 280 feet. The higher coal bed is triple, 4 feet thick, with 3 feet of worthless coal, and is separated by 25 feet of sandy shale from the Waynesburg limestone below. The Benwood limestone, practically absent on the railroad, is thick at 8 miles south, where it is 25 feet above the Lower Sewickley, which is about 4 feet thick. The Redstone horizon shows only black

shale. The roof division of the Pittsburg, rarely thicker than 3 inches north from the railroad, increases southwardly to 6 inches and 1 foot, and at 4 miles the bed shows:

Roof, 3-4 feet 4 inches; clay 1 to 18 inches; Main coal, 7 feet 9 inches,

the roof consisting of coal and clay interleaved. Eight miles farther south, near Mount Pleasant, the Waynesburg, underlying its sandstone, is 5 feet thick and 66 feet above the Uniontown coal bed. Here one sees the Little Waynesburg coal bed; the Waynesburg, Uniontown, and Benwood limestones are present and thick, the last two being separated by 30 feet of sandstone. The Lower Sewickley coal bed, underlying the Sewickley sandstone, is only 18 inches thick and 40 feet above the Redstone, which shows 2 to 4 feet of coal and is somewhat more than 80 feet above the Pittsburg.*

There are few exposures above the Pittsburg in northern Fayette county and erosion by tributaries of Jacobs creek and Youghiogheny river has removed much of the Monongahela. The conditions south from the Youghiogheny are little better, but records of shafts and borings are numerous and show notable variation in the lower part of the section, quite like those of the Potomac areas and the Salisbury basin.

The Waynesburg coal bed is exposed near Mount Braddock, about 6 miles from the river, where it is 4 feet thick and 71 feet 6 inches above the Uniontown coal bed, as measured in a boring there. Four miles farther south the interval is 77 feet. The Little Waynesburg is present at both localities, 31 and 25 feet below the Waynesburg and resting on the Waynesburg limestone. The Waynesburg and Uniontown limestones are persistent, though thin, to the last exposure of their horizons, and in the southern part of the basin the Uniontown coal bed underlies an impure limestone containing many small lamellibranchiates of undetermined relations. The lower part of the column is shown in the Leisenring shaft, 3 or 4 miles south from Connellsville, an exposed section at 3 miles southeast from Connellsville, and at the Leith shaft, 12 miles south. The measurements are:

	Feet	Inches	Feet	Inches	Feet	Inches
1. Limestone	29	0			25	9
2. Shale	3	0	52	0	21	3
3. Limestone	26	0			22	6
4. Shale or clay	5	0	15	0	9	6
5. Upper Sewickley coal bed	2	3	3	0	5	3
6. Sewickley sandstone or shale	30	0	25	0	0	0

* J. J. Stevenson: (K 2), pp. 266, 267, 271, 272, 273, 274, 279, 281, 283, 284. W. G. Platt: Indiana county (H 4), p. 157.

	Feet	Inches	Feet	Inches	Feet	Inches
7. Lower Sewickley coal bed	0	6	0	10	0	0
8. Fishpot limestone and clay	7	6	11	0	28	6
9. Shale and black shale	8	0	20	0	39	0
10. Redstone coal bed	2	0	4	0	5	11
11. Redstone limestone	14	0	5	0	13	9
12. Slates	24	0	25	0	24	0
13. Pittsburg coal bed						
Coal	0	2	1	0	1	0
Slate	31	0				
Coal	1	0	50	0	27	6
Slate	21	0				
Coal and slate	5	0	5	0	12	6
Main coal	10	0	10	0	10	0

Thus giving for the Pittsburg horizon the thickness of 68, 66, and 51 feet, decreasing southwardly.

Both of the Sewickley beds are present near the Youghiogheny and are separated by the Sewickley sandstone; but the sandstone disappears southwardly, and at Uniontown as well as at Leith there is only one bed, and that at the place of the Upper, while the Fishpot limestone has made a notable increase. The interval from the Benwood limestone to the Redstone coal bed shows a great increase southwardly, but that from the Redstone to the Pittsburg, as here defined, shows little change, only 3 inches. The interval from the Redstone coal bed to the main division of the Pittsburg decreases from 96 feet at Leisenring to 78 at Leith. The condition shown in the lower part of the section prevails certainly to some distance north from the Youghiogheny river, for at Connellsville a "rider" coal, one foot thick, is at 14 feet above the roof division. The decrease is slow in the northerly direction, for at Mount Pleasant, in southern Westmoreland, the Redstone is still a little more than 80 feet above the main division of the Pittsburg; but the decrease southwardly is rapid, for on the National road, at two miles southeast from Leith, the Redstone and Sewickley are 50 and 90 feet above the Pittsburg, both Redstone and Fishpot limestones being present. Six or 8 miles south from Leith the normal condition of the Pittsburg is found and a complete measurement along the road shows:

	Feet
Waynesburg coal bed	316
Uniontown coal bed	241
Lower Sewickley coal bed	80
Redstone coal bed	30

feet above the Pittsburg, with the Waynesburg, Uniontown, Fishpot, and Redstone limestones all present and the Sewickley sandstone over-

lies its coal bed. The Benwood is represented by several thin beds. Farther south the Lower Sewickley becomes variable, 1 to 5 feet, the Redstone coal is but one foot 6 inches and its limestone disappears.*

The Greensburg basin.—This is a canoe within central Westmoreland in which the Monongahela passes out southwardly at a few miles south from the Pennsylvania railroad. The strong Blairsville and Saltsburg anticlines separate it from basins at the east and west. It retains two small but important areas of Monongahela. The section reaches to fully 400 feet above the Pittsburg coal bed, but the shales and limestones break up under the weather so readily that there are no natural exposures. Long, deep cuts on the railroad east and west from Greensburg give this section:

	Feet	Inches
1. Limestone	2	6
2. Shale and limestone	119	0
3. Shale	40	0
4. Coal bed	3	4
5. Shale and flaggy sandstone	48	0
6. Limestone and shale	26	0
7. Shale	48	0
8. Pittsburg coal bed:		

	Feet	Inches	Feet	Inches
Coal and shale	2	6 to	5	4
Shale	9	0 to	18	0
Clay and coal, roof	0	3 to	5	8
Clay	0	6 to	3	0
Coal	6	6 to	7	8

The main division of the Pittsburg shows comparatively little variation on the west side, being usually 8 feet, but the changes in the roof are abrupt. The little coal above at the top of the horizon is thoroughly persistent, its blossom having been observed at many places within the basin. There seems to be no trace of the Redstone, for its place is well exposed. The coal bed, Number 4, is equally persistent, but is fully shown only along the railroad, where it is a double bed with from 16 to 30 inches of coal. It may be at the Upper Sewickley horizon, but its place is uncertain. Limestone is present in large proportion and in this respect the section differs greatly from that at a few miles east in the Blairsville-Connellsville and west in the Lisbon Irwin basin.†

The Lisbon-Irwin basin.—This lies west from the Saltsburg-Fayette anticline and extends westwardly to the Waynesburg fold. A small area

* J. J. Stevenson: (K 2), pp. 134, 135, 136, 144, 146, 147, 153, 154, 155, 156, 179, 180, 191. The writer is under obligation to Messrs W. Beeson, A. D. Ewing, and J. V. Thompson of Uniontown, Pennsylvania, for records of shafts and borings.

† J. J. Stevenson: (K 2), 272, 298, 299, 300.

of Monongahela, known as Elders ridge, and north from the Kiskiminetis river along the Armstrong-Indiana border, was studied by Mr W. G. Platt and, 25 years later, by Mr R. W. Stone. Another small area remains in Westmoreland at 1 mile and the continuous body is reached at 7 miles south from the Kiskiminetis. The first clear section is at the Youghiogheny shaft near Irwin, 20 miles south from Elders ridge; at somewhat more than 4 miles north is a boring, and at 4 miles farther north is another, very near the end of the continuous area. These may be compared as follows:

	Feet	Inches	Feet	Inches	Feet	Inches
1. Uniontown coal bed.....	3	0	0	11	0	5
2. Shale, limestone, sandstone.	106	0	72	7	50	8
3. Coal bed	1 to 3	0	4	9	1	3
4. Shale, limestone, sandstone.	50	0	67	6	70	0
5. Pittsburg coal bed.....	11	2	15	6	Not measured	

Along the Pennsylvania railroad the Uniontown coal bed is about 160 feet above the Pittsburg and is above its limestone. In the first section it is about 60 feet below the Waynesburg, which is exposed on the hillside and about 3 feet thick. The Benwood limestone is 15 feet thick and 35 feet below the Uniontown limestone, so that it represents the upper part of the mass. A hard sandstone, 25 feet thick, rests on the middle coal bed along the railroad, while at 8 to 11 feet below that coal is a limestone; this condition suggests reference of the coal bed to the Lower Sewickley. The interval from the Uniontown to the Pittsburg decreases northwardly, being 158, 145, and 122 feet in the measurements given, while one intermediate between the last two shows 131. The coal beds of the section are present in Elders ridge, where they are 98 and 35 feet above the Pittsburg. An intermediate observation shows the lower bed at 65 feet above the Pittsburg, marking the renewed decrease in that direction. No higher coal is recorded in northern Westmoreland, where a record gives the overlying beds for 85 feet; the highest is a limestone, 7 feet 6 inches, evidently the same with that seen in Elders ridge at 83 feet above the Uniontown. The Fishpot and Uniontown limestones disappear northwardly, only the Benwood persisting in Elders ridge.

The Pittsburg retains its complex structure along the Pennsylvania railroad, where one often finds the "rider" coal of this, as in the Greensburg basin. In the Youghiogheny shaft this little coal is distributed in fragments throughout 2 feet of sandstone. The roof division is as variable here as elsewhere; at one pit it is 7 feet 4 inches thick, in nine layers, with, in all, 3 feet 5 inches of coal, but in another less than a

mile away it is 2 feet 1 inch thick and with but 2 inches of slate. The main division is very uniform, though often cut out badly by descent of the sandstone roof, and so sometimes distorted by clay-veins.

Southwestwardly the limestones increase as rapidly as in the Blairsville basin, for within a few miles the Benwood limestone is about 80 feet thick, with, directly under it, a richly carbonaceous shale representing the Upper Sewickley. The Waynesburg coal bed is shown farther south, near the Youghiogheny, thick and 25 feet above 7 feet of Waynesburg limestone. The Benwood is 65 and the Fishpot is 20 feet thick on the Youghiogheny. The Upper Sewickley coal bed, directly under the Benwood, is 5 inches thick and separated by the thinly bedded Sewickley sandstone from the limestone below. The Redstone coal bed is 60 feet above the Pittsburg and its ferruginous limestone is 6 feet thick. Between the Youghiogheny and the Monongahela an imperfect measurement gave 260 feet as the interval from Waynesburg to Pittsburg. The Waynesburg, Uniontown, and Upper Sewickley are all very thin, but the Redstone is often 3 feet. The last bed is much cut by clay veins, which bear no relation to disturbances in coal beds above or below. Such clay veins are characteristic of the Redstone and explain its absence from many records and sections. In this space between the rivers the Fishpot and Redstone limestones become very irregular at and in many places are represented only by nodules.*

Passing over into Fayette county, one finds the intervals increasing rapidly, though showing some irregularity. Between the Youghiogheny and the Monongahela, all members of the section except the Lower Sewickley coal bed are exposed frequently. The Waynesburg coal bed is sometimes 4 feet thick, the Upper Sewickley is from 3 inches to 30 inches thick, and the Redstone 3 to 4 feet, but the Little Waynesburg and the Uniontown are very thin. The limestones are important, the Benwood occasionally becoming 90 and the Fishpot 35 feet thick. The interval from Waynesburg to Pittsburg is 330 feet in Franklin township, where the Upper Sewickley is 118 feet above the latter bed. The Redstone coal bed is 25 to 40 feet above the Pittsburg and the Redstone limestone is somewhat indefinite. Near Brownsville, on the Monongahela, the Waynesburg is 345 to 360 feet above the Pittsburg and the Upper Sewickley is only 6 inches thick. In this direction the Benwood limestone becomes broken by a sandstone which at Brownsville is 20 feet thick.

* J. J. Stevenson: (K 2), pp. 329, 335, 336, 339, 351, 352, 353, 361, 362, 363, 364. R. W. Stone: U. S. Geol. Survey folios, Elders ridge, p. 6.

Important mining operations in German and Redstone townships have led to making many shafts and borings, which exhibit conditions unsuspected from the surface exposures. Four of these from a small area may be compared.

I, Brier Hill shaft; II, Hibbs farm boring; III, Edenton shaft; IV, Lambert shaft.

	I	II	III	IV
	Feet	Feet	Feet	Feet
1. Waynesburg coal	5.3	7	6	8
2. Sandstone fireclay	14		23	33
3. Little Waynesburg coal...	3.5		4	0.2
4. Waynesburg limestone....	10.6		3	31
5. Interval	47.5	69	55	4
6. Uniontown coal bed.....	4.2		2	2
7. Interval	7.8		28	2
8. Uniontown limestone	8.8	8		
9. Interval	7.9	23	120	159
10. Benwood limestone	121.2	136		
11. Interval	2.3	2	5	0
12. Upper Sewickley coal.....	3.4	1	0.8	Trace
13. Sandstone, shale	36.1	28	38	27
14. Lower Sewickley coal.....	0.0	..	..	2
15. Interval	0.0	..	..	3
16. Fishpot limestone.....	24.3	18	21	18
17. Interval	21.4		19	21
18. Redstone coal	0.0		1	1
19. Interval	0.0	51	3	0
20. Redstone limestone	16.0		12	15
21. Interval	0.0			23
22. Pittsburg coal	..	..		
Coal and shale.....	7.8	3	45	2.6
Shale, fireclay, black shale	23.7	22		20.6
Main coal	7.0	7	7	7

The interval from Waynesburg to Pittsburg varies between 360 and 380 feet. The Benwood and Uniontown limestones are continuous in the Lambert shaft, where the mass contains only 3 feet of sandstone, and they are almost continuous in the Brier Hill, where, however, there is a much greater amount of shale and sandstone. The Redstone and Fishpot limestones retain their importance. The interesting feature is the wide separation of the parts of the Pittsburg coal bed, recalling conditions already observed in the Potomac, Salisbury, and Connellsville areas. The intervening 22 feet in the Hibbs boring is filled with carbonaceous shale, but in the other records a thin sandstone is reported. The interval from the Upper Sewickley to the Pittsburg main coal is from 139 to 112 feet, and the Sewickley sandstone is sometimes only a

sandy shale. Farther south, in German township, the interval is only 104 feet and the top part of the Pittsburg is represented by 8 feet of black shale, with 2 inches of coal in the lower part at 8 feet above the roof division. There also the Waynesburg coal is 102 feet above the Uniontown and 42 feet above the Waynesburg limestone. The Waynesburg coal bed, in numerous layers, is 7 feet 2 inches thick, but the Little Waynesburg and the Uniontown are thin, only 30 inches each. Still farther south the Sewickley sandstone decreases and the interval between Upper Sewickley coal bed and the Fishpot limestone diminishes, until near the last exposure the coal and limestone are almost in contact, the former at only 64 feet above the Pittsburg. There one is on the extreme eastern edge of the basin, practically on top of the fold. The Sewickley and Redstone coal beds are 5 and 4 feet respectively, the latter separated from the Pittsburg by 25 feet of sandstone; but the Fishpot limestone is still important, being 10 feet thick.

On the opposite side of the Monongahela, in Greene county, one is on the west side of the basin and there is less variation in the section. At about 12 miles north from the West Virginia line the Waynesburg is 90 to 95 feet above the Uniontown, which is double, its benches separated by 10 feet of sandstone. The Benwood limestone, resting on the Upper Sewickley, is 76 feet thick and separated by 30 feet of sandstone from the Uniontown limestone above. The Sewickley sandstone is 40 feet thick and the Waynesburg coal bed is 370 feet above the Pittsburg. Southward the section changes little, except that the Benwood limestone becomes thinner, its lower portion is replaced by sandstone, and the interval from Upper Sewickley to the Fishpot diminishes. The Redstone coal bed, 36 to 54 feet above the Pittsburg, is almost invariably accompanied by its limestone. The interval between Waynesburg and Pittsburg is 390 feet at the last complete exposure near the West Virginia line.*

The Waynesburg basin.—In this basin, between the Waynesburg and Bradys Bend (Washington) anticlines, detached areas remain in Allegheny county north from the Monongahela river, but beyond that stream the area is continuous southwestwardly into West Virginia.

In southern Plum township of Allegheny, about 10 miles west from the most northerly bore-hole in Westmoreland county, the hills rise to nearly 200 feet above the Pittsburg coal bed, but show nothing, aside from shales and sandstones, except a limestone, 8 to 10 feet thick and 70 feet above the coal. This may be some portion of the Benwood. Four

* J. J. Stevenson: Greene and Washington (K), pp. 92, 94, 97, 98, 116, 118, 123, 134, 135; (K 2), pp. 204, 207, 208, 209, 210, 213, 215, 216, 233, 238, 239, 240, 241, 250.

miles southward a limestone 5 to 7 feet thick was seen 150 feet above the coal, and at 2 miles farther south it is 170 feet. It yields a dark but very strong lime and underlies a flaggy sandstone. Stevenson took it to be the Waynesburg limestone, but it is more likely to be the Uniontown, as the other does not extend so far north, and the overlying sandstone may be the Waynesburg in the Dunkard formation. Sandstone or sandy shale overlies the Pittsburg coal and extends upward 40 feet to a black shale holding some coal. No other exposure was seen and the Benwood limestone if present must be very thin; but that limestone is not less than 60 feet thick at 10 miles farther south, where the Waynesburg coal bed is 250 feet above the Pittsburg. At 8 miles west from the Monongahela river, in Snowden township, the Waynesburg coal bed, resting on the yellow Uniontown limestone, is 250 feet above the Pittsburg and the Benwood limestone, in many layers separated by shale, is 70 feet thick.*

Passing over into Union township of Washington county, one finds the intervals increasing, for at 6 or 7 miles from the last locality the Waynesburg coal bed is 55 to 60 feet above the Uniontown and the Waynesburg limestone is not present. The Benwood limestone, 60 feet thick, is very largely calcareous shale and the Fishpot seems to be wanting, but the Redstone makes its appearance, one foot thick and 6 feet below its coal bed, which is 50 feet above the Pittsburg. Sandstone fills the interval below the limestone. Three miles farther southwest the Fishpot is seen, 5 feet thick, and the Lower Sewickley horizon is marked by 2 feet of black shale separated by 35 feet of Sewickley sandstone from the Benwood limestone, of which 50 feet were seen. The Redstone limestone has increased to 3 feet. The Waynesburg coal bed is 50 to 55 feet above the Uniontown, which is almost in contact with its yellow limestone, 15 feet thick. Nine miles west, in Peters township, the Waynesburg is 175 feet above the Redstone, or barely 225 feet above the Pittsburg. The Uniontown coal bed is persistent in this region and seems to be about 3 feet thick, though not often yielding good coal. The Redstone coal bed is from 3 to 4 feet thick and sometimes has a limestone roof and floor. Southwardly the section shows comparatively little change, except in increasing intervals and in the appearance of the Waynesburg limestone. The Little Waynesburg coal bed is apparently wanting and the Sewickley horizons show coal only occasionally. Combining measurements by Doctor White one has:

* J. J. Stevenson: (K), p. 303; (K 2), pp. 375, 385, 388, 390.

	Feet	Feet
1. Waynesburg coal bed	5 to	8
2. Interval		30
3. Waynesburg limestone		Thin
4. Interval		66
5. Uniontown coal bed		3
6. Uniontown limestone	8 to	12
7. Shale and sandstone		28
8. Benwood limestone		80
9. Shale		5
10. Upper Sewickley coal bed	2 to	3
11. Sewickley sandstone	35 to	40
12. Fishpot limestone	25 to	30
13. Shale		25
14. Redstone coal bed		2
15. Pittsburg sandstone		40
16. Pittsburg coal bed	7 to	8

and near the Greene County border the Waynesburg is 362 feet above the Pittsburg.

In Morgan and Jefferson townships of Greene county the Waynesburg is triple to quadruple, varying in thickness from 6 to 12 feet, with from 4 to 7 feet of rather inferior coal, and is nearly 40 feet above its limestone, 6 to 8 feet thick. The Uniontown coal bed becomes irregular and is almost directly in contact with its limestone. About 40 feet of sandstone separate the latter from the Benwood, which, including much calcareous shale, is about 80 feet thick. The Sewickley sandstone and Fishpot limestone retain their importance, but the Redstone coal and limestone become indefinite. Farther southwest the Monongahela quickly passes under cover and the information from oil records is very imperfect. A record near the West Virginia line reported by Doctor White gives 345 feet as the interval between Waynesburg and Pittsburg, with a trace of the Upper Sewickley at 95 feet above the latter bed.*

The Western basins in Pennsylvania.—Petty areas of the Pittsburg coal bed, widely separated, remain in Allegheny county north from the Ohio river. The cover rarely exceeds 30 feet and is the massive Pittsburg sandstone. Even near Butler County line the bed retains its characteristic structure, showing:

	Feet	Inches		Feet	Inches
Coal and shale	3	3	to	6	6
Clay	1	2	to	1	4
Main coal	4	10	to	5	5

* J. J. Stevenson: (K), pp. 136, 140, 141, 143, 210, 211, 212, 221, 222, 223, 224, 225, 227, 228, 303.

I. C. White: (K), pp. 180, 201, 203, 215. Geology of West Virginia, vol. Ia, p. 122.

An imperfect section south from the Ohio, about one mile from Pittsburg, notes a coal blossom at 70 feet above the Pittsburg coal bed and underlying one foot of ferruginous limestone. Sandstone and shale fill the well exposed interval to the Pittsburg, and there is no other limestone in 140 feet above the thin coal blossom. At about 8 miles south from Pittsburg and very near the line of Washington county, a section is:

	Feet	Inches
1. Limestone [Uniontown]	2	6
2. Shale, sandstone, concealed	49	0
3. Benwood limestone	40	0
4. Clay	1	0
5. Black shale [Upper Sewickley coal bed]	1	6
6. Shale, sandstone [Sewickley]	30	0
7. Black shale [Lower Sewickley coal bed]	1	0
8. Limestone, shale [Fishpot]	21	0
9. Shale	50	0
10. Pittsburg coal bed	11	8

At a mile north from this locality only sandstone and shale appear in 93 feet above the Pittsburg coal, so that the Benwood and Fishpot limestones enter the section abruptly. The thin limestone seen near Pittsburg at 70 feet above the Pittsburg evidently represents the Benwood, and its underlying coal is at the Upper Sewickley horizon. The highest limestone in this southern section, 193 feet above the Pittsburg, is probably the Uniontown and is very near the place of the Waynesburg coal bed. Ten miles northwest the Pittsburg coal bed is only 6 feet 3 inches in all and the Benwood limestone at 100 feet higher is 25 feet thick. The Fishpot at 60 and the Redstone at 30 feet above the Pittsburg are clearly present.

Crossing over into the northwest corner of Washington county, one finds a little area in which the Pittsburg coal bed is quite thin, 4 feet to 5 feet 2 inches, with nodular limestones representing the Redstone and Fishpot at 20 and 40 feet above it. The limestones are irregular north from the Pennsylvania railroad as well as in the northwest corner of the county. Limestones were seen on that railroad just west from the Allegheny line at 35 to 48, 60 to 73, and 130 to 143 feet above the Pittsburg, but they are irregular. At a mile south from the railroad the limestones appear abruptly, the thick Benwood is at 65 feet above the Pittsburg and 20 feet above the Lower Sewickley coal bed, while the Fishpot is 15 feet thick and 20 feet above the Pittsburg coal.

The section varies much in northern Washington and it must be followed in detail from the West Virginia line eastward across Jefferson,

Cross Creek, Mount Pleasant, Cecil, and Allen townships, a distance of about 25 miles.

At Eldersville, in the northern part of Jefferson, the measurement is:

	Feet
1. Washington coal bed	5
2. Interval	85
3. Limestone	1
4. Concealed	100
5. Sandstone	30
6. Pittsburg coal bed	5

The Washington coal bed, the great bed of the Dunkard formation, is 216 feet above the Pittsburg, and at 2 miles away it is 50 feet above the Waynesburg, making the interval from the latter bed to the Pittsburg only 166 feet. Three miles farther east, in western Smith township, the Uniontown limestone, bright yellow and thin, is 15 feet below the Waynesburg coal bed, but near Eldersville the coal and limestone are almost in contact. The Benwood is thin and in two layers, together not more than 10 feet. The Pittsburg coal, as in the more northerly townships, occasionally becomes block or even cannel. In northern Cross Creek, the Monongahela is buried under Dunkard, but in the southern part of that township the intervals are greater, for the Waynesburg is 90 feet below the Washington and 200 feet above the Pittsburg, the increase in the latter interval being in the upper part of the section, as the Waynesburg is now 50 feet above the Uniontown limestone, on which rests the Uniontown coal bed. No trace of the Waynesburg limestone is here. In the extreme southern part of the township the interval is 55 feet and the yellow Uniontown limestone is 8 feet thick.

An exposure in northwest Mount Pleasant shows the Waynesburg coal bed 3 feet thick and 20 feet above the Uniontown coal bed, which is separated by 2 feet of clay from its bright yellow limestone, 6 feet thick. At a little way farther north, in western Smith, the interval between the Waynesburg coal and the Uniontown limestone is but 15 feet. At Hickory, in Mount Pleasant, Doctor White made a direct measurement, giving the interval between Waynesburg and Pittsburg as 235 feet, showing that this interval increases southeastwardly as well as southwardly. In northern Cecil the Waynesburg is 210 feet above the Pittsburg only about 3 miles from the locality where the Uniontown limestone is 193 feet. There is no Waynesburg limestone anywhere along this line until one reaches the western part of Peters township, near the Monongahela river, where it is 12 feet below the coal bed.

In the next tier of townships southward exposures are very poor, as the soft calcareous rocks, there predominating, have yielded readily and the shaft records near Washington, 10 miles south from the Cecil line, are the only trustworthy sections. Near the Cecil line the Waynesburg is 230 feet above the Pittsburg, but at Washington a record shows that the interval has increased to 274 feet. There the Waynesburg is but 8 inches thick, and all of the other coal beds are wanting to the Pittsburg. A shaft north from Washington has 3 feet of coal at 21 feet above the Pittsburg and the Uniontown is present at 45 feet below the Waynesburg. The limestones are of noteworthy thickness. Near Washington the Fishpot is at 70 feet above the Pittsburg, and the Benwood is apparently continuous with the Uniontown and Waynesburg in one shalt, where 170 feet of limestone and shale are reported, beginning at 11 feet below the Waynesburg coal bed. The imperfect surface exposures show that the record is probably not incorrect. About midway in this mass salt water was found in a white limestone.

Westward the Monongahela is under deep cover for several miles until in Hopewell and Donegal townships one reaches the deep valleys of Brush run and Buffalo creek. There the Waynesburg is exposed, always very poor and, including the clay partings, varying from 2 feet 6 inches to almost 7 feet. The Waynesburg limestone makes its appearance on Brush run, where it is nodular and 25 feet below the coal; but farther south on Buffalo creek it is a solid bed 3 feet thick, with the Little Waynesburg at 13 feet above it. On these streams the Uniontown coal bed is 40 to 65 feet below the Waynesburg and practically rests on the right yellow Uniontown limestone, which is 12 feet thick at one place. In Independence township, north from Donegal along the West Virginia line, Cross creek cuts down to the Pittsburg coal bed. On that stream the Uniontown limestone is 96 feet below the Washington coal bed, 45 feet more than at Eldersville, 5 miles north. It is 6 feet thick and 15 feet above the Benwood limestone, of which 50 feet were seen. The Waynesburg and Uniontown coal beds are very thin, but the Pittsburg has increased southward in the interval from Eldersville, so that it is 8 feet.

Southward in Washington and Greene counties the Monongahela becomes buried more and more deeply under the Dunkard. Little information can be gleaned from well records, for they are mostly incomplete. Those which are available show that in Greene county the Waynesburg, one Sewickley, and the Pittsburg are the persistent coal beds. Two records in northern Greene give the interval from Waynesburg to Pitts-

burg as 302 to 306 feet; another, father east, shows 348, while along the West Virginia border the interval varies from 348 to 362 feet.*

THE NORTHERN PANHANDLE OF WEST VIRGINIA

Passing over into that portion of West Virginia which lies between the Pennsylvania line and the Ohio river, one finds the Pittsburg coal bed mined at Lazearsville on the Ohio river, in Brooke county, about 20 miles north from Wheeling and 5 miles south from Steubenville, Ohio, but it certainly extends in patches for several miles farther north. The full section must be present on Buffalo creek in this county, since at the Pennsylvania line the Pittsburg coal bed is below the bed of the stream. Farther south along the Ohio some sections are available in the vicinity of Wheeling. Two of them, one at Wheeling and the other between 3 and 5 miles east from that city, give:

	Feet	Inches	Feet	Inches
1. Sandstone	..	..	5	0
2. Limestone	..	..	0	10
3. Shale	..	..	2	0
4. Waynesburg coal bed	..	..	2 to 3	0
5. Clay, sandy shale	..	..	38	0
6. Uniontown coal bed	0	10	0	0
7. Shale, thin limestone on top	33	0	41	0
8. Alternating limestone and shale	115	0	103	0
9. Coal bed	1	2		
10. Fireclay, thin sandstone	6	4	3	0
11. Coal and shale	1	0		
12. Clay and sandstone	14	0	17	0
13. Coal and shale	1	8	3	6
14. Limestone and shale	24	0		
15. Coal and shale	1	0	56	0
16. Limestone and shale	20	0		
17. Shale	6	0	5	0
18. Pittsburg coal bed	7	11	6	8

The Waynesburg is identified clearly, the overlying limestone characterizes the Cassville shales of the Dunkard in much of western Washington county, and the Uniontown limestone is present, though thin, while higher in the hill appear the coals of the Dunkard in proper succession. Doctor White finds this bed at Wheeling 2 feet thick and 256 feet above the Pittsburg; the interval at 5 miles east is 266 feet. The Uniontown coal bed is not shown in the second section, but it

* J. J. Stevenson: (K), pp. 227, 228, 230, 231, 238, 248, 249, 258, 259, 260, 270, 274, 275, 277, 280, 287, 289, 292, 308, 317, 322.

I. C. White: (K), p. 268; (Q), p. 23. Geology of West Virginia, *1a*, pp. 121, 122, 126, 127, 128, 130, 132, 281, 282, 283, 284, 285, 293, 294.

was seen at Wheeling. Number 8 is the Benwood limestone and is made up of alternating layers of shale and limestone 3 to 6 feet thick. The Sewickley horizon includes Numbers 9 to 14. In these sections the vertical thickness is about 24 feet, but Doctor White found the three Wheeling beds in a vertical space of 43 feet at another locality within the limits of that city. The bottom bed is the Lower Sewickley and rests on limestone which may be taken as the Fishpot; the upper two at Wheeling are equivalent to the single bed of the second section and to the Upper Sewickley of Pennsylvania, the Meigs Creek of Ohio. The section remains above the river to a mile below Benwood or five miles below Wheeling. At 12 miles below Wheeling, near Moundsville, Doctor White obtained measurements showing the Waynesburg coal bed 3 feet thick and 265 feet above the Pittsburg. The Uniontown limestone is 2 feet and separated by sandstone from the great Benwood limestone. At 25 feet below the last is a thin coal bed, 44 feet above the Pittsburg, which is at the place of the Lower Sewickley. The place of the Uniontown coal bed is concealed. At about 12 miles south from Moundsville Mr J. E. Barnes made borings with diamond drill which show a notable increase in thickness, especially in the upper part of the section.

	Feet	In.	Feet	In.	Feet	In.	Feet	In
Waynesburg coal bed.....	2	0						
Interval.....			77	0				
Uniontown coal bed.....	207	0	0	9				
Interval			146	3				
Sewickley coal bed.....	3	0	2	4	3	6	3	6
Interval			59	10			1	2
Redstone coal bed.....	87	11	1	1	83	0	60	0
Interval			23	0			27	1
Pittsburg coal bed.....	5	5	5	11	7	9	5	7
Total	297	11	310	3	83		88	3

In the second section the interval from Waynesburg to Uniontown is an estimate, as the core begins below the upper bed. The Waynesburg is about 300 feet above the Pittsburg, but the interval from the Uniontown to the Pittsburg is almost the same as at Wheeling; the relations of the Upper Sewickley show equally small change. The limestone is still in notable quantity throughout the section. A new feature appears in the presence of red shale, unknown in the Monongahela of Pennsylvania and farther north in West Virginia. One of these borings shows four layers, in all 8 feet thick, between Waynesburg and Sewickley, the lowest at 60 feet above the latter coal bed; another shows six

layers, in all 18 feet 6 inches thick, the lowest at 70 feet, while a third shows 6 feet in 118 feet above the Upper Sewickley, the lowest being at 74 feet above that bed.*

OHIO

Passing over into Ohio, one finds the most northerly exposure at Knoxville, in Jefferson county, about 15 miles north from Steubenville, where Henry Newton obtained this section:

	Feet	Inches
1. Olive and red shale, with thin bands of buff limestone	76	0
2. Coal bed [Waynesburg]	1	6
3. Olive shale	108	0
4. Coal bed [Sewickley (?)]	2	6
5. Olive shale	30	0
6. Pittsburg coal bed	4	0

This is farther north than any locality in Pennsylvania giving measurements above the Pittsburg. Twelve miles southeast, at Eldersville, in Washington county of Pennsylvania, the interval, Waynesburg to Pittsburg, is 166 feet. Here the upper coal is 140 feet and is most probably the Waynesburg, with red shale of the Dunkard above it. All trace of limestone has disappeared and the lower coal bed is at a Sewickley horizon.

At 8 miles farther south, Stevenson found a thin coal bed at 65 feet above the Pittsburg underlying 50 feet of shale and flaggy sandstone, no trace of coal appearing. At a little way west both Professor Newberry and Professor Brown note a coal bed 29 to 34 feet above the Pittsburg with limestone above the lower bed and at one locality above the upper. The limestone and coal disappear farther west, near the edge of Harrison county, where the Waynesburg coal bed is 100 feet above the Upper Sewickley, which is 69 feet above the Pittsburg. Some thin limestone appears above the Upper Sewickley, but none below. The interval between Sewickley and Pittsburg increases within 3 miles southward to 81 feet, and in the lower 21 feet of that interval are two thin limestones and two thin coal beds. In the southern part of the county, near the Belmont border, the interval, Waynesburg to Upper Sewickley, increases to 160 feet and the Benwood limestone attains a thickness of 60 feet. The Upper Sewickley is 4 feet thick, with a thin coal bed 35 feet below it, just midway to the Pittsburg. This lower interval

* I. C. White: Catalogue of West Virginia University, 1883-1884, pp. 56, 60. Geology of West Virginia, vol. II, pp. 131, 132, 133, 134, 135.
J. J. Stevenson: Manuscript notes.

has 50 feet of limestone. The interval from Waynesburg to Pittsburg along the western border of Jefferson county is 140, 171, 182, 209, and 235 feet, and at 4 miles east from the last is 245 feet, 10 miles north from Wheeling, where it is approximately 260 feet. The Waynesburg is Number 11 and the Upper Sewickley is Number 10 of Stevenson's Jefferson County report.

Professor Brown finds the Upper Sewickley (Meigs Creek) at 92 feet above the Pittsburg, on the Harrison county line. In Harrison, west from Jefferson, the generalized section shows:

	Feet	Inches
1. Waynesburg (11) coal bed.....	2	0
2. Mostly sandstone	91	0
3. [Upper Sewickley] (10) coal bed....	11	0
4. Sandstone	60 to 75	0
5. Coal bed [Redstone (?)].....	2	6
6. Mostly limestone	15 to 30	0
7. Pittsburg coal bed.....	7 to 8	0

Here, as in Jefferson county, a coal bed (12) is at 50 feet above the Waynesburg. The Upper Sewickley, insignificant in most of Jefferson county, is an important bed, triple, the middle bench 4 feet 6 inches and the others 1 foot 2 inches. It averages about 90 feet above the Pittsburg, though at times decrease in the lower interval makes it less. The limestone above the Pittsburg is replaced by sandstone along the western outcrop. There are mere traces of the Benwood limestone, but at times a thin limestone appears below the Waynesburg coal bed which may represent the Uniontown. The Pittsburg coal bed in the main division varies from 4 to almost 6 feet and the coal is much more variable in quality. At some localities it is excellent, while at others it is decidedly inferior. The roof division is of uncertain occurrence, being absent from considerable areas. It is usually thin, little more than one foot, but it was measured 4 feet at one pit, where the whole thickness was not exposed.*

Returning to the Ohio river, one enters Belmont county, south from Jefferson and Harrison. At Bridgeport, opposite Wheeling, Stevenson found the Waynesburg (11) coal bed 245 feet above the Pittsburg by barometer, 3 feet 6 inches thick, 2 feet above a limestone and 188 feet above a thin coal bed, apparently the Lower Sewickley of the Wheeling section. Professor Brown saw the Redstone near by at 20 to 23 feet

* Jefferson county. J. S. Newberry: Ohio Geology, vol. iii, pp. 753, 763. J. J. Stevenson: Vol. iii, pp. 767, 773, 777. C. N. Brown: Vol. vi, p. 601.
Harrison county. J. J. Stevenson: Vol. iii, pp. 202, 215, 217.

above the Pittsburg, and the Upper Sewickley (8c of the Belmont report) is 3 feet thick at a little way back from the river.

Four miles south from Bridgeport, at Bellair, is Professor Brown's carefully leveled section:

	Feet	Inches
1. Coal bed	Blossom	
2. Interval	53	0
3. Coal bed [Waynesburg]	2	0
4. Shale and sandstone	18	0
5. Coal bed [Little Waynesburg]	Blossom	
6. Limestone [Waynesburg]	3	0
7. Concealed	5	0
8. Coal bed	Blossom	
9. Concealed	14	0
10. Coal bed	Blossom	
11. Shale, sandstone, concealed	103	0
12. Calcareous shale, limestone	24	6
13. Meigs creek [Upper Sewickley] coal bed	4	0
14. Sandy shale	14	0
15. Coal bed	0	8
16. Clay shale	6	0
17. Coal bed and shale [Lower Sewickley]	3	0
18. Limestone, shale, concealed	38	0
19. Coal bed [Redstone (?)]	2	0
20. Interval	17	0
21. Pittsburg coal bed	7	0

The Sewickley coals are in a vertical space of 28 feet and the top of the Upper Sewickley is 84 feet above the Pittsburg; at Wheeling this interval varies from 80 to 97 feet. The Waynesburg is 167 feet higher, and the blossom, Number 10, is at the place of the Uniontown coal bed.

The variations in the section between the Ohio river and the western outcrop have proved very perplexing and the sections have been interpreted differently by different observers. One must depend upon the measurements made by Professor Andrews, those by Stevenson being without value in certain portions of the county, where he clearly lost hold of the section. At Barnesville, 22 miles west from the Ohio river, Professor Andrews obtained a long section, which, condensed is:

	Feet	Inches
1. Shale	8	0
2. Coal bed	Blossom	
3. Clay	4	0
4. White limestone	1	0
5. Sandstone, clay, slate, concealed	38	0
6. Coal bed, Tunnel seam	2	0

	Feet	Inches
7. Shale, sandstone	24	6
8. Coal, slate, black slate, coal	6	9
9. Clay, limestone, shale	71	3
10. Cumberland [Meigs creek, Upper Sewickley] coal bed	6	7
11. Clay	3	0
12. Sandstone	35	0
13. Limestone, concealed	9	0
14. Coal bed	Blossom	
15. Clay, limestone	19	0
16. Coal bed	Blossom	
17. Clay, sandstone, shale	30	0
18. Pomeroy [Pittsburg] coal bed	4	4

Eastwardly from Barnesville the surface rises rapidly and the beds fall so that the highest portion of the section alone can be followed for 10 miles. A deep cut on the railroad summit several miles east from Barnesville shows the highest bed 2 feet thick and, near by, the Tunnel seam is represented by 2 feet of black shale containing some coal. It underlies yellow shale as at Barnesville and a thin coal below answers to Number 8 of the section. Near Belmont, 7 miles from Barnesville, the three coal beds are recognized, the intervals being approximately 40 and 30 feet, and just beyond Belmont the lowest coal bed is 27 feet above a limestone. At 3 miles south from this locality a coal bed is at 100 feet above the Tunnel seam and another at 40 feet below. The section remains perfectly clear along the railroad to Lewis mills, in Smith township, where the succession is:

	Feet	Inches
1. Black shale	10	0
2. Interval	33	0
3. Coal bed	Blossom	
4. Interval	53	0
5. Tunnel coal bed	4	6
6. Interval	37	0
7. Coal and partings	2	7
8. Interval	23	0
9. Limestone	4	0

The group is followed to this place from Belmont easily, as the road falls somewhat more rapidly than the beds; but there is a notable increase in the intervals. At Barnesville, from the bottom of the highest coal bed to that of the lowest, the interval is 76, but here it is 97 feet. These beds are present at 7 or 8 miles south from Lewis mills, where they are 5, 2, and 3 feet thick respectively and the intervals are 46 and 42,

the full interval being 93 feet. Eastward from Lewis mills, on the railroad, one descends rapidly in the section, and at Warnock a coal bed underlying 26 feet of sandstone is at 96 feet above the Upper Sewickley.

At Lewis mills the lowest coal bed underlies 23 feet of "sandrock with more or less of sandy shale." Three miles east from Warnock, Professor Andrews reports a coal bed at 174 feet above the Upper Sewickley, which would be very near the place of the highest coal bed at Lewis mills, if there be no change in the section. No measurement is available along the railroad, but there is one reported by Professor Andrews in Washington township, 8 miles south from Glencoe and about 3 miles east from one already given from the same township; this shows:

	Feet	Inches
1. Tunnel seam	Not measured	
2. Interval	47	6
3. Coal and shale	3	0
4. Interval	122	0
5. Cumberland [Upper Sewickley] coal bed	3	5

giving 172 feet as the interval from the Tunnel seam to the Upper Sewickley; so that the high bed at Glencoe is the Tunnel seam.

Passing Glencoe, one has the lower portion of the formation exposed repeatedly to Bellair, where the measurements by Professor Brown make the interval from Waynesburg to Upper Sewickley 165 feet. The correlations for the higher beds at Bellair, Lewis mills, and Barnesville, with the intervals, are:

	Feet	Feet	Feet
Waynesburg A			
Interval	53	53	43
Waynesburg (Tunnel)			
Interval	40	39	31
Uniontown			

The interval below the Waynesburg is to the bottom of the Uniontown coal bed. The Waynesburg A belongs to the Dunkard formation. At Bellair the Uniontown is 127 feet above the Upper Sewickley—at Glencoe, 96, and at Barnesville 71 feet. Between Glencoe and the river the interval between the Upper Sewickley and the Pittsburg varies in Professor Andrew's sections from 72 to 79 feet, while at Barnesville it is 96 feet, the increase being due to the appearance of a thick sandstone almost directly under the upper coal bed. The Lower Sewickley and the Redstone are still recognizable at Barnesville, but they are very thin. The interval from the Pittsburg to the Waynesburg (Tunnel)

coal decreases from 252 feet at Bellair to 202 feet at Barnesville, where the higher bed is 103 feet above the Upper Sewickley.

Stevenson's measurements in northern Belmont, beyond the central part of the county, are confirmatory of these conclusions. His section is:

	Feet	Inches
1. Coal bed [Waynesburg A]	2	0
2. Sandstone	40	0
3. Coal bed [Waynesburg]	1	3
4. Sandstones and thin limestones	95	0
5. Coal bed [Upper Sewickley]	4	6
6. Concealed	30	0
7. Coal bed [Lower Sewickley]	2	6
8. Fireclay	0	3
9. Mostly limestone	65	0
10. Shale and clay	3	0
11. Pittsburg coal bed seen	2	0

But this is very near the western limit of the Fishpot-Redstone limestone, for at a short distance toward the west a measurement shows the interval between Upper Sewickley and Pittsburg, 105 feet, filled almost wholly with sandstone, there being no trace of limestone. The Benwood limestone practically disappears within 11 miles west from the river, there being thence only a few irregular streaks and those quite argillaceous. The Upper Sewickley is usually triple, as in Harrison county, with a thick middle bench; sometimes, however, the other benches are wanting; the thickness varies from 4 feet 6 inches to nearly 9 feet. The Pittsburg bed becomes thinner toward the west, and on that outcrop does not always show the roof division.

In Guernsey county, west from Belmont, the limestones have practically disappeared, there being only 5 feet in 140 feet above the Pittsburg coal bed. The Upper Sewickley is single, underlies 30 feet of sandstone, and is from 100 to 112 feet above the Pittsburg. In the extreme southwest corner of the county, Professor Andrews's sections show no trace of either Uniontown or Waynesburg in 113 feet above the Upper Sewickley, which is 97 feet above the Pittsburg. These sections show red shale 25 and 19 feet at 30 and 82 feet above the Upper Sewickley. Followed westward, the Pittsburg is seen growing thinner and yielding poorer coal.*

The Pittsburg coal bed is present in southeastern Muskingum, on the Guernsey-Noble border, but is very irregular, 2 feet 5 inches to

* Belmont. E. B. Andrews: Vol. II, pp. 547, 555, 556, 557, 563, 564, 569. J. J. Stevenson: Vol. III, pp. 274, 280, 281. C. N. Brown: Vol. VI, pp. 613, 619
Guernsey. Andrews: Vol. II, pp. 536, 537. Stevenson: Vol. III, 225.

somewhat more than 5 feet thick. It underlies 27 feet of massive sandstone. The Upper Sewickley coal bed in the same area is triple, about 5 feet thick and 113 feet below the Waynesburg, which is coal and black shale 22 inches thick and underlies a coarse white sandstone. Professor Brown found the interval to the Uniontown 128 feet in one place, where the Upper Sewickley is less than 90 feet above the insignificant Pittsburg.

In Morgan county, south from Muskingum, the Pittsburg shows a ragged boundary. Along the western border it is wanting at the north, then reappears 2 feet thick and increases southwestwardly until, in the southwest township, it becomes 9 feet; but it disappears abruptly, so that in a well no trace of it was found and two beds of red shale 12 and 24 feet thick were found at 150 and 281 feet above the Ames limestone. The lower bed is at the place of the Pittsburg and underlies the Pittsburg sandstone, while the higher bed is at the place of that seen on the Guernsey-Noble border at 30 feet above the Upper Sewickley. Eastwardly the Pittsburg is equally variable and it disappears before the eastern boundary has been reached. A thin coal bed, almost midway between the Upper Sewickley and the Pittsburg, is reported at several places. The Upper Sewickley coal bed, 238 to 250 feet above the Ames limestone, is as variable as the Pittsburg, being important along the Muskingum border, but thinning and finally disappearing toward the southwest. In the central townships it rarely exceeds 2 feet 6 inches, while on the eastern side, where the Pittsburg is absent, it thickens to 4 feet. The interval to the first coal above the Upper Sewickley is given as 120 feet near the Muskingum border, but at the south, near the Athens line, it is from 96 to 115 feet. For the most part this bed is thin and it nowhere exceeds 2 feet. In Center township a coal at 156 feet above the Upper Sewickley may represent the Waynesburg; it is 100 feet below the Washington. The same bed is in Marion at 150 feet above the Upper Sewickley and 54 feet above the blossom of the Uniontown. Limestone beds are not thick, but they are numerous in the interval below the Uniontown, recalling the condition observed in eastern Belmont.*

Noble county, south from Guernsey, is east from Muskingum and Morgan. The Pittsburg coal bed, 92 feet below the Upper Sewickley (Meigs Creek), is present in the northeast township at a few miles southwest from Barnesville, in Belmont county. A mere trace of the

* Muskingum. E. B. Andrews: Vol. i, pp. 339, 340. C. N. Brown: Vol. v, pp. 1070, 1071.

Morgan. Andrews: Vol. i, pp. 294, 295, 296, 301, 302, 304, 305, 307, 309, 310, 312, 317. Brown: Vol. v, 1067, 1069. J. A. Bownocker: Bulletin 1, p. 136.

bed was seen at one place in the adjoining township, but elsewhere it seems to be wanting. Its horizon is exposed in most of the townships, and oil borings have been made in others where its place is below the surface. Its place is 92 to 102 feet below the Upper Sewickley and 140 to 160 feet above the Ames limestone. The Lower Sewickley is present in the northeast corner at 20 to 25 feet below the Upper, and in some other parts of the county traces of a lower bed were seen at 50 to 60 feet. Limestone in thin bands often occurs within 70 feet below the Lower Sewickley, and in the eastern townships the beds are 5 to 11 feet thick.

The Upper Sewickley is the important coal bed of Noble county and usually shows the triple structure. It is present in all of the townships and ordinarily is of workable thickness, though varying from 20 inches to 7 feet. It is best in the southern part, near the Washington border, where it is known as the Macksburg coal. Along the northern line it is 240 feet above the Ames limestone, but near the southern line that interval increases to 258 feet. In one of the eastern townships the upper division of the bed is replaced by a thin white limestone, which rests on the clay parting without any irregularity. The roof is a thin shale, underlying a sandstone sometimes 30 feet thick. In much of this county limestone is more abundant above the Upper Sewickley than in western Belmont, notably in some of the eastern townships, where it persists even to the southeast corner. Some sections show as much as 30 feet.

The Uniontown coal bed, 195 to 215 feet above the Pittsburg, is reported occasionally at 103 to 113 feet above the Upper Sewickley, the greatest interval being at the east on the Monroe border. It is usually very thin, but at one exposure near the Monroe line it is double, with 12 and 5 inches of coal, separated by 5 inches of clay. A bed about 50 feet higher and exceedingly thin is reported at a few localities and is very near the Waynesburg horizon. Red shale, 14 feet, was seen at 46 feet above the Upper Sewickley in a section near the Guernsey line. Elsewhere this horizon is concealed.*

Monroe county, south from Belmont, is east from Noble. In going eastward one is in the direction of increasing intervals and increasing limestones, so that the somewhat widely separated measurements seem at first to be irreconcilable.

It will be remembered that the Uniontown coal bed is persistent in southern Belmont county; it is thin along the Baltimore and Ohio

* E. B. Andrews: Vol. II, pp. 511, 512, 513, 518, 519, 522, 523, 524, 526, 527.
C. N. Brown: Vol. V, pp. 1075, 1077, 1080, 1081.

railroad, but is better developed in Washington and York townships near the Monroe line. In Warren township at the west it is 71; in Wayne, 87; in Smith, 96, and in Washington 122 feet above the Upper Sewickley. In Wayne it is 74 feet above a peculiar magnesian limestone; farther east the interval varies from 75 to 80 feet, the increasing interval between Uniontown and Upper Sewickley being caused by increase in and below this limestone, the "Cement" of Professor Andrews. This relation may serve in working out the conditions in Monroe as well as to explain the increased interval between those coal beds along the westerly outcrop southwest from Belmont county. In Belmont the Waynesburg coal bed becomes insignificant south from the Baltimore and Ohio railroad and at most localities appears only as an insignificant blossom.

Along the western side of Monroe county, into which the section can be followed from Noble county, everything is simple. The Pittsburg seems to be wanting at all exposures, but it is reported very thin, in a well within Summit township. The Upper Sewickley is a double bed, 3 feet 8 inches to more than 6 feet, with a parting 4 inches to 2 feet 6 inches, varying at expense of the coal; the lower division is commonly thicker than the upper. The horizon of this bed soon passes below the surface at the north, but at the south it remains above drainage for fully 8 miles from the west line.

In passing from the western tier of townships, one crosses a space without clear exposures, beyond which the succession is distinct enough. A series of sections along Sunfish creek across Center, Adams, and Salem townships at 6 to 8 miles from the Belmont line makes the connection. In Center, Professor Andrews gives:

	Feet	Inches
1. Red shale, ore bearing	63	0
2. Concealed, elsewhere 20 feet of sandstone at base	51	0
3. Coal bed	0	6
4. Concealed	23	0
5. Coal bed	1	6
6. Shales	70	0
7. Coal bed	Blossom	
8. Interval	99	0
9. Coal bed	5	9

and he states that a very thin coal bed is at about 50 feet above Number 9. This lowest bed is complex, the structure being

Coal, 1 foot 8 inches; clay with plant impressions, 2 feet 8 inches; coal, 2 inches; clay, 5 inches; coal, 10 inches.

A "Cement" limestone is persistent at 70 to 80 feet below this coal. The interval to the coal bed, Number 7, is roundly 170 feet. The bottom coal bed and its magnesian limestone are shown along the creek into Adams township, where Professor Andrews gives another section, showing the red beds of Center and the three coal beds, 74 and 96 feet apart, the total interval being 170 feet, with the magnesian limestone at 85 feet below the bottom bed. The limestone goes under soon after entering Salem township, but the coals remain above, and at a mile from the Ohio river Professor Andrews finds the three beds as before, 70 and 100 feet apart, the middle one being 3 feet 6 inches, making the total interval 173 feet 6 inches. At the mouth of the creek, at Clarington, Doctor White's section shows the red beds on top, with the three coal beds 65 and 98 feet apart, the whole interval being 166 feet, and, according to Professor Andrews, the magnesian limestone was reached there in a shaft at 75 feet below the lowest coal bed.

All the conditions point to correlation of this lowest bed with the Uniontown. The relation to the magnesian limestone is that shown by the Uniontown in southern Belmont. At the mouth of Pike creek, in southern Belmont, the Uniontown is 55 feet below the Waynesburg and 179 feet below the Washington. It is about 100 feet below the Waynesburg A. Evidently the Waynesburg coal bed is wanting or so thin as to have no observed trace except in Center township, where, at 50 to 55 feet above the Uniontown coal bed, there is a bed of fireclay known as the "potters' bed," which sometimes carries a trace of coal, and in Perry township, where the record of an oil boring shows trace of coal at 240 feet above the Pittsburg. The Uniontown coal bed retains its peculiar structure to the Ohio river. It resembles the structure of the same bed in central West Virginia along the Baltimore and Ohio railroad.

The Uniontown coal bed is recognized southward in Greene and Perry townships, in each case triple, with the characteristic plant bed, but much reduced. Along the Ohio river the interval to the Washington increases, being 190 feet at Sardis and 191 at Baresville, both in the township south from Salem. This increase of interval is in accord with measurements in Tyler county of West Virginia and is evidenced by an intermediate measurement reported by Doctor White, which gives 125 feet as the interval between the lower coal beds. The Uniontown grows thinner southwardly along the Ohio, being only 2 feet at Baresville, while still farther south it seems to be wanting; for in a section by Professor Andrews its place is exposed at 188 feet below what certainly seems to be the Washington, but no trace of coal appears.

Red beds are represented scantily in Monroe county. One of 6 feet is at 36 feet below the Upper Sewickley in the southwest part of the county, and an oil record reports 13 feet at 100 feet above the Pittsburg in the southwest; but exposures are so incomplete throughout that no conclusion respecting distribution of these beds can be drawn.*

Returning to the western outcrop in Athens county, south from Morgan, one has Professor Lovejoy's generalized section for these two counties:

	Feet
1. Sandstone	60
2. Coal bed [Uniontown]	Blossom
3. Shale	10
4. Limestone	0 to 3
5. Shale	35
6. Limestone	0 to 10
7. Shale	15
8. Limestone	0 to 7
9. Shale	25
10. Limestone	0 to 12
11. Shale	10
12. Coal bed [Upper Sewickley, Meigs Creek]	—
13. Shale and sandstone	20
14. Limestone	0 to 12
15. Shale, limestone, or sandstone	10 to 75
16. Pittsburg coal bed	—

The average intervals are, Number 2, 190, and Number 12, 95 feet above the Pittsburg. The great sandstone on top is evidently the 200-foot conglomerate of Professor Andrews. The Pittsburg coal bed is as irregular in Athens as in Morgan. It is 4 feet to 9 feet 6 inches in the northeastern townships, usually absent in the central, and thin in the southern portions. At one locality, where the overlying sandstone is replaced by shale, thin coals are at 15 and 67 feet above the main coal bed, the former underlying 14 feet of red shale; at another exposure 9 feet of red shale overlie the sandstone.

The Upper Sewickley is absent from many townships, but occasionally on the eastern (Washington) border it is 6 feet thick. The interval to the Pittsburg is said to vary from 95 to 128 feet, this variation appearing to depend much upon the thickness of the sandstone deposit. Notwithstanding the variations in this interval, that between the Pittsburg and Uniontown (Hobson of Andrews) has 185 and 195 as its extremes.

* E. B. Andrews: Vol. II, pp. 571, 586.
J. A. Bownocker: Bulletin 1, pp. 196, 210, 212, 213.
I. C. White: Catalogue of West Virginia University for 1883-1884, pp. 61 to 65.

The Uniontown is wholly unimportant. The limestones are variable to the last degree.*

Washington county, south from Noble and Monroe, is east from Morgan and Athens. On the western border the Uniontown (Hobson) coal bed is at 104, 89, and 105 feet above the Upper Sewickley (Meigs Creek, Cumberland) coal bed and in three townships there is a very thin coal bed at 140, 150, 135, and 147 feet above the Upper Sewickley, which is at the place of the Waynesburg and underlies a coarse sandstone, evidently the 240-foot conglomerate of Andrews. The Uniontown is usually a double bed, frequently underlying plant-bearing shales, apparently equivalent to the bed's upper parting in Monroe. As in other counties, it rests on clay and limestone, and generally one finds a sandstone at a few feet above it, though at times this is replaced by shale. In the northwestern part of the county a "limestone group," at most 30 feet thick, inclusive of shale, is at 11 to 18 feet above the Upper Sewickley; but this disappears eastwardly, so that in Noble, as in most of Washington, it is replaced by sandstone. It seems to disappear in southwestward direction also, and no trace of it remains in Decatur township at the southwest corner.

The section can be followed readily across the greater part of Washington county almost to the Ohio river, as the Cowrun anticline brings up the lower part of the formation. Along the northern border, in Salem, Liberty, and Ludlow townships, the Uniontown (Hobson) coal bed is about 95 feet above the Upper Sewickley, which is 85 to 100 feet above the Pittsburg. The Uniontown is very thin, apparently seldom more than one foot thick. Mr Minshall's section in Liberty shows it resting on its clay and limestone, with a coarse sandstone at 6 feet above. No trace of the sandstone at "240 feet" remains here, and the sandstone overlying the Uniontown is coarser than at any other locality away from the Ohio river in this county, though in other counties it is noted as very coarse. In this section the Waynesburg A is 100 and the Washington 160 feet above the Uniontown, just as in Pleasants county of West Virginia, 8 or 9 miles east of south. The interval below the Uniontown is filled mostly by shales and sandstone and the sandstone at one to 6 feet above the Upper Sewickley sometimes becomes 50 feet thick. Occasionally, however, the upper part of that sandstone is replaced by red shale, 52 and 27 feet being recorded at 27 and 18 feet above the coal bed. At one locality 10 feet of shale and limestone overlie the upper

* E. B. Andrews: Vol. I, pp. 270, 273, 274, 282, 286, 287.
C. N. Brown: Vol. v, pp. 1061, 1062, 1063.
E. M. Lovejoy: Vol. vi, pp. 629, 646.

red bed. The Upper Sewickley is from 5 to 6 feet thick, double, with a clay parting varying at expense of the coal, from 2 inches to 2 feet thick. This bed yields a good fuel, though somewhat high in ash. The Pittsburg coal bed is thin, from 1 foot 2 inches to 2 feet 10 inches, occasionally cannel. It underlies alternating limestone and shale, about 10 feet, and a similar "group" is at 20 feet higher. The Pittsburg is known as the "limestone" and the Upper Sewickley as the "sandstone" vein.

The section is equally clear in the tier of townships next south. The Uniontown is 95 feet above the Upper Sewickley in Muskingum, but only 82 feet in Lawrence, 8 miles east. It overlies its clay and limestone and varies in thickness from 2 feet 4 inches to 4 feet 3 inches. At the west it is double, but in Lawrence it is broken into six layers of coal and shale and a variable sandstone is above it. The bed seems to be irregular farther east in Independence township, where it is shown in one section, but is wanting in another, where, however, its overlying sandstone is shown at somewhat less than 100 feet above the Upper Sewickley. This sandstone is especially well marked along the river townships and is rather uncertain at the west, where the higher sandstone is present. For the most part the sandstone overlying the Upper Sewickley is coarse and massive, sometimes pebbly and occasionally 60 feet thick. In Lawrence township, 7 or 8 miles northeast from the city of Marietta, Professor Andrews found, at 42 feet above the Upper Sewickley, a coal bed varying from a mere trace to 4 feet 6 inches. It seems to be confined to a very small area, for no trace of it appears anywhere else in the sections, though Andrews says that he has observed some traces of it in other townships. The Upper Sewickley becomes thin and uncertain in the eastern townships, occasionally 3 feet thick, but usually much less and often wanting. The Pittsburg, 85 to 91 feet lower, is wholly unimportant, usually little more than a trace, but the limestone above it persists. These conditions closely resemble those observed in Tyler and Pleasants of West Virginia.

East from the Cowrun anticline the beds fall rapidly to the east and details are lacking in the river townships, Grandview, Independence, and Newport. Doctor White's long section in southern Grandview, about 7 miles below the Monroe line, shows what appears to be the Washington of the Dunkard at 150 above the river, so that the place of the Uniontown is not reached; but at 4 miles lower down the Uniontown is reached, 3 feet thick, 10 feet under a massive sandstone and 161 feet under the Washington coal bed. Two miles farther down, in Newport township,

this sandstone is very coarse, sometimes thickening so as to fill the whole interval to the place of the Waynesburg, while the underlying Uniontown coal bed is 3 feet thick and double, as in Lawrence township 3 or 4 miles west north of west. At 3 or 4 miles farther the Cowrun anticline or "oil break" is reached. The Pittsburg and Upper Sewickley seem to be wanting.

On the westerly side of the fold exposures are poor and information is wanting. An oil boring at Marietta shows the Pittsburg and Upper Sewickley absent, and the same is true at Parkersburg, West Virginia, about 10 miles below Marietta. The record at Marietta begins about 220 feet above the place of the Pittsburg, and that at Parkersburg at about 400 feet above the same horizon, but no evidence that the Uniontown is present appears in either record. No trace of the sandstone overlying the Uniontown coal bed is present in the Parkersburg well, opposite Belpre, Ohio, but the higher sand, about 240 feet above the Pittsburg, is present, 15 feet thick. Four or 5 miles farther down it comes up from the river bed as a coarse rock, and thence for many miles is an important member of the section.

The sections published are for the most part imperfect, as exposures are bad, so that one may not speak with certainty respecting distribution of red shale. On the western border a bed 24 feet thick is shown in one section at 30 feet above the Upper Sewickley; in Adams township the same horizon shows 52 feet at 27 feet, and in Ludlow 27 feet at 18 feet above the same coal bed. In the southern part a record at Marietta shows a great mass beginning in the Conemaugh and continuing upward into the Monongahela for at least 50 feet, and other beds are at 85 and 120 feet higher, the lower one apparently at the horizon above the Upper Sewickley.*

Meigs county is south from Athens and borders the Ohio river. The Monongahela is only on the eastern half of the county. From the northeast corner of Washington county the Ohio river flows almost west of southwest, so that when Meigs county is reached one has come near to the western outcrop of the Monongahela; but from the Athens line the river flows almost southward for more than 20 miles and for the greater part of the distance one seldom sees anything below the lowest beds of the Dunkard. At Antiquity, on the river, 16 miles south from the Athens line, is a measurement by Doctor White:

* E. B. Andrews: Vol. II, pp. 460, 461, 462, 463, 471, 472, 475, 476, 478, 479, 482, 483, 496, 499, 503, 504, 505, 506, 507.
E. Orton: Vol. VII, pp. 399, 400.
J. A. Bownocker: Bull. 1, pp. 136, 142.
I. C. White: Catalogue of West Virginia University, 1883-1884, pp. 73, 74, 75, 76.

	Feet	Inches
1. Red and variegated shale	30	0
2. Massive sandstone	20	0
3. Red shale and concealed	30	0
4. Coarse massive pebbly sandstone	40	0
5. Sandy shale	10	0
6. Concealed	90	0
7. Massive sandstone	15	0
8. Concealed in shaft	125	0
9. Pittsburg coal bed	5	8

	Feet	Inches
Coal	2	6
Clay	0	2
Coal	3	0

The coarse pebbly sandstone is that which made its appearance in the Ohio river bed at the southern point of Washington county and is evidently that noted in the Parkersburg record. Where it first appears it is 25 feet under a coal blossom. Near Long Bottom, in Meigs county, 25 miles below Parkersburg, a coal blossom is said to have been seen under this sandstone, and at 7 miles east from Antiquity a thin bed is reported at 40 feet above it. Six miles below Antiquity this sandstone is 250 feet above the Pittsburg and no trace of coal appears in the interval. At Pomeroy the Pittsburg coal is above water and shows:

	Feet	Inches
Coal	1	0
Clay	0	2
Coal	4	0
Coaly shale	1	2

There, as throughout Meigs county, a great sandstone comes down upon the Pittsburg or is separated from it at most by 15 feet of shale; it is from 60 to 70 feet thick.

The higher coal beds are to all intents wanting, as in southern Washington county. The Pittsburg reappears at perhaps 16 miles below Parkersburg, where it has been found in an oil boring; thence it increases and becomes of importance at Antiquity, whence it is a workable bed into Gallia county.

The great sandstone shown at Antiquity is readily traceable along the Ohio from its first appearance at the southern edge of Washington county. As described by Doctor White, it is coarse and massive, with pebbly streaks containing quartz pebbles at times an inch in diameter. No reference is made to it by Professor Andrews in his report on Athens county and none of his sections reaches to it, the longest being only

to 187 feet above the Pittsburg coal bed; but Professor Lovejoy gives in his generalized section for Meigs county a sandstone, 30 to 50 feet thick, at about 270 feet above the Pittsburg. In Athens county, very near the Meigs border, Professor Andrews has this sandstone at about 40 feet above that resting on the Uniontown coal bed, and Professor Lovejoy seems to have followed it around. It seems, therefore, altogether probable that the lower sandstone, that overlying the Uniontown coal bed, has disappeared as a great sandstone throughout Meigs, as it did on the Ohio river in Washington county, and that here in this higher sandstone we have the equivalent of the Waynesburg sandstone belonging to the Dunkard formation; but the Waynesburg coal bed seems to be represented only by a mere blossom, as is also the Upper Sewickley in Meigs county, while no trace of the Uniontown remains.

Professor Andrews's sections show a bed of red shale 12 to 18 feet thick at 164 feet above the Pittsburg in two localities; one of 14 feet at 140; one of 18 feet at from 117 to 120, and one of 6 feet at 100 feet above the Pittsburg, while at times the upper part of the Pittsburg sandstone is replaced by red shale.*

Gallia county is south from Meigs, along the Ohio river. The Pittsburg coal bed is present in the northern part of the county, near the Meigs border, but only in isolated patches, and the coal has little cover. It is 4 feet 6 inches near the Meigs line, but, decreasing, is only 1 foot 6 inches at a few miles south. It is overlain by sandstone, which at one locality near Gallipolis is broken by red shale, 10 feet, at 17 feet above the coal.

An insignificant area remains on Greasy ridge, in Lawrence county, 8 to 10 miles west from the Ohio river. There Mr McMillin measured a thickness of 4 to 5 feet. This is the last fragment in Ohio, and the Monongahela is not reached by the Kentucky section.†

WEST VIRGINIA

Returning now to the east and entering West Virginia from Pennsylvania, one finds an insignificant patch of Monongahela remaining in the Blairsville-Connellsville basin, where the Pittsburg coal bed underlies a thick coarse sandstone and the Redstone coal bed, with its limestone, is absent. Two miles westward, beyond the Monongahela river, this sandstone has disappeared, and one finds a section very similar to

* E. B. Andrews: Vol. I, pp. 253, 256 to 278.
E. M. Lovejoy: Vol. VI, pp. 627, 628, 629.
I. C. White: Op. cit., pp. 83, 84, 85, 86.
† E. B. Andrews: Vol. I, pp. 235, 236, 239, 240, 243.
Emerson McMillin in personal communication.

that of Greene county of Pennsylvania. The formation soon passes below the surface, and thence across the state it can be followed by means of oil-well records.

In Monongalia county, at a few miles south from the Pennsylvania line, one has the carefully measured section by Doctor White:

	Feet	Inches
1. Waynesburg coal bed	10	10
2. Black shale	1	0
3. Sandy shale	25	0
4. Waynesburg limestone	8	0
5. Sandy shales, layers of limestone	30	0
6. Massive sandstone	20	0
7. Limestone and shale	15	0
8. Black shale, Uniontown horizon	2	0
9. Limestone and thin shales	105	0
10. Sewickley sandstone	40	0
11. [Lower] Sewickley coal bed	5	0
12. Shale and sandstone	15	0
13. Limestone	15	0
14. Shales and concealed [Fishpot]	23	0
15. Limestone	7	0
16. Concealed	15	0
17. Redstone coal bed	4	0
18. Redstone limestone	18	0
19. Shale and slate	10	0
20. Pittsburg coal bed	13	10

The multiple Waynesburg bed has this structure:

Coal, 2 feet; shale, 1 foot; coal, 1 foot 4 inches; shale, 1 foot 6 inches; coal, 5 feet;

and the Pittsburg is:

Roof, coal, and slate, 3 feet 3 inches; clay, 1 foot; Main coal, 9 feet 7 inches.

The total thickness of the formation is 372 feet 8 inches. The interval from Waynesburg to Uniontown is 99 feet and that to the Lower Sewickley is 246 feet. At Fairmont, 20 miles south, in Marion county, the intervals are almost the same, the Redstone coal bed is absent, and the Waynesburg, with 4 feet 6 inches of coal, is barely 6 feet thick. The Waynesburg, Uniontown, Benwood, Fishpot, and Redstone limestones are all present and distinct, but no trace of the Little Waynesburg coal bed appears in any of the sections.

The measurements of two cores from diamond drill are available a few miles west—one in Monongalia county measured by Mr J. E. Barnes,

the other near Farmington, in Marion county, measured by Doctor White,

	Feet	Inches	Feet	Inches
Waynesburg coal bed.....	7	7	6	0
Interval	225	0	299	9
Lower Sewickley	6	8	6	4
Interval	77	4	107	2
Pittsburg coal bed.....	9	1	9	1
Totals	325	8	428	4

showing a remarkable increase in intervals southward; so that at the latter locality, 8 miles west from Fairmont, one has the greatest recorded certain thickness for the Monongahela. At the northern locality the Uniontown limestone, as near Morgantown, in Doctor White's section, is almost continuous with the Benwood, but at the southern it is distinctly separate. The Uniontown coal bed, wanting in the Monongahela core, is present in that from Farmington, where, however, the Redstone is not present. The sandstones are very pronounced in the Farmington section, and that just below the Waynesburg coal bed is so massive that it is named by Doctor White the Gilboy sandstone. Red shale, absent in the northern core, is present at Farmington, 5 feet thick at 47 feet below the Uniontown coal bed.

In Monongalia county the formation thickens westwardly. Some wells about 10 miles west from the river record 330 to 340 feet between the Waynesburg and Pittsburg and one at 20 miles gives the interval as 363 feet, with total thickness of 377. The Lower Sewickley coal bed is present in all the records giving any details. In Marion, along a line passing southwest about 12 miles northwest from Fairmont, the interval from Waynesburg to Pittsburg is 325 near the Monongalia line, but at Mannington, 2 or 3 miles west from Farmington, it is 390 feet. The Lower Sewickley is present in all of the records at 225 to almost 290 feet below the Waynesburg, but the Redstone seldom appears. The Sewickley sandstone is well marked except near Mannington. As the records are of the ordinary type, they afford no information respecting the limestones. The Waynesburg, Lower Sewickley, and the Pittsburg coals persist to the western border of the county, but records on that side give no information respecting the intervening rocks.*

Wetzel county, west from Monongalia and Marion and south from Marshall, extends to the Ohio river, where it adjoins southern Monroe

* I. C. White: Geology of West Virginia. Vol. i, pp. 232, 234, 236, 238, 239, 241, 246, 247, 248; vol. ia, pp. 163, 164, 165; vol. ii, 127, 128, 129. Bulletin U. S. Geol. Survey, no. 65, p. 48.

J. E. Barnes: Cited in vol. ii, p. 127.

of Ohio. In the eastern part of the county the Waynesburg is 237 to 244 feet above the Lower Sewickley and 330 to 350 feet above the Pittsburg. A core obtained at Pine Grove, midway in the county, and measured by Doctor White, shows the Pittsburg, Redstone, Lower Sewickley, Uniontown, and probably the Waynesburg coal beds, all of them very thin, none exceeding 2 feet 2 inches. The Waynesburg and Uniontown limestones are wanting, but the Benwood, Fishpot, and Redstone are still present. The intervals shown by this core are:

	Feet	Inches
Waynesburg coal bed	0	6
Interval	96	0
Uniontown coal bed	1	6
Interval	143	11
Sewickley coal bed [Upper (?)]	2	2
Interval	79	6
Redstone coal bed	1	7
Interval	24	9
Pittsburg coal bed	2	2

In the northeast corner of the county, adjoining Monongalia, the Waynesburg is 340 feet above the Pittsburg and in the southeast corner the interval is 350 feet, with the Washington at 165 feet above the Waynesburg. Midway along this line the Uniontown is recorded at 277 feet above the Pittsburg and 230 feet below the Washington, the intervals being greater than at Pine Grove. There the Washington is but 484 feet above the Pittsburg, and at a little way northeast the interval is 475. Very possibly the little coal at Pine Grove correlated with the Waynesburg may be a local streak or one whose thinness has prevented recognition at surface exposures. The interval to the Pittsburg, 359 feet, is too great, in view of decrease in other intervals. The Waynesburg and Uniontown coal beds are so thin that they have been overlooked by the drillers at most places, but on the northern border of the county, at 10 miles east from the Ohio river, the interval from the Washington has decreased to 446 feet, and there is another bed at 356 feet. One mile farther north, in Marshall county, cores obtained by Mr. Barnes show the Waynesburg at 306 feet and the Uniontown at 233 feet above the Pittsburg. The first coal bed above the Waynesburg would be about 120 feet above the Uniontown. Where the formation comes to the surface, 10 or 12 miles farther northwest, the Waynesburg, 55 feet above the Uniontown, is but 238 feet above the Pittsburg and 110 to 115 below the Washington. There are no well records near the Ohio river, but a section at that river in the extreme northwest corner of the county shows the Uniontown, said to be 3 feet thick, at 75 feet above the river and, as

at Proctor, 10 miles east, 120 to 125 feet below the Waynesburg A coal bed. The Waynesburg seems to be wanting, but a sandstone answering to the Gilboy horizon and extending upward to beyond the place of the Waynesburg is present.

The Pittsburg coal bed is persistent in eastern and northern Wetzel, though evidently varying much in thickness, but in western Wetzel it is extremely irregular, often represented only by black shale. There is much sandstone above the Uniontown coal at Pine Grove as well as along the Ohio river, but in the eastern part of the county the interval to the place of the Waynesburg seems to carry mostly shale. Red shales are wanting at Pine Grove, but a detailed record at a few miles east shows 5 feet resting on the Pittsburg and 35 feet at 238 feet higher, underlying the place of the Uniontown coal bed. The Pine Grove boring shows 88 feet of limestone in the Benwood interval, the Fishpot is represented by 11 feet of limestone and 14 feet of calcareous shale, while limestone fills half the interval from the Redstone to the Pittsburg. The other records give no trustworthy information respecting the limestones.*

Returning now to the east, one finds the outcrop in the western third of Taylor and Barbour counties and in eastern Harrison, where the lower part of the formation is above drainage. The only available section in the former counties shows no Waynesburg, Uniontown, or Sewickley, as their places are concealed, but a coal bed, probably the Redstone, is at 32 feet above the Pittsburg, 5 feet thick and accompanied by its limestone, 11 feet. A white limestone 5 feet thick and 175 feet above the Pittsburg is thought by Doctor White to be the only representative of the Benwood. A succession of sandstones beginning at 125 feet above the Redstone coal bed culminates in a massive rock, very pebbly at 458 feet above the Pittsburg, whose place is very uncertain. A section by Mr J. L. Johnson at Clarksburg in Harrison county is:

	Feet	Inches
1. Massive sandstone	Not measured	
2. Concealed and yellow shale	65	9
3. Sandstone	25	0
4. Concealed some limestone	80	0
5. Sandstone and sandy shale	46	0
6. Sewickley sandstone	40	0
7. Shale	10	0
8. Sewickley coal bed [Lower]	1	0
9. Limestone [Fishpot]	9	0
10. Concealed, shale, sandstone	31	0
11. Redstone coal bed, slaty	3	0

* I. C. White: Vol. i, 339, 340; vol. ia, pp. 177, 178, 187, 192, 196, 202; vol. ii, pp. 136, 139. Catalogue of West Virginia University, 1883-1884, p. 66.
J. E. Barnes: Cited in vol. ii, p. 131, 132.

	Feet	Inches
12. Shale	5	0
13. Redstone limestone	6	0
14. Shale	13	0
15. Pittsburg coal bed	8	6

The sandstone at the top of the section is 320 feet above the Pittsburg coal bed. Stevenson's sections along the railroad beyond Clarksburg show the Redstone and Sewickley at 20 and 41 feet above the Pittsburg, with the Sewickley sandstone, 40 feet thick, at 6 feet above the coal bed. On top of the sandstone is black shale, 6 feet, containing 2 inches of coal and marking the place of the Upper Sewickley. The Benwood limestone is represented by only 7 feet of limestone and calcareous shale, at about 8 feet above the Upper Sewickley. Stevenson reports a coal bed at Clarksburg, 160 feet by barometer, above the Lower Sewickley; but this interval cannot be depended on, as all of the intervals by barometer given in the paper here quoted are too small. This bed may be at the Uniontown horizon. It is identified with a bed seen at 9 miles west from Clarksburg, 4 feet thick, divided by one foot of clay.

At Brown's mills, 10 miles northwest from Clarksburg, a record kept with unusual care shows:

	Feet
1. Waynesburg sandstone	25
2. Waynesburg coal bed	3
3. Slate	15
4. Gilboy sandstone	35
5. Shale	80
6. Uniontown coal bed	5
7. Shale and "limestone"	265
8. Pittsburg coal bed	10

Doctor White has recognized the Waynesburg, Waynesburg A, and Washington coal beds in surface croppings near this boring, so that there remains no room for doubt respecting the correlation. The Gilboy sandstone, whose top is 385 feet above the Pittsburg, is no doubt included in the great sandstone at Clarksburg, whose bottom is 320 feet above that coal bed, for, as will be seen, the bed varies greatly in thickness. A detail record 3 miles eastwardly from Browns shows no coal at the place of the Waynesburg, the sandstone is wanting, and the Washington coal bed is 538 feet above the Pittsburg, 23 feet more than in southeast Wetzel, 10 miles northwest. Near Cherry Camp, on the Baltimore and Ohio railroad, 10 miles west of south from Browns and a similar distance west from Clarksburg, a detailed record shows the Washington at 568, the Waynesburg A at 481, and the Uniontown, 2 feet thick, at 287 feet above the Pittsburg. The intervals are all larger than at Browns. The

Gilboy sandstone is 25 feet thick and 94 feet above the Uniontown, the same as at Browns, making allowance for thinning of the rock. At Salem, west from Cherry Camp, the Washington is 546 feet above the Pittsburg; no Waynesburg is here, but a 35-foot sandstone is at 405 feet, as at Browns. Farther south, in western Harrison, a Sewickley coal bed is at 80 and the Uniontown coal bed at 280 feet above the Pittsburg.

The Pittsburg coal bed attains great thickness in Harrison, Barbour, and Lewis counties. The roof division, so well marked in most of Pennsylvania and Ohio, is seen rarely, but very often a black slate rests on the "over-clay." The thickness from Clarksburg eastward is not far from 8 feet and one opening shows almost 9. There is a tender middle bench, the "bands," answering to the "bearing-in-bench" of Pennsylvania and Ohio, separating the "breast" from the "bottom." The "breast" usually contains a good deal of hard coal, often much semi-cannel, but the "bottom" is a softer coal, lower in ash, and all very good except a few inches on the floor. The whole bed gives marketable coal. The thickness decreases west from Clarksburg and at times falls to 5 feet.

The only red shale recorded in the Clarksburg region is a thin bed, sometimes replacing the upper part of the Sewickley sandstone. There is none in the Brown record; but records farther south, on the west side of the county, show 10 and 30 feet at 250 and 349 feet above the Pittsburg, the former belonging to the deposit below the Uniontown and the latter underlying the Gilboy sandstone, which in turn underlies almost immediately the place of the Waynesburg coal bed.*

Doddridge county, west from Harrison, is south from Wetzel and Tyler. At Sedalia, on the eastern border, 7 or 8 miles south of west from Browns and 6 or 7 miles northwest from Cherry Camp, is the measurement of a core obtained by Mr Barnes, thus:

	Feet	Inches
1. Mostly shale	61	0
2. Black and gray shale	2	0
3. Blue shale	4	0
4. Sandy shale	12	0
5. Sandstone	83	0
6. Blue shale	17	8
7. Coal bed [Uniontown]	3	2
8. Shales and limy shales	184	2
9. Coal bed	0	6
10. Shales and sandstones	83	0
11. Pittsburg coal bed	6	10

* I. C. White: Bulletin no. 65, pp. 49. Geology of West Virginia, vol. i, pp. 248, 250; vol. ia, pp. 316, 317, 319, 320; vol. ii, pp. 139, 140, 141.
J. J. Stevenson: Proc. Am. Phil. Soc., vol. xiv (1875), pp. 377, 378, 381.

Here one is 18 miles southeast from Pine grove, in Wetzel county. The Uniontown coal bed is almost 268 feet above the Pittsburg. At Browns the interval is 265, and at Cherry Camp 287 feet. The top of the Gilboy sandstone at Browns is 385, at Cherry Camp about 400, and at Sedalia 371 feet above the Pittsburg. At Sedalia there is a little black shale at 388, and at Browns the Waynesburg coal bed is at 400, underlying a sandstone which at Salem is 405 feet above the Pittsburg. The elements of the section are the same throughout and the varying intervals are but sums of variations in the subordinate intervals. The great sandstone at Sedalia is the Gilboy of earlier records, increased downward so as to embrace most of the underlying shale at Browns. The interval decreases westwardly, and at 10 miles from Sedalia the Uniontown is 250 feet above the Pittsburg, with no coal in 168 feet above to the top of the well. The Waynesburg is evidently gone, as no trace of it appears in intervening records. Here one is on the border of Tyler county and about 11 miles southwest from Smithfield, in Wetzel, where the Waynesburg is present, and 350 feet above the Pittsburg.

Long run, on the Baltimore and Ohio railroad, is 7 miles west from Cherry Camp. A well record gives the Pittsburg as 3 feet thick, but no clear record is given above that coal bed. Along the railroad from Long run westward to West Union, midway in the county, one often sees a coal bed underlying a massive pebbly sandstone. The structure of the bed is remarkably like that of the Waynesburg farther north, and for that reason Stevenson correlated it with that bed, regarding the overlying plant shales as equivalent to those now known as the Cassville. The section at Smithton is:

	Feet	Inches
1. Shale, with impressions of plants	4	0
2. Coal	2	2
3. Clay	0	3
4. Coal	0	2
5. Cannel	0	3
6. Shale	8	6
7. Coal	1	6

The material here available may not suffice to justify positive correlation of this bed, but it can hardly be the Waynesburg, for that bed seems not to extend so far south, while the conditions at Long run and in counties beyond seem to justify the assertion that it must be very near the place of the Uniontown, as Doctor White has suggested. Its resemblance in structure to the Uniontown of Monroe county, Ohio, is very remarkable. Detailed records are too few in Doddridge county to

enable one to speak finally about distribution of the red shales. The bed belonging under the Uniontown coal bed is 15 feet thick on the Tyler border, but along the eastern side the beds are thin and unimportant.*

Tyler county, southwest from Wetzel along the Ohio river, is northwest from Doddridge and adjoins northern part of Washington county of Ohio. The number of oil wells in this county is very great, but for the most part the records are merely skeletons in much of the county, comparatively few making any note above the Pittsburg horizon. That coal bed is recorded in many wells along the Doddridge border, but is absent from many others, while in by far the greater part of the county it is represented by a mere trace or is wholly wanting; but the horizon can be carried without difficulty along the strike lines by means of the Logan (Big Injun) sandstone.

A record just over the line in Doddridge county notes the Uniontown coal bed at 250 feet above the Pittsburg. In southeast Tyler, near Wick, a detailed section shows the Uniontown, very thin, at 253 feet above the Pittsburg and 36 feet above a 15-foot bed of red rock, which is very near the place of a bed in a Doddridge well 10 miles northeast. At Wick this coal bed underlies 30 feet of coarse sandstone, as it does near Smithton, 5 or 6 miles southeast on the railroad, and it is 191 feet below the Washington, a very notable decrease from Harrison county, where the interval is 273 feet within the Sardis district. The Washington is 538 feet above the Pittsburg in Sardis, but only 444 feet in southeast Tyler. The interval, Uniontown to Washington, is almost 30 feet less than at Pine Grove, in Wetzel, 20 miles north-northeast.

More information is available along a line 7 to 8 miles northwest from this Pine Grove-Wick line. The Uniontown coal bed is noted in most of the records giving any information above the Pittsburg horizon. On the Wetzel border, 6 miles east of south from New Martinsville and at the same distance southeast from Sardis, in Monroe of Ohio, the interval from Uniontown to Pittsburg is 240 feet; farther southwest to the Ritchie-Pleasants line the Uniontown is almost constantly present at 1,460 to 1,470 feet above the Logan sandstone and 220 to 230 feet above the Pittsburg, where that bed is present. The interval to the Pittsburg decreases still more toward the west, becoming 210, and then 200, while at 8 miles from Middlebourne, on the Pleasant border, a record shows what seems to be this bed at 177 feet. The changes in relation to the Washington are quite as interesting as those in relation to the

* I. C. White: Vol. i, pp. 325, 328, 330, 331, 332; vol. ia, p. 283; vol. ii, p. 138.
J. E. Barnes: Cited in vol. ii, p. 138.
J. J. Stevenson: Proc. Am. Phil. Soc., vol. xiv, pp. 376, 377.

Pittsburg. The latter interval has decreased gradually from 288 feet in Harrison to certainly 200 and possibly 177 in western Tyler; that from the Washington has decreased from somewhat more than 270 in Harrison to 180 at the last record in western Tyler, the decrease in this case being as gradual as in that of the other interval. The Waynesburg coal bed is not noted anywhere in Tyler. No coal or trace of coal appears in record between the Uniontown and the Pittsburg. Only two detailed records are available for this county. That in the southeast corner shows red beds at 203 and 283 feet above the Pittsburg, and one in the southwest shows a bed 75 thick at 79 feet below the Uniontown horizon, that coal bed being absent, having been cut out by downward extension of the overlying sandstone.*

Pleasants county, west from Tyler along the Ohio river, adjoins Washington county of Ohio. A coal bed is reported in a well near the northeast corner of the county at 1,227 feet above the "Keener" sandstone. Near Middlebourne, in Tyler, the Pittsburg is 1,229 feet above the "Keener," and in another well near the Pleasants border it is 1,252 feet above the bottom of that sandstone. The bed in northeast Pleasants is very near the place of the Pittsburg, but its occurrence is of merely geological interest, as the bed is insignificant, the driller reporting only 3 feet in all. At Saint Marys, on the Ohio river, the Uniontown coal bed is 2 to 3 feet thick and underlies a massive sandstone which is traceable up the river almost to the Tyler line. There the interval to the Washington has decreased to 160 feet, 20 feet less than at the last measurement in Tyler county. No record is here to determine the distance to the Pittsburg, but at a few miles west, in Washington county of Ohio, the Uniontown is 186 feet above the Pittsburg. Borings along the Ohio river find no trace of the Pittsburg coal bed, which is very thin in the adjacent part of Ohio.†

Ritchie county, west from Doddridge, is south from Tyler and Pleasants. The Monongahela is deeply buried except near the western border, where the Cowrun anticline brings up still lower rocks. The Pittsburg coal bed is of extremely uncertain occurrence and the detrital beds vary abruptly, as appears in numerous detailed records. In the northeast corner the Uniontown, very thin, is 237 feet above the Pittsburg, 16 feet less than at Wick, 3 or 4 miles northeast; 2 miles farther south 25 feet of hard sandstone appear at 230 feet above the Pittsburg, evidently that belonging over the Uniontown coal bed on the railroad in Doddridge county. Farther south along this eastern side, for 9 or 10 miles the Pittsburg coal

* I. C. White: Vol. i, 332; vol. i*a*, pp. 240, 248, 249, 250, 251, 252, 255, 256, 258, 266, 268.

† I. C. White: Vol. i, p. 354; vol. i*a*, 269, 273.

bed is rarely absent from the records and varies from 2 to 6 feet, shale included, but all the records are skeleton and give no information above that bed. Westward the Pittsburg soon disappears, but its place in relation to the Logan sandstone is clear, so that the horizon is followed for the most part without difficulty. At 8 miles west from the Doddridge line the Uniontown, 2 feet thick, is about 235 feet above the Pittsburg, while midway in the county it is 3 feet thick, with a streak of coal at the Waynesburg horizon, 51 feet higher. North from the railroad and 12 miles from the Doddridge line a coal bed is at 215 feet below the Washington; 9 or 10 miles southwest, near Harrisville, this bed is at 223 feet below the Washington, but at Harrisville no trace of coal is recorded, though the bed is present 3 miles south from that village. This seems to be the Uniontown, though it is about 260 feet above the calculated place of the Pittsburg. All coals are wanting in the western part of the county, there being no trace in any record of any below the Washington.

Limestone appears to be wholly wanting, as the drillers rarely make mention of even "limy shale;" but the red beds appear throughout the section. Tabulating the records, one finds that red shale occurs in some well or other at every foot in 300 feet above the place of the Pittsburg coal bed. Such shale is found in widely separated wells, filling part to all of the first 40 feet; thicknesses of 50, 45, 29, 35, 26 are recorded between 28 and 100 feet; between 100 and 165 feet are 60, 50, and 7 feet in different wells; in two wells, beds of 60 and 31 begin at 165 feet; in three wells one finds beds 85, 110, and 25 feet, beginning at about 180. The interval 180 to 290 feet is marked by thick red beds, sometimes a continuous mass; at others divided into two or more; in one case divided by the Uniontown coal bed. The highest which can possibly be in the Monongahela is at 308 feet, 10 feet below a sandstone which may be the Waynesburg. Two great beds are on the west side of the county, 75 and 100 feet thick, but it seems hardly possible to determine their relations.*

Wirt county is southwest from Ritchie. Very little information is available for this county. The Pittsburg is brought to the surface in the Cowrun anticline, or "Oil-break," and a section by the late Mr Minshall obtained near Burning Springs shows:

	Feet	Inches
1. Waynesburg [Uniontown] coal bed.....	1	8
2. Concealed and shales.....	207	0
3. Pittsburg sandstone	30	0
4. Shale	10	
5. Pittsburg coal bed.....	1	8

* I. C. White: Vol. I, pp. 302, 303, 304, 305, 311, 313, 317; vol. Ia, pp. 410, 426, 435, 439.

giving a total of 250 feet. It is evident that the Waynesburg coal bed of the section is that which has been followed across the region as the Uniontown. A record on the east side of the county reports 5 feet, and one on the west side 3 feet of coal at the Pittsburg horizon; but Doctor White states that the coal is frequently absent.*

Wood county, west from Pleasants, Ritchie, and Wirt, adjoins Washington and Meigs of Ohio. In this county there is little to correlate; the coal beds have disappeared, even the Washington, the persistent bed of the Dunkard, becomes indefinite; the varying thickness of the Lower Carboniferous limestone makes it impossible to use either the Logan sandstone or the Berea grit as a datum except within the narrowest areas. At Parkersburg, on the Ohio, the presence of the Brookville coal bed enables one to fix approximately the place of the Pittsburg; it is at the top of a mass of red and blue shale, not far below a sandstone 31 feet thick, above which red shale seems to predominate. The most notable feature of the well records in various parts of the county is the great quantity of red shale, beginning often in the Conemaugh and continuing many feet up into the Monongahela. The conditions change abruptly in short distances, thick reds in one well being absent in another and sometimes replaced by sandstones.†

Returning to the east, we find that the Pittsburg coal bed has been mined in Upshur county near Buckhannon, where it is 4 to 5 feet thick, and an opening near the line of Barbour county shows it 5 feet 6 inches, with a very thin parting almost midway. The coal in the upper bench is hard, contains much semi-cannel, and leaves a bulky red ash; that in the lower bench is tender, with thick layers of brilliant, structureless coal, showing no lamination and with conchoidal fracture. These layers are 2 to 4 inches thick and the coal from the whole lower portion leaves a white ash. The roof division of the bed seems to be wanting there. In Lewis county, the Pittsburg is from 4 to 8 feet thick, the variation being mostly in the upper bench. The same distinction in character of the coal is shown here, and so marked is it that where no parting exists the limits of the benches are well marked. Another coal bed is at a little distance above the Pittsburg, and in Lewis county the Uniontown is 275 feet above the Pittsburg and very thin.

The Pittsburg is present in Braxton county south from Lewis, but in economic quantity only on the western or Gilmer side, where it is from 5 to 6 feet thick, the variation being in the upper bench. It becomes thin toward the southeast and disappears before the outcrop has

* I. C. White: Vol. I*a*, pp. 467, 468.
† I. C. White: Vol. I, pp. 285, 286, 292, 293, 294, 295.

been reached. The bed persists toward the southwest to the boundary line, though sometimes only 3 feet thick. In the extreme southwest it is 175 feet below a massive sandstone. The coal is present in separated patches across northwestern Clay and southern Roane county, varying from 2 to 4 feet. It underlies a sandstone which persists southeastwardly and is present at Clay courthouse, though the coal has disappeared. No higher coal bed is reported anywhere within Braxton, Clay, Roane, and the immediately adjacent part of Kanawha county, and at the border of the last county the Pittsburg has only a few inches of very impure coal. Thence it is wholly wanting for about 10 miles, but reappears suddenly, about 4 feet thick, at the head of Two-mile creek, where it shows:

	Feet	Inches
Roof coal	0	6
Clay	1	0
Bony coal	0	6
Coal	3	0
Bony coal	0	1
Coal	3	6

But its occurrence is very uncertain. It is mined within some small areas near Raymond City and Winfield, in Putnam county, where at times it becomes thick and has a structure like that observed in typical localities at the north; but for the most part in this Kanawha region it is wanting and coal rarely appears above it; so that one recognizes the force of Mr M. R. Campbell's statement, that no line can be drawn between Allegheny and Dunkard for the Kanawha area. He groups the upper Conemaugh, Monongahela, and Dunkard together into one, which he terms the Braxton formation—a succession of greenish and reddish shales and sandstones. Doctor White's sections show an abundance of red shale in 200 feet above the Pittsburg horizon. The Pittsburg coal bed appears to be practically wanting in Cabell county west from Putnam, but is caught near Central City and Huntingdon, where it is more than 4 feet thick. A petty area remains in Wayne county 8 miles south from Central City, where the bed is 3 feet thick. No place is known in Kentucky where the section is high enough to reach this coal.*

In Gilmer county, west from Lewis, a massive pebbly sandstone very like the Waynesburg overlies the Uniontown coal bed and is apparently the same with that in the Sedalia boring and along the Baltimore and Ohio railroad in Doddridge county. The Uniontown coal bed is shown

* I. C. White: Vol. ii, pp. 144, 149, 162, 163, 181, 185, 186, 188, 190, 191.
M. R. Campbell: U. S. Geol. Survey folios, Huntingdon.
J. J. Stevenson: Proc. Am. Phil. Soc., vol. xiv, pp. 377, 378.

under it quite frequently in Gilmer county, where, as in Lewis, it is known as the Chestnut Oak coal. Doctor White found impure limestones, 2 and 3 feet, at 135 and 22 feet above the Pittsburg, the higher bed only 10 feet below the great sandstone. Other massive, more or less pebbly sandstones, each 40 feet thick, are at 55 and 147 feet above the Pittsburg coal bed. That bed varies greatly in Gilmer county, sometimes double and 7 feet thick; at others with only the lower bench, while in a large part of the county it is wanting. Red shale is reported from a few places in Gilmer; there is much of it at the southeast, near the Braxton border, and a well at the northeast near the Lewis line reports 76 feet at 175 feet above the Pittsburg—a deposit widespread in other counties—while on the western border 88 feet thickness overlies the calculated place of the Pittsburg coal.*

Calhoun county, southwest from Gilmer and southeast from Wirt, is east from Roane. The conditions are very obscure in Calhoun and Roane and one may draw only tentative conclusions from the records, which prove little more than that the series is unbroken by any physical boundary from the Conemaugh to the Dunkard. One Calhoun record shows a thin coal bed, not far from the place of the Pittsburg, underlying 125 feet of red shale, on which rests a sandstone 50 feet, but another gives only 60 feet of red shale in two beds within the same interval. A record in northern Roane shows apparently the same sandstone resting on 15 feet of red, but there is no more red in 250 feet below. The red shales are less important in northern Roane than in Ritchie and Wood, the greatest thickness being 84 feet in four beds within 225 feet above the presumed Pittsburg horizon.†

Jackson county, west from Roane and Wirt, is south from Wood, along the Ohio river. In the southern part, near Kenna, 10 miles from Sisson, north from Sissonville, in the Kanawha area of Pittsburg coal, a detailed record shows no coal at that horizon; but it may be that the horizon is represented by 24 feet of carbonaceous shale underlying 22 feet of sandstone. Above the sandstone for 316 feet are only shales holding two red beds, 92 and 58 feet, at 84 and 240 feet above the black shale. Twenty-two miles northwest is a record at Ravenswood, on the Ohio, starting near the place of the Washington coal bed. The Pittsburg coal bed is here, reported 5 feet thick, and underlying a sandstone of 53 feet. Red shales 12, 8, and 10 feet are at 73, 151, and 186 feet above the coal, and above the highest bed there is evidently a sandstone, though it is not

* I. C. White: Vol. i, p. 257; vol. ia, p. 386; vol. ii, pp. 142, 182, 186.

† I. C. White: Vol. i, p. 264; vol. ia, pp. 395, 396; vol. ii, pp. 398, 399.

differentiated. At Ravenswood this sandstone, coarse and pebbly, is in the river bed, and at Murraysville, 10 miles farther up the river, it has a thin coal bed under it. This sandstone, which passes under the Ohio at Blennerhassett island, 4 miles below Parkersburg, is apparently the same with a sandstone, 15 feet, in the Parkersburg well, 28 miles from Ravenswood, and it apparently becomes unimportant farther north, as there seems to be no trace of it at Marietta, Ohio.*

In Mason county, west from Jackson, there is no information available except along the Ohio and Great Kanawha rivers. At Letart falls, 12 miles west from Ravenswood, the sandstone is 273 feet above the Pittsburg, which is worthless, its carbonaceous matter, as at Kenna, being distributed through a great thickness of black slate. It underlies 8 feet of sandstone on which rests a red bed 115 feet thick. Other red beds succeed, but they are not differentiated in the record, until at 213 is another, 60 feet thick and extending to the sandstone. At Antiquity, 6 miles below Letart falls, the sandstone is 241 feet above the Pittsburg, with the interval mostly concealed; but at 11 miles another section shows the interval 250 feet, with several beds of red shale. A massive, somewhat pebbly sandstone, 70 feet thick, is separated from the Pittsburg coal bed by 15 feet of plant-bearing shale. Limestone seems to be wholly wanting, aside from some nodules at 193 feet.

The Pittsburg coal bed, as in Ohio, very soon becomes unimportant below Pomeroy, and at Point Pleasant, near the mouth of the Great Kanawha river, it is only 2 feet thick and impure. The decrease continues southeastwardly, for a boring at Arbuckle, 15 miles from the mouth of the river, shows only some coaly slate at its horizon. A coal bed, possibly at a Sewickley place, is 89 feet higher, and at 268 feet is a mass of coal and slate, 3 feet thick, underlying a massive sandstone, which may be the Waynesburg.†

The Dunkard Formation

CORRELATION

The Dunkard area is much smaller than that of the Monongahela, embracing little more than 7,000 square miles. It is confined to Washington and Greene counties of Pennsylvania, the western central counties of West Virginia and Belmont, Noble, Monroe, Washington, and Meigs of Ohio. Small outlying areas occur in other counties, but they are

* I. C. White: Vol. 1*a*, p. 478. Catalogue of West Virginia University, 1883-1884, pp. 83, 84.

† I. C. White: Vol. I, p. 281; vol. II, pp. 142, 143. Catalogue of West Virginia University, pp. 85, 86, 87. Bull. U. S. Geol. Survey, no. 65, p. 54.

insignificant. At one time the beds of this formation were continuous eastward to beyond the Alleghenies, as fragments remain in Maryland and west central Pennsylvania. The extreme thickness, as found in the southwest corner of Pennsylvania at the West Virginia line, and determined by oil-well records, is a little less than 1,200 feet. The thickness decreases greatly toward the north, the bottom 475 feet becoming about 165 feet at the most northerly exposure and the succeeding 240 feet is reduced to 150 feet at its northernmost exposure, nearly 30 miles south from that of the lower interval. There is a similar decrease in a northwestward direction, and toward the southwest one finds the bottom 700 feet of the thickest area reduced to barely 500 feet in Tyler of West Virginia, 35 miles away. Nothing can be determined respecting conditions toward the east, as erosion due to great anticlines prevents comparison with the fragments east from the Alleghenies in the deep basins of Broad Top and Maryland.

In the original description of this formation as it is in Pennsylvania, Stevenson divided it into the Washington County and the Greene County group, placing the plane on top of the Upper Washington limestone. Aside from the convenience of a division in a column of such length and complexity, one must recognize in the physical conditions good reasons for this separation. These, as will be seen, appear only in part along Dunkard creek, where Doctor White's studies led him afterwards to group the whole succession into one formation, the Dunkard. They are best shown farther north, in central Greene county, where they justify a return to the original grouping and to the recognition of the Washington and Greene formations as of equal rank with the Monongahela and others below.

As the Dunkard column is almost as long as the total of Allegheny, Conemaugh, and Monongahela in the northern part of the field, the characteristic deposits are numerous, most of them exhibiting peculiarities deserving of notice. In ascending order they are:

Washington formation:
- Cassville shale.
- Waynesburg sandstone.
- Waynesburg A coal bed.
- Colvin limestone.
- Waynesburg B coal bed.
- Little Washington coal bed.
- Washington sandstone.
- Washington coal bed.
- Lower Washington limestone.

Washington formation:
- Blacksville limestone.
- Washington A coal bed.
- Middle Washington limestone.
- Jollytown coal bed.
- Franklin limestone.
- Canton coal bed.
- Upper Washington coal bed.

Greene formation:
- Boyd coal bed.
- Ten-mile limestone.
- Pursley coal bed.
- Rogersville limestone.
- Jollytown limestone.
- Dunkard coal bed.
- Fish Creek sandstone.
- Hostetter coal bed.
- Nineveh limestone.
- Nineveh coal bed.
- Nineveh sandstone.
- Limestone XI.
- Limestone XII.
- Baresville coal bed.
- Jackson limestone.
- Gilmore sandstone.
- Windy Gap coal bed.
- Windy Gap limestone.*

The Cassville shale (I. C. White, 1891), 5 to 10 feet thick and resting directly on the Waynesburg coal bed, carries an important flora at many places. The type locality is in Monongalia county of West Virginia, where were obtained the plants described by Fontaine and White. This shale was removed from much of the area during deposit of the overlying Waynesburg sandstone. Limestone is persistent in it within western Washington county and thence across Ohio of West Virginia into Belmont of Ohio, but it is wanting in eastern Washington as well as in Greene and in the small areas of Fayette and Westmoreland.

The Waynesburg sandstone (J. J. Stevenson, 1872) is persistent around the borders of the area. In Maryland, Westmoreland, Fayette, eastern Washington, and Greene of Pennsylvania, as well as southward to Harrison county of West Virginia, it is a sandstone, usually massive

* While preparing this description the writer learned that not all of the original note books had been lost in the fire which destroyed the state capitol at Harrisburg. By request of Messrs A. S. McCreath and E. V. d'Invilliers, search was made and those covering Greene and Washington counties were discovered. By means of these it has been possible to remove some misconceptions due to incomplete publications of sections and to correct some errors of correlation due to rapid preparation of the report on that area.

and often to some extent conglomerate. In the interior of Washington county, as well as in Allegheny county, it is apt to be shaly, but in the western part of the former county it is usually massive. Oil-well records show it to be persistent as a massive sandstone in Greene county and the northern counties of West Virginia, often 70 feet thick and sometimes continuous downward to the Uniontown sandstone. Farther south the conditions are irregular; sandstone, often very thin, is generally present within the interval in Doddridge, Ritchie, and Wood counties. Farther south a sandstone is in Putnam county at about 240 feet above the Pittsburg. Though the tracing is not complete, enough is known to render most probable that this is the same with the sandstone of Jackson county and of Meigs in Ohio, which is the Waynesburg. Along this southern border the rock is massive, more or less conglomerate, with white quartz pebbles often an inch in diameter. In Meigs, Morgan, and Athens of Ohio it is the upper sandstone and conglomerate mentioned by Professor Andrews. Along the western outcrop it is insignificant in Muskingum, but farther north, in western Belmont, in Harrison, and southern Jefferson, it is a well marked sandstone. The sandstone of this interval is insignificant and at times replaced by sandy or even clayey shale within a large interior area embracing Ohio, western Marshall and Wetzel, Tyler, Pleasants, and Wood county of West Virginia as well as eastern Belmont, Monroe, and most of Washington county of Ohio.

The Waynesburg A coal bed...Maryland and Pennsylvania: Waynesburg A. J. J. Stevenson, 1876. Ohio: XII, Washington. West Virginia: Waynesburg A, Washington.

This coal bed, just above the sandstone, is rarely more than 3 feet thick, usually much less and nowhere of even local importance. It is apparently absent from Allegheny county, but it was seen at almost every place in the four southwest counties of Pennsylvania, as well as in the northern counties of West Virginia. In Ohio it is distinct in Harrison, Jefferson, Belmont, and Monroe, where the observations are numerous, and it has been reported occasionally in Muskingum, Noble, and Washington, where recorded observations are very few. The geographical extent of this small bed is even more remarkable than that of the Uniontown, for the latter is of real value in a few areas, whereas this bed is always too thin to be of use. It differs from the Uniontown in that it is almost invariably coal, whereas the lower bed is often merely black shale for long distances.

The Waynesburg B coal bed (J. J. Stevenson, 1876) is equally insignificant in thickness and is found in only a limited area within south-

west Fayette, eastern Greene, and southern Washington of Pennsylvania. Even there it is irregular, being absent at many places where its horizon is fully exposed. The Little Washington coal bed (J. J. Stevenson, 1876) has much the same distribution as that of Waynesburg B, but the area is somewhat smaller.

A limestone, the Mount Morris (I. C. White, 1891), sometimes underlies the Waynesburg A coal bed, but it seems to be confined to small spaces. The typical locality is in southeastern Greene, but limestone is found occasionally at this level in West Virginia and eastern Ohio. The Colvin limestone (I. C. White, 1891), I*a* of the Pennsylvania volume K, is just above the coal bed and is present in Fayette and most of Washington county. It was seen at many places in eastern Greene, but is wanting in the western part of that county and is irregular in the southern part. It attains considerable thickness in Washington, but is usually thin in Greene. It barely enters West Virginia at the south. Another limestone, termed I*b* by Stevenson, is apparently confined to five townships in the west central part of Washington county, where it attains a maximum thickness of 10 feet. These limestones are all either nonfossiliferous or contain at most some indeterminate forms related to freshwater types. The rock is not magnesian in any case and sometimes the lime obtained from it is of excellent quality. The source of these calcareous muds is uncertain.

The Washington sandstone (J. J. Stevenson, 1876), underlying the Washington coal bed, is curiously persistent. Rarely more than 12 feet thick, it accompanies the Washington coal bed throughout Washington and Greene of Pennsylvania, Ohio and Monongalia of West Virginia, everywhere showing the same features. How much farther it extends is not known. It is thinly laminated, often crowded with fragments of carbonized vegetable matter, but seldom contains a leaflet in recognizable condition. Very often it is seamed vertically, and the slender seams are filled with lead-colored clay belonging to an underlying bed. These seams have no relation to jointing in the overlying and underlying coal.

The interval between the well marked Waynesburg and Washington coal beds shows the same kind of variation as that between the Waynesburg and Uniontown. At the extreme northern exposure of the Washington in Smith and Jefferson townships of Washington county, Pennsylvania, it is 50 feet above the Waynesburg. As one goes southwardly along the western side of the county he finds the interval 65, 83, 90, 95, 110, and 130 feet at the southern part of the county, beyond which in Greene the upper bed soon passes under. In a southeastward direction the interval becomes 65, 90, 110, 120, 125, and 142 and at the Greene

county line 160 feet; in this county it increases to 180. Westwardly, beginning in Donegal township of Washington, it is 90, near Wheeling, 96 to 100, at Bellair, 4 miles south, in Belmont, 117, while in western Belmont it is 100 feet, which seems to be maintained on most of the western outcrop. The Bellair interval seems to be approximately that for a considerable distance along the Ohio river, while in the northern counties of West Virginia the interval is from 160 to 170 feet. It is somewhat less by the time one reaches the central part of the state.

The Washington coal bed..... J. J. Stevenson and I. C. White, 1876.	Maryland: Washington. Pennsylvania: Waynesburg, Washington. Ohio: XIII, Hobson, Washington. West Virginia: Washington.

This coal bed, 50 to 180 feet above the Waynesburg coal bed, has been found almost invariably wherever its horizon is reached in Maryland, Pennsylvania, Ohio, and West Virginia. It was termed Brownsville by Doctor White, but to avoid confusion with the Pittsburg, already known as the Brownsville in much of western Pennsylvania, the name was changed with his consent to Washington. In all probability it is the thick coal bed near the top of Round Knob in Broad Top and it is clearly recognized in the Maryland area. Its distribution in West Virginia toward the eastern border is a little uncertain, as there seems to be no doubt that it and the Uniontown have been mistaken each for the other in the earlier observations; but Doctor White has made clear that the bed is present at the southeast almost to the border of Clay county, while borings show it across the state to the Ohio, where from Wheeling to Pomeroy it is rarely missing; and in Ohio wherever the record is high enough to reach this bed it is shown in Belmont, Monroe, Muskingum, Morgan, Washington, and Meigs, all of the counties in which its horizon is reached.

The bed is multiple in by far the greater part of the area; even at the extreme east, in Maryland, it is triple, and of its 3 feet 6 inches 1 foot is in the clay partings. East from the Monongahela river, in Pennsylvania, it is rarely more than 4 or 5 feet, but one opening in Westmoreland county shows 9 feet 3 inches in five benches, of which the lowest is 4 feet 2 inches, while another, 3 or 4 miles away, has the bed in eight benches and 8 feet 10 inches thick. It is thin in Allegheny county and very irregular in northwestern Washington, where it is from 2 to 5 feet; but at less than 5 miles south it is a great bed, showing 5 feet of coal at one opening, on which rests a varying alternation of coal and clay 2 to 3 feet thick; still farther south one finds 1 foot 3 inches of coal under-

lying a great mass of black shale, while at a mile away the carbon is gathered into four benches and the bed is 6 feet 6 inches. The bed is usually thin in eastern Washington and Greene, but along the same area in Marion county of West Virginia it thickens and one section shows 10 feet 9 inches in 14 layers of coal and clay. Along the Baltimore and Ohio railway it is exposed frequently in Doddridge and Ritchie counties, showing the same complex structure observed at the northern exposures. Still farther south, in Calhoun and Roane counties, it is thin, rarely exceeding 2 feet 6 inches and containing, as so often at the north, the best coal at the bottom. Toward the west it becomes thin, being only 1 foot 3 inches in Ohio of West Virginia and reported in Ohio only as a blossom.

Almost without exception, coal from the Washington is inferior to that from the Waynesburg; yet it is mined for domestic fuel in a great area within the middle portion of the great trough, where the lower coals have disappeared. The coal-making conditions extended for the first time over practically the whole area, a notable change in geographical conditions.

The interval between the Washington coal bed and the Upper Washington limestone contains five important limestones and three coal horizons.

The Lower Washington limestone (J. J. Stevenson, 1876), 3 to 15 feet above the Washington coal bed, has been recognized in Maryland, and it is present at almost all places in Pennsylvania where its horizon is exposed. Doctor White has recognized it on the eastern side in West Virginia as far south as Tyler and northern Harrison, but toward the west it becomes insignificant, being very thin along the Ohio river and apparently wanting in most of Ohio. It is thin and often only calcareous shale in most of eastern Washington, but in the central part of the county it is from 15 to 33 feet thick, while on the west side it varies from 6 inches to 20 feet, these measurements being separated by only half a mile. In Greene county it rarely exceeds 3 feet. In Ohio county of West Virginia it is 20 feet thick at a few miles east from Wheeling, though thin at that city and apparently wanting 4 miles south at Bellair, Ohio. It usually underlies a black shale rich in carbon and often containing fish remains.

The Blackville limestone (I. C. White, 1891), III of volume K, at 25 to 70 feet above the Washington coal bed, is not reported from any locality east from the Monongahela river except in Redstone of Fayette county, Pennsylvania, but it is persistent in Allegheny, Washington, and Greene counties. It is not more than 3 or 4 feet thick at the most north-

erly exposure of its place in Allegheny county, but it quickly increases in northern Washington to 10 and to 30 feet. Unlike the Lower Washington, this deposit is insignificant in the central part of Washington county, where it is represented only by thin streaks; but it becomes better characterized in the southern part, where, as in Greene county, it is 3 to 4 feet thick. It disappears quickly west and south from the Pennsylvania line and it cannot be recognized certainly in any of the sections. It may be represented by one of the red beds. A black shale overlies this limestone at many places, and at times is rich in well preserved remains of fish. The Blacksville limestone was mistaken for the Middle Washington at several places in Allegheny and northern Westmoreland.

The Middle Washington limestone (J. J. Stevenson, 1876), numbered IV in volume K of the Pennsylvania reports, is not exposed in Pennsylvania east from the Monongahela river, where in all probability it is wanting. A limestone in Maryland has been correlated with this. The Middle Washington is present in most of Washington county, where its variations are very like those of the Blacksville, but its thickness is greater in a larger area; it practically disappears soon after passing into Greene county, and farther south it has been recognized only near the West Virginia border. There it is extremely sandy and weathers like sandstone; but it may be present in this condition elsewhere in the county. Unlike the Blacksville, this is always impure and often ferruginous.

The Franklin limestone (V of Stevenson, 1876) is exceedingly characteristic in Greene county, where it is coarsely brecciated and very hard, resisting the weather. It was mistaken by Stevenson for the Upper Washington in northwest part of the county where the higher limestone is very thin. This limestone, rarely more than 3 feet thick and often much less, is from 20 to 35 feet below the Upper Washington in Greene, where it is present at all localities exposing its place; it is present in the western townships of Washington at about 30 feet below the Upper Washington and its thickness exceeds 2 feet only twice. It was not seen in place in the central or eastern parts of the county, but its characteristic fragments were found in Franklin and Amwell townships very close to its proper position. It seems to be absent west from these Pennsylvania counties and Doctor White does not report it from West Virginia at the south.

The Upper Washington limestone (J. J. Stevenson, 1876), numbered VI, is the most persistent and in many respects the most striking member of this group. Its northernmost exposure is in northwest Washington

county, and thence southward it appears in every section, exposing its place in Pennsylvania until very near the West Virginia line. A limestone in Maryland has been correlated with this bed; the interval to the Washington coal bed, 192 feet, seems excessive, in view of changes in lower intervals in that direction, but no comparison can be made directly, as a gap of about 70 miles separates exposures. This limestone disappears southwardly very soon after entering West Virginia, and it cannot be recognized with any certainty in any of the long sections along the Ohio river south from Moundsville, West Virginia, where it is 244 feet above the Washington coal bed. In some of those sections, however, a red bed, with limestone nodules, is very near the place of this limestone.

The Upper Washington is flesh-colored, blue, and dark gray in its several portions, but all alike weather to an almost snowy white faintly tinged with blue; much of it is very pure and several of its layers waste very slowly on exposure. These features make the bed an unmistakable stratigraphical guide from its most northerly exposure to beyond central Greene county, as well as in the portions of Fayette county in which its place is reached. At the extreme north the bed is thin, but thickens southwardly to central Washington, where it is a mass of limestone and calcareous shale 20 to 30 feet thick. Along the southern border of the county it is 8 to 12 feet, and in Greene county, where the middle or dark portion has disappeared, it seldom exceeds 3 feet.

The coal beds in this interval are unimportant.

The Washington A coal bed (J. J. Stevenson, 1876), between the Blacksville and Middle Washington limestones, was supposed at the time it was described to be confined to three townships of southeast Greene county. There it is an alternation of coal and shale 3 to 4 feet thick and possessing no value. It is a fairly well marked horizon elsewhere, showing black shale at many places in eastern Greene and coal in two townships on the west side of the county, the only ones exposing its place. Occasionally one finds a coal streak in Washington county at varying distances below the Middle Washington limestone which may or may not be contemporaneous in part with the deposit of Greene county.

The Jollytown coal bed (I. C. White, manuscript, 1875; J. J. Stevenson, 1876), named from a village in southwest Greene county of Pennsylvania, is 25 to 40 feet below the Franklin (V) limestone in eastern and southern Greene, but is irregular in the northwest part of the county, where its place is reached again. It is distinctly present in Amwell and Franklin townships of Washington, into which it was traced from Greene county, and a blossom or thin coal marking this horizon was seen

in several other townships. Failure to recognize the Franklin limestone in this county led Stevenson to confound the Canton horizon with this at a number of localities. The bed is present in Fayette county of Pennsylvania, but it is not the Jollytown coal of Maryland, which is higher in the column. Some confusion has existed respecting the proper application of this name, due to omission of part of the section at Jollytown, so that in reading the text as published* one might easily imagine that Limestone V and Limestone IX of two sections there given may be the same; but the full measurements taken from the original notes as given on a succeeding page make the matter wholly clear. This coal bed is always thin, seldom even 2 feet thick, but it is apparently continuous under an area of several hundreds of square miles, as it is never absent where its place is exposed. It is certainly continuous southward into Monongalia and Wetzel of West Virginia, but it is absent from the published sections within Marshall of that state. There are two thin coal beds in southwest Greene within a vertical space of 55 feet, the Jollytown at about 50 feet below the Upper Washington limestone and the Boyd just above that limestone. The disappearance of the limestones makes it difficult to determine which of these beds persists. In the succeeding pages a bed at Bellair, Ohio, is taken to be the Jollytown; it is 183 feet above the Washington coal bed. At Moundsville the Upper Washington limestone is 244 feet above that coal bed, and at Bellair the interval should not be more than 210 feet. Evidently the same bed is at Baresville, in Monroe county of Ohio, and Liberty, in Washington county, at 149 and 140 feet above the Washington. Oil-well records give information respecting the distribution of the bed in the deeper parts of West Virginia, and its place is concealed in Doctor White's sections along the Ohio river.

The Canton coal bed is wholly insignificant and without interest except in respect to its distribution. It is confined to Washington county of Pennsylvania, where, in the central and western parts, one usually finds a thin streak of coal at 12 to 30 feet below the Upper Washington limestone. The thickness is usually less than 1 foot and the bed disappears westwardly in the West Virginia panhandle at little more than a mile from the state line. No trace of this deposit was seen in Greene county.

The variations in the interval between the Washington coal bed and the Upper Washington limestone resemble those observed in the interval below. The numerous elements of the section make the tracing comparatively simple. At the extreme northern exposure of the whole in-

* Pennsylvania reports, vol. K, p. 111.

terval, in Smith township of Washington, the beds are 110 feet apart. Along the west side of the county this increases to 140, 150, and 160 at the Greene county line; but thence the increase is more rapid, so that in southeastern Richhill township of Greene it is 240, and at a little southwest in Aleppo it is 308 feet; the same interval is found in Marshall county of West Virginia, 7 or 8 miles farther southwest. One finds the increase in a southeasterly direction, 110, 135, 140, and as one approaches the Greene county line, in Amwell of Washington, 180 to 190 feet. Where the beds are reached again, in Franklin of Greene, the measurement is 270, and in Perry, near the West Virginia line at the south, it is about 300 feet. Westwardly, in Ohio county of West Virginia, the interval is 140, and in the adjacent part of Washington county it increases south of west in 15 miles to 244 feet at Moundsville, and in 23 miles southward to 308 feet at Belton. What the conditions are beyond one may not assert positively, but if one may decide from the relations of the Jollytown coal bed, the interval decreases notably toward the southwest.

The variations in character of the rocks in this interval is important. The limestones are the chief features of the section in Washington county, especially in the central portion of the county; in all directions they become thin, so that in Marshall of West Virginia at the west all have disappeared except the Upper Washington; in Fayette, all are thin; southward, in West Virginia, all disappear quickly except the Lower Washington. Massive sandstone is rare in Washington and Greene, though occasionally one finds in those counties as well as in Fayette a massive rock underneath the Upper Washington. Other sandstones become noteworthy farther south until in Washington county of Ohio and the adjacent counties of West Virginia one finds the great sandstones quarried for grindstones and termed by I. C. White the Marietta sandstones (1903). He has found these beds more or less prominent in the southern part of the Dunkard area within West Virginia.

The next characteristic interval, that between the Upper Washington and Nineveh limestones, is followed with great ease within Pennsylvania. The Nineveh limestone, at the top, is 25 to 35 feet below the Nineveh coal bed, which underlies the massive Nineveh sandstone. The massive rock above has protected the underlying beds in the most important localities, so that there is little danger of error in identification of the Nineveh limestone. The lower limiting bed, the Upper Washington limestone, is equally well defined, not only by its associated beds, but also by its peculiar features.

The Ten-mile limestone, VII of volume K, is a persistent bed about 14 feet above the Upper Washington in central Washington county; but

the interval increases southwardly to 20, 30, and in central Greene county to 40 feet. The increase is less rapid southwestwardly, for it is only 27 feet in Richhill of northwest Greene. The place of this limestone is not reached north from the borough of Washington. It is thick in Washington, but in Greene it is rarely more than 3 feet, is usually earthy, and it disappears toward the southwest. The Rogersville limestone, VIII of volume K, must be regarded as confined to central Greene county, where it is 19 to 35 feet above the Ten-mile. Where last seen before passing under the higher beds, it is earthy, so that one is not surprised to find no traces of it in western Greene. A limestone is reported occasionally in five townships of Washington county at 65 to 80 feet above the Upper Washington, the place of the Rogersville. There are evidently many limestone lenses at this horizon.

The Jollytown limestone (I. C. White, 1891), IX*a* of volume K, is a persistent deposit in a small area. It seems to be continuous in western Greene and the adjacent part of West Virginia and it may be present in the extreme southwest corner of Washington county. Its place is concealed at all localities examined in Franklin, a central township of Greene, but the Rogersville is persistent there, as also farther east in Jefferson where a limestone is present at the proper distance above the Rogersville, as measured in Center township. This bed was seen in Perry township 9 miles south. The evidence is rather in favor of regarding this limestone, which Stevenson took to be the Nineveh, as at the Jollytown horizon. The interval from the Jollytown to the Upper Washington limestone decreases southwardly, in 12 miles, from 140 feet in Center township to 29 feet at Jollytown, on the West Virginia line; and this small interval prevails along the southern line, for near Belton and Board Tree, in Marshall of West Virginia, it is shown by Doctor White's sections to be only 30 feet. The maximum is in Center, for westward in Aleppo the measurement gives only 115 feet, while northwardly it decreases rapidly.

The Nineveh limestone (I. C. White, 1891), X of volume K, is 25 to 35 feet below the Nineveh coal bed which underlies the Nineveh sandstone. It remains in several townships along the southern line of Washington county, the most northerly point at which it has been recognized with certainty being about 30 miles south from the extreme northern outcrop of the Upper Washington. It was seen at every place in Washington and Greene exposing its place. It is equally well marked in West Virginia, where Doctor White has recognized it in almost every county, reaching its place as far south as Jackson county, beyond the Little Kanawha river. It is evidently the high limestone of Professor Andrews's

long sections in Monroe county of Ohio. The remarkable persistence of this limestone bed, so much in contrast with the limited extent of all other beds below, makes it not improbable that it may be that in the Maryland area which Doctor Martin has correlated with the Jollytown. The interval there is 238 feet above the Washington coal bed. The limestone in Pennsylvania and West Virginia is almost unmistakable, the color being a peculiar blue and the associated shales, black. It is often thin, but increases southwardly, so that beyond the Pennsylvania line it has sometimes 10 or 15 feet of limestone and calcareous shale, and at almost the last exposure in Jackson county at the south the mass is almost 30 feet.

The coal horizons are unimportant.

The Boyd coal bed refers not to a bed, but to a horizon. In the interval between the Upper Washington and Ten-mile limestones one finds oftentimes a coal streak, now almost on the lower limestone, again almost directly under the upper, and occasionally almost midway, the last condition being in localities where the interval between the limestone is greatest. The deposits can hardly be contemporaneous, but the interval is a small one and they may overlap in time. The name is taken from Boyd run, in Greene, the only place at which the coal is of workable thickness. A coal at this horizon is in West Virginia just south from the state line, where it rests on the Upper Washington. The term Pursley coal bed is used in the same way, to designate a coal horizon between Ten-mile and Rogersville limestones, an interval in which isolated deposits of coal occur at numerous localities.

The Dunkard coal bed (J. J. Stevenson, 1876), a thin but very persistent bed in western Greene, is absent from Washington and it was not recognized in the northern border of Greene county. It is not present in eastern Greene. The bed is rarely more than 2 feet thick, but is double and, like some of the lower beds, is associated with a plant-bearing shale. Though very thin, it is of much local importance, as it yields good coal. In the southwest corner of Greene, it is about 125 feet above the Jollytown coal. A trace of coal found by Doctor White on the Ohio river, in Tyler county, at about 100 feet above the bed already taken as the Jollytown, may be at the Dunkard horizon. Another coal bed, apparently that termed the Hostetter by Doctor White (1891), is in the interval between the Dunkard coal and Nineveh limestone, at about 40 feet below the latter. It is present in Springhill, Aleppo, Richhill, and Morris townships of Greene. A coal in this interval is shown in Wetzel of West Virginia.

The Fish Creek sandstone (J. J. Stevenson, 1876) is present at most localities just above the Dunkard coal bed. Sometimes it fills the whole interval to the Nineveh limestone. It differs from most of the Dunkard sandstones, in that it is well cemented and answers well for building stone. This is a characteristic feature for many miles southward in West Virginia.

The variations in the interval between the Upper Washington and Nineveh limestones deserve especial consideration. As has been remarked, the limiting beds are traceable with the utmost ease, and the connecting lines as well as the measurements are so numerous as to leave no room for doubt respecting the relations in by far the greater part of the area.

At the southwest corner of Washington county, Pennsylvania, these limestones are 150 feet apart; 5 or 6 miles east the interval is 180, decreasing to about 160 in 3 or 4 miles farther. If the highest limestone in Franklin of Washington, 5 miles northeast from the last, be the Nineveh, as supposed, the interval there is but 150 feet. In the northern townships of Greene this interval, 150 feet near the West Virginia line, increases gradually to about 180 at the most easterly measurement, say 15 miles away. These measurements are barometric, but they are checked by a well record near Nineveh, 12 miles east from the West Virginia line, where the Nineveh coal bed is 488 feet above the Waynesburg, making the distance from the Nineveh limestone about 450; so that the interval under consideration cannot be more than 150 feet. A high ridge crosses Greene county in a south-southwesterly direction from near Nineveh. Following the east side of this ridge from Nineveh into Center township, one finds a remarkable increase within 5 miles, for the measurement is

Nineveh limestone.	
Interval	120
Dunkard coal bed	2
Interval	35
Jollytown limestone	7
Interval	135
Upper Washington limestone.	

practically 300 feet, and showing the Pursley coal bed, Rogersville and Jollytown limestones, and the Dunkard coal bed, all of which seem to be wanting in the Nineveh region. On the other side of this ridge, 5 or 6 miles northwest, the interval is little more than 150 feet, with these beds wanting; but westward, in Jackson township, the Dunkard and

Jollytown are present, and still farther west Doctor White's Aleppo section shows the succession completely and the interval is 313 feet. But southwardly the decrease is rapid, for in southern Center, a direct measurement gives only 262 feet, and at a few miles farther, near the West Virginia line, it is only 208. At Belton, in Marshall of West Virginia, about 10 miles west from the last, the interval is 238. Eastward the Nineveh limestone is exposed in no section south from the northern tier of townships, but the Jollytown limestone seems to persist and the interval to it from the Upper Washington is 145 feet at, say, 15 miles east from the Center measurement and the general conditions are apparently as in Center; but in the southeastern part of the county the interval between these limestones is less than 100 feet, showing a decrease in that direction.

No detailed sections are available in West Virginia until the Ohio river is reached, where are the long sections by Professor Andrews and Doctor White, which show the Nineveh limestone 368 to 380 feet above the Washington coal bed. That interval at Belton, in Marshall county, is 551 feet. Using the Jollytown coal bed for comparison, the interval from the Upper Washington to the Nineveh is about 200 feet at New Martinsburg, in Wetzel county, and apparently the same in Tyler county, showing very gradual change in 40 miles southwestwardly.

The changes are particularly in the lower half of the interval and differ materially from those of the preceding intervals. That portion lying between the Fish Creek sandstone and the Ten-mile limestone appears very abruptly as one approaches central Greene from the north; its greatest thickness is in a narrow east and west strip across the central part of the county. Southwardly almost the whole interval between the Upper Washington and the Jollytown limestones disappears, and apparently it is almost wholly unrepresented southwestwardly in West Virginia. The contrast in conditions is almost as great as that between the Conemaugh and Monongahela.

The remaining beds of the Dunkard require only a brief reference, as the area in which they have been recognized in detail is very small.

The Nineveh coal bed (J. J. Stevenson, 1876) is double, seldom exceeds 2 feet, but, like the Dunkard, yields such good coal that it is mined by stripping and possesses not a little of local importance. It is persistent in southern Washington and Greene and in West Virginia to many miles beyond the state line. It underlies the Nineveh sandstone (I. C. White, 1891), which is persistent for at least 30 miles southwestward in West Virginia. This is a massive rock, very similar to the Fish Creek sandstone, overlying the Dunkard coal bed.

On the high ridge of central Greene there are several limestones which Stevenson designated by numbers. XI and XII are, in round numbers, at 80 and 160 feet above the Nineveh limestone and are persistent in the five townships of Greene county in which their place is exposed; they are concealed in the southwest townships of Greene and in the adjacent part of West Virginia. XI is always thin, but XII is from 8 to 15 feet thick and appears to be associated with much chert in Morris township of Washington county. This was not seen in place, but it is above XI on a hill which reaches almost to XII. A thin limestone at 30 feet higher underlies a coal blossom which is at the place of the highest coal in Professor Andrews's Baresville section, 150 feet above the Nineveh limestone, and the name has been assigned to it for that reason. Two higher limestones are present on this ridge, of which the upper is 275 feet above the Nineveh coal bed and about 30 feet below the Gilmore sandstone. It is exposed only in Center and Jackson townships of Greene, but it was found in a well in Gilmore township. It is evidently the limestone found in Wetzel township at about 100 feet below the Windy Gap limestone. This, which may be termed the Jackson limestone, seems to be clearly persistent along a line of more than 30 miles, beyond which information is lacking. It is a tough, impure rock containing some crystalline sphalerite and is associated with plant-bearing shales in Jackson township near White Cottage.

The Gilmore sandstone (J. J. Stevenson, 1876), 30 feet thick, caps the high knobs of southwest Greene, and it has been followed along the middle line of the trough for 40 or 50 miles by Doctor White. It is soft, somewhat incoherent, and is apt to weather into large cavities. At 30 feet higher is a black shale, which occasionally carries some coal, and Doctor White has called it the Windy Gap coal bed (1891). The Windy Gap limestone (I. C. White, 1891), 30 feet above the coal bed, is on two or three knobs within Greene county and in Monongahela and Wetzel to 10 miles south from the Pennsylvania line. It is a rather pure limestone and, like the Jackson, contains some sphalerite. The formation is capped by a massive sandstone seen occasionally in Marshall and Wetzel counties of West Virginia the highest stratum of the Paleozoic in the Appalachian basin.

Red shales in the interval between the Waynesburg and Washington coal beds find their chief development in what may be termed the "red area" of West Virginia and Ohio. The individual beds within Wood, Jackson, and Mason of West Virginia and Meigs of Ohio are from 25 to 100 feet thick. In Tyler, Doddridge, Ritchie, Wirt, and Calhoun of West Virginia, east Washington and east Monroe of Ohio, a bed is very

often found within 50 and another at about 100 feet below the Washington; a bed near the Waynesburg A is in Muskingum of Ohio and Harrison of West Virginia; but reds are unknown elsewhere, except at one locality in southwest Washington county of Pennsylvania, where a bed 10 feet thick is at 30 feet below the Washington. In geographical extent, the reds of this interval are inferior to the Tyler reds and far inferior to the Ritchie reds.

An expansion appears in the interval between the Washington coal bed and Upper Washington limestone. Well records are wanting in several counties within the "red area," but enough is known from surface observations to show that, as before, the chief importance is in that area. In Wood county of West Virginia red shale is present in some well or other at every foot of the interval, and in Washington county of Ohio the same statement is true for 150 feet above the coal. In those counties the beds are 50 to 100 feet thick. Reds are in the bottom 70 feet of the interval as far north as Wetzel and as far east as Harrison county, but they are wanting apparently in Marshall and in Belmont of Ohio. A very persistent deposit begins at 70 to 90 feet above the coal and is present in all of the counties named, including Marshall and Belmont, and a still higher deposit is shown at Moundsville, 45 feet thick and directly underlying the Upper Washington limestone. Its place is not reached in any recorded section farther north, but it is doubless represented farther south by some of the thin beds. No records are available for Monongalia and Marion counties of West Virginia, but in all probability these reds are there, for a well record just over the line in Greene county of Pennsylvania notes three beds in this interval, in all 50 feet; but elsewhere in Greene, Washington, and Fayette of Pennsylvania and eastern Marshall of West Virginia there appears to be no trace of reds in this interval except at three widely separated places, one in west central Greene, 2 feet, under the Franklin limestone, one in Perry township, 10 feet, at the Middle Washington horizon, and a third in southwest Washington, where a deposit 60 feet thick is divided by the Middle Washington. The reds of this interval have less extent than that of the Washington reds in the Conemaugh.

One riding over the counties of Ritchie, Wood, and Calhoun of West Virginia recognizes the great amount of red shale in the next interval, that reaching to the Nineveh limestone; but details are not accessible. Measurements of surface exposures would be worthless for comparison, owing to variability of the beds, and there are no well records, as the drillers see nothing worth recording in the dreary alternations of shale and sandstone. Doctor White mentions a "great mass" of reds under-

lying the Nineveh limestone in central Wood county, but the reds of this interval very soon become unimportant northward, for in Tyler of West Virginia and Washington of Ohio the total in three or four beds is not more than 40 feet, while in Wetzel all are insignificant, that under the Nineveh being only 5 feet; it is thicker in Monroe of Ohio, being 14 to 18 feet; but in Pennsylvania and Marshall of West Virginia reds are wanting everywhere in this interval except on the state line in Greene and Marshall, where thin deposits are near the Dunkard coal. Clearly, the reds of the Upper Washington-Nineveh interval are confined practically to the central part of the "red area."

Little can be said of the column above the Nineveh limestone. Reds in very thin beds were seen just above the Nineveh limestone in Monroe and Wetzel, but this deposit is apparently unknown elsewhere, except in southwest Washington of Pennsylvania, where it is spread through a vertical interval of 50 feet. Much red is in eastern Marshall, in the space of 180 feet above the Nineveh coal bed, and three beds, 11 feet thick in all, are in the same interval in southern Greene; but no other reds are reported from Greene county, except at one exposure where the Jackson limestone rests on a thick deposit.

It is evident that the reds of the Dunkard, outside of the "red area," are less important than are those of the Conemaugh, and that they can be compared only with the reds of the Monongahela. Their distribution is extremely irregular and in many cases the deposits seem to be due to local conditions of very limited extent.

EAST FROM THE ALLEGHENIES

A few acres of Dunkard rocks remain on Round knob, the highest point of the Broad Top area in Bedford county of Pennsylvania. There a coal bed, somewhat less than 275 feet above the Pittsburg, underlies 100 feet of concealed measures. Conditions west and south suggest that this coal bed is not far from the Washington horizon. Where exposed in 1881 it is 1 foot 4 inches thick, but Professor J. P. Lesley saw an opening in 1856 showing 7 feet of coal and shale. It seems to be almost in contact with a thick underlying limestone.*

Some isolated patches of Dunkard have been examined in the Georges Creek area of the Potomac basin in Maryland. The extreme thickness is in Allegany county, where about 400 feet remain. The sandstones, except the Waynesburg, are insignificant and the shales are mostly reddish green. The succession as given in the Maryland reports is:

* J. J. Stevenson: (T 2), pp. 59, 60, 249.

	Feet	Inches
1. Massive sandstone	10	0
2. Concealed	25	0
3. Jollytown limestone	Thin	
4. Concealed	15	0
5. Jollytown coal bed	2	2
6. Concealed	20	0
7. Upper Washington limestone	4	0
8. Concealed	80	0
9. Middle Washington limestone	2	0
10. Concealed	110	0
11. Limestone and shale	2	6
12. Washington coal bed	3	6
13. Concealed	10	0
14. Shales	63	0
15. Waynesburg A coal bed	2	0
16. Waynesburg sandstone	45	0
17. Waynesburg coal bed.		

The thicknesses are probably extreme, as separate sections have been combined to obtain the details. The correlations above the Washington coal bed are to be taken only as tentative; those which seem more probable have been given on a preceding page. The Washington coal bed retains the features characterizing it at western exposures, as appears from the diagrams given in the reports.*

EAST FROM THE MONONGAHELA RIVER, IN PENNSYLVANIA

No Dunkard beds have escaped erosion in the First and Second bituminous basins of Pennsylvania; but west from Chestnut Ridge to the Monongahela they are found in somewhat widely separated patches, at times embracing several square miles. The rocks belong to the lower portion of the column and are soft, so that exposures as a rule are very poor and the information is scanty.

In the Blairsville-Connellsville trough one finds traces of the Waynesburg sandstone at almost the northern extremity, near the Conemaugh river. Farther south, in Unity of Westmoreland county, that sandstone is 40 feet thick, and in Mount Pleasant the section reaches to what seems to be the Colvin limestone. South from the Youghiogheny river, in Fayette county, the Washington coal bed, 4 feet thick, is shown at one locality where the hills are high enough to catch the Upper Washington limestone. The Waynesburg sandstone is distinct to at least 14 miles south from the river, beyond which its place is not reached.

* C. C. O'Harra: Allegany county, p. 129.
G. C. Martin: Garrett county, pp. 144, 145; vol. v, p. 258.
W. B. Clark et al.: Vol. v, pp. 312, 313, 314, 406, 407.

It is wholly probable that some portion of the Dunkard column remains within the Greensburg trough of northern Westmoreland, but no correlation of the imperfectly exposed beds can be made.

The lower beds of the Dunkard are present in western Westmoreland almost to the Kiskiminetis river at the north, but no exposures are noted until near the Fayette border at the south. The Washington coal bed underlies the Lower Washington limestone and varies from 5 to 9 feet, in the latter case having almost 8 feet of coal in 8 benches. It is 135 feet above the Waynesburg coal bed, and the Waynesburg A, 3 feet below the bright yellow Colvin limestone, is 55 feet above the lower coal bed. Small patches in northern Fayette occasionally show the Waynesburg A and Washington coal beds with the Lower Washington limestone, but the important area is farther south, in Redstone, Luzerne, and German townships, where one has surface observations supplemented by detailed shaft records. A massive sandstone was seen in Redstone, 330 feet above the Waynesburg coal and only a few feet above a thin coal bed correlated with the Jollytown. It is like that underlying the Upper Washington limestone at some places in Washington and much of Greene, so that the correlation is probably correct. The Washington coal bed in these townships, from 3 to almost 6 feet thick, is always multiple and yields poor coal, rich in ash and sulphur. The Lower Washington and Blacksville limestones are usually present, and the Colvin limestone, with the Waynesburg A coal bed below it, is always shown where its place is exposed. The Waynesburg sandstone is prominent, though sometimes replaced in part by sandy shale; ordinarily it rests on the coal, the Cassville shale having been removed.*

The irregularity of the coal beds and the ease with which one depending only upon imperfect road exposures may be deceived are shown by comparison of the Brier Hill and Lambert records, the former in Redstone and the latter in German township:

	Feet	Inches	Feet	Inches
1. Washington A coal bed, clay, sandstone	18	9	13	0
2. Sandstone, shale, thin limestone	22	6	27	7
3. Coal bed	Thin		0	5
4. Clay, limestone, calcareous clay	8	5	9	2
5. Coal bed	3	0	2	3
6. Sandstone, shale, thin limestone	22	8	27	11
7. Washington coal bed	4	0	2	5
8. Clay and sandstone	11	8		
9. Little Washington coal bed	3	0	31	11
10. Shale	25	0		

* J. J. Stevenson: (K 2), pp. 154, 178, 211, 226, 227, 229, 231, 259, 273, 356-359, 365, 366, 381.

		Feet	Inches	Feet	Inches
11. Coal		3	0		
Sandstone, shale	Waynesburg B	7	10	2	0
Coal, black shale		2	3		
12. Limestone and clay		3	0		
13. Sandstone		47	0	50	9
14. Colvin limestone and clay		9	0		
15. Waynesburg A coal bed and black shale		4	5	3	5
16. Clay, sandstone, shale, thin limestone		59	10	61	0

to the Waynesburg coal bed. The coal beds are approximately

	Feet	Feet
Waynesburg A	60	61
Waynesburg B	124	115
Washington	176	149

feet above the Waynesburg. The first coal above the Washington is reported from only one other locality in Pennsylvania. The Washington A at Brier Hill shaft has three coal layers in all, 2 feet 1 inch thick, but at the Lambert the three layers of almost equal thickness have 5 feet 7 inches. Southward the section does not reach to the Dunkard, but westward, toward the Monongahela river, the Waynesburg sandstone becomes very massive.

WEST FROM MONONGAHELA RIVER, IN PENNSYLVANIA

The Washington coal bed at its most northerly exposure in Allegheny county is 3 feet thick and 320 feet above the Pittsburg, with the Blacksville limestone 25 feet above it and 4 feet thick. At 4 miles west the coal bed is 75 feet above the Waynesburg, while 3 miles south, in Snowden township, the interval is 90 feet, and the Waynesburg A is seen at 50 feet below the upper bed.*

The Lower Washington and Colvin limestones appear first in Cecil township of Washington county, 8 miles south from the last locality, and at 8 miles west the Blacksville limestone, 20 feet thick, is 30 feet above the Washington coal bed, which almost directly underlies its limestone. Here the Little Washington as well as the Waynesburg A is seen and the Colvin limestone is 15 feet thick. The Waynesburg sandstone is represented only by sandy shale and the Cassville shale contains 4 feet of limestone. The Washington and Waynesburg coal beds are 85 feet apart, but at 4 miles northwest, in Smith township, this interval decreases to 65 feet, and the Upper Washington limestone, 6 feet thick, is only 110 feet above the Washington coal bed. This is the most

* J. J. Stevenson: (K), pp. 303, 306, 313.

northernly exposure of that limestone. Within a mile and a half toward the west the interval between the Washington and Waynesburg coal beds is reduced to 50 feet, and that from the Upper Washington limestone to the lower coal cannot be more than 160 feet. The Lower Washington limestone is 8 feet thick and the interval between the Washington coal and the Colvin limestone varies from 20 to 6 feet, the least interval being at the last northward exposure. Southwardly the intervals increase along the western border, and in southern Independence they become 158 and 100 feet. The Blacksville limestone is 20 to 30 feet thick in Cross Creek and Independence townships, where a massive sandstone underlies the Upper Washington. The Middle Washington limestone appears abruptly in Independence with a thickness of 20 feet, and there also one sees for the first time the Franklin limestone, 35 feet below the Upper Washington and directly underlying the Canton coal bed. The conditions are much the same in Hopewell east from Independence, where the limestones are present and thick, except the Colvin and Franklin. The Waynesburg sandstone is massive, but it has not cut away the Cassville shale, which carries some limestone here, as almost everywhere on this side of the county.

A thin coal bed marking the Boyd horizon was seen just above the Upper Washington limestone in Smith, but not in the other townships named, where only black shale was seen. The Jollytown coal bed appears first in Hopewell and Independence, where it is about 20 feet below the Franklin limestone. The Washington coal bed, 4 feet to 5 feet 6 inches thick and multiple, is 109 feet above the Waynesburg in southern Hopewell. The Waynesburg A, not seen in the townships along the West Virginia line, makes its appearance in Hopewell at 40 feet below the Washington.*

Farther east, in North Strabane, the Upper Washington limestone is 145 to 160 feet above the Washington coal bed, which is 110 to 120 feet above the Waynesburg, the intervals increasing southwardly. The Canton coal bed, very thin, seems to be continuous at 12 feet below the Upper Washington. The interval from the Canton coal to the Blacksville limestone is usually concealed here, as well as in Nottingham and Peters townships farther east, so that the Franklin and Middle Washington limestones are not reported. The other limestones of this interval are from 8 to 25 feet thick. The massive sandstone underlying the Upper Washington makes a "rock city" in Peters.

* J. J. Stevenson: (K), pp. 269, 270, 281, 282, 283.
I. C. White: (K), pp. 229, 285, 288, 291, 292, 293, 294.

The Washington coal bed is thin and unimportant throughout. No trace of the Jollytown coal bed was observed in these townships, nor was the Canton seen east from North Strabane. The Waynesburg B, seen for the first time in North Strabane, and the Waynesburg A, with the Colvin limestone, are present in Nottingham as well as still farther east in Union, Carroll, Fallowfield, and Somerset. These coals are worthless.

The interval from the Upper Washington limestone to the Washington coal bed changes very slowly, being still 160 feet in Somerset, but that between the Washington and Waynesburg coal beds, only 120 feet in North Strabane, becomes 140 in Fallowfield and Somerset. The Cassville shale, carrying no limestone in these townships, is of irregular occurrence, often cut out by the overlying Waynesburg sandstone, which becomes massive and very prominent toward the Monongahela valley.*

In the neighborhood of Washington borough measurements were obtained in Canton, South Strabane, and Franklin townships, giving the following succession:

	Feet
1. Limestone, dark blue, Nineveh	Fragments
2. Concealed	10
3. Limestone	Fragments
4. Concealed	35
5. Limestone, light in color	5
6. Concealed	55
7. Limestone, light blue, Rogersville	3
8. Coal bed, Pursley	Blossom
9. Concealed	30
10. Limestone [Ten-mile]	5 to 10
11. Shale	2 to 5
12. Coal bed [Boyd]	Blossom
13. Clay, sandstone, shale	9 to 21
14. Upper Washington limestone	6 to 20
15. Concealed	30
16. Coal bed [Canton]	Blossom
17. Concealed	20
18. Coal bed [Jollytown]	Blossom
19. Concealed	15 to 25
20. Middle Washington limestone	6 to 20
21. Shales	10 to 15
22. Coal bed, Washington A	Blossom
23. Shales and thin limestones	40
24. Lower Washington limestone	23 to 33
25. Washington coal bed	4 to 7
26. Washington sandstone, clay, shale	12 to 17

* J. J. Stevenson: (K), pp. 212, 220, 228, 237, 238, 239.
I. C. White: (K), 218, 219, 224, 226, 227.

	Feet
27. Little Washington coal bed.....	1
28. Shale and clay	2 to 10
29. Limestone	2
30. Concealed	79
31. Cassville shale	21

to the Waynesburg coal bed. Fragments of the Franklin limestone were seen at one place in Franklin township, but elsewhere it is concealed. The Blacksville limestone, so prominent in most of the Dunkard area, has almost disappeared, being represented by a few streaks. The Waynesburg sandstone is somewhat indefinite and at best is only a sandy shale; the Cassville shale has limestone in the shaft at Washington, which is the most easterly appearance of the limestone. The interval from Upper Washington limestone to the Washington coal bed is 150 to 160 feet, and that from the Washington to the Waynesburg coal bed is 115 to 124, decreasing westwardly.

The conditions are very similar southward in Morris, Amwell, and West Bethlehem along the southern border of the county, except in increase of the intervals, that from the Upper Washington to the Washington coal becoming 180 and 190 as one approaches the Greene county line, and that from the Washington to the Waynesburg becoming 165 feet. The Boyd, Canton, and Jollytown coals are present, as are also the Ten-mile and Franklin limestones. A massive sandstone, 250 feet above the Upper Washington and very near the place of the Nineveh sandstone, remains in West Bethlehem as a rock city on the Hillsborough knob.*

Buffalo, Donegal, East and West Finley townships form the southwest corner of Washington county. In the former two, at the north, the exposed section reached to 76 feet above the Upper Washington limestone. The Ten-mile limestone is 6 feet thick 20 feet above the Upper Washington and 40 feet below another whose relations are very uncertain. Coal was seen at the Boyd horizon in one exposure, and a blossom at 10 feet above the Ten-mile may be taken as representing the Pursley horizon. The Canton coal bed, 20 feet below the Upper Washington, was seen in both townships, very thin and 6 inches to 2 feet above the Franklin limestone, which is 1 foot 6 inches to 7 feet thick. A thin coal bed at a little way below the Middle Washington limestone seems to mark the Washington A horizon, but no trace of the Jollytown coal bed was seen. The Washington coal bed is 6 inches to 9 feet thick and for the most part of little worth. Of all the limestones, only the Colvin is absent.

* J. J. Stevenson: (K), 181, 184, 185, 188, 190, 241-244, 247, 248, 250, 251, 252.
I. C. White: (K), pp. 184, 187, 201.

Here, for the first time, red beds are seen in the Dunkard, there being in Donegal a mass, about 60 feet thick, resting on the Blacksville limestone and extending above the Middle Washington. At another exposure a purely local bed, 15 feet thick, is at the place of the Franklin limestone.

East and West Finley adjoin Greene county and the latter extends to the West Virginia line at the west. In Morris township the Upper Washington limestone is almost constantly in view from the east side of the township until within about half a mile of the East Finley line. There the Nineveh sandstone is 180 feet above the Upper Washington, and fragments of the Nineveh limestone were seen 35 to 40 feet lower, while at a little way farther west the Nineveh coal bed was seen under the sandstone. Chert appears in great abundance above the Nineveh sandstone, but it was not found in place; it seems to belong somewhere near the Limestone XII.

Crossing into East Finley and descending to Hunter's fork of Wheeling creek, one quickly reaches the Upper Washington limestone at little more than 150 feet below the Nineveh limestone, and at half a mile farther there is a coal bed 1 foot 6 inches thick and about 50 feet above the lower limestone. This seems to be not far from the Pursley horizon, but, in view of the changing intervals southwardly, one is hardly justified in making the correlation at present. The Middle Washington and Blacksville limestones are exposed at a little way farther and remain in sight to the west side of the township. The rapid fall of the stream in West Finley brings the lower rocks into the section, and the Waynesburg coal bed is reached at a considerable distance east from the state line. Exposures in the Finley townships are for the most part incomplete; the limestones are numerous and evidently not all of them are persistent. It seems to be clear that in preparing his report on Greene and Washington counties Stevenson erred in some of the correlations.

The highest limestone observed in place is coarse, dark on fresh fracture, and weathering with a rough surface. It is the bed numbered XI. At the West Virginia line it is 211 to 220 feet above the Upper Washington and it is exposed frequently on the west side of West Finley; it is reached again in the northwest part of the township and the adjacent part of East Finley, where the interval is 234 to 240 feet and the limestone rests on 50 feet of red shale, the Nineveh sandstone being absent. As in the case of the lower interval, this decreases eastwardly, so that on the east side of East Finley it is 200 feet, and at a mile or two farther east, in Morris, Doctor White found it 195 feet above the Upper Washington. The bed varies from 6 to 8 feet and gives a good strong

lime for the farmer. Fragments of a higher limestone, XII, were seen 50 feet above XI near the West Virginia line, but its place was not reached elsewhere in Washington county.

The Nineveh limestone, 145 to 153 feet above the Upper Washington near the West Virginia line, is reached at many places in these townships. The interval increases eastwardly to 180 feet on the border of East and West Finley, but farther east it decreases to 160. The rock is coarse, dark, and weathers blue and rough, though some portions become yellow. A third limestone, rarely exceeding 2 feet 5 inches, is very persistent at 103 to 123 feet above the Upper Washington. It may be equivalent to a limestone seen in the western part of Greene, but it is not safe to make any correlation of these limestones in this variable interval—at least until more detailed information has been secured.

The Upper Washington is 15 to 20 feet thick, and the Franklin, 30 to 40 feet lower, is a persistent dark limestone 20 to 30 feet above the Middle Washington. The Blacksville and Lower Washington appear wherever their places are exposed, but they vary greatly in thickness. The coals are wholly unimportant, and nothing to represent the Boyd, Jollytown, Waynesburg A or B was seen. The Waynesburg is the only prominent sandstone. A shale, apparently equivalent to the Cassville, overlies the Waynesburg coal bed at many places, but it carries no limestone.*

Passing over into Greene county, one soon reaches an area retaining the highest members of the Dunkard formation. A high ridge separating Wheeling and Fish creeks at the west from Ten-mile and Dunkard creeks at the east passes from Morris and East Finley of Washington county into Morris, Richhill, and Center of Greene. From this ridge in Greene long, irregular "hogback" ridges pass off into the townships of Jackson, Aleppo, Gilmore, and Springhill and thence into West Virginia, most of them capped by the Gilmore sandstone, and occasionally one shows some higher rocks. The section shows great variation in western Greene.

A principal fork of Wheeling creek heads up against this ridge in Aleppo township and flows northwest into Richhill. The succession along this stream as ascertained by Doctor White, somewhat condensed from the original notes, is:

* J. J. Stevenson: (K), pp. 192, 193, 194, 196, 199, 253, 256, 259, 260, 261, 264, 265, 266.
I. C. White: (K), pp. 198, 200, 201.

	Feet	Inches
1. Limestone [Windy gap]	4	0
2. Shale	25	0
3. Black shale [Windy Gap coal bed]	2	0
4. Shales	30	0
5. Gilmore sandstone	30	0
6. Concealed	300	0
7. Nineveh coal bed	1	0
8. Shales	25	0
9. Limestone and black shale [Nineveh]	8	0
10. Shale and sandstone	40	0
11. Coal bed [Hostetter (?)]	1	2
12. Brecciated limestone	2	0
13. Sandstone and concealed	30	0
14. Light-colored limestone	8	0
15. Shales and Fish Creek sandstone	70	0
16. Impure coarse limestone	2	0
17. Reddish shale	15	0
18. Dunkard coal bed	2	0
19. Limestone IX*b*	1	6
20. Sandstone	25	0
21. Limestone, coarse [Jollytown]	2	0
22. Red shale	10	0
23. Blue shale, flaggy sandstone	30	0
24. Red shale	4	0
25. Shales and sandstones	71	0
26. Upper Washington limestone	8	0
27. Sandstone and shale	40	0
28. Limestone, coarse [Franklin]	2	0
29. Red shale and sandstone	60	0
30. Shale and massive sandstone	75	0
31. Limestone, Middle Washington	2	0
32. Shale, clay	15	0
33. Coal bed [Washington A]	1	6
34. Shale	10	0
35. Limestone, light, good [Blacksville]	6	0
36. Shale and sandstone	30	0
37. Black shale, brecciated limestone, Lower Washington	6	6
38. Washington coal bed	3	6

The great gap between the Nineveh coal bed and the Gilmore sandstone is concealed throughout southwestern Greene and apparently in most of the West Virginia area; but it is shown more or less in detail within Morris, Richhill, and Center of Greene. The first two adjoin Morris and the Finleys of Washington; Center is south from Morris and eastern Richhill and contains the highest rocks, just failing to catch the Gilmore sandstone. The sections above the Nineveh limestone are:

					Feet	Inches
1. Jackson limestone					Fragments	
2. Red beds, sandstone					80	0
3. Limestone					5	0
4. Sandstone	Not measured		Not measured		40	0
5. Baresville coal bed	Blossom		Blossom		Concealed	
6. Shale	0	0	3	0		
7. Limestone	0	8	3	0	30	0
8. Shale	30	0	30	0		
9. Limestone XII	13	0	12	0	8	0
10. Sandstone, concealed	80	0	90	0	80	0
11. Limestone XI	2	6	2	11	2	6
12. Nineveh sandstone	42	0			35	0
13. Nineveh coal bed	1	0	78	0	1	8
14. Sandstone, shale	36	0			36	0
15. Black shale	1	0			1	0
16. Nineveh limestone	2	0	6	2	2	0

Thus far the sections are practically in accord. The highest limestone in Center, about 275 feet above the Nineveh coal bed, is the same with a limestone found in Jackson township at 30 feet below the Gilmore sandstone. It has been seen also in Springhill. No trace of the Baresville coal was seen in Center township. The Nineveh coal and sandstone, concealed in southeast Richhill, are shown at many places in Morris, Center, Jackson, and Aleppo. The coal is always thin, but is so good that it is mined at many places by stripping.

Below the Nineveh limestone to the Washington coal there is much variation in the sections. This portion, ill exposed in Morris and Richhill, is well shown in Center. A direct measurement in southeast Morris shows the interval between the Nineveh limestone and the Upper Washington limestone to be certainly not more than 160 feet, and the record of a boring in the central part of the township confirms this by giving the interval between the Nineveh and Waynesburg coal beds as 488 feet, or about 300 feet less than in Aleppo township. A coal bed, possibly the Hostetter, is reported in this well at 63 feet below the Nineveh coal, and in southeast Richhill its blossom was seen at 20 feet below the Nineveh limestone. The Ten-mile limestone is present, but the Rogersville seems to be wanting in Morris; one of these is present in Richhill, but which one was not determined. A direct measurement in southeast Richhill gives 150 feet as the interval between the Nineveh and Upper Washington limestones, showing that the condition is practically the same as in Morris.* But at 3 or 4 miles southward, in Center township, one finds the increased interval shown in Doctor White's Aleppo section,

* It should be remembered that the measurements are barometric throughout.

which prevails in Center, Jackson, and Aleppo. The section in western Center is:

	Feet	Inches
1. Nineveh limestone	2	0
2. Shale, sandstone, concealed	70	0
3. Fish Creek sandstone	50	0
4. Dunkard coal bed	1	8
5. Limestone 1 x 6	1	6
6. Sandstone, shale	35	0
7. Jollytown limestone, shale 1 x *a*	10	0
8. Shale, sandstone, concealed	100	0
9. Ten-mile limestone	2	0
10. Shale, sandstone	35	0

to the Upper Washington limestone. The Rogersville limestone is here, but concealed where the measurement was made. The Pursley coal bed, underlying the Rogersville limestone, is shown at numerous places and is mined on Pursley creek, where its thickness is 20 inches. The interval between the Nineveh and Upper Washington limestones is about 300 feet in northern Center, but in southwest Center it is about 260 feet and the Ten-mile limestone seems to be replaced by red shale. The Rogersville limestone disappears westwardly, becoming only calcareous shale near the line of Jackson township.

In Jackson township the Dunkard coal bed is only 100 feet below the Nineveh limestone, as it is also at an exposure in western Center; but in Aleppo that interval is 168 feet and one finds there at 40 feet below the limestone a thin coal bed, apparently the same with that in Morris and Richhill, at 20 to 24 feet, and perhaps the Hostetter bed. The place of this bed is concealed at the Jackson and Center localities. The Dunkard coal bed is constant in Center, Jackson, and Aleppo, but seems to be wanting in Morris and Richhill. It is thin, not exceeding 2 feet, in two nearly equal benches, separated by 1 to 3 inches of clay. The coal is good and is mined by stripping at many places. The little limestone, IX*b*, is always present with the coal, and the Jollytown limestone is equally persistent in Center, Jackson, and Aleppo, but it has not been recognized certainly in either Morris or Richhill. Its thickness is greatest in western Center; it is thinner and more shaly in Jackson, and is thin where last observed in western Aleppo. The interval from the Jollytown to the Upper Washington decreases westwardly from 137 feet in Center to 115 in western Aleppo. The Ten-mile limestone and Boyd and Pursley coals are evidently wanting in Aleppo near the West Virginia line.*

* J. J. Stevenson: (K), pp. 153, 154, 155, 157, 158, 159, 160-162, 172-174.
I. C. White: (K), pp. 161-163.
J. F. Carll: I 5, p. 308.

The section below the Upper Washington limestone is not reached in Morris or Jackson, but is shown in northwestern Aleppo, in western Richhill, and for the greater part in eastern Center, the distance between the outcrops of the Washington coal bed being about 12 miles. The interval between the Upper Washington limestone and the Washington coal bed is about 300 feet in Aleppo, where one finds the Franklin, Middle Washington, Blacksville, and Lower Washington limestones, all thin and more or less brecciated. There is no trace of coal at the Canton or Jollytown horizon, but the Washington A is seen in the Aleppo section at 52 feet above the Washington. In southern Richhill the Washington limestone rarely becomes 2 feet, while the Franklin, 20 feet below it, is 6 feet thick and brecciated; this great thickness led to mistaking it for the Upper Washington. The other limestones are insignificant. The Canton horizon carries no coal, but a thin streak marks the Jollytown. The interval between the Upper Washington and the Washington coal bed is about 230 feet in southern Richhill, but decreases northwardly until, near the Washington County border, it is not more than 160 feet. The Washington coal bed, seen always where its place is exposed, varies little from 3 feet 6 inches and is double, with a thick clay parting. The Waynesburg coal bed is reached in western Richhill, where the interval to the Washington coal is 130 feet, as ascertained by direct measurement in the northwest corner. This is much smaller than at localities farther east along the Washington County border where the coal is reached again. The insignificant Waynesburg A and B are both present, but the Colvin limestone is absent. The Waynesburg sandstone is massive and ordinarily rests on the Waynesburg coal bed.*

Following the section eastward along Ten-mile creek, across Center, Franklin, and Jefferson townships, one reaches the bottom of the column in Jefferson. The Rogersville limestone is a constant member into Jefferson, where it is 70 feet below a thick limestone which Stevenson took to be the Nineveh, but which on a preceding page has been correlated at least tentatively with the Jollytown. The earlier correlation may prove to be the true one, as the limestone is more like the Nineveh than the Jollytown, and the interval to the Upper Washington is nearly the same as at 5 or 6 miles farther north; but the persistence of the Rogersville limestone and its relations to the higher limestone, nearly the same as in western Center, seem to justify the tentative correlation with the Jollytown—the more so since the Pursley coal is persistent into Jefferson. The Ten-mile limestone is present everywhere along this

* J. J. Stevenson: (K), pp. 168-171.
I. C. White: (K), p. 163.

line to the most easterly exposure of its place. The Upper Washington is 270 feet above the Washington coal bed at Waynesburg, and an almost direct measurement by Doctor White in Jefferson 6 or 7 miles east makes the interval 254 feet. The Franklin limestone is always present at 30 to 35 feet above the Jollytown coal bed, which rarely exceeds 1 foot, but is always present. The Middle Washington limestone is absent, but the Blacksville and Lower Washington persist, though they rarely are more than 3 feet thick. The Waynesburg A and B coal beds seem to be continuous and the Colvin limestone is prominent. The Waynesburg sandstone, shown in Franklin and Jefferson and thence eastward to the Monongahela river, is sometimes 75 feet thick, more or less shaly or flaggy above, but massive and at times is slightly conglomerate below. The Cassville shale, carrying no limestone, is somewhat irregular in occurrence, but at several places is rich in plant impressions. The interval between the Washington and Waynesburg coal beds is 173 feet in eastern Franklin, and the greatest interval is 180 feet on the eastern edge of the county.

Washington and Morgan townships are north from Franklin, on the Washington county border. The Middle Washington was seen in the former at 98 feet below the Upper Washington, and a thin coal bed, perhaps at the Jollytown horizon, is at 83 feet below the latter limestone. A direct measurement between the Nineveh and Upper Washington limestones in Morgan gives 180 feet. This is 2 miles south from Ten-mile village, in Amwell of Washington county, and the Nineveh limestone was seen at many places along the northern border where there is a coal bed at 50 feet below it. A dark limestone, probably the Ten-mile, is 40 feet above the Upper Washington, and the Boyd coal bed, 30 inches thick, 15 feet above the Upper Washington, is mined on Boyd run, in Washington township. The Franklin limestone and the Jollytown coal bed persist, but the Washington coal bed and the other limestones are insignificant. The Waynesburg A and B and the Colvin limestone are here and the Washington coal bed is 160 feet above the Waynesburg.*

The southern townships from the Monongahela river westward along the West Virginia border are Dunkard, Perry, Wayne, Gilmore, and Springhill. In the first the exposed section reaches to little above the Washington A coal bed, which is very thin. The Waynesburg sandstone is prominent and at many exposures rests on the Waynesburg coal, but occasionally the Cassville shale, carrying no limestone, is present, 3 to 7 feet thick and crowded in the lower portion with fine impressions of

* J. J. Stevenson: (K), pp. 133, 134, 139, 141, 143, 145, 146, 149, 151, 152.
I. C. White: (K), pp. 138, 139.

plants. The Waynesburg A and Washington coal beds are both thin, and the latter is 160 feet above the Waynesburg at the only locality for direct measurement. The section is longer in Perry township. The Waynesburg passes under Dunkard creek at 8 miles west from the Monongahela, and at barely 3 miles farther west, where the Waynesburg A has passed under this succession, was found:

	Feet	Inches
1. Franklin limestone	Fragments	
2. Concealed	35	0
3. Jollytown coal bed	Blossom	
4. Shale, mostly	90	0
5. Limestone, sandy [Middle Washington]	4	6
6. Sandstone, mostly	75	0
7. Washington A coal bed and shale	3	0
8. Shale	20	0
9. Limestone III [Blacksville]	3	6
10. Sandstone	40	0
11. Shale	3	0
12. Lower Washington limestone	1	6
13. Shale and concealed	5	0

to the Washington coal bed, of which only the blossom was seen. The interval between the Franklin limestone and the Washington coal bed is about 280 feet; in Jefferson township, 9 miles east of north, it is 220 and in Franklin township, 9 miles west of north, it is 240 feet. The Jollytown coal bed is very thin, not more than 6 inches. Doctor White has published a section obtained two miles farther east, on Colvin run, in which the Franklin limestone is 10 feet thick and 35 feet above the Jollytown coal bed, which is 1 foot 6 inches; the Franklin is 281 feet above the Washington coal bed. He finds a limestone 9 feet thick at 135 feet above the Franklin, which is evidently the same with that seen in Jefferson. As at that locality, the rock resembles the Nineveh in several features, but the lessening interval in this direction seems to be related to the conditions seen in western Wayne and in Gilmore, so that on a preceding page this highest limestone has been referred tentatively to the Jollytown horizon. In this section Doctor White finds 10 feet of red shale very near the place of the Middle Washington limestone. The Washington A coal bed, seen at several places here, as well as in Whitely township, at the north, is 2 to 4 feet thick and so much broken by shale as to be unimportant. The limestones are all thin and even the Colvin is irregular, being only 3 feet on Colvin run. The Washington coal bed, 5 feet 8 inches thick, is triple and its coal is poor.

Doctor White measured a section on Dunkard creek, in Wayne township, which is almost the same with that obtained by Stevenson in Perry.

The Jollytown coal bed is 25 feet below the Franklin limestone and 110 feet above the sandy Middle Washington. The Washington A coal bed, 4 feet 3 inches of coal and shale is 85 feet lower and 73 feet above the Washington coal. The Upper Washington limestone is not exposed in this township except on the Gilmore border, but the Ten-mile limestone was seen in the northern portion and the Nineveh limestone is on the ridge at the line of Center township. Exposures are very bad in the greater part of this township.*

Ascending Dunkard creek, one finds the lower rocks passing under, so that at the line of Gilmore township the lowest rocks visible are only 56 feet below the Jollytown coal bed. There one has Doctor White's measurement:

	Feet
1. Shale	20
2. Franklin limestone	2
3. Shale	24
4. Jollytown coal bed	1
5. Shale, sandstone, fully exposed	56

with 2 feet of red shale at 30 feet below the Jollytown coal bed. This layer was not seen in Wayne township. The Jollytown coal bed, though very thin, yields good coal and is stripped at many places. It is in the road at Jollytown, on the east side of Gilmore. Some difficulty was encountered in making the section above the Franklin limestone, but the line in Gilmore and Springhill was revised very carefully by Stevenson and White, and Doctor White's measurements appeared to be very close to the truth. Since that time they have been confirmed by records of well borings in Marshall county of West Virginia just beyond the west line of Springhill township. Doctor White's section, not published in full in volume K, extends from a high knob in the middle of the township to Jollytown. As recorded in the note book, the lower portion is:

	Feet	Inches
1. Nineveh coal bed	1	2
2. Shales	25	0
3. [Nineveh] limestone and shale	7	0
4. Concealed	140	0
5. Dunkard coal bed	1	2
6. Limestone IX*b*	2	0
7. Shales	25	0
8. Limestone IX*a* [Jollytown]	1	6
9. Shale and sandstone	28	0
10. Coal bed [Boyd]	1	1

* J. J. Stevenson: (K), pp. 99, 104, 105, 153, 155.
I. C. White: (K), pp. 100, 106, 107, 108. U. S. Geol. Survey Bulletin, no. 65, p. 23.

	Feet	Inches
11. Dark shale	0	6
12. Upper Washington limestone	4	0
13. Sandstone	15	0
14. Shale	10	0
15. Impure limestone	1	0
16. Shale	10	0
17. Limestone [Franklin]	2	0
18. Shales	25	0
19. Jollytown coal bed	1	10

The interval between the Upper Washington and Franklin limestones is 36 feet. The section from the Dunkard coal bed to the Upper Washington limestone is shown at a mile and a half above Jollytown. If the limestone, Number 12, be the same with that seen at Jollytown, which seems to be practically certain, the interval between the Jollytown coal bed and the Jollytown limestone is 74 feet less than the interval in eastern Perry, 114 feet less than in Jefferson township. The interval between the Dunkard and Nineveh coals was not obtained by direct measurement; it is 172; at White Cottage, 6 miles north, in Jackson, it is 127; but in Aleppo, 8 miles northwest, it is 200 feet. The Gilmore sandstone is reached at the head of Dunkard creek, 30 feet thick and 30 feet above the Jackson limestone. The whole interval to the Dunkard coal bed, 300 feet, is without detailed exposures. These high rocks are reached on the divide between Dunkard and Fish creeks, over which one crosses into Springhill township.

Fish creek descends rapidly toward the west, so that within a mile one is below the Nineveh limestone. Everything between the Gilmore sandstone and that limestone is concealed in by far the greater part of the township, but there are frequent exposures of lower beds. The interval between the Nineveh limestone and Dunkard coal bed, measured directly at several places, varies from 120 to 150 feet, being greatest near the West Virginia border at the west. In the eastern part of the township a coal bed, 1 foot 1 inch thick, is at 45 feet below the Nineveh limestone and 80 feet above the Dunkard coal bed, and at 30 to 40 feet lower is an impure limestone. The coal bed is probably that termed Hostetter by Doctor White. Toward the west side of the township the Fish Creek sandstone, overlying the Dunkard coal bed, becomes continuous with a higher sandstone and extends almost to the Nineveh limestone, replacing the other beds. The Nineveh limestone retains its thickness to the western line, but becomes earthy. The Jollytown limestone is rarely exposed and it seems to be quite impure. As seen at one place, it is 6 feet thick and 165 feet below the Nineveh. A trace of

coal at 50 to 60 feet below it may be at the Jollytown horizon, as fragments of brecciated limestone are at a little way above it, and a thin coal bed at about 60 feet below the Dunkard may be at the Boyd horizon, which carries coal at a little way south in West Virginia.*

THE NORTHERN PANHANDLE OF WEST VIRGINIA

Passing westward into the northern panhandle of West Virginia, one finds information respecting the Dunkard in Marshall and Ohio counties, adjoining Greene and Washington. The lower part of the formation undoubtedly extends farther north into Brooke county. At a few miles east from Wheeling, in Ohio county, the Middle and Lower Washington limestones, each 20 feet thick, are 90 and 6 feet above the Washington coal bed, which is only 1 foot 3 inches thick. The Washington and Waynesburg coal beds are 96 to 104 feet apart, the Waynesburg A is 50 feet above the Waynesburg, and the Cassville shale carries 4 feet of limestone. The section is very like that 5 or 6 miles east, in Washington county. Doctor White finds the Washington coal bed 3 inches to 2 feet 6 inches at Wheeling, where it is 100 feet above the Waynesburg.

Doctor White's long section at Moundsville, 11 miles south from Wheeling, reaches upward to what appears to be the Upper Washington limestone, 224 feet above the Washington coal bed. That coal bed is 105 feet above the Waynesburg. A thin limestone, 53 feet below the upper coal, is at the place of one seen at Wheeling under Waynesburg A, but that coal bed is concealed. The Cassville shale contains 2 feet of limestone and the Waynesburg sandstone is replaced by shale. Five miles farther down the Ohio river the Washington coal is 5 feet thick. Thick limestones are above the Washington coal bed, but it is difficult to correlate them. Red beds, 10, 45, and 45 feet, are at 94, 139, and 199 feet above the coal, the last underlying the limestone taken to be the Upper Washington. Bellton, in Marshall county, is 15 miles southeast from Moundsville and is on Fish creek, about 2 miles west from the Pennsylvania line. There one has Doctor White's section, which confirms the measurements in the southern tier of townships in Greene county. Somewhat condensed they are:

	Feet	Inches
1. Windy Gap limestone	5	0
2. Shales	30	0
3. Windy Gap coal bed	Blossom	
4. Shales, sandstones, concealed	275	0
5. Limestone [XI (?)]	3	0
6. Shales, concealed	20	0

* I. C. White: (K), pp. 112, 113, 114.

	Feet	Inches
7. Nineveh coal bed	1	0
8. Shale, sandstone	35	0
9. Nineveh limestone and shale	10	0
10. Shale, sandstone, concealed	115	0
11. Limestone and thin coal bed	0	9
12. Shale, sandstone, concealed	40	0
13. Coal bed	1	0
14. Shales, concealed	30	0
15. Dunkard coal bed	1	3
16. Limestone IX*b*	5	0
17. Shales	13	0
18. Jollytown limestone	2	0
19. Shales and sandstone	30	0
20. Coal bed [Boyd]	0	8
21. Upper Washington limestone	5	0
22. Shale, sandstone	42	0
23. Fireclay [place of Jollytown coal bed]	7	0
24. Shales, sandstones	54	0
25. Coaly shales	9	0
26. Sandstones, shales	196	0
27. Washington coal bed	6	0
28. Shales, sandstones, thin limestone	140	0

to the assumed place of the Waynesburg coal bed. The portion below the Upper Washington limestone is taken from the record of an oil boring. Here one is at the extreme southeast corner of the county.

The Nineveh coal bed is, in round numbers, 230 feet above the Dunkard; at Board Tree, 3 miles southeast, this interval is 203, and in Gilmore township of Greene only 172 feet. The Jollytown limestone is 348 feet above the Washington coal bed, the loss as compared with central and eastern Greene being due to disappearance of most of the rocks between the Jollytown and Upper Washington. The interval, Washington to Waynesburg, has increased from 105 at Moundsville to 150 feet at Board Tree. All of the coals have become insignificant; the Boyd horizon still carries some coal, but the Jollytown as well as Washington A, Waynesburg A and B is either absent or so thin as to be overlooked by the drillers. The higher limestones have become insignificant and those between the Upper Washington and the Washington coal bed have disappeared.

Doctor White has preserved many records of oil borings in the southern part of Marshall county. At Cameron, 5 miles northwest from Bellton, the Waynesburg coal bed is 336 to 345 feet above the Pittsburg; a coal bed, 60 to 70 feet higher, is at the place of Waynesburg A, and a third, at 321 feet above the Waynesburg, seems to be at the place

of the "coaly shales" in the Bellton record. The Washington coal does not appear in any records here. In Meade district, farther west, where the Waynesburg is 280 to 290 feet above the Pittsburg, the Washington is 110 to 120 feet higher and the highest bed of the Cameron wells is 247 to 255 feet above the Waynesburg coal bed.*

OHIO

In the northern part of Jefferson county, Ohio, one finds near Knoxville a high knob retaining 78 feet of red and olive shales, above the Waynesburg coal bed, but the locality is too far away from any other exposure to admit of correlation. Farther south, in Mount Pleasant township, 110 feet of Dunkard remain, for the most part ill exposed; but in that as well as Smithfield township the Waynesburg A, evidently very thin, is at 50 feet above the Waynesburg, the interval being filled with sandstone, while sandy shale overlies the upper bed. Limestone is wholly absent. In Belmont county, 7 miles southeast, an imperfect section obtained almost opposite Wheeling shows the Washington coal bed at 95 feet above the Waynesburg and 4 to 6 feet thick. The Cassville shale, 9 feet 6 inches thick, has 3 feet of limestone on top underlying 15 feet of Waynesburg sandstone. A section by Mr Henry Newton, at 1 mile farther down the river, shows a limestone outcrop at 30 feet above the Washington, and at 90 feet there begins a mass of shaly sandstone streaked with red shale. In the northern part of the county the Waynesburg A, 1 to 2 feet thick, is shown frequently at 40 feet above the Waynesburg. The same coal is reached at one place in southeast Harrison, where it is 50 feet above the Waynesburg, the interval being filled with sandstone.

The section is longer in southern Belmont. Professor Brown's carefully leveled section was obtained at Bellair, 4 miles below Wheeling. It is:

	Feet
1. Coal bed [Jollytown]	2
2. Concealed, shale, sandstone	144
3. Limestone	7
4. Coal bed [Washington]	2
5. Concealed, mostly shale	64
6. Coal bed [Waynesburg A]	Blossom
7. Concealed	6
8. Limestone	2
9. Shale, thin limestone	45
10. [Waynesburg] coal bed	2

* J. J. Stevenson: (K), p. 266, and unpublished notes.

I. C. White: U. S. Geol. Survey Bulletin, no. 65, pp. 25, 26, 27. Catalogue of West Virginia University for 1883-1884, pp. 55, 59, 61, 63. Geology of West Virginia, vol. Ia, pp. 215, 216, 217, 219, 221, 222.

Waynesburg A is 53; Washington, 117, and Jolleytown 303 feet above the Waynesburg coal bed, the Jollytown being 183 feet above the Washington. There are no exposures above this highest coal bed. If the highest limestone in Doctor White's Moundsville section be the Upper Washington—and the decreasing intervals at Cameron and in Meade seem to leave no room for doubt respecting the correlation—Number 1 of Professor Brown's section must be the Jollytown coal bed.

Mr Newton's section at Wegee, 3 miles south from the Moundsville section, reaches to a limestone at 18 feet above the Washington coal; the interval, Washington to Waynesburg, is 117 feet; the place of Waynesburg A is concealed, but there is a limestone, 39 feet above the Waynesburg, answering to number 9 of the Bellair section. Doctor White obtained a measurement below this, in the river hills, and found the Washington and Waynesburg 120 feet apart, with the interval almost wholly concealed. Few of the sections away from the river go above the Waynesburg, but one in Washington township, 8 or 9 miles back, shows the Waynesburg A at 46 feet above the Waynesburg, while at Barnesville, on the west side of the county, the interval is 42 feet and the thin limestone is 4 feet below the coal. Midway between Bellair and Barnesville the interval is 53 feet, as at Bellair, filled mostly with shale, red in the bottom, 2 feet 6 inches. The place of the Washington is seldom exposed, but the blossom was seen occasionally at 100 feet above the Waynesburg.*

Information respecting Muskingum, Noble, and Morgan counties along the western outcrop is scanty. The Dunkard is wholly without economic interest and few of the measured sections extend above the Uniontown coal bed. In southeast Muskingum a limestone, 2 feet thick, is 101 feet above the Uniontown and thick red beds at 10 feet higher, but no coal is shown. The Waynesburg A is mentioned at two places in Morgan county and has been opened at one where it is double, the benches, 16 and 24 inches, separated by 8 inches of shale. It is about 100 feet above the Uniontown. The Waynesburg sandstone is certainly here being the second conglomerate of Professor Andrews. No sections by Andrews in Noble county go above the Uniontown, but he notes the occurrence of Waynesburg A in the southeast corner. Professor Brown speaks of a few coal blossoms, one in Marion at 113 feet above the

* E. B. Andrews: Vol. ii, pp. 546, 554, 555, 567.
J. J. Stevenson: Vol. iii, Jefferson, pp. 760, 767; Belmont, pp. 271, 274, 277, 280; Harrison, p. 202.
H. Newton: Atlas to vol. ii, chart 3, fig. 18; chart 4, figs. 14, 18.
I. C. White: Catalogue of West Virginia University, pp. 60, 61, 63, 64.
C. N. Brown: Vol. vi, p. 619.

Uniontown, which is apparently at the place of Waynesburg A, the same with that in Brookfield at 55 feet above the Waynesburg coal bed and 2 feet 6 inches thick.*

Monroe county, east from Noble, is south from Belmont along the Ohio river. Only the lowest part of the Dunkard remains in the western townships, but the section lengthens eastwardly and on the Ohio river line one finds the highest rocks in the state. In Center township Professor Andrews measured

	Feet	Inches
1. Red beds, with a thin limestone	63	0
2. Concealed	31	0
3. Massive sandstone	20	0
4. Coal bed	0	6
5. Concealed	23	0
6. Coal bed [Washington]	1	6
7. Shales	70	0
8. Coal bed [Waynesburg A]	Blossom	
9. Interval with trace of [Waynesburg] coal bed	100	0
10. Coal bed and partings [Uniontown]	5	9
11. Interval	75	0

to the Cement limestone above the Upper Sewickley coal bed. This succession is characteristic of the valley of Sunfish creek; thence to the Ohio river, where, at Clarington, Doctor White's section shows the three coal beds 65 and 98 feet apart and the Waynesburg A is 3 feet, so that the Washington is 166 feet above the Uniontown (Clarington) coal bed. Massive sandstone rests on the Waynesburg A and 5 beds of red shale are within 190 feet above the Washington. All are rather thin and the total is 50 feet. Limestone seems to be absent from Doctor White's section, which extends above the place of the Upper Washington. The Jollytown coal, if present, is concealed. The relations here are very nearly the same as at Bellair, where the Washington is 64 feet above the Waynesburg A. Professor Andrews traced the Washington and Waynesburg A into the northwest corner of Salem township, where the beds, 70 feet apart, are 2 feet and 3 feet 8 inches thick. The lower bed is double.

Coal, 2 feet 8 inches; clay, 0 feet 2 inches; coal, 0 feet 8 inches.

At half a mile north, in Switzerland township, the Washington coal bed is 4 feet thick and a crumbling limestone, the Nineveh, 6 feet 2 inches thick, is 368 feet above it by barometer, the dip being neglected. A red bed, 18 feet thick, and a massive sandstone, 48 feet, are at 23 and

* E. B. Andrews: Vol. I, pp. 311, 312, 342.
C. N. Brown: Vol. V, pp. 1066, 1069, 1075, 1077.

70 feet below the limestone, but the rest of the interval is concealed. A limestone seen elsewhere was supposed to be about 150 feet below the Nineveh. The longest section in the state is that measured by Professor Andrews at Baresville, in Ohio township. Somewhat condensed, it is:

	Feet
1. Coal bed [Baresville]	Blossom
2. Concealed	145
3. Limestone [Nineveh]	6
4. Shale	18
5. Sandy limestone	2
6. Red shale	14
7. Shale	41
8. Sandstone	36
9. Mostly shales, two red beds	84
10. Coal bed [Jollytown]	Blossom
11. Shales, sandstones, quite well exposed	149
12. Coal bed [Washington]	1
13. Clay, shale, sandstone	20
14. Concealed	156
15. Sandstone shale	18
16. Coal bed [Uniontown]	2

ending at 45 feet above the Ohio river. The highest coal bed is taken to be equivalent to that seen in southwestern Pennsylvania. This correlation is especially probable, because, unlike the lower intervals of the Dunkard, that from the Nineveh limestone to the Gilmore sandstone is strangely uniform in the area of western Greene and the immediately adjacent part of West Virginia. The succession below the Nineveh limestone is the same as at Switzerland. The same limestone is seen on the opposite side of the river, where Doctor White made the interval 382 feet to the Washington coal bed; the difference is due, no doubt, in part to neglect of dip and in part barometric variations, for the measurement is not direct in either case. Doctor White long ago correlated this limestone with the Nineveh, and his suggestion has been confirmed by the observations in northern West Virginia, which show one constant limestone horizon between the place of the Upper Washington and the Gilmore sandstone. The exposure appears to be practically complete at Baresville between the Jollytown and Washington coal beds, but there is no red shale present, which accords with the New Martinsville section on the opposite side of the river, where the red beds are so insignificant that they might be overlooked. The interval between the Washington and Uniontown coal beds is 24 feet more than in Center township. The Waynesburg A is concealed here as well as at Sardis, in the southern

part of the township, where the Washington, 190 feet above the Uniontown, is double and 2 feet 3 inches, including a clay parting of 3 inches. In the extreme southern part of the county, on the river and about 2 miles west from Sistersville, in West Virginia, the interval is still 190 feet and only a trace of the Waynesburg A remains. A massive sandstone overlies Waynesburg A and underlies 35 feet of red shale.*

On the western border of Washington county, south from Monroe, the Waynesburg sandstone, 240 feet above the Pittsburg coal bed and 30 to 50 feet thick, is 40 to 60 feet above the Uniontown (Hobson) coal bed. In Decatur township this sandstone overlies a trace of the Waynesburg coal, and in Fairchild there is an impure limestone at 10 feet above it. Along the northern border of the county Professor Andrews's sections extend to only a few feet above the Uniontown coal, except in one case, where a limestone in red shale is noted at 91 feet above the Waynesburg coal, which is 147 feet above the Upper Sewickley. This is the red sometimes found under the Washington coal. In Liberty township, about 14 miles west from the Ohio river, Mr Minshall measured

	Feet	Inches
1. Shales and sandstones	100	0
2. Coal bed [Jollytown]	1	8
3. Shales, sandstones	140	0
4. Coal bed [Washington]	2	6
5. Shales, limestone, sandstone	59	0
6. Coal bed [Waynesburg A]	1	3
7. Limestone, shales	66	0
8. Pebbly sandstone [Uniontown]	28	0
9. Shales	6	0
10. Coal bed [Uniontown]		

The interval, Uniontown to Washington, is 160 feet, 10 feet less than in Center of Monroe, 16 miles north, and 30 feet less than at Baresville, while that between Washington and Jollytown is only 9 feet less than at Baresville, 14 miles northeast. On the Ohio river about 2 miles south from the Monroe county line and almost due east from Mr Minshall's section, Professor Andrews found

	Feet
1. Coal and shale [Jollytown]	5
2. Concealed	150
3. Coal bed [Washington]	Blossom
4. Concealed	18
5. Limestone	Not measured
6. Concealed to Ohio river	68

* E. B. Andrews: Vol. II, pp, 578, 585, 586, 587, map 13, figs. 6, 10, 11, 23.
I. C. White: Catalogue, pp. 63, 64, 69.

Doctor White has a section near Grandview, 4 miles farther down the river, in which the Washington coal bed is 150 feet above low water, the rocks rising in this direction, and at 3 miles farther down he finds on the West Virginia side the Washington at 150 to 160 feet above the Uniontown. In the Grandview section, obtained on a steep hill overlooking the river, the measurement reaches to 370 feet above the Washington, but does not reach the Nineveh limestone; so that the measurement at New Martinsville is to be accepted rather than those by Professor Andrews. A mark of coal is at 250 feet above the Washington, but the Jollytown, if present, is concealed. There is no sandstone in the Waynesburg interval and the Washington coal bed rests on 10 feet of red shale. The sandstones of the section are mostly fine grained and laminated and the massive grindstone beds of the Marietta region seem to be unrepresented. As stated on a preceding page, the red beds are numerous, beginning at 15 feet above the Washington coal bed; there are 5 beds in 330 feet, in all 65 feet thick. The Cowrun anticline, or "Oil-break," is crossed by the Ohio river at a few miles below Grandview, and Dunkard rocks are reached again only as one approaches Marietta.

At about 3 miles west from the Grandview section the Waynesburg is represented by a laminated sandstone 40 feet above the Uniontown (Hobson) coal bed, and a massive rock, rather coarse and 30 feet thick, is at 102 feet above that bed. A coal bed is reported in Muskingum township at 114 feet above what is taken to be the Uniontown (Hobson) coal bed; this is west from the anticline. The higher bed underlies 36 feet of reds, and another red bed, resting on 2 feet of limestone, is 56 feet higher. The Uniontown seems to be recognizable in Barlow, on the Meigs County border, where a thick red is at 140 feet above it. The Washington coal bed is present in Marietta township and the associated rocks are shown along the river just below Marietta, in Warren township, where Professor Andrews found the coal bed at 46 feet above the river with the grindstone beds above it. Farther down is Doctor White's section:

	Feet
1. Sandstone, quarried for grindstones	45
2. Concealed, some red marly shale	30
3. Gray sandy shale	10
4. Sandstone, quarried for grindstones	45
5. Shale	3
6. Coal bed [Washington]	1
7. Concealed	60
8. Coarse massive sandstone to low water	15

The grindstone beds, the Marietta sandstones of I. C. White, are thicker than where they are shown just below Marietta; they are absent from the few recorded sections west from the Ohio. The lowest member of Doctor White's section may be taken as the Waynesburg sandstone, which farther down the river becomes so prominent. As the course of the river changes, the rocks fall, and at 7 miles down below Marietta the Washington coal bed is but 20 feet above low water. A higher coal bed is reported here by Professor Andrews, but the interval is not given. The Washington coal is in the river bed at Belpre, opposite Parkersburg, but the river changes its direction there and within 4 miles the coal is 90 feet above low water and 25 feet above a massive pebbly rock, exposed for 20 feet. This at times is continuous below with the Waynesburg sandstone, giving a thickness of 100 feet and practically filling the interval from the Washington to the place of the Waynesburg coal bed.*

The Waynesburg sandstone, 250 feet above the Pittsburg coal bed and occasionally resting on a thin representative of the Waynesburg coal bed, is present in eastern Athens county. Professor Brown found a coal blossom at 135 feet above the Uniontown, or 330 feet above the Pittsburg. The Dunkard should be present within a considerable area in eastern Meigs, south from Athens and Washington, but there is little available information respecting it. Professor Lovejoy has traced the Waynesburg sandstone into the county, finding it coarse and 30 to 50 feet thick, with occasionally the Waynesburg blossom under it. In two townships he finds a coal blossom at 110 feet above the Waynesburg blossom. Professor Andrews notes a coal bed, approximately 336 feet above the Pittsburg, in Sutton township, and in Chester, about 3 miles north from the river, he measured

	Feet
1. Shale	50
2. Sandstone and shale	11
3. Coal bed [Washington]	2
4. Clay and shale	5
5. Sandstone and conglomerate	49
6. Shales	46
7. Sandstone and shale	35

At Lebanon the coal bed is 3 feet thick and 160 feet above the Ohio river. The conglomerate sandstone, rising or falling according to the course of the river, was followed by Doctor White from the Washington line to about 16 miles east from Pomeroy, where it passes under the river

* E. B. Andrews: Vol. II, pp. 461, 462, 463, 465, 466, 467, 472, 477, 505.
I. C. White: Catalogue, pp. 73, 74, 80, 82, 83.
F. W. Minshall cited by I. C. White: Bulletin no. 65, p. 29.

bed with the Washington coal bed at 40 feet above it. It comes up again at Letart Falls, and at Antiquity it is exposed to the thickness of 40 feet, its bottom being 240 feet above the Pittsburg coal bed as measured in a shaft.*

WEST VIRGINIA

Returning now to the eastern border in West Virginia.

The surface observations thus far available are comparatively few, as the studies have been confined almost wholly to economic matters. Doctor White has recorded incidental observations along the middle of the great trough, showing clearly that he has traced the more important higher horizons from the Pennsylvania line southwestwardly through western Monongalia, Marion, and Harrison, eastern Wetzel, Tyler, and Doddridge counties, where the Gilmore sandstone caps most of the highest hills, on some of which there still remain the Windy Gap limestone and a higher sandstone, which is exposed at only one place in Pennsylvania. The Jackson limestone, 100 to 120 feet below the Windy Gap limestone, extends into Wetzel county. The Nineveh coal bed has been recognized in Monongalia and Wetzel counties, where it is from 6 to 25 inches thick and yields excellent coal. The Nineveh limestone is persistent, appearing wherever its place is exposed as far south as Jackson county and possibly almost to the Great Kanawha river. The Dunkard coal bed and another, either the Boyd or Jollytown, are present to a considerable distance from the Pennsylvania line. The Upper Washington limestone disappears quickly, the Lower seems to be present almost to the line of the Baltimore and Ohio railroad in Harrison county, but the Middle Washington and Blacksville appear to be practically wanting throughout. Notes respecting lower formations are given in some of the well records.

The Washington coal bed is present in Monongalia and Marion counties on the northeast side of the area, retaining its characteristic features throughout. Near Farmington, in the latter county, it is 10 feet 9 inches thick, with 14 layers of coal and shale. A single record in Marion county gives the interval to the Waynesburg as 143 feet, with the Waynesburg A at 45 feet above the lower bed. The Waynesburg sandstone, 35 to 62 feet thick, is a well marked horizon in all of the records and it frequently cuts out the Cassville shale. No record gives details above the Washington coal bed and those giving details below that coal

* E. B. Andrews: Vol I, pp. 258, 259, 268.
I. C. White: Catalogue, p. 83.
C. N. Brown: Vol. v, p. 1062.
E. M. Lovejoy: Vol. vi, p. 627, 628.

show no red beds. The Wetzel county records, though very numerous, give little information respecting the Dunkard. The Nineveh limestone in the northeast corner of the county is 615 feet above the Waynesburg, which is 340 feet above the Pittsburg. The Waynesburg coal bed becomes an uncertain horizon in this county, but it is often recorded on the east side, where it is 340 to 350 feet above the Pittsburg, and the Washington varies little from 515, or 170 feet above the Waynesburg. Midway in the county the Washington is usually about 475 feet above the Pittsburg, and exposures above a boring at Pine Grove show it 221 feet above the Uniontown coal bed of that record. The Washington is exposed at many places between Pine Grove and New Martinsville, on the Ohio river, and it is mined for domestic use, though it yields only a small proportion of good coal. On the northern border of the county, at 10 miles east from the Ohio river, the Washington is 109 feet above the thin Waynesburg and 446 feet above the Pittsburg, but near the river, just over the line in Marshall county, the Waynesburg is only 306 feet, so that the Washington would be not more than 410 feet above the Pittsburg, or about 175 feet above the Uniontown. The Washington is exposed at several places along the river and is mined at New Martinsville, where it is 382 feet below the Nineveh limestone. Red beds, though numerous, are comparatively unimportant in Wetzel county, and are rarely more than 5 feet thick.*

The Washington coal bed seems to be persistent in western Harrison county, and it has been mined at places along the Baltimore and Ohio railroad. In the northwestern part of the county it rests on a thick sandstone, and red beds 5 and 90 feet thick are at 6 and 50 feet above the coal. The Waynesburg A rests on 11 feet of reds, and a bed 20 feet thick overlies the place of the Waynesburg coal. At Sedalia, in Doddridge county, a diamond-drill core shows neither coal nor red shale in 189 feet above the Uniontown coal bed, but at 3 or 4 miles west the Washington coal is 190 feet above the Uniontown, and two red beds, 50 and 12 feet, are at 20 and 123 feet below it, both in the Dunkard. Another bed, 10 feet thick and 100 feet above the Uniontown, is in a well on the western side of the county where the others are wanting. A well near the Tyler line shows the Washington 504 feet above the Pittsburg, 64 feet less than in northwest Harrison county. That coal bed is present in Doddridge southward to beyond the Baltimore and Ohio railroad and it is mined in a small way at many places. It is double or triple and always yields poor coal.

* I. C. White: Catalogue, pp. 67, 69. West Virginia Geology, vol. I, pp. 238, 241; vol. Ia, pp. 127, 128, 178, 202, 212, 213; vol. II, pp. 106, 107, 109, 110, 112, 114, 137.

Near the eastern border of Tyler county, northwest from Doddridge, the Washington seems to be about 465 feet above the Pittsburg and the Waynesburg A is about 65 feet lower. A detailed section at Wick shows the Washington 191 feet above the Uniontown, with red beds, 46, 23, and 50 feet thick at 35, 225, and 260 feet above it, and another of 15 feet at 95 feet below it. The interval to this lower red is filled almost wholly with sandstone. Massive sandstones 15, 38, 20, and 60 feet thick are at 20, 115, 135, and 165 feet above the Washington, the first three certainly falling within the Marietta interval. Here the Washington is 444 feet above the Pittsburg. At a few miles northwest in Ohio, opposite Sistersville, this interval has decreased to 407 feet. Doctor White's section on the Ohio river 9 miles below New Martinsville shows red beds 10, 10, 15, 5, 10, 5, and 35 feet thick at 70, 92, 117, 232, 333, and 348 feet above the Washington coal bed, the last being that under the Nineveh limestone. Only the fourth bed is recorded at Wick. The Marietta sandstones are insignificant. At Middlebourne, midway in the county, the well records show the Washington at 185 to 190 feet above the Uniontown, as at Sardis, Ohio, 10 miles north.

In Pleasants county, west from Tyler, one approaches the "Oil break," and the rocks rise rapidly toward the west, so that the oil borings seldom begin in Dunkard rocks. The only available information is Doctor White' s section on the Ohio river at Raven rocks, about 3 miles below the Tyler line, where are two massive sandstones 20 and 45 feet thick at 63 and 123 feet above the Washington coal bed and therefore in the Marietta interval; there are at least 30 feet of red rock in 48 feet above the coal bed. These sandstones, evidently the Upper and Middle Proctor of Doctor White's earlier studies, have been seen frequently along the river and they are reported as present at many places in the interior from Marshall county southward. A variable sandstone makes its appearance below the Washington coal bed which becomes coarse beyond Parkersburg, where the Waynesburg sandstone, wholly unimportant in much of Wetzel, Harrison, Doddridge, Tyler, and Pleasants, becomes an important member of the section. The interval, Washington to Uniontown, is about 160 feet at Raven rock, 20 feet less than at the last recorded measurement in Tyler and very nearly the same as in northern Washington of Ohio.*

In Ritchie county, south from Tyler and Pleasants and west from Doddridge, there is nothing above the Washington coal bed except a dismal succession of shales and sandstones, all variable to the last degree.

* I. C. White: Catalogue, pp. 71-74. Geology of West Virginia, vol. I, pp. 328, 329, 332; vol. Ia, pp. 249, 250, 258.

The Marietta interval is as variable as the rest, but at most localities it contains sandstone and occasionally that rock predominates. A great sandstone is usually present at 40 to 50 feet below the Washington coal, and it is sometimes continuous with the Uniontown sandstone below. The Washington coal seems to be persistent throughout the county, being reported at many places by both White and Stevenson; it is 1 foot to 2 feet 9 inches thick and usually double. Records giving details above the Washington are few, but they show that the red beds are as variable as the rest; for in three wells, reds, 26, 35, and 50 feet are at 44, 100, and 130 feet above the coal; but each is in only one well, its place in the others being filled with sandstone.*

Wood county, west from Ritchie and Pleasants, adjoins Washington of Ohio. The Washington coal bed, thin and slaty, is in the Ohio river at Parkersburg with one of the Marietta sandstones at 90 feet above it. The persistent Nineveh limestone is in the hills, 3 or 4 miles east from the river, where a well record shows a great sandstone, 119 feet thick, at 236 feet below the limestone and 10 feet above a coal bed. This direct measurement gives as interval between the limestone and the coal bed, 365 feet, placing the coal at the Washington horizon and the sandstone in the Marietta interval. A great mass of red shale underlies the Nineveh limestone; a bed 16 feet thick rests on the Marietta sandstone and a thin bed is at 5 feet above the Washington. This coal bed rests on 55 feet of red, with at 55 feet lower a great sandstone belonging mostly to the Uniontown; but the section is excessively variable. At 3 miles northeast the Marietta sandstone is wanting, and for 200 feet above the coal one finds an alternation of red and other shales, with the beds differing even in adjacent wells; thus one well shows two beds of red, 100 and 40 feet, while another only a few rods away has 60 and 20 feet in the same interval. But it is sufficiently evident that red shales are in greatly increased thickness, both above and below the Washington coal bed. The Nineveh limestone is exposed in eastern Wood, at the corner of Wood, Jackson, and Wirt counties, as a mass of limestone and calcareous shale 30 feet thick.†

There is practically no detailed information for counties south from those already followed. Dunkard is certainly present in Jackson, Wirt, Roane, Calhoun, and Gilmer, and no doubt it crosses the Great Kanawha river. Doctor White has recognized the Marietta sandstones in the counties named, and the Washington coal bed has been opened at many

* Geology of West Virginia, vol. i, pp. 311, 313, 317; vol. ia, pp. 406, 416, 431, 434, 435; vol. ii, p. 114.

† Geology of West Virginia, vol. i, pp. 291, 294, 295, 296; vol. ii, p. 109.

places in Roane county; for, though only 12 to 24 inches thick it is the only coal bed in the region. It is hardly probable that the succession will ever be worked out. The limestones and coal beds, with the exception of the Washington, have all disappeared, the sandstones are indefinite, and the red beds are inconstant to the last degree. To follow the section with any degree of certainty seems almost impossible. In this part of the field there are no natural division planes above the Allegheny.

Geographical Changes during the Pennsylvanian*

Toward the close of the Devonian, the Appalachian water area had decreased to a basin at the east, 70 to 80 miles wide at most, extending from the Catskill mountains of New York across Pennsylvania, Maryland, and Virginia to a short distance beyond New river, in the last state. The Catskill beds, deposited in this narrow basin, which in southern Pennsylvania reached westwardly only to Laurel hill, about 60 miles east from the western boundary of the state, are red to green shales and sandstones, fine grained and argillaceous, many of them little more than indurated clay beds.†

The close of the Devonian was marked by elevation at the east and slow subsidence toward the west and south—a reversal of the conditions prevailing during the later Devonian. The earlier Mississippian deposits, comparatively coarse on the easterly side to beyond New river, in Virginia, eventually reached far into Ohio. The subsidence toward the west was not of long continuance in the northern part of the basin and was followed by elevation on that side, so that the western limit of each Mississippi formation in Ohio and northern Kentucky is east from that of its predecessor; but the subsidence continued toward the south for a much longer period, and the later Mississippian overlaps even the earlier Devonian, while its limestones pass into sandstone in approaching the old land area of eastern and southern Alabama, though even there some elevation occurred before this time closed. The narrowing of the basin brought about conditions at the close of the Mississippian resembling those at the close of the Devonian.

* As the writer is preparing another work, in which the facts thus far gathered will be discussed in their bearing upon the origin of coal and the accumulation of coal beds, it is necessary here only to summarize the varying relations of land and water during Pennsylvanian time.

† The term Catskill is used here as by Vanuxem, who first defined and named the "Catskill group." It has no reference to color of the beds, which is due to a condition beginning in New York at the close of the Hamilton and thence gradually extending southward until, at the close of the Devonian, it prevailed throughout the area of deposit.

That all but an insignificant part of the Appalachian basin had become dry land at the beginning of the Pennsylvanian was suspected long ago. In 1874 Professor Newberry * thought that some of the West Virginia coal beds were older than the Ohio conglomerate, and in the following year Professor Andrews † asserted respecting certain plants obtained at the bottom of the Ohio column that "their stratigraphical position is more than 2,000 feet above the base of the series as revealed in the geosynclinal basin of West Virginia, which was first filled with strata of the Coal Measures before any similar formations took place upon the ancient marginal Waverly plateau of Ohio." A year later Mr Maury,‡ making use of measurements by Professors W. B. Rogers and W. M. Fontaine, called attention to the great difference in extent of the deposits in the northern and southern parts of the basin; but the erroneous conceptions concerning correlation then prevailing prevented him from recognizing the full value of his data. Fifteen years afterward Doctor White § compared the Ohio and Pennsylvania Pottsville with that of West Virginia and indicated the vast thickness in West Virginia of rocks below the Jackson Shaft coal horizon of Ohio, illustrating his understanding of the relations by a diagram. In the interim Mr Lesquereux ‖ had tabulated the distribution of plants obtained from Pennsylvania and had shown the existence of horizons in Tennessee below those of Ohio, and had compared the lower horizons with those in the anthracite region of Pennsylvania. It was reserved for Mr David White, after study of fossil plants collected systematically in many portions of the basin, to present the conclusion in definite form and to determine the relation of the earlier anthracite deposits to deposits in other parts of the great area.¶ His studies, based primarily upon paleontology, led to practically the same conclusions with those reached by the writer from study of stratigraphy and presented in the following pages. The two lines of investigation have not led in all cases to full agreement in correlation, but it must be conceded that the disagreements are confined mostly to localities where the stratigraphical evidence is incomplete.

At the beginning of the Pennsylvanian the water area was confined to lakes on the eastern side of the basin, one in northeastern Pennsyl-

* J. S. Newberry: Geology of Ohio, vol. ii, 1875, p. 167.

† E. B. Andrews: Palæontology of Ohio, vol. ii, 1875, p. 415.

‡ M. F. Maury, Jr.: Resources of West Virginia, 1876, p. 187.

§ I. C. White: U. S. Geol. Survey Bulletin, no. 65, 1891, p. 182.

‖ L. Lesquereux: Coal flora of the Carboniferous formation of Pennsylvania and throughout the United States, 1880, pp. 636 et seq.

¶ D. White: Deposition of the Appalachian Pottsville. Bull. Geol. Soc. Am., vol. 15, 1905, pp. 267 to 282, and map.

vania, another in West Virginia and Virginia, and possibly a third in eastern Alabama, though evidence for the last is very indefinite. The lakes were bordered by flats covered with Shenango muds, while farther away on each side were rocks of greater age. That the land on the west side had been exposed for a long period to subaerial erosion is evident from the existence of deep valleys, clearly shown for Kentucky and Ohio in sections by Andrews, Read, Crandall, Sullivan, and Campbell; for Tennessee and Pennsylvania by Hayes, D. White, W. G. Platt, and other observers. The highland of the basin was in New York and western Pennsylvania. From the latter the surface declined gently westward into the broad valley of eastern Ohio and eastward to the deep valley now occupied by the Southern Anthracite field. Toward the south the decline was long and gradual, with more rapid descent on the east than on the west side. The great depth of the northern valley basin and the steepness of its immediately bounding slope at the west are evident, because, even at the close of the Rockcastle, deposits reached barely into the Northern Anthracite field. The land was trenched by great valleys, hundreds of miles long, ending in bays, some of which opened into the Atlantic, others into the interior sea.

The northern lake basin containing the Pocahontas, or lowest beds of the Rockcastle, included the Southern and much of the Western Middle anthracite fields. This, first made evident by Mr David White's studies, is equally evident from the stratigraphical conditions. The southern lake basin may have been somewhat larger than indicated by Mr White, who, out of abundant caution, did not place the boundary beyond that indicated by undoubted evidence in his possession. The stratigraphical evidence seems to justify farther extension southward to very near the Tennessee line, at least for the higher beds. The basin thus extended would be about 100 miles long, with an extreme width in southern West Virginia of not more than 60 miles. These small basins, now separated by an interval of 300 miles, may have been united; but if they were, the connecting water strip must have been very narrow, for even in southern Pennsylvania the Sharon sandstone, the latest Rockcastle deposit, is the oldest bed in Broad Top of Fulton county.

The eastern shoreline of the northern basin lay not far from the south side of the Southern Anthracite field and nearer to the eastern than to the western end. Mr David White * has shown that pebbles in the lower third of the Pottsville there are less rounded than those in the upper Pottsville, at times even subangular, while along with the prediminating quartz fragments there are in this lower portion

* D. White: 20th Ann. Rept. U. S. Geol. Survey, 1900, p. 764.

others of shale and sandstone. He states also that fragments increase in size eastwardly, there being at the east end many 5 to 6 inches in diameter. These large pieces, as well as those of shale and sandstone, could not have been transported far. Mr Lyman* calls attention to the rapidity with which the fragments decrease in size northwardly as evidence of speedy loss in transporting power. Comparisons of tabulated sections given in the Anthracite atlases of the Pennsylvania survey shows that conglomerate areas are separated by areas of finer deposits in which shale is abundant. The conditions are such as would be found in a lake basin filled with confluent delta deposits.

The eastern border of the West Virginia-Virginia basin is not so apparent. At both the north and the south end the lower beds of the Pocahontas are more or less conglomerate, but midway along the outcrop no conglomerate is seen and even such sandstones as are present are not coarse. But in this basin the deposits quickly lose their coarseness toward the west, and the Pocahontas coal bed itself diminishes in that direction, so that there is much probability in Mr M. R. Campbell's† suggestion that the present outcrop line is not far from the original eastern limit of the basin.

Elevation at the east and depression on the west side of the great basin became more pronounced after the Pocahontas deposits had been laid down. Great sandstones were spread over the region, all extending farther northward on the east than on the west side, while each in turn overlaps its predecessor and for some distance before disappearance rests on Mississippian beds. The Rockcastle sandstone was the first to reach the deep valleys of Kentucky and Ohio, and in the latter state it seems to occupy a broad valley along the western margin of the Carboniferous field, extending from Lake Erie southwardly into Kentucky, where it may be that the valleys described by Campbell and Sullivan were its tributaries. In the northern and northwestern parts of the great basin the subsidence was nearly uniform, there being but slight variations in the section; but from Kentucky southward there was clearly a constant increase along the easterly side into Alabama, where throughout the subsidence was very great, the Rockcastle deposits being several times as thick in Alabama as along the western escarpment of the Tennessee plateau. Yet this subsidence was not without irregularities and local foldings, for intervals between the great sandstones show at times remarkable variation. There were long periods of comparative quiet,

* B. S. Lyman: Original southern limit of the Pennsylvania anthracite beds. Trans. Am. Inst. Min. Eng., 1902.

† Cited by D. White in Bull. Geol. Soc. Am., vol 15, p. 276.

during which coal beds of great extent and great economic importance were formed.

The ocean found ingress at few localities and apparently for only brief periods. Professor Safford * discovered a limestone in Grundy county of Tennessee within the Bonair and very near the extreme western outcrop. This, as he states, a rare occurrence in Tennessee, contains a marine fauna, evidently marking the head of a bay communicating with the interior sea. Mr M. R. Campbell reports a fossiliferous shale not far above the Etna horizon in McDowell county of West Virginia, 300 miles northeast from Professor Safford's locality and only about 15 miles from the extreme eastern outcrop; and Mr David White has observed marine forms very near the same horizon on New river, east from Sewell. This may mark the head of a bay opening to the Atlantic. No marine fossils have been observed anywhere in the intervening space. In central Alabama, Mr McCalley found several beds with marine fauna in the higher part of the column, but no observer has recorded the presence of marine forms in either Georgia or eastern Alabama.

The post-Pocahontas sandstones of the Rockcastle give a clue to the land boundaries. In ascending order they are the Etna, Bonair, Rockcastle, and Sharon. All are conglomerate to coarse, more or less pebbly sandstones at most localities along the easterly border. Followed westwardly in Alabama, the Etna becomes a not very coarse sandstone and the Bonair shows only occasional pebbles; but beyond the central part of the state both beds thicken toward the western border, indicating that the land area, so distinct on the east and south, must have extended northwardly on the west side through Mississippi almost to the Tennessee line. There, however, one is beyond the strict limits of the Appalachian basin and is in line with the Indiana-Illinois area, cut off abruptly by erosion in Kentucky 200 miles north from the Alabama exposures. At the extreme western outlier in Tennessee these two sandstones are cross-bedded and not coarse, and the Etna retains these characteristics at most localities in central and western portions of the Tennessee coal field; but the Bonair is usually more or less conglomerate and is very coarse near its termination, in the northern portion of the state.

The Rockcastle and Sharon sandstones cannot be recognized in central Alabama; there is good reason to suppose that the higher bed is no longer present, having been removed by erosion. But sandstones and conglomerates are so numerous and so considerable in the upper part of the column as to leave no room for doubt respecting continuing elevation of the inclosing area east, west, and south. In much of the central and western part of

* J. M. Safford: Geology of Tennessee, p. 367.

the Tennessee coal field the Rockcastle is a more or less pebbly sandstone, but on the west side, at the north, it becomes distinctly conglomerate and it retains this character in Kentucky. It is notably conglomerate, especially in its lower portion, everywhere in Ohio, and in the northern 150 miles of its extent it carries abundant fragments of chert or cherty limestone containing Mississippian fossils; while near Lake Erie it holds not only quartz and chert pebbles, but also very numerous flat and angular fragments of rock. This distribution in Ohio clearly indicates a broad gravel-filled valley like that of the upper Ohio. The nature of the fragments shows that they were derived for the most part from the vicinity of the present Lake Erie. The chert at one time was supposed to come from the Maxville limestone of southern Ohio, but the deposit is far to the north and west of the original limit of that limestone, which is not reported anywhere as cherty; the source must be looked for in the cherty Mississippian limestone of Michigan. The valley holding the Rockcastle lay for the most part west from the present area of Pennsylvanian deposits, being well marked only near Lake Erie and in Pike and Jackson counties of Ohio. In the intervening space one finds only the eastern edge of the valley and in many places apparently the insignificant deposits laid down in lateral valleys. In Kentucky and Tennessee the distribution of this sandstone is not confined to narrow areas. The Sharon sandstone tells the same story as the Rockcastle, but has a wider distribution. It, like the Rockcastle, is coarser at the sides than in the middle of the great basin, so that the material forming it was derived not from one but from both sides.

At the close of the Rockcastle, water extended to but a little distance within New York. Practically the whole of the Pennsylvania bituminous area, the Northern Anthracite field, the northwestern third of West Virginia, and nearly all of the present coal area of Ohio were dry land. A shallow, rather narrow arm of the interior, or Mississippian, sea extended northward from Kentucky to the east side of what is now Lake Erie, occupying the old valley partly filled with Rockcastle deposits, while other valleys communicated with the Atlantic at the east. The elevation of the land must have been insignificant throughout, for at the close of the Beaver the whole region had received deposits.

The passage from Rockcastle to Beaver is somewhat abrupt at many places along the western and northern sides of the great basin. The surface of the Sharon sandstone is irregular, so that in western Pennsylvania and in Ohio the Sharon coal bed occurs in saucer-like patches, while in Kentucky the interval from Sharon sandstone to Sharon coal varies abruptly from 10 to 50 feet or even more. These variations may

be due to irregularity in distribution of sediments or even to local elevation or subsidence, but in many cases they are such as to suggest genuine lack of conformability due to a broad elevation along the western side, which, in addition, would explain the abrupt change from coarse sandstone to fine shale, if it be supposed sufficient to divert the drainage temporarily and to make the low interior land the important source of sediments. Subsidence during the Beaver seems to have been comparatively uniform in the northern part of the basin, though there is evidence of somewhat more subsidence in the east than in the west; but in Kentucky and southern West Virginia the rate of subsidence increased southwardly and eastwardly with notable rapidity. The shales below the Sharon coal bed are but 10 feet thick at the western outcrop in Kentucky. Mr J. Lesley followed them across the state to the West Virginia border, where they are 150 feet, while on the Kanawha river, in West Virginia, they are 400 feet thick. This differential sinking continued throughout the Beaver, for intervals above the Sharon coal bed show notable variations in the southern part of the remaining area.

In southern Pennsylvania and the immediately adjacent part of West Virginia the sedimentation was continuously marine from the Shenango up to the middle of the Beaver, there being no recognizable members of the Beaver or older beds below the Quakertown coal bed, and the passage beds are largely red shale, with locally important deposits of iron ore. These contain in some places marine forms, thoroughly well developed and of large size, as if living amid favorable conditions. This continuous sedimentation prevailed in a broad area and leads to uncertainty in the attempt to interpret oil-well records within the interior counties of West Virginia, where a sandstone sometimes divides them. In northern Kentucky Professor Crandall found in shales below the Sharon coal bed numerous calcareous concretions, apparently non-fossiliferous. These increase in number as well as size farther south, at the same time ascending in the series until in the southern part of the state they reach to what has been taken by the writer to be the Mercer horizon; but concretions above the Sharon coal become more and more arenaceous. Mr J. Lesley observed these concretions long ago and followed them from the western outcrop across the state to the West Virginia line, where they are the silicious limestones of Doctor White's Winfield section. This deposit is reported from Logan county of West Virginia, but thence eastward, possibly because of imperfect exposures, at no place until the Kanawha river is reached. There one finds the concretionary Campbells Creek limestone above, with the Stockton cement and the Eagle limestone below the Sharon (Campbells Creek) coal bed. No fossils are reported from

any locality west from the Kanawha, but Doctor White discovered an abundant marine fauna in shales associated with the Eagle limestone.

For the most part fresh-water conditions prevailed during the early part of the Beaver, and one may regard the marine forms found near the bottom of the formation on the east side as due to communication there with the Atlantic. At a much later time, however, subsidence on the westerly side admitted seawater to the broad valley on that side; so that in Ohio one finds extending southwestwardly from Mercer county of Pennsylvania to Perry county of Ohio the important Mercer limestones, extending farther eastward than does the Sharon sandstone, but apparently not so far west. As shown by Mr Read's * descriptions and as figured in one of his diagrams, the Ohio valleys were not filled by deposits until after the Mercer limestones had been formed. As the deep, broad valley in which the Rockcastle beds and the Mercer limestones were deposited was for the most part west from the present area of Coal Measures, the limestones can not be traced beyond Perry county, where the Lower Mercer is very thick at its western outcrop. These limestones carry a typically marine fauna.

The sandstones of the Beaver are the Connoquenessing and the Homewood. These can not be recognized farther south than northern Tennessee. Along the eastern outcrop they are sandstones, with few pebbles northward to northern West Virginia, beyond which into the Northern Anthracite field they are pebbly and at times largely conglomerate. On the western side they are sandstone, often shale, until near the last exposures at the north, where they sometimes contain pebbles. The one exception on the west side is in Knox county of Ohio, where one is on the extreme western outcrop. In the deeply buried interior area more or less sandstone is present at one or other of the intervals in nearly every boring, though there is great variation and very many borings show little aside from shale; but in an irregular east and west strip crossing Clearfield, Jefferson, Clarion, and Mercer counties of Pennsylvania, at a considerable distance south from the northern outcrop, one finds the Homewood sandstone coarse and at times coarsely conglomerate. The Homewood is pebbly also along a line extending from southern Fayette of Pennsylvania to the eastern outcrop in Maryland, as though a valley had existed there. The strip farther north evidently marks a river valley, but the source of the pebbles is difficult to determine. The distribution of the sandstones shows that the elevation continued on the east side, strongly at the north, but less and less strongly toward the south, while the pebbly rocks of Knox as well as of Summit and Portage, on the

* M. C. Read: Geology of Ohio, vol. III, p. 544.

northern border in Ohio, may be evidence of slight elevation on that side, and the pebbles may have been derived from upraised Rockcastle beds.

The existence of land at the south and southwest is indicated by the distribution of the coal beds. These appear to be persistent around the borders of the basin, even at the south and southwest, to the last localities where one may recognize the formation; but they are wanting in the interior area within Ohio and West Virginia, where in thousands of square miles no trace of them appears in the well records.

At the close of the Beaver, though the whole basin had received deposits, the water was very shallow and the surface of the latest sandstone or shale showed surprisingly little irregularity. The abruptness of change in many localities from Homewood sandstone to fine shale of the Allegheny is one of the most notable conditions. Not less remarkable is the regularity of the subsidence in a vast area. The interval from Homewood sandstone to the Brookville (Stockton) coal bed varies little from 10 feet in a space of more than 1,000 square miles within West Virginia, while in other tracts equally extensive that interval varies from 5 to 20 feet. Whatever may have been the cause, a long period of very gentle change succeeded the Beaver, during which coal at the Brookville horizon, with greatest thickness at the east, gradually spread over the greater part of the area in which Allegheny rocks remain. Its extent is unequaled by that of any deposit at a later horizon.

The Allegheny is a thin formation, but its variations in thickness are considerable. Along the easterly side one finds 160 feet in Broad Top of Pennsylvania, 350 to 260 in the Potomac area, decreasing toward the west; 175 in Taylor county of West Virginia, beyond which it decreases to 140 feet, a thickness which is retained for many miles. Increasing again, it becomes 200, and at the Kentucky border about 210 feet, which seems to be approximately the thickness assigned to its beds in southeastern Kentucky by Mr Hodge. In the First and Second basins of Pennsylvania the measurements vary from 235 to 275, but along the west side of Chestnut hill it is 230 in Indiana county of Pennsylvania, 206 at the West Virginia line and 195 feet at Clarksburg, about 40 miles south from that line. The greatest thickness is in Jefferson, Armstrong, and Butler counties of Pennsylvania, becoming 340 feet in the last, whence it decreases toward the west and is barely 200 feet at the Ohio line. In that state the variation is between 175 and 240 feet, the least thickness being on the western border, whence it thickens eastwardly toward the middle of the basin, where in the deep portion of Ohio and West Virginia it is about 250 feet. There seems to be no reason for supposing that the Allegheny becomes thicker southward in Kentucky,

and at present there is little ground for supposing that it ever reached much farther south than northern Tennessee.

The sandstones of the Allegheny contrast greatly with those of the Rockcastle, even with those of the Beaver. They are persistent only as narrow bands, and in any given area are apt to be replaced for considerable distances by sandy or even by clayey shale. Along the eastern outcrop from Kentucky northeastwardly into Randolph and Upshur counties of West Virginia the sandstones are very conspicuous, very coarse, and at times for miles almost continuous from bottom to top of the formation, composing in part Mr Campbell's Charleston sandstone. Farther north, in the Potomac area, the sandstones are differentiated, broken by beds of shale; yet even there the Butler and Clarion are massive, the former at times pebbly. The sandstones are irregular in Broad Top and the pebbles are few. Within western Pennsylvania the Butler and Freeport sandstones appear to be most nearly persistent and each of them occasionally shows some pebbles; but they vary greatly in thickness and each of them is often replaced by shale in tracts containing hundreds of square miles. Well records in the deep portion of Ohio and West Virginia usually show more or less of sandstone in one or more of the intervals, but many show so little aside from shale that the sandstone must be due merely to local sorting of material. Pebbles are reported only from Wirt county of West Virginia. The great sandstones of the eastern outcrop in West Virginia break within a few miles toward the northwest; thin shales appear, which soon increase in thickness, and the sandstones become unimportant. Along the western outcrop in Ohio, sandstone is most nearly persistent in the Butler and Freeport intervals. Ordinarily fine in grain, the latter shows pebbly streaks in Stark, Carroll, Harrison, Wayne, Tuscarawas, and Muskingum counties—that is, along the northwestern side; yet in all of these counties not a few sections show only shale. The Clarion (Hecla) sandstone becomes very conspicuous in southern Ohio and is equally so farther south and southwest in Kentucky. It is noteworthy that a conglomerate is present in parts of Kentucky near the horizon of the Vanport limestone, and that at one locality the ore associated with that limestone is so crowded with quartz pebbles as to be worthless.

The character and distribution of the sandstones show sufficiently a great advance of the shoreline or a considerable elevation of land at the southwest. The former condition seems the more probable, and the Allegheny deposits can have extended hardly so far in that direction as did those of the Beaver. The shoreline at the east-southeast must have been at only a short distance from the present outcrop, as the strip of

sandstone is very narrow. Coarse material could be pushed only a little way in the shallow water of that time. There is much to suggest a similar advance of the shore at the northwest, not only in the unexpected coarseness of the sandstone, but also in distribution of the limestones. The presence and great predominance of sandstone in Kentucky, on the southern and southwestern borders, is equally suggestive of land encroachment in that direction.

The Brookville coal bed, the lowest of the Allegheny, underlies in most of the area sandstone or shale, but in Ohio, from Mahoning county on the Pennsylvania border at the north to Hocking and Perry counties at the south, one finds the Putnam Hill limestone, which is sometimes in direct contact with the coal. Throughout this distance the western edge of the limestone lies west from the present outcrop, and south from Perry and Hocking the place of the limestone is west from the present coal area; but conditions in Knox county seem to show that the limestone strip was narrow and that it did not extend beyond the valley region in which the Rockcastle and Sharon sandstones occur. Like the Mercer limestones, it carries an abundant marine fauna and marks the line of a sea invasion from the west. One finds on the Kanawha river, in West Virginia, and at the same horizon, the Black Flint, sometimes accompanied by limestone, at times fossiliferous itself and often associated with fossiliferous shales. This deposit is confined to a narrow branching area, which may have been near the head of a bay communicating directly with the Atlantic. A limestone at this horizon in northern West Virginia is non-fossiliferous.

The Vanport (Ferriferous) limestone marks a still greater inroad of the interior, or Mississippian, sea, reaching in northwest Pennsylvania almost to the New York line. Its easterly and westerly boundaries are distinct in Pennsylvania. At the north and northwest, in Elk, Clarion, Jefferson, and Butler, it passes into chert and cherty sandstone, while on the southeast a prong extends into central Indiana. The deposit is wholly wanting east from the Monongahela and farther north in the First and Second basins of Pennsylvania as well as in West Virginia; but a marine limestone belonging very near this horizon is in Maryland, 150 miles southeast from the nearest locality in Pennsylvania where the bed can be recognized. On the Kanawha, in West Virginia, Professor W. B. Rogers* found a bed crowded with marine forms at 140 feet above the Black Flint, too high for the Vanport horizon, but of interest as proving access to the Atlantic at more than one time during the Allegheny. During the deposit of the Vanport the water was evidently very

* W. B. Rogers: Rept. Geol. Survey of Virginia for 1839, p. 135.

shallow near the Pennsylvania-Ohio line, for in a considerable area that limestone is represented only by occurrences of fossiliferous shale, more or less calcareous; but the limestone reappears in central Tuscarawas county, and thence southward it is recognized as limestone or as ore to Breathitt county of Kentucky. In central and southern Ohio as well as in Kentucky the main body of the limestone lay west from the outcrop, and in much of the present area the horizon is traceable only by means of the ore bed, which extends eastwardly for some distance beyond the last trace of the limestone. The Vanport is richly fossiliferous.

No later important inroad of the sea occurred. The fossiliferous shale overlying the Middle Kittanning is found only as far north as central Ohio, while the Lower and Upper Freeport limestones, though extending over a great part of the basin at the north, are either non-fossiliferous or contain only fresh-water forms; but south from the Ohio river in Kentucky the Upper Freeport limestone carries a characteristic Carboniferous fauna.

It is wholly probable that the Appalachian and the Indiana-Illinois fields were not united during the Allegheny, though they may have been during the Rockcastle, as they were during the Mississippian.

Observers in Pennsylvania note at many places that the Homewood, the last deposit of the Beaver, is continuous with a sandstone in the Allegheny reaching at times to the Lower Freeport coal bed, but for the most part to about the Vanport horizon. At a little distance on each side the Allegheny portion of the sandstone disappears and the proper section is found. Records of borings in West Virginia show the same condition, with in some portions of the deeper area a much greater vertical extent. Mr Read gives a section in Coschocton county of Ohio where a continuous sandstone, 280 feet thick, occupies a trough in Beaver and Allegheny beds. Borings in Greene of Pennsylvania and Marshall, Tyler, and Wetzel of West Virginia seem to show narrow areas in which sandstone is continuous from Homewood far up into the Allegheny and in some instances even into the Conemaugh. These may mark stream courses, constantly agraded. It has been suggested that they are evidence of local foldings and elevations in which valleys were made by subaerial erosion. This explanation applies to very few of the examples, since there is no nonconformity on either side. For example, in the Ohio instance the Brookville coal bed rests on the sandstone, while at a short distance away the same bed is shown with the Beaver beds below, each with its proper interval for the region.

Beyond all doubt, there were serious local irregularities, for intervals often vary with extraordinary abruptness; but one must be cautious in

generalizing here. The interval between Upper Freeport and Lower Kittanning coal beds varies little and apparently according to rule in very considerable areas, while in the same areas the intervals between intervening coal beds vary without any reference to the principal interval. The coal beds of the Allegheny above the Brookville in no case extend far into the interior of the basin and all are mere fringes around the border. The coals mentioned in oil-well records can rarely be referred to any definite horizon, and in most cases they represent carbonaceous material drifted upon mud lumps or sand banks.

Toward the close of the Allegheny a small area in west central West Virginia near the Ohio river received deposits of red mud, more or less calcareous, accompanied often by greenish muds; and, somewhat earlier, similar deposits were made in northeastern Kentucky. This is the beginning of a condition which in gradually enlarging or contracting area was to continue until the close of Carboniferous time, always predominating, however, within a small area in West Virginia and the adjoining part of Ohio.

In many respects the Conemaugh is but the continuation of the Allegheny; the variations in thickness are, geographically, very similar in both. Along the easterly side the Conemaugh is approximately 500 feet thick in Broad Top, at the northeast, while at Charleston, on the Kanawha, 250 miles southwest, the thickness has increased to 643 feet; but in the intervening space for nearly 200 miles it averages not far from 600 feet. Along the northern border, in Pennsylvania, it is about 600 feet, and slowly decreases southwardly to 560 feet at the West Virginia line, this being apparently about the average thickness in West Virginia east from the line passing through Ritchie county. Midway in the basin the sections show decrease southwestwardly, 600 in western Pennsylvania, 480 in Monroe, and 430 in Lawrence of Ohio, while along the western outcrop in Ohio the thickness varies from 325 to 350 feet. The least thickness reported, 275 feet, is on the extreme western outcrop, in Perry county of Ohio, while farther east in that county it becomes 329. This decrease westwardly across the basin is due to differential subsidence and not to overlapping, for the notable members of the section persist to the last. The rapid shortening of the section in Perry county of Ohio seems to show that the shortline lay not far toward the west.

Except in a very narrow strip along the southeasterly border in West Virginia, the Conemaugh sandstones are more irregular than are those of the Allegheny. One generally finds some sandstone of some sort in the sandstone intervals, but shales predominate in by far the greater part of the area. Certain sandstones appear with great regularity in oil-

well records of West Virginia, but comparisons show quickly that the drillers' identifications are too often made at haphazard. Away from the southeastern border, pebbles are extremely rare, except along a narrow rudely east and west strip across Indiana, Armstrong, Butler, Lawrence, and Beaver counties of Pennsylvania. This lies many miles south from the northern outcrop and south from the similar strip in the Beaver formation; its variations are such as one finds in the gravels of the upper Ohio river. Many similar valleys filled with standstone during the long subsidence are recognizable in various parts of the area, and occasionally one is found along an anticlinal crest which seems to have been made by subaerial erosion. The sandstones for the most part are indefinite within Ohio, but in Tuscarawas county the Lower Mahoning interval is filled with conglomerate and farther south the Buffalo interval is filled with very coarse sandstone at many places. Similar conditions were observed in the Allegheny here.

While in a general way the conditions were similar to those of the Allegheny, showing a gradually contracting area, yet the subsidence was such as to admit seawater to a much greater space. At the very beginning one finds at somewhat widely separated localities in West Virginia a marine fauna in the Uffington shale which rests directly on the Upper Freeport coal bed, while at most exposures the shale yields only impressions of land plants. Not enough information is available to justify any suggestion respecting the relations of the marine localities, which are confined to the easterly side of the great basin.

The Brush Creek limestone, separated from the Uffington shale by the Mahoning interval, is confined in its best development to the northeastern part of the area. It occurs irregularly in northeastern Ohio and is continuous in a not very broad area eastwardly and southeastwardly across Pennsylvania into western Maryland and northeastern part of the West Virginia coal field. It is wanting along the northern border in Pennsylvania as well as east from the Alleghenies. No trace of it appears in most of Ohio and it is wanting under the Cowrun anticline, in the central part of the basin; but a limestone at its place is present in the extreme southern part of the area in West Virginia. The fauna is distinctly marine and the distribution of the deposit leads one to look toward the east for its connection with the sea. The Cambridge limestone, on the other hand, represents an invasion by the interior, or Mississippian, sea, for as a marine limestone it prevails from Armstrong county of Pennsylvania westward into Ohio and thence southwardly into Kentucky. It is wanting in the interior area, but reaches the middle line of the basin in the southern part of West Virginia, in Cabell and Wayne counties, as

well as in Johnson county of Kentucky. Its area, narrow in Pennsylvania and northern Ohio, becomes much wider southward. On the east side of the great basin in Maryland and 90 miles from the nearest locality in Pennsylvania where the Cambridge is clearly recognizable, a marine limestone is found certainly not far from the Cambridge horizon, indicating continuance of communication with the ocean on that side.

The Ames limestone is not reported east from the Alleghenies in Pennsylvania, but is distinctly present in Indiana and Somerset of that state, whence it has been followed across Maryland into Barbour county of West Virginia. This limestone is shown farther west in Pennsylvania, wherever its place is exposed, south from the line of Cambria, Clearfield, and Jefferson counties, and it is equally persistent in Ohio, where, as in Pennsylvania, it is the most useful stratigraphical horizon, being midway between the Pittsburg and Upper Freeport coal beds. It is well shown in the central part of the great basin, under the Cowrun anticline, in Washington of Ohio as well as in Pleasants and Wirt of West Virginia; it is present in the southern portion in Wayne and Cabell counties, and it may be the Fourth Fossiliferous limestone of Kentucky. No borings with diamond drill have been made in the deeper portions of West Virginia and no statement is possible respecting its presence there. It has not been reported along the eastern outcrop south from Barbour county of West Virginia, but at Charleston one finds a limestone, without marine fossils, midway between the Pittsburg and Upper Freeport coal beds and, like the Ames, associated with deep red shale. At all exposures, except that near Charleston, the Ames carries a marine fauna, and at many places on both sides of the basin it rests on fossiliferous shale or, where that is wanting, on the Harlem coal bed. The fauna seems to differ slightly on the opposite sides, some forms characteristic of the Indiana-Illinois field being present on the west side, but wanting on the east side. It may be discovered, when the fauna has been studied thoroughly, that communication was open to the ocean on both sides. It is not improbable, as suggested by Doctor White, that the fossiliferous limestone of the Northern Anthracite field belongs very near the horizon of the Ames. That bed contains many forms obtained from the Conemaugh and in addition several which have not been reported from any other locality within the Appalachian basin; so that there one may have another problem respecting relation to the ocean.

With the Ames limestone, inroads of the sea practically ceased. Marine conditions unquestionably were repeated, but never for periods long enough for good development of animal invertebrate life. Limestones

appear frequently during the upper half of the Conemaugh, several of them widely, though irregularly, distributed, but in no case are they distinctly marine. Some are crowded with minute univalves of undetermined relations; others are associated with carbonaceous shales, filled with fragments of plants and fishes, which point rather to fresh-water conditions.

The most notable feature of the Conemaugh is the red and green shales, in color resembling those of the Catskill and Shenango but deeper. The greatest development is in west central West Virginia and the adjacent part of Ohio, where at times nearly the whole section is red shale. The greatest geographical expansion was just preceding the deposition of the Ames limestone, when the reds reached southeast nearly to the outcrop and northward to the outcrop in Pennsylvania; but they did not reach into northern Ohio and they are practically wanting east from the line of Chestnut hill in Pennsylvania. From that time to the end of Conemaugh the area contracted and reds occur in irregular patches. These beds frequently contain nodules of limestone, which, at least in the Pittsburg reds, underlying the Ames limestone, are usually fossiliferous. The red shales in some cases mark horizons elsewhere carrying limestone and they may indicate a marine condition.

The exceeding shallowness of the water and the long periods of quiet during the Conemaugh are indicated by the coal beds, which, though extremely thin, have great extent. The most remarkable is the Harlem, which underlies the Ames limestone. It rarely exceeds 15 inches, yet is present in much of Pennsylvania, Maryland, and Ohio, persisting in the interior of the basin within West Virginia, where it is brought up under the Cowrun anticline. The peculiarities of this and other Conemaugh coal beds are of much importance in any discussion respecting the accumulation of coal in beds, and they will be examined carefully in another connection.

Toward the close of the Conemaugh the streams bringing in materials had become sluggish and the deposits, except within limited areas, are fine in grain. The Monongahela began with a long period of exceedingly slow subsidence, during which the Pittsburg coal bed gradually extended across the northern part of the great basin and southward along the east and west sides; but from all sides it became thinner toward the central part of the basin and it is practically wanting in a great part of West Virginia and eastern Ohio, where it occurs only in widely separated patches. The bed may have been almost continuous around the basin. The singular uniformity of conditions and the extreme slow-

ness of the movement are shown by the structure of this great bed, persisting in such minute details as partings in tracts of thousands of miles and reappearing even in isolated patches within West Virginia.

The area of greatest subsidence during the Monongahela did not coincide with that of the earlier formations, as appears abundantly from comparison of sections along several lines. The deepest deposits of Allegheny and Conemaugh were at the north and east; not so in the Monongahela. Going west-northwest from the eastern outcrop in Maryland, the measurements are 250 feet in the Potomac basin, 316 in the Connelsville, 375 to 380 in Greene county of Pennsylvania, and 213 in Belmont county, on the western outcrop in Ohio. Along a south-southwest line near the middle of the basin one finds 150 feet in Allegheny county of Pennsylvania, 225 in northern Washington, 355 in southern Washington, 360 to 375 in Greene, and 428 in western Marion of West Virginia. Similar variations appear along a west-northwest line farther south in West Virginia as well as along a south-southwest line farther west in the basin. The greatest subsidence was in north central West Virginia, whence the thickness decreases in all directions. The change is due to differential subsidence, as the intervals between the important members of the section become thinner. The change bringing this about began after deposit of the Pittsburg coal bed, for that is not overlapped toward the outcrop by the higher beds; it certainly extends farther north than do some of the later beds. The absence of that coal bed in so large an area may be due merely to slight irregularities of the swampy surface, for in some parts of that area the underclay with a black streak above it marks the place of the bed.

With this change in place of chief subsidence there came clearly a farther contraction of the basin, while elevation at the north led to spreading out of sandstone along much of the northern border. This Pittsburg sandstone is not present in the eastern localities of Pennsylvania and Maryland, but is persistent in the Chestnut Ridge area of Fayette and Westmoreland counties, in that state, as well as southward along the eastern outcrop in West Virginia to the last exposure near Charleston, where Doctor White found it 70 feet thick. Evidently it prevailed along the western outcrop in Ohio, for it is present on the northwestern outcrop and also in the central counties along that line, where one is again much farther west than in the intervening counties. This sandstone becomes more and more indefinite from all sides toward the interior of the basin. The Sewickley sandstone, underlying the Upper Sewickley coal bed, is fairly persistent on the east side, but is wholly insignificant in Ohio. There, however, an important sandstone overlies the Upper Se-

wickley, not pebbly at the northwest, but coarse and often pebbly in southern Ohio. In Pennsylvania and northern Ohio a more or less persistent sandstone, the Uniontown, overlies the Uniontown coal bed, but ordinarily it is unimportant and many sections show little aside from shale in the interval. In West Virginia, however, a strip of coarse conglomerate, evidently at this horizon, crosses the state from east to west, passing through Lewis, Gilmer, Doddridge, Tyler, and Pleasants counties and extending into Washington, Morgan, and Athens of Ohio, where it is the 200-foot conglomerate of Professor Andrews. It is coarser in West Virginia than in Ohio. The strip is very narrow in the former state and fine-grained rocks replace the coarse material at a short distance north and south; but in Ohio the area is broader, as though additional material had been brought in from that side. This east-and-west line of coarse rock recalls those of the Beaver and Conemaugh in Pennsylvania and may be explained in the same way. The general distribution of coarse material indicates a rising border land and for the southwest a notable encroachment.

The limestone deposits of the Monongahela deserve more careful consideration than can be given here, under the limitations set for this description. These rocks vary greatly in composition. The Redstone is an impure limestone, yielding a fair lime when burned carefully; the Fishpot, when thin, usually resembles the Redstone, but when thick it is apt to contain some layers of cement rock; the Benwood has several beds of hydraulic limestone, even of cement rock, among its most persistent members, while some of the beds are so impure as to break into small angular fragments after continued exposure; the Uniontown and Waynesburg are rarely more than slightly magnesian.

Of the numerous limestones, only the Uniontown can be regarded as really persistent; it is present in western Pennsylvania and in Ohio at nearly every locality where its place is shown. The others may be regarded as confined to southwest Pennsylvania, the West Virginia panhandle, and the immediately adjacent part of Ohio. Their great development is between the Monongahela river at the east and the Ohio river at the west, where in considerable areas limestone and calcarous shale fill more than one-half of the interval between the Redstone and Uniontown coal beds. In all directions from this small area the limestone diminishes quickly and is replaced by shale and sandstone; toward the southwest only some thin streaks remain in West Virginia, and in some portions of that state those streaks seem to be replaced by red shale.

These limestones are spoken of commonly as merely calcareous muds, and that explanation of their origin was accepted tentatively on a pre-

ceding page. But it is insufficient. The enormous thickness in an area of almost 3,000 square miles, central in the northern part of the Monongahela area, as it now exists, can hardly be explained in this way, as there is no known source whence the calcareous mud could be derived by erosion or by solution. One is shut off completely from consideration of the Michigan Mississippian, for the Monongahela limestones disappear wholly in that direction long before the outcrop has been reached. Equally impossible is the supposition that they could have been derived from the West Virginia Mississippian far toward the southeast. That they accumulated as marls in fresh-water areas is equally difficult to believe, for the immense Benwood limestone on the Monongahela is equivalent to very nearly the same thickness of shale and sandstone within a very short distance. The magnesian beds, seemingly the most persistent, can hardly be regarded as fresh-water limestones. Marine origin seems questionable, owing to absence of marine invertebrates. It is true that no careful search for fossils has been made in these rocks; yet the beds have been measured at so many places that some forms should have been found, if such exist. Weathered surfaces of the harder layers in the Benwood occasionally show what bear close resemblance to sections of branching bryozoans, but in every case the fossil is replaced by calcspar and is unrecognizable. Fish remains, teeth, and spines of sharks occur, the most characteristic being *Ctenacanthus marshii*. These are certainly marine, and the specimens obtained were of such size as to show that the surroundings were not unfavorable. Additional evidence that the sea was not wholly shut out is the presence of *Solenomya* in shale above the Sewickley coal bed in Monongalia county of West Virginia. *Naiadites* occurs in the Uniontown limestone at Uniontown, Pennsylvania; but the ingress of seawater does not appear to have continued long enough to permit an invertebrate fauna to make its way. For the present, the origin of the limestones must be regarded as an unsolved problem.

Toward the close of the Monongahela the condition marking the later portion of the Conemaugh was reached once more. In by far the greater part of the area the deposits are fine in grain, and at the end the Waynesburg coal bed was formed, in the northern part of the basin, a bed of curiously multiple structure, which is retained. Like the Pittsburg, it is wanting in the interior region, but it seems to have reached irregularly southward to a long distance on each side.

The Washington opens with a plant-bearing shale like that overlying the Pittsburg, succeeded by a great sandstone, recalling in some respects the sandstones of the Rockcastle. As the area grows smaller in ascend-

ing, it becomes necessary for comparison to consider separately the lower and the upper portion of the Washington. The lower, extending from the Waynesburg to the Washington coal bed, is shown broadly. The length of the column along a west-northwest line from the eastern outcrop is 120 feet in Maryland, 135 feet in Fayette, and 180 in Greene of Pennsylvania, 117 in eastern Belmont of Ohio, and 100 feet at the western outcrop. Along a south-southwest line one finds 50 feet at the most northerly exposure in Pennsylvania, which increases gradually to 130 feet at the Greene County line and becomes 170 feet in Wetzel county of West Virginia, where well records are very numerous; and this 170 feet seems to be the interval in much of central West Virginia; but it decreases farther south. The upper portion, seen in much smaller area, shows similar variation. The full section is not found exposed anywhere east from the Monongahela in Pennsylvania, but in Fayette county an approximate measurement gives about 200 feet from the Washington coal to the Upper Washington limestone; westwardly in Greene the interval increases to 240, and then to 300 feet, while at Moundsville, on the Ohio river, it has decreased to 244 feet. Along a south-southwest line it is 110 feet at the most northerly exposure, increases steadily to 190 feet at the northern line of Greene, and across that county it increases to 308 feet in West Virginia. The formation thus increases from 160 feet in northern Washington of Pennsylvania to above 480 feet in the northern counties of West Virginia, thus showing a continuance of the Monongahela conditions, with the greatest subsidence in north central West Virginia.

The sandstones tell the story of steadily contracting area. The Waynesburg sandstone is persistent in Maryland, in most of Pennsylvania, as well as southward in West Virginia for a long distance. It is massive and at times pebbly, though, like all sandstones of the higher formations, it is sometimes replaced abruptly by shale. In Ohio, along the northwestern border, it is not a coarse sandstone, but farther south it becomes coarser and more prominent, being Professor Andrews's upper sandstone and conglomerate. Thence southeastwardly along the southern border, in Jackson and Putnam of West Virginia, the rock marking this horizon is a coarse sandstone, with quartz pebbles sometimes an inch in diameter. In the interior portion of West Virginia records of oil borings show sandstone persistent in this interval except in a small area. The Waynesburg is the first sandstone of wide extent in the interior region. No notable sandstone above the Waynesburg appears in Pennsylvania, except that underlying the Upper Washington limestone, which is confined to the borders of the remaining area and disappears southwardly. Below

this one finds local sandstones, but they are unimportant. In the southern portion of the basin, on the contrary, the interval above the Washington coal bed is characterized by great sandstones, the Marietta of Doctor White, which appear in their greatest development toward the southwest outcrop, though they are prominent features across West Virginia, extending northward to midway in the state.

The limestones of the Washington are quite as perplexing as those of the Monongahela and they are confined to a smaller area. They attain great thickness in central and southern Washington of Pennsylvania, become comparatively insignificant southward in Greene county, and practically disappear very soon in West Virginia. Limestone is most abundant above the Washington coal bed, and in many places the mass is largely calcareous shale. Few layers yield good lime, but the Upper Washington limestone is ordinarily very good. Fossils of any sort are very few, but occasionally one finds a great abundance of bivalve crustaceans, usually thought to be of fresh-water types. Fish remains occur plentifully in shales associated with some of the limestones, and they, too, are probably fresh-water, as some of the genera are the same with those found in the cannel of Linton, Ohio. Inroads of the sea are not clearly shown. A shale containing some marine forms is reported from one locality in West Virginia, but this is at the very bottom of the formation. One of the Washington limestones shows obscure markings like fragments of brachiopods, but they are wholly indefinite and the evidence seems to point to final exclusion of the sea from the contracting basin. The limestones of the Washington bear much more resemblance to calcareous muds than do those of the Monongahela, but it is difficult to discover the source whence they were derived.

During the Washington the crustal movements were sluggish within the basin of deposition. Thin streaks of coal extend over great areas, many of them showing complex structure; but toward the close the movements became more pronounced, and during the early portion of the Greene the deep portion of the basin was confined to Greene county of Pennsylvania and a narrow strip adjoining at the west in West Virginia. A comparison of sections shows that in southern Washington county, following the Greene County line eastward, the interval from the Upper Washington to the Nineveh limestone varies from 150 to 180 feet, each of these measurements being obtained twice, those of 180 being separated by one of 150, showing two shallow troughs cut by this east-and-west line; but within half a dozen miles southwardly, in the central part of Greene county, the interval increases, becoming 300 to 313 feet with a number of new limestones and coal beds. The chief

increase is in the lower portion, between the Upper Washington and Jollytown limestones, but there is a marked increase in the upper portion also. This lower interval, 130 to 140 feet in the deepest area, of Greene county, becomes only 30 feet at the West Virginia line midway in the basin, and the interval, Upper Washington to Nineveh, seems to be about 200 feet thence south-southwestwardly for many miles.

That the area of deposit was contracting rapidly appears also from the sandstone deposits. The important Fish Creek sandstone is a notable bed in Greene county and extends for a long distance in West Virginia. The Nineveh sandstone, well cemented like the other, is persistent from its northern outcrop, in southern Washington county, across Greene into Wetzel of West Virginia, beyond which no information respecting it is available. The Gilmore sandstone, a poorly cemented massive rock, remains on high knobs in Greene county, as well as far southwestward in West Virginia, while the highest rock of the series is a massive sandstone of which only isolated patches remain on knobs in West Virginia. All of these are along the middle line of the basin, where during deposition of all formations prior to the Washington the sandstone intervals were usually filled with shale. The sources of supply were much nearer than in earlier periods. But the basin, though rapidly losing in width, still extended for not less than 200 miles in north-northeast to south-southwest direction when the Nineveh limestone was laid down.

The limestones, except the Nineveh, are of little importance. No conclusions respecting the highest limestones can be offered, as those beds remain only on very high knobs and in small patches; yet they are of no little interest, in that they extend southward beyond most of the lower limestones and yield good lime. The Nineveh limestone is persistent throughout the whole region in which its place is reached. It has been followed by Doctor White from southern Washington of Pennsylvania to Jackson county of West Virginia, about 140 miles, and it is present at localities on the Ohio river, where its place is reached in Tyler of West Virginia and Washington of Ohio. Even at its most southerly exposure it has 30 feet of limestone and calcareous shale.

No marine forms have been reported from any place. There is much in the character of the Nineveh limestone to lead one to expect such forms, but none has been obtained. Animal remains of all sorts are rare, but Doctor R. P. Whitfield has described some pulmonate forms from Greene beds near Marietta, Ohio, and a few lamellibranchs of doubtful relations have been obtained in Pennsylvania and West Virginia. There is no evidence that the sea actually entered the area in which rocks of the Greene formation remain.

The Red beds retained their importance apparently to the end within the half dozen interior counties of West Virginia and Ohio, and twice during the Monongahela the area showed a very considerable expansion, though in neither case equaling that of the Washington or lower reds of the Conemaugh and in each very much less than that of Pittsburg reds of the same formation. After the deposition of the Uniontown coal bed their area diminished, and during the Washington and Greene the reds became less and less important, appearing at last in, for the most part, thin and rather widely separated deposits, though occasionally, as in Marshall of West Virginia and northern Greene of Pennsylvania, they attain considerable local importance.

In reviewing the conditions within the north central part of the basin, one is led to believe that the loss by erosion is much less than has been supposed. From the crest of Chestnut ridge, in Fayette county of Pennsylvania, the whole of the Carboniferous has been removed and the Chemung rocks are exposed at several places along the summit; but within 5 milles toward the west the section reaches almost to the top of the Washington formation, while at 20 miles farther, beyond the broad valley of the Monongahela river, one finds the highest beds of the Greene. It seems wholly probable that the Gilmore sandstone is but a few hundred feet below the last deposit made in the Appalachian basin.

Notes on the Paleontology of the Pennsylvania

THE FAUNA

Comparatively little attention has been paid to the Pennsylvania fauna. When the early surveys were made, fossils were to most geologists little more than interesting curiosities; during prosecution of the later surveys, the urgent necessity for prompt determination of mineral resources left little time for collecting fossils, which indeed seemed hardly necessary, as the fossiliferous horizons are comparatively few and the forms observed in them appeared to be identical for the most part with those described in the Illinois and other volumes published by western states. It results that for comparison one has only the partial lists given by Messrs Meek, Whitfield, White, and Stevenson.* The forms thus far reported, with their horizons, are:

* F. B. Meek: Rept. Regents of West Virginia University for 1870, pp. 66-73; Rept. progress of Geological Survey of Ohio for 1870, p. 79; Palæontology of Ohio, vol. ii, p. 326.

R. P. Whitfield: Palæontology of Ohio, vol. vi, p. 482.

I. C. White: Second Geological Survey of Pennsylvania, Q, p. 62; Q Q, p. 46, 61; Q Q Q, p. 25.

J. J. Stevenson: Trans. Am. Phil. Soc., vol. xv, pp. 22, 28; Second Geological Survey of Pennsylvania, K K K, p. 309; Geology of Ohio, vol. iii, pp. 207, 222.

1. Mercer limestones.
2. Vanport limestone.
3. Uffington shale.
4. Brush Creek limestone.
5. Ames limestone in West Virginia and Pennsylvania.
6. Ames limestone in Ohio.
7. Lower Coal Measures of Ohio, horizon not given.

Lophophyllum profundum Ed. & Haime	.	2	3	4	.	.	.
Hydreionocrinus mucrospinus McC. sp	.	2	3	4	.	.	.
Eupachycrinus mooresi Whitf. sp	.	.	.	.	.	.	7
Cyathocrinus somersi Whitf	.	.	.	.	.	.	7
Archæocidaris wortheni H	.	2	.	.	.	.	.
Pentremites pyriformis	.	2	.	.	.	.	.
Erisocrinus sp	.	.	3	4	.	.	.
Fenestella sp.	.	.	.	4	.	.	.
Polypora sp.	1	.	.	.	.	.	.
Septopora biserialis Swall sp	1	2	.	.	.	.	.
Cystodictya carbonaria M	.	.	.	.	.	.	7
Prismopora serrata M. sp	.	.	.	.	.	.	7
Discina meekana Whitf	.	.	.	.	.	6	7
Chonetes mesolobus N. & P	1	2	.	4	.	.	.
Chonetes smithii N. & P	.	.	.	4	5	6	.
Chonetes granulifer O	.	.	.	.	5	6	.
Chonetes sp.	1	.	.	.	.	.	.
Productus equicostatus Shum	1	.	.	.	.	.	.
Productus nebrascencis O	1	2	3	.	5	6	.
Productus semi-reticulatus Martin	1	2	.	.	5	6	.
Productus punctatus Martin	1	.	.	.	.	6	.
Productus longispinus Sow	1	2	.	4	5	6	.
Productus cora D'Orb	1	2	3	4	5	6	.
Productus pertenuis M	.	.	.	4	.	.	.
Orthotetes crassus M. & H. sp	1	2	3	4	5	6	.
Meekella striato costata Cox sp	.	.	.	.	5	.	.
Rhipidomella pecosii Marcou sp	.	.	.	.	5	6	.
Pugnax uta Marcou sp	.	.	.	.	.	6	.
Spirifer cameratus Norton	1	2	.	4	5	6	.
Spirifer rocky-montani Marcou	1	2	.	4	.	.	.
Squamularia perplexa Swall. sp	1	2	.	.	5	6	.
Ambocœlia planoconvexus Shum. sp	.	.	.	.	5	6	.
Spiriferina kentuckensis Shum	.	.	.	.	.	6	.
Hustedia mormonii Marcou sp	.	.	.	.	.	6	.
Seminula subtilita H	1	.	3	4	5	6	.
Lima retifera Shum	.	.	.	4	5	.	.
Pernopecten aviculatus Swall. sp	1	.	.	.	.	.	.
Nucula ventricosa H	.	2	3	.	5	6	.
Nucula (?) anodontoides M	.	.	.	.	5	.	.
Nucula parva McCoy	.	.	.	.	5	.	.
Yoldia carbonaria M	.	.	3	.	5	6	.

Yoldia stevensoni M.	.	.	.	.	5	.	.
Leda bellistriata Stevens.	.	2	.	.	.	.	.
Leda bellistriata var. *attenuata* M.	.	.	.	.	5	.	.
Leda arata H.	.	.	3	.	.	.	.
Macrodon tenuistriatus M. & W.	1	.	.	.	.	.	.
Macrodon obsoletus M.	1	2	.	.	5	.	.
Schizodus cuneatus M.	1	.	.	.	.	.	.
Schizodus sp.	.	.	3	.	5	.	.
Avicula longa Geinitz.	1	.	.	.	.	.	.
Aviculopinna Americana M.	1	2	.	.	5	.	.
Pseudomonotis sp.	.	.	.	.	5	.	.
Myalina subquadrata Shum.	.	.	.	4	5	.	.
Myalina recurvirostris M. & H.	1	.	.	.	.	.	.
Myalina swallovi McC.	1	.	.	.	.	.	.
Deltopecten occidentalis Shum. sp.	1	.	.	.	5	.	.
Acanthopecten carboniferus Stevens. sp.	1	2	3	4	5	.	.
Aviculopecten interlineatus M. & W.	1	.	.	.	.	.	.
Aviculopecten whitei M.	.	2	.	.	.	.	.
Aviculopecten hertzeri M.	1	.	3	4	.	.	.
Aviculopecten coxanus M. & W.	1	.	.	.	.	.	.
Aviculopecten sp.	1	.	.	.	.	.	.
Placunopsis recticardinalis M.	1	.	.	.	.	.	.
Posidonomya fracta M.	1	.	.	.	.	.	.
Pleurophorus tropidophorus M.	1	.	.	.	.	.	.
Pleurophorus sp.	.	.	.	.	5	.	.
Solenomya anodontoides M.	1	.	.	.	.	.	.
Solenomya radiata M. & W.	.	2	.	.	5	.	.
Astartella newberryi M.	1	.	.	.	.	.	.
Astartella varica McC.	1	.	.	.	.	.	.
Astartella vera H.	.	.	.	4	.	.	.
Astartella concentrica	.	2	3	4	5	.	.
Edmondia aspenwallensis M.		.	.	4	5	.	.
Edmondia 2 sp.	1	.	.	.	.	.	.
Pleurophorella costata M. & W.	.	.	.	.	.	.	7
Pleurophorella sp.	.	.	.	.	5	.	.
Cypricardinia carbonaria M.	1	.	.	.	.	.	.
Euphemus carbonarius Cox sp.	.	2	3	4	5	.	.
Patellostium montfortianus N. & P. sp.	.	2	3	4	5	.	.
Bellerophon percarinatus Con.	.	2	3	4	5	.	.
Bellerophon stevensanus	.	2	.	.	5	.	.
Bucanopsis marcouiana Geinitz sp.	.	.	.	.	5	.	.
Euomphalus catilloides Con. sp.	.	2	3	4	5	.	.
Naticopsis tortum M.	.	2	.	.	.	.	7
Sphaerodoma primigenius Con. sp.	.	2	3	4	5	6	.
Soleniscus brevis White	.	2	3	.	5	.	.
Soleniscus klipparti M. sp.	.	.	.	.	.	.	7
Soleniscus regularis Cox sp.	.	.	.	.	.	.	7
Loxonema plicatum Whitf.	.	.	.	.	.	.	7

Polyphemopsis peracutus M. & W.	2	3	4	.	.	.
Phanerotrema grayvillense N. & P. sp.	2	3	.	5	.	.
Pleurotomaria carbonaria	2	3	4	.	.	.
Worthenia speciosa M. & W. sp.	.	3	.	.	.	.
Worthenia tabulata Con. sp.	.	.	.	5	.	.
Orthoceras cribrosum Geinitz	2	3	4	5	.	.
Tainoceras occidentalis Swall. sp.	2	.	4	5	.	.
Nautilus ortoni Whitf.	.	.	.	.	.	7
Nautilus subquadrangularis Whitf.	.	.	.	.	.	7
Phillipsia sangamonensis M. & W.*	.	3	.	.	.	.

The Monongahela and higher formations, so far as known, have yielded very few forms: a *Solenomya* from shale above the Sewickley coal bed, two species of *Naiadites* from the Uniontown limestone, and undetermined ostracoids from some of the limestones make up the list.

The number of species recorded is considerable, but the distribution as given in the table shows the scantiness of material for comparison, for it is very certain that the vertical range of some of the species is much greater than represented. No locality has been studied with any degree of care, except a little area near Morgantown in West Virginia, where was obtained the collection examined by Mr Meek in 1870. The Ames limestone fauna alone has been observed on both sides of the basin, and even this only in the northern portion. There, however, one interesting feature has been noted, for in Ohio four species occur abundantly, which are very common in the Mississippi Valley areas, but are wholly unknown at any of the numerous localities where the bed has been examined along the east side of the Basin. There is no information on the western border respecting the fauna of the Putnam Hill and Vanport limestones or that of the shales overlying the Middle Kittanning coal bed. Until proper study of the fauna at each horizon has been made, no opinion can be expressed as to the value of the fauna for correlation. The forms already reported are for the most part only those which are the most familiar, with extended vertical as well as geographical distribution.

Some lists of fossil invertebrates by Messrs Meek, Prosser, Bennett, and Hall,† giving forms obtained from the higher Carboniferous beds along the Missouri river in Kansas and Nebraska, afford opportunity for comparison with the northern part of the Appalachian basin.

Mr Meek's fossils came from the higher beds of the Upper Coal

* The writer is under obligation to Mr George H. Girty, who has corrected the generic names in this list; but Mr Girty is not to be held responsible for any errors, as he has not had the opportunity to read the proof.

† F. B. Meek: Final Rept. of U. S. Geol. Survey of Nebraska, pp. 124-127.
Bennett and Hall: University of Kansas Geol. Survey, vol. iii, pp. 68-72.
C. S. Prosser: The same, vol. ii, p. 59.

Measures of Nebraska. Of the 43 species common to his list and that from the Appalachian, only 7 are confined to the Upper Coal Measures of Illinois, the others occurring throughout the section in that state; but of those 7 one finds that in the Appalachian 3 begin at the Mercer horizon, 1 at the Brush Creek, and 3 at the Ames. The short lists by Messrs Bennett and Hall of forms from the Upper Coal Measures of Kansas show 18 of the 43 species, all of which except 5 are found as low as the Vanport; of those, 2 are in the Brush Creek and 3 in the Ames. In Professor Prosser's list of Permian forms, 5 are in the Appalachian list, of which 2 begin in the Maxville, 1 in the Mercer, 1 in the Vanport and 1, *Yoldia subscitula,* is so near to *Yoldia stevensoni* from shales underlying the Ames, that the latter name is little better than a synonym. As far as the present imperfect information goes, the Allegheny and Conemaugh seem to be equivalent to the Lower Coal Measures of the Mississippi valley; further than that, one may not go.

Comparatively little is known respecting the vertebrate fauna of the Pennsylvanian, such studies as have been made being confined practically to forms occurring at a single locality. Professor Newberry * described fish remains from the Upper Freeport and Tionesta coal beds of Columbiana county, Ohio, with a few forms obtained elsewhere. According to his reference of these forms, there are elasmobranchs, ganoids, and lepidosteids present, of which 20 are peculiar to one locality. Three elasmobranchs and lepidosteids have a wider distribution. *Ctenobranchus marshii* Newb. was described from Allegheny beds near Zanesville, Ohio. Doctor Newberry identified with this species, whose associations are wholly marine, a spine from the upper Monongahela, obtained near Washington, Pennsylvania, where it is accompanied by *Helodus* and *Lophodus.* The features show no change whatever. *Petalodus, Peripristis, Deltodus,* and *Lophodus* were found in shale underlying the Ames limestone near Morgantown, in West Virginia, and *Petalodus* occurs in the Ames of northern Ohio. Large scales, belonging to *Rhizodus,* were found by Doctor White in shale accompanying the Middle Washington limestone of Washington county, Pennsylvania.

Professor Cope † described 35 species of batrachians, all except one confined to the Upper Freeport coal bed at Linton, Columbiana county, Ohio. No remains of this class have been reported elsewhere, though one finds occasional mention of what appears to be footprints.

THE FLORA

The earliest attempt at systematic study of American Coal Measures

* J. S. Newberry: Palæontology of Ohio, vol. ii, pp. 41 et seq.
† E. D. Cope: Palæontology of Ohio, vol. ii, pp. 351 et seq.

plants was in 1854, when Professor Newberry* described without figures a large number of forms collected by him from roof shales of the Sharon coal bed in northern Ohio. Simultaneously Mr Lesquereux† was engaged in the study of remains collected within the Anthracite region of Pennsylvania; but his results were not announced until 1856, when they appeared in preliminary form, the final publication being in 1858. His collections were incomplete and the locality labels, apparently, were not always correct; but the work was marked by great care and his figures by exactness. Unfortunately the species, of which the range was known only imperfectly, were used in correlating the coal beds of Pennsylvania and Kentucky, with results so erratic that for a long time the testimony of plant remains was thought to be of little service in correlation. In 1873 Professor Newberry‡ described and figured a few forms from the Sharon horizon, one of which, belonging to a new genus, seemed to be somewhat closely allied to *Tæniopteris;* and two years later Professor Andrews§ gave figures and descriptions of 17 new species obtained in Perry county of Ohio, at the very bottom of the Ohio Coal Measures as then limited. This flora is described as having close affinity with the Devonian, while, like that described by Newberry, it yields a new genus, thought to belong to the Tæniopteridæ. In the interval Professor Fontaine|| had collected a few forms from the Sewell coal bed of New river, West Virginia, and had emphasized the Devonian aspect of the flora. In 1876 Mr Lesquereux¶ published, without figures, a list of species obtained in eastern Alabama from the lower portion of the Coal Measures of that state, and recognized the forms as older than the "Millstone grit," apparently the same with the Sharon conglomerate, which he seems to have regarded as the basal member of the Upper Carboniferous. He lays stress upon the intimate relationship of some of the forms to Devonian types. In 1880 was published Mr Lesquereux's** descriptive catalogue of Coal Measures plants, in which are enumerated 599 species and varieties then known in the United States. A table showing the vertical distribution of the forms brings out clearly the fact that the flora of the New River beds is not related to that of post-Sharon beds in Ohio, and that it has much in com-

* J. S. Newberry: Annals of Science, vol. ii.

† L. Lesquereu: Proc. Bost. Soc. of Nat. Hist., Geology of Pennsylvania, vol. ii, pp. 837-884.

‡ J. S. Newberry: Palæontology of Ohio, vol. i, pp. 359.

§ E. B. Andrews: Palæontology of Ohio, vol. ii. p. 415.

|| W. M. Fontaine: The Great Conglomerate. Am. Jour. Sci., III, vol. vii, p. 574.

¶ L. Lesquereux: Geological Survey of Alabama, Rept. for 1875, p. 75.

** L. Lesquereux: Description of the coal flora of the Carboniferous formation in Pennsylvania and throughout the United States, vol. i.

mon with that of the lower beds in Tennessee and southward. Separate lists of forms collected at many localities in Pennsylvania, Ohio, Kentucky, Tennessee, and Alabama afford means for a closer comparison, which is made in a chapter on Stratigraphical Distribution. This work marks a great advance in application of plant remains in problems of correlation and an equal advance in methods of studying the remains themselves.

In the same year Professors Fontaine and White* published figures and descriptions of species obtained from the roof and partings of the Waynesburg coal bed, together with some from other horizons in the Monongahela and higher formations. Here one finds a serious attempt to utilize the testimony of plant remains in broad correlation of horizons. The effort in the introductory chapter to compare floras characterizing the several formations exposes the neglect of which students had been guilty throughout the Appalachian field, for the collections were so scanty that the authors had to be content with, for the most part, only general statements. Comparisons were made between plants collected from the upper part of the Rockcastle on New river of West Virginia, those listed by Lesquereux from Alabama, and the forms obtained in Ohio by Newberry and Andrews, and the important conclusion was drawn that the Pottsville flora has a genuine facies, distinguishing it from those of formations below as well as from that of the Allegheny above. Material for comparison was almost wholly wanting from the Allegheny, Conemaugh, and Monongahela formations, being confined for each to one or two localities. The forms described in this volume were obtained chiefly from the roof shales of the Waynesburg coal bed at Cassville, in West Virginia, 4 or 5 miles south from the Pennsylvania line; but small collections had been made from that horizon elsewhere in West Virginia and from Greene county of Pennsylvania. The peculiar feature noted at Cassville is that the plants are "distributed in the most singular manner, they being grouped in colonies, which are confined within very narrow limits; so that the plants which abound at one opening for coal will be entirely wanting in another only a few hundred yards distant, where we find instead of them a collection of species so different that it might well characterize a different horizon."

In all, 107 species and varieties are given as obtained from the Cassville shale and higher horizon. Of these, 56 are peculiar to the Cassville shale, 15 are common to the Cassville shale and that overlying the coal bed in Doddridge county, taken by the writer to be the Uniontown,

* W. M. Fontaine and I. C. White: The Permian or Upper Carboniferous flora of West Virginia and southwestern Pennsylvania.

but at that time believed by all to be the Waynesburg; 14 are peculiar to the Doddridge horizon; 9 are confined to the Washington coal or higher horizons, while 11 have a great vertical range, some surviving from the Doddridge shale to 600 or 800 feet above the Waynesburg coal bed.

The final chapter of the work is an elaborate comparison of this flora with European forms, including also a comparison of the physical changes closing the Carboniferous of this area with those closing the Carboniferous and Permian of Europe. The conclusion reached by the authors is that the Upper Barrens of the Appalachian field (Washington and Greene formations) are of Permian age, and this is based on evidence from identical or allied species, the decadence of Coal Measures forms, the introduction of types characteristic of later formations as well as on that from physical contrasts between the Upper Barrens and the preceding formations. They find that 28 species are common to the Upper Barrens and the Permian of Europe, of which 12 have been found in the United States Coal Measures, while 2 are exclusively Permian and 4 others are closely allied to European Permian forms.

The importance of this communication was recognized at once, but the conclusions were not accepted as final, chiefly because of the paucity of known material from the Allegheny, Conemaugh, and Monongahela formations which might be used for comparison. No further investigation of the problem was made for almost 23 years, until Mr David White, after study of extensive collections from the earlier formations, undertook preliminary revision of the horizons discovered and discussed by Professors Fontaine and I. C. White. The results of this revision were published in 1903.* The collections, made at the typical as well as at other localities and horizons, led Mr White to place the forms in five categories:

a, those characteristic of the Rothliegende or higher formations of the Old World; *b,* those closely allied to Permian types; *c,* those whose habit or facies suggests a late date; *d,* those of Mesozoic aspect; *e,* Coal Measures type.

In the first category Mr White places 3 species of *Callipteris,* one each of *Goniopteris, Pecopteris, Alethopteris, Odontopteris, Caulopteris, Equisetites,* and *Sigillaria,* with 2 species of *Sphenophyllum;* in all, 12 species. In the second are also 12, but the author states that the number might be extended according to the personal equation of the observer or to the amount of material available for comparison, while, at best,

* D. White: Permian elements in the Dunkard flora. Bull. Geol. Soc. Am., vol. 14, pp. 538 et seq.

evidence of this class is of subordinate value, some of the forms placed here belonging with equal propriety also in succeeding categories. He places in the third category 14 forms, all of them new and unknown elsewhere; these in their general facies suggest a later date than Coal Measures. He places 9 forms in the fourth category and regards their presence as an interesting and important argument for Permian age, for they are types whose nearest relatives are Mesozoic or whose facies strongly suggests types characteristic of Mesozoic. Here are species of *Equisetites, Saportæa, Jeanpaulia,* and *Tæniopteris,* as well as of other genera. On the other hand are forms belonging to the fifth category, a considerable element of Coal Measure species, whose presence is invincibly against reference of the beds to a level above the basal Permian. The number of species common to the Dunkard and lower formations, only 22 at the time when Professors Fontaine and I. C. White published their work, is now known to be much greater, as the Monongahela flora has been studied in part. Mr White enumerates 29 common forms which are of ordinary occurrence in the Coal Measures, these being only the more widespread forms, more than one-half of them appearing frequently in the Allegheny or Conemaugh.

Mr White finds in the Dunkard plants a transitional flora, such as should be expected in a region where conditions remained practically the same. The boundary between Coal Measures and Dyas is to be determined by the appearance of characteristic Rothliegende species rather than by the presence of persistent Coal Measures types. In western Europe the presence of *Callipteris,* simple-fronded *Tæniopteris, Callipteridium* of the *gigas* or *regina* type, and the genus *Walchia* in a flora consisting largely of forms common to the Coal Measures is regarded as sufficient evidence of Rothliegende age, though *Callipteris conferta* and even *Walchia* may appear lower down. In the Appalachian region a small form of *Callipteris conferta* appears at the horizon of the Lower Washington limestone, while the typical larger form, with *Callipteridium gigas* and others, is unknown below the Dunkard coal bed. The evidence of Rothliegende age for beds below the Lower Washington limestone consists in the presence of *Equisetites rugosus* and several less important forms and of some others which have Mesozoic or Permian aspect; but these latter are extremely rare, having been found only in a single coal drift, though careful search has been made for them elsewhere.

Mr White regards the beds below the Lower Washington limestone as containing a transitional flora and not distinctly Rothliegende, but above that limestone the flora becomes increasingly characteristic. As in that

limestone is the first appearance of *Callipteris conferta,* he thinks the lower limit may be drawn safely at that horizon. The flora of the upper Dunkard is to be compared with the Stockheim and Cusel beds in Germany and the series in the basin of Brives in France. None of the characteristic coniferous genera, *Ullmannia, Tylodendron, Walchia,* occurs in Dunkard beds, though all are in Prince Edward island and *Walchia* is reported from Texas; and similarly many genera of ferns characterizing the Rothliegende of Europe seem to be wholly unrepresented.

In connection with Mr White's conclusions, it is well to recall some relations noted in preceding pages. The general physical conditions during Allegheny and Conemaugh were practically the same; for, while the basin was contracting, there was no material variation in character of the movements; but with the beginning of the Monongahela the area of greatest subsidence was shifted a hundred miles and the new condition remained unaltered throughout the Monongahela and Washington, which in this respect are one as the Allegheny and Conemaugh are one. A notable change occurred at the Washington, and Mr White has shown that the strongly marked lower Rothliegende flora makes its appearance near the bottom of the Greene formation.

After the publications in 1880, no others, aside from a supplement to Mr Lesquereux's catalogue, appeared until 1894, when Mr White presented a discussion, which, like that by Fontaine and I. C. White, marks a stage in the development of paleobotanic study within the United States. In this paper * the term "Pottsville" is applied to beds extending from the base of the Pennsylvanian to and including the Nuttall sandstone, which passes under New river at Kanawha falls, this use of the term being in accord with usage then prevailing for that region; it is equivalent to Rockcastle. The discussion was based on study of collections made by the author at 12 horizons whose relations were determined by his stratigraphic work along New river. He availed himself of previous studies by Professor Fontaine and of collections made away from the river by Mr M. R. Campbell, whose stratigraphic work left no room for doubt respecting relations of the localities.

The lowest two horizons seem to belong to the Mississippian, but the third, at 375 feet from the bottom, yielded 4 forms characterizing the Pocahontas coal bed at the Virginia-West Virginia line, 75 miles away. Soon after this determination was announced, Mr Campbell proved the stratigraphic equivalence of the horizons. The fifth horizon, that of

* D. White: The Pottsville series along New river, West Virginia. Bull. Geol. Soc. Am., vol. 6, pp. 303-320.

the Quinnimont coal bed, about 800 feet from the bottom, yielded 40 forms, which were compared with those collected at localities in Ohio, Tennessee, and Alabama. One form is common to the Pocahontas, 10 are in Alabama, and one is allied to a form described by Newberry from Ohio. About one-third of the species are of such vertical range as to be valueless for correlation, but nearly one-half of the forms or their varieties are confined definitively to the small middle part of the section, in which one finds the Horsepen coal beds farther south in Virginia. The eighth horizon, about 1,175 feet from the bottom, is that of the Sewell coal bed. At all localities the forms collected resemble closely those obtained from the Sewanee, Rockwood, and Tracy mines of Tennessee so closely that the author regarded the horizon as one throughout—a conclusion reached ten years afterward by Stevenson on purely stratigraphic grounds and without any reference whatever to Mr White's researches. The eleventh horizon, 1,500 feet from the bottom, is in the Nuttall sandstone, where 10 forms were obtained—a flora whose preponderating elements are characteristic of the Sharon coal bed in Ohio.

Mr White's correlations were very important. He found that the Sharon flora was confined to the highest portion of the section, and was led to assert that the great mass of sediment in the New River region and southward was older than the Sharon sandstone of Pennsylvania and Ohio, thus confirming the observation made 20 years before by Professor Andrews and overlooked by all students, because made incidentally and buried in a paper referring to other matters. But Mr White was able to extend the generalization to the Anthracite fields of Pennsylvania. The forms from the bottom of the thick sections of Pottsville have much in common with the Culm or Lower Carboniferous series of the Old World, while those from the middle present the general facies of the Ostrau-Waldenburg flora of Moravian Silesia.

These conclusions were wholly at variance with those reached by stratigraphers who had studied the Coal Measures of Pennsylvania and West Virginia. Six years later Mr White published another paper, also preliminary, in which the floras of various horizons in the Allegheny formation of Pennsylvania were compared with those of the Kanawha formation of West Virginia. These had been regarded by most of the stratigraphers as equivalent, though, as stated on a preceding page, the tracing was incomplete, being interrupted by a space of about 60 miles in northern West Virginia—a space where, as already shown, notable changes take place in both Allegheny and Beaver and in which the Rockcastle has its northern boundary.

Mr White's* discussion was based on study of collections made by himself from the Clarion, Kittanning, and Freeport groups of Pennsylvania as well as from the upper and lower portions of the Kanawha group, this latter term being applied to the rocks above the Nuttall sandstone up to and including the Stockton coal bed, underlying the Kanawha Black Flint. The study is reported in detail, full lists of plants at each horizon being given and their relations compared closely. It is necessary here to note only the author's conclusions.

Some forms are common to the lower Kanawha and the Allegheny, but they are either those of wide vertical range or such as originate in the upper zone of the Pottsville as now understood. A very large proportion of the forms which can be identified positively are either the same with upper Pottsville (Beaver) forms or are modifications of them. The plant life of the lower Kanawha is distinct from that of even the Clarion or lower Allegheny, not only in the different forms of ferns, but also in the more important relations of the flora as a whole. The fern elements of the Pennsylvania Allegheny are essentially different from those of the lower Kanawha and are in contrast with those below the Homewood sandstone (top of Beaver) of western Pennsylvania and below the Buck Mountain conglomerate in the Southern Anthracite field. The flora of the Freeport group is allied to that of the Upper Coal Measures of Pennsylvania or the Middle Coal Measures of the Old World; even that of the Clarion group is still bound to the higher floras and is comparable to the Middle Coal Measures of Britain, the upper portion of the Westphalian series; but the floral associations in the lower half of the Kanawha are almost totally lacking in characteristic elements of the Allegheny flora. Many of its elements are slight modifications of types in the West Virginia "Pottsville" (Rockcastle) and in the Southern Anthracite field, while the greater part of the rest are closely allied to Pottsville plants elsewhere or are unfamiliar forms. The lower Kanawha is comparable to the Westphalian or Lower Coal Measures of European basins. It is an elaborate connecting link between the typical Pottsville or Millstone grit flora and the Clarion flora of the Allegheny.

The flora of the Stockton coal bed, or upper Kanawha, on the contrary, shows a large proportion of forms identical with those found in the Allegheny valley; it is a typical Allegheny flora. Absence of the higher pecopterids as well as the proportion and range of the identical forms bespeak for the Stockton flora a place probably not higher than the Clarion

* D. White: Relative ages of the Kanawha and Allegheny series as indicated by the fossil plants. Bull. Geol. Soc. Am., vol. ii, pp. 145-178.

group of the Allegheny in Pennsylvania.* Collections from beds above the Black Flint yield floras typical of the higher Allegheny groups.

This paper contains important generalizations respecting isostatic movements in the southern Virginia region, anticipating in full much that has been given on preceding pages respecting geographical changes. The conclusion is reached that the Allegheny formation shows no extraordinary expansion in the Kanawha region, and that the Conemaugh retains its Pennsylvania thickness. Detailed information published after the appearance of Mr White's paper shows that the Allegheny, so far from thickening on the Kanawha, is thinner there than on the Allegheny river of Pennsylvania.

In the same year appeared a delayed paper by Mr White,† referring to the Anthracite region. This discussion is based on a careful stratigraphical study of the Pottsville in the Southern Anthracite field, whereby many indefinite conceptions of the relations, especially in the western part of the field, were corrected. During this study collections of plants were made in many localities which were compared with each other and with those obtained elsewhere within the Appalachian basin. The conclusions, like those in the other papers already cited, were preliminary and subject to revision in a monograph of the Pottsville flora which has not been published.

The type locality is at Pottsville, in the eastern part of the field, where a detailed section was obtained. Plants were collected at 41 places, covering the whole field, and 14 plant horizons were discovered at the type locality, the highest being about 200 feet below the Buck Mountain coal bed, long taken as the conventional base of the Allegheny. Another plant bed is at 43 feet below the Buck Mountain, the interval being filled with conglomerate and coarse sandstone, while an abundant flora is present in the roof shale of that coal bed. The study of collections obtained at Pottsville enabled Mr White to divide the column at about 700 feet below the Buck Mountain. The lower division contains plants characterizing the Lower Lykens Valley coal beds, Coal 4 and lower, at the westerly end of the field; a transition flora appears in three beds, 640 to 570 feet below the Buck Mountain, and an Upper Lykens flora, Lykens coals 2 and 3, is present up to about 375 feet below the Buck Mountain, the higher plant bed underlying about 100 feet of conglomerate; while in beds at 245 and 210 feet below the Buck Mountain is a higher flora,

* Mr White in a later paper gave reasons for placing this flora at an even lower horizon, possibly in the Pottsville.

† D. White: Fossil floras of the Pottsville formation in the Southern Anthracite coal field of Pennsylvania. 20th Ann. Rept. of U. S. Geol. Survey, pp. 755-930.

transition to that of the Buck Mountain and partaking in some respects of features characterizing the Allegheny flora.

In correlating these floras with those from other portions of the Appalachian basin, Mr White recognizes in the lower part of the Lower Lykens division forms wholly characteristic of the Pocahontas coal in the Virginias and occurring there, as in the Southern Anthracite field, with very narrow vertical distribution. The upper portion of this Lower Lykens division is closely related to the Quinnimont or middle portion of the New River section, and the correlation is clear for that as for its equivalent in Kentucky, Tennessee, and Alabama. The Upper Lykens flora is even more sharply characteristic. The elements of the flora in the roof of Lykens 3 are so preponderatingly identical with those in the roof of the Sewell coal bed in West Virginia and of the Sewanee in Tennessee that Mr White regards those coal beds as practically contemporaneous. As has been stated already, the stratigraphic study confirmed Mr White's correlation of the Sewell and Sewanee horizons; those localities are separated by an interval as great as that between the Sewell and Lykens Valley localities. The highest flora, 245 and 210 feet below the Buck Mountain, that of Lykens coal 1, is nearly allied to the flora of the Mercer coal beds and possibly contemporancous with a flora in the Gladesville sandstone of southwest Virginia, as well as in Breathitt county of Kentucky, which accords closely with stratigraphic determinations in Stevenson's summary, made several years afterwards.* This upper portion, ending at 210 feet below the Buck Mountain, appears to be equivalent to the lower part of the Kanawha formation. The Campbell's Ledge flora, in the northern Anthracite field, only a few feet above the Shenango shale, or highest beds of the Mississippian, seems to be related to that of this upper or transition series, its place being near the Mercer horizon, a little way higher than given in Stevenson's Pottsville correlation, where it was placed at the horizon of the Sharon coal bed.

The relations of the Buck Mountain flora are considered in this paper. In all other publications referring to the Anthracite fields the Buck Mountain coal bed has been taken as the bottom of the Allegheny. This boundary, fixed arbitrarily by Professor H. D. Rogers, is convenient, as that coal bed is persistent and important in by far the greater part of the Southern and Middle fields. But Mr White has shown conclusively

* In a later paper, "Deposition of the Appalachian Pottsville," Mr White is inclined to see the Sharon coal horizon above the Gladesville sandstone, which would carry the upper limit of the Pottsville above the plane assigned by Stevenson. It is wholly probable that the stratigraphic evidence will confirm this conclusion, for the measurements on which Stevenson based his correlation of the Gladesville sandstone with the sandstone of Kentucky have been proved defective.

that this arbitrary boundary does not coincide with the paleontologic boundary, which is lower, 100 feet or more; he would include in the Allegheny a small coal bed, 72 feet below the Buck Mountain at Pottsville, and would carry the boundary downward to a still undetermined line between that coal bed and the plant horizon at 210 feet below the Buck Mountain. The flora of the Twin or Buck Mountain coal bed is comparable to that of the Clarion group in western Pennsylvania.

Table of Formations

Later information, as well as better knowledge of the relations obtained during the progress of this work, makes necessary some revision of the nomenclature employed.

No change is suggested for the Mississippian (A. Winchell, 1870) or Lower Carboniferous, and the terms, Logan, Tuscumbia, Maxville, and Shenango are retained; but paleontological studies, of which preliminary results have been published, seem to make clear that the writer has included under the Logan some deposits which may be of earlier age. The observations on which dependence was placed for connection around the northwestern and western outcrop in Pennsylvania and Ohio appear to be defective. There is apparently no room for doubt in the great part of the basin, for the vast number of oil-well records in southwestern Pennsylvania and in West Virginia make abundantly evident that the great oil-bearing sandstone is essentially continuous throughout and the same with that which both Andrews and Orton term Logan in southeastern Ohio.

But a new grouping for the Pennsylvanian or Upper Carboniferous seems to be required, in view of conditions described under the caption of Geographical changes. It is presented in the following table:

Pennsylvanian (H. S. Williams)	Pottsville (J. P. Lesley)	Rockcastle (A. R. Crandall)
		Beaver (J. P. Lesley)
	Athens (J. J. Stevenson)	Allegheny (H. D. Rogers, restricted by F. Platt)
		Conemaugh (F. Platt)
	Wheeling (J. J. Stevenson)	Monongahela (H. D. Rogers, restricted by I. C. White)
		Washington (J. J. Stevenson)
	Dunkard (I. C. White, restricted by J. J. Stevenson)	Greene (H. D. Rogers, restricted by J. J. Stevenson)

The term "Athens" refers to the county of that name in Ohio, and "Wheeling" to the stream which flows through the western portions of Greene and Washington counties of Pennsylvania, Marshall and Ohio counties of West Virginia, localities in which the respective columns are shown in their full extent.