

LOWER CARBONIFEROUS OF THE APPALACHIAN BASIN

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INTRODUCTION

It is the writer's purpose in this work to describe in detail the Carboniferous deposits of the Appalachian basin, to correlate them, to ascertain as far as possible the conditions existing during the deposition of the various rock masses, and finally to apply the facts in a discussion of the origin of coal and coal beds.

Appalachian basin, as here used, refers to the area bounded at the east by the old Appalachian land, at the west by the Cincinnati uplift to central Kentucky, and thence southward to Alabama by the area whence erosion has removed the newer rocks and thereby separated the eastern from the western Carboniferous region. In a general way, it includes Pennsylvania, Maryland, and Virginia west from the Blue ridge, the whole of West Virginia, eastern Ohio and Kentucky, east-central Tennessee and northern Alabama. In Alabama the Appalachian and Mississippi areas are continuous; in Tennessee they are separated by the Great Central valley, while in Kentucky the dividing strip is but a few miles wide. The basin, as thus rudely defined and with an extent of probably 150,000 square miles, was almost wholly covered with Carboniferous rocks of one period or another; but the beds have been removed from nearly one-half of it, so that in some portions, especially at the east, there remain only outlying strips, preserved in synclinals or along the borders of great overthrust faults.

A general description of the deposits is possible now because of the detailed work done by the geologists of Pennsylvania, Ohio, Maryland, and West Virginia at the north, as well as by those of Tennessee and Alabama at the south, supplemented by the studies of the United States geologists and others in Kentucky, Virginia, and Tennessee. The detailed work of the United States geologists for the most part is still unpublished, and one has within reach only the synopses given in connection with the individual folios. Acknowledgment of the writer's indebtedness to these observers is made in the proper connection. It is more than probable that there are omissions or errors in the references, and that there are misinterpretations in statements of other's opinions. As such defects not only do injustice to fellow-students in the same field, but also detract from the usefulness of the work, the writer urges those who detect them to inform him, that the corrections may be published with the succeeding chapter.

In the descriptive portions the names applied to formations will be, as far as possible, those employed by the geologists whose work is quoted for a locality, but questions of nomenclature will be considered in the discussion closing each chapter. The names employed by the second

Geological Survey of Pennsylvania for formations along the eastern outcrop are :

Lower Carboniferous (Mississippian) . . .	}	Mauch Chunk.
		Pocono.
Upper Devonian	}	Catskill.
		Chemung.
		Hamilton.

THE POCONO OF LESLEY ; VESPERTINE OF ROGERS

DISTRIBUTION AND CHARACTERISTICS OF THE ROCKS

Nomenclature.—To the lower division of the Mississippian in Pennsylvania, Professor H. D. Rogers applied the name Vespertine, which was not accepted generally by geologists. Many years later Professor J. P. Lesley offered instead the geographical name, as the formation had been described by him as characteristically developed in the Pocono mountains of eastern Pennsylvania. This term was used in the Pennsylvania reports, and it has been adopted by the Maryland survey as well as by some of the United States geologists.

In the eastern part of the Appalachian basin, the Pocono, containing many thick beds of hard rocks, is a notable mountain maker. It surrounds the anthracite coal fields of Pennsylvania, the Broad Top coal field of the same state, and a small outlier remains farther east in Fulton county, almost on the edge of the Great valley ; the outcrop is practically continuous along the Alleghenies of Pennsylvania, and similarly long outcrops are shown along the Alleghenies and other mountains in Maryland and the Virginias. The character changes westwardly along the northern border, but the information now available renders recognition of the varying conditions a matter of little difficulty.

For knowledge of this formation along the northern and eastern exposures in Pennsylvania geologists are indebted to Messrs J. F. Carll, H. M. Chance, and C. A. Ashburner, but especially to Dr I. C. White, whose reports cover by far the larger part of the area within which the Pocono is shown. For this reason the writer prefers Doctor White's measurements and determinations to his own, where the observations overlap in that state, the more so because those by Doctor White are later in date and are to be regarded as completing his study of the formation in Pennsylvania.

The region to be studied in review is so large that it must be described in areas, the first being that in Pennsylvania and Maryland eastward from the Allegheny plateau, which may be termed

The anthracite strip.—The most northerly exposures, respecting which detailed information exists, are in the northern Anthracite field, within Wayne county, at about 10 miles south from the New York line. There the section * is

	Feet
1. Sandstone.....	40
2. Shale and sandstone.....	200
3. Massive sandstone.....	125
4. Shale and current bedded sandstone.....	265
5. Griswold Gap conglomerate.....	35
6. Sandstone and shale, imperfectly exposed.....	150
7. Sandstone and sandy shale.....	200
8. Mount Pleasant conglomerate.....	25
Total.....	1,140

Doctor White is inclined to regard the beds below number 5 as transition from the Catskill. He finds great resemblance between the highest sandstone of the section and the Shenango sandstone of Crawford county, which in the northwestern part of Pennsylvania is the most notable feature of the Pocono. The Mount Pleasant conglomerate is recognizable in Monroe county, 20 miles farther east.† Near Pittston the thickness is less, only 753 feet, of which the upper 353 feet‡ is mostly massive sandstone, but the increase southward and southwestward in the other fields is very notable, for the upper portion becomes 600 feet at Shickshinny and between 700 and 800 feet in the gaps of Little mountain. Thin irregular streaks of coal occur in this portion on North mountain which separates Columbia and Luzerne counties.§ Mr Winslow's sections, as given by Professor Lesley, though measured instrumentally, do not differ materially from those of Doctor White. Including the transition beds, he finds 1,177 feet in the northern field, 1,110 feet on Nescopec mountain, and 1,253 feet near Mauch Chunk, all sandstone except about 75 feet at the last locality.||

According to H. D. Rogers's summary description, the Pocono (Vespertine) shows greatest thickness and coarseness at the southeast. It is 2,000 feet on the Susquehanna, 1,800 feet at Pottsville, 1,100 feet in the Nescopec mountain, while in the mountains enclosing the Northern or Wyoming field it is but 500 or 600 feet. The section at Pottsville is

* I. C. White : Geology of Wayne and Susquehanna counties (G 5), 1881, p. 56.

† I. C. White : G 5, p. 90.

‡ I. C. White : Geology of the Susquehanna region (G 7), 1883, p. 39.

§ I. C. White : G 7, pp. 47-49.

|| J. P. Lesley : A summary description of the geology of Pennsylvania, vol. ii, 1892, p. 1635. This will be quoted as Final Report.

	Feet
1. Sandstone, more or less conglomerate.....	521
2. Slate.....	22
3. Sandstone with much conglomerate.....	726
4. Sandstone with little conglomerate.....	240
5. Sandstones variegated.....	409
Total.....	1,918

Underlying this he found 687 feet of red, gray, olive, and yellow sandstones, with some shale and some conglomerate, which he regarded as transition. These lower beds are 525 feet on the Susquehanna and less than 400 feet in Nescopeck and Shickshinny mountains.* Professor Claypole made the total thickness at the Susquehanna in Perry county about 1,950 feet.†

The measurements made by Doctor White and by the writer along the westerly side of the Broad Top coal field, in Huntingdon and Bedford counties of Pennsylvania, show the thickness to be not far from 1,100 to 1,200 feet, and the section consists mostly of sandstone; but at somewhat more than 400 feet above the bottom Doctor White discovered a thick bed of shale, portions of which are rich in *Spirifer*, *Rhynchonella*, and productoid forms. Not a few of the sandstones show some conglomerate. Mr Ashburner reports a thickness of 2,133 feet in Sideling hill, on the east side of this field in Huntingdon county, which appears to be excessive, being greater than that obtained by Claypole on a line of outcrop which should pass nearly 20 miles eastward from Sideling hill, and being nearly double the thickness observed by Stevenson in eastern Fulton county, where it appears not to exceed 1,100 feet. Evidently, as suggested by Doctor White, beds belonging to a lower series have been included.

In eastern Bedford of Pennsylvania and in Allegany of Maryland the thickness varies little from 1,100 to 1,000 feet. The mass consists almost wholly of sandstones, some of them conglomerate and becoming coarser in Maryland, where the pebbles are sometimes three-fourths of an inch long.‡ Streaks of coal, usually not more than 3 or 4 inches thick, are found at various horizons, but especially in the upper portion. Whether or not any of these are continuous to any considerable distance could not be ascertained. Owing to the flattening of the anticlinals southward, exposures within this area cease at a little way beyond the Virginia line.

* H. D. Rogers: *Geology of Pennsylvania*, 1858, vol. ii, pp. 8, 9.

† E. W. Claypole: *Prelim. Rep. on Palæontology of Perry county* (F 2), 1885, p. 227.

‡ C. C. O'Harra: *Maryland Geological Survey, Allegany county*, 1900, p. 109.

The Allegheny plateau.—Returning now to the north and following the backbone of the Allegheny plateau, a line of outcrop about 30 miles westward from that nearest in the anthracite fields, one finds a notable decrease, for in western Wyoming county Doctor White gives but 300 feet for entire thickness of the Mississippian,* and in Sullivan it appears to be no greater. In Lycoming county, which lies on both sides of the Allegheny crest, numerous measurements by Franklin Platt and Andrew Sherwood are available. In the northeast corner Mr Sherwood estimates the Mississippian at 813 feet, of which he places 480 feet in the Pocono. Mr Platt, however, averages the interval for the same area at 730 feet, of which he thinks 665 feet should be referred to the Pocono. Mr Platt's section is the more satisfactory, as the exposure is practically complete. The rock is almost wholly current-bedded sandstone, and shows a one-foot coal bed at 80 feet from the bottom. In northwestern Lycoming Mr Platt finds, beginning at 120 feet below the Pottsville, gray current-bedded sandstones 350 feet thick and resting on red shales and sandstones of the Catskill.† No conglomerate is reported in any of the Lycoming sections. The measurements in Bradford county are rather indefinite, but Mr Platt found in the Barclay coal field a greenish gray current-bedded sandstone 300 feet thick, beginning at 110 feet below the Pottsville. Professor Lesley, quoted by Mr Platt, describes these rocks as "gray flaggy sandstone" several hundred feet thick.‡ No conglomerate appears in this county. It is evident that the lower transition beds have practically disappeared.

Doctor Chance's upper Pocono, in Clinton county, varies little from 400 feet, and consists of 60 to 80 per cent sandstone, the rest being sandy shale. At 15 feet from the top is a layer 3 feet thick, composed of mixed limestone and sandstone, but in no sense a conglomerate. The sandstone overlying it is rather coarse and gray. The sandstones, which for the most part are hard, massive, fine grained, and show a foliated or laminated structure, are made up of rounded grains and are usually greenish gray. The lower layers are coarse, and some contain pebbles.§ Doctor Chance's lower Pocono represents the remnant of the disappearing Catskill with the upper shales of the Chemung. For the most part it appears to be equivalent to the shales overlying the first Venango oil sand, which, according to the writer's classification, are Chemung. Mr d'Invilliers gives as the generalized thickness of Pocono in Center county 625 feet, and reports the section as consisting along the Allegheny plateau

* I. C. White: G 7, p. 43.

† Geology of Lycoming and Sullivan counties (G 2), 1880. Andrew Sherwood, p. 16; Franklin Platt, pp. 105, 107, 127.

‡ Franklin Platt: Rep. of Prog. in Bradford and Tioga counties (G), 1878, pp. 121, 127.

§ H. M. Chance: Geology of Clinton county (G 4), 1880, pp. 98, 125, 126.

mostly of white and gray sandstones, sometimes holding rounded pebbles and frequently showing bands of greenish and reddish argillaceous beds. The sandstones are fine grained and thin bedded.* Here the lower beds are increasing in importance.

Mr Sanders's section, in Blair county, south from Center, makes the Pocono 1,241 feet thick, but he has included about 350 feet at the bottom clearly belonging to the Catskill, so that the thickness is about 900 feet, of which the upper two-thirds is a practically continuous gray, current-bedded sandstone, broken only by two shale beds, one 3 and the other 20 feet thick.† No coal is reported from the Blair county Pocono; the Tipton coal of that county belongs to the Coal Measures, as originally asserted by I. C. White, and not to the Pocono. Still farther south, in Bedford county, and about 10 miles eastward from the face of the plateau, Stevenson found that the Pocono can not exceed 920 feet, and suggested that the interval may contain some Catskill rocks, so that the thickness is approximately the same with that in Blair.‡ Mr O'Harra states that a little south from the Pennsylvania line, in Maryland, and not far off the strike from the Bedford locality, the thickness is but 258 feet, the rock being a grayish green flaggy sandstone, with some shale and some bands of conglomerate. He finds it but 30 feet thick in the gorge of the Potomac, where it is a gray cross-bedded sandstone, with a few widely scattered pebbles.§ Doctor White's detailed section in Maryland, along the Baltimore and Ohio railroad, where the Potomac emerges from the Allegheny plateau, shows about 1,150 feet of gray, cross-bedded, mostly flaggy sandstones, apparently free from conglomerates and red shales.||

The strip west from the front of the Allegheny plateau.—Returning to the north outcrop, the first Pennsylvania survey found in Tioga county (adjoining Bradford at the west) 300 feet of sandstones underlying the shales and sandstones of the Mauch Chunk (Umbral), divided midway by 5 feet of shale, and showing near the bottom a calcareous bed.¶ Doctor White estimates 573 feet as the extreme possible thickness for Pocono near Blossburg, in this county, but the estimate is not given with assurance, as exposures below the Mauch Chunk are wanting.** In view of observations in counties on both sides of Tioga, the interval appears to be excessive. In Potter county (west from Tioga) Mr Ashburner finds the extreme thickness for Mississippian not more than 400 feet,

* E. V. d'Inville's : Geology of Center county (T 4), 1884, p. 122.

† R. H. Sanders : Geology of Blair county (T), 1881, pp. 13, 23.

‡ J. J. Stevenson : Geology of Bedford and Fulton counties (T 2), 1882, p. 70.

§ C. C. O'Harra : Allegany county, pp. 109, 110.

|| I. C. White : Notes on the Geology of West Virginia. Proc. Am. Phil. Soc., vol. 'xix, p. 443.

¶ H. D. Rogers : Geology of Pennsylvania, vol. ii, p. 520.

** I. C. White : G 5, 1881.

and he regards the upper 70 feet as unquestionably Mauch Chunk.* Some of the lower portion is Chemung, but that, is unimportant here, as the thickness suffices to show the rapid decrease westward along the northern outcrop in Pennsylvania. In Potter county is found the most easterly line at which Doctor White's Shenango sandstone, the sub-Olean conglomerate of other authors, has been recognized fully; but the reader who has followed these notes can have no difficulty in finding traces of it along the northern outcrop in the persistent sandstone, often conglomerate at the top of the Pocono, which is so characteristic that Doctor White when he reached the northeastern outcrop was almost ready at once to identify it with his Shenango.† From Potter westward its pebbles are flat like those of the persistent Chemung conglomerates, but it becomes conglomerate westward. In Clinton county it is only coarse, while in Cameron (west from Clinton) and in western Potter, at the north, it is conglomerate.

McKean county adjoins Potter at the west. There Mr Ashburner finds this Shenango sandstone, 40 feet thick, sometimes largely conglomerate, at others largely hard, massive, fine grained ferruginous sandstone. His lower Pocono, which is the lower portion of Doctor Chance's upper Pocono, is said to be 150 to 190 feet thick, extending downward to the Marvin Creek Limestone, which contains Chemung fossils. This may be the persistent limestone already referred to as found in Tioga county. Mr Ashburner regards it as equivalent to that occurring at the same horizon in Elk county (south from McKean) and to Doctor White's lower Meadville limestone of Crawford county.‡

In Cameron county (south from McKean and west from Clinton) Mr Ashburner finds the Pocono varying from 745 feet in the extreme middle east to 470 feet in the extreme northeast, but for the most part the sections are too imperfect to justify definite conclusions respecting either thickness or boundaries. It is sufficiently clear, however, that at 50 to 60 feet below the Pottsville sandstones begin, and that some of them are coarsely conglomerate. Fragments of the Shenango sandstone (sub-Olean) occur in northern Elk, west from Cameron. A fossiliferous limestone occurs at 200 feet below the Pottsville. For this county the Pocono is given as from 500 to 610 feet, including some fossiliferous limestones.§ The discrepancies between the descriptions by Mr Ashburner and those by Doctor Chance in G 4 are apparent rather than real. Doctor Chance has presented the conditions more methodically

* C. A. Ashburner: *Geology of Potter county* (G 3), 1880, p. 104.

† I. C. White: G 5, p. 66.

‡ C. A. Ashburner: *Geology of McKean county* (R), 1880, pp. 64-69.

§ C. A. Ashburner: *The township geology of Elk and Forest counties* (R 2), 1885, pp. 18, 19, 105, 247.

and with a clearer conception of the relations. The statement of facts is practically the same in both reports.

No measurements are available for Clearfield and Jefferson counties, lying south from Elk and Forest, and nothing can be obtained until one reaches the Conemaugh gaps through the Viaduct, Laurel, and Chestnut hill, and the Youghiogheny gaps through the same anticlines farther south. In the Conemaugh gap through Chestnut ridge, Westmoreland county, Stevenson found the Pocono a massive sandstone, 443 feet thick, broken only by two shale beds, 3 and 10 feet respectively. Much of it is current-bedded, and many layers, especially toward the bottom, are conglomerate, with pebbles as large as a plum and often flat. A 4-inch bed of impure limestone was seen near the middle. The thickness in the Youghiogheny gap through the same ridge is not far from 375 feet, the rock being mostly fine grained sandstone, though layers of conglomerate are numerous, as on the Conemaugh in the bottom 60 feet. In the Youghiogheny gap through Laurel ridge the thickness appears to be not more than 300 feet.* The conglomerate layers with small flat pebbles show a singular parallelism at exposures on both rivers as well as at several localities on both sides of Chestnut ridge along the National road in Fayette county.

Doctor White records several sections in northern West Virginia. In southeastern Preston county, along the Baltimore and Ohio railroad, under the Viaduct axis of Pennsylvania—the Briery mountain of West Virginia—he finds 566 feet of sandstones and shales with an impure limestone, 1 foot thick, at 150 feet from the bottom, this possibly representing the thin limestone of the Conemaugh gap through Chestnut ridge. The section is interesting as exhibiting a structure very familiar in the oil-well records in the interior of the state. Somewhat condensed it is

	Feet
1. Sandstone.....	120
2. Mostly shale.....	115
3. Sandstone.....	75
4. Shales, shaly sandstone, and sandstone.....	105
5. Limestone, impure.....	1
6. Mostly shale.....	150

Number 2 contains 10 feet of sandstone, number 4, 12 feet of apparently massive sandstone, and number 6, 18 feet, besides beds of shaly sandstone and sandy shale.† The Laurel Hill anticline decreases south-

* J. J. Stevenson: Report of progress in [the Fayette and Westmoreland district, part i, 1877. (K 2), p. 291. The same, part ii (K 3), 1878, pp. 54, 77, 105.

† I. C. White: University of West Virginia Catalogue, 1882-'83, p. 50.

ward, so that where cut by Cheat river, in Preston county, it brings up only the topmost 50 feet of the Pocono, which is a massive sandstone. About 425 feet of Pocono is above the river in its gap through Chestnut ridge, in the same county. There it appears to be wholly sandstone, massive and pebbly at the top, where it is current-bedded, but hard and flaggy below.*

The western counties of Pennsylvania.—Returning now to the northern border, Mr Carll says that the Shenango (sub-Olean) is not always conglomerate in Warren county (west from Potter and north from Forest). He finds at Warren the Shenango 30 feet thick, resting on 53 feet of shales and sandstone, containing some fossiliferous beds, below which are shales and sandstones for 363 feet. Near the same place Mr Randall found 40 to 50 feet of Shenango resting on an equal thickness of buff, sandy shales, succeeded by sandstones and shales, about 250 feet, to a flat pebble conglomerate, which is evidently the first Venango oil sand, the Upper Chemung conglomerate of Stevenson. Mr Randall says that the Shenango and the immediately underlying shales are fossiliferous, and suggests that the species show a mingling of Chemung and Carboniferous forms.† Here the lower transition beds and the Catskill have disappeared.

Passing over into Crawford county, on the Ohio line, one finds Doctor White's detailed studies, which make the section clear and prepare for the Ohio conditions. The Shenango sandstone, the topmost portion of the Pocono, is a flat pebble rock, 15 to 35 feet thick in Crawford and Erie counties. It has been traced by Doctor White eastward from the Ohio state line through Crawford, Warren, and McKean, and, farther south, from the same line across Mercer and Clarion. It is white, always sandstone, and becomes massive and coarser eastward. It shows notable variations in thickness, 15 to 35 feet in Crawford, while in southern Mercer, near Sharon, it is only 3 to 7 feet, though always retaining its character. It is pebbly near the Ohio line, but the pebbles are fine. The bottom layers become pebbly at Meadville, in Crawford. At Garland, in Warren, they are quite pebbly. At Warren, in the same county, the rock is pebbly throughout and 40 to 50 feet thick. At many places it contains fish remains.

Doctor White's Meadville shales underlie the Shenango sandstone, are 60 to 80 feet thick, and are divided above the middle by 6 to 18 inches of limestone. These shales are persistent also in Mercer and Venango counties. The limestone, Upper Meadville of White, is very

* I. C. White: Notes on the geology of West Virginia. Proc. Am. Phil. Soc., vol. xx, 1882, pp. 488-492.

† J. F. Carll: Geological report on Warren county (14), 1883, pp. 190, 298, 305.

fossiliferous, often simply a fish-bone conglomerate. Dr O. St. John regards the fishes as presenting the aspect of the lower Mississippian. Doctor White states that the molluscan remains are related to the Kinderhook, but he is inclined to regard the total evidence as pointing toward the lower Keokuk or upper Burlington. The Sharpsville sandstone underlies the Meadville shales; it contains in the lower part a flinty limestone, non-fossiliferous in Crawford county, but fossiliferous at Garland, in Warren county, and at Tidioute, in Venango, where it is full of distorted shells, among which *Spirifer disjunctus* or a closely allied form is most abundant.

Below the Sharpsville are the Orangeville and the Oil Lake group, the latter being equivalent to the Berea sandstone of Ohio. The total thickness is approximately 440 feet, and the whole is referred to the Pocono.*

Doctor Chance has summarized the variations of the "upper or gray Pocono" as they appear along the northern border in Pennsylvania. From the edge of the Allegheny plateau until one reaches western Clinton county, the sandstones are fine grained, foliated and hard, gray or greenish gray. In that county from 60 to 80 per cent is sandstone, the rest is sandy shale; but westward, along the lines followed by him, the rocks become more shaly and less arenaceous, until more than half of the hard sandstone below the Shenango has been replaced by olive and gray shales. The thickness of the Pocono averages not far from 400 feet in Clinton, Cameron, Elk, McKean, Warren, and Mercer counties, and the series is regarded by him as equivalent to the Waverly of Ohio.†

Southward from Mercer and Venango counties the anticlines do not bring the Pocono to the surface, so that, in the southern counties, one is dependent upon oil-well records, many of which have been tabulated by Mr Carll. Here quotations are made only from his latest Pennsylvania reports, which give the essential facts for Beaver, Butler, Allegheny, Washington, and Greene counties, the last three being west from Westmoreland and Fayette, in which are the Conemaugh and Youghiogeny gaps, already referred to as offering good exposures of the Pocono.

The Shenango sandstone is followed easily in the records, but apparently the Meadville shales and limestone become irregular at no considerable distance southward, and sometimes are replaced by sandstone. In northern Mercer county the Shenango is 15 feet thick, with the upper Meadville limestone at 25 feet below it; 30 miles southeast, at Edenburg, on the western border of Clarion county, a record shows that the sandstone is 64 feet, resting on 233 feet of shale, extending downward

* I. C. White : Geology of Erie and Crawford counties (Q 4), 1881, pp. 77-96.

† H. M. Chance : G 4, p. 98.

to the Upper Chemung conglomerate or first Venango oil-sand; while in Brady township of Butler, about 25 miles southwest from Edenburg, sandstone is 90 feet, divided midway by 10 feet of shale; at Pittsburg, about 30 miles south from the last, the sandstone is 170 feet, with 10 feet of shale at 20 feet from the bottom. Here one is 45 miles due west from the Conemaugh gap through Chestnut ridge, where the upper plate of the Pocono is a sandstone 250 feet thick. At Murraysville, Westmoreland county, 15 miles east from Pittsburg, the sandstone is 200 feet thick resting on shales. The record in Mount Pleasant township of Washington county shows 106 feet of white sandstone, separated by 22 feet of shale from 11 feet of fine white sand, below which are shale and sand for 112 feet, a total of 251 feet; at Washington, in the center of the same county, the record is incomplete; it gives sandstone 120 and 30 feet, separated by 2 feet of shale; but at Waynesburg, in Greene county, the record shows 230 feet of white sandstone underlying the Mauch Chunk.* It is quite possible that the sandstone in the borings may represent the Shenango and the Sharpville, and that the intervening shale, so irregular, may be the Meadville. Where thin it may have been neglected by the driller. The records in West Virginia bear out this suggestion.

Along the northern and western outcrop in Ohio.—The Shenango sandstone has been followed by Doctor White into Trumbull county of Ohio, where it is about 15 feet thick and rests on 80 feet of Meadville shales. Professor Orton regards the Logan sandstone of Ohio as the Shenango sandstone, but includes also in the equivalence the overlying Shenango shales of White, which, as will appear in the second chapter, must be considered with the Mauch Chunk.

The Logan, in Ohio, is double sandstone above and conglomerate below, at the typical localities. Followed into Ohio from Pennsylvania, the rock becomes finer, the sandstone becoming shale and the conglomerate, sandstone. In the counties of Knox, Holmes, Richland, and Cochoc-ton, the sandstone is represented by the Olive shales of M. C. Read, which are upward of 200 feet thick, but farther south the mass becomes a fawn-colored, even-bedded, fine grained sandstone. The conglomerate gains in coarseness westward and southward, being a coarse rock in Wayne, Holmes, Cochoc-ton, Knox, Licking, Fairfield, Hocking, Vinton, and Ross counties, which, as Professor Orton observes, mark "the northwestern arc of the sea boundary in Sub-Carboniferous time." The conglomerate is not always continuous, there being usually, as Professor C. L. Herrick has shown, two beds of conglomerate separated by layers of fine sand-

*J. F. Carll: Ann. Rep. second Geol. Surv. Penn. for 1886. These notes have been taken from the plates in Mr Carll's discussion, forming part ii of this annual report.

stone or even of shale. The pebbles are usually flat, small, and of practically uniform size. Southward from Ross county, along the western outcrop, the rock is less coarse and it ceases to be conglomerate before reaching the Ohio river, where it is the upper portion of the Kentucky Knobstone. The Logan rests upon the Cuyahoga shales of Orton, varying from 150 to 400 feet, with the Buena Vista sandstone at the base, a persistent bed, identified with the Sharpville of White and continuous from the Pennsylvania line around the outcrop to the Ohio river at Buena Vista. Below this is the Berea shale, regarded as the equivalent of White's Orangeville, and at the base is the Berea grit, continuous from lake Erie to the Ohio river, 50 to 75 feet thick, a fine sandstone at the north, but somewhat argillaceous at the south. This ripple-marked sandstone is thought by Professor Orton to be equivalent to the upper part of White's Oil Lake group.* This rests on the Bedford shales. Herrick has shown that the Logan does not extend so far northward as do the Cuyahoga shales.

The eastern outcrops in the Virginias.—Let us return to the east and follow the outcrops southward from the Potomac river.

Professor W. B. Rogers, in his "Reconnaissance," states that the Pocono (Vespertine) contains coal beds in Berkeley, Frederick, Shenandoah, Rockingham, Augusta, Botetourt, and Montgomery counties of Virginia, but he gives no details respecting the character or thickness of the rocks.

Professor Fontaine regards the Pocono (Vespertine) of Augusta and Rockingham as triple—a lower division consisting of sandstone, a middle division of sandstone and shales with coal beds, and an upper division consisting mostly of red shale and sandstone. He assigns to the lower division about 400 feet of sandstone, gray below and white above. No estimate of thickness of the higher divisions was made, as exposures are imperfect and the region very seriously disturbed.† Mr Darton for the same region, as well as a part of Pendleton county of West Virginia, assigns to the lower division 300 feet of white or buff quartzite, sometimes slightly conglomerate. His upper division—sandstones, shales, and coal beds—has an extreme thickness of 450 feet. It shows no shales on North mountain, or on Shenandoah mountain along the West Virginia boundary. Farther north on the latter mountain the whole thickness is about 700 feet.‡

Messrs Taff and Brooks find little more than 100 feet of Pocono in Randolph county, West Virginia, nearly 30 miles west from Shenandoah mountain.§

* E. Orton: Ohio Survey Reports, vol. vii, 1893, p. 28 et seq.

† W. M. Fontaine: Am. Jour. Sci., vol. xiii, p. 116 et seq.

‡ N. H. Darton: Staunton folio, U. S. Geological Survey, 1894.

§ J. A. Taff and A. H. Brooks: Buchhannon folio, U. S. Geological Survey, 1896.

Professor Fontaine found the Pocono near Lewis tunnel, on the Greenbrier river, about 6 miles east from White Sulphur Springs, West Virginia, as well as at Caldwell station, 12 miles farther west. At the latter locality 250 feet of red crumbling marlites underlie the Greenbrier or Mauch Chunk limestone. These had been referred by Professor W. B. Rogers to the Mauch Chunk (Umbral), but Fontaine prefers to place them in the Pocono. Below these he finds 290 feet, representing his middle division of Augusta and Rockingham, consisting mostly of sandstones, in which are many carbonaceous streaks—not coal beds, as no fireclay is associated with them. But at Lewis tunnel this division is 350 feet, with irregular coal beds underlain by fireclays. Below this is a coarse, more or less conglomerate sandstone, 80 feet thick, resting on transition beds 500 feet, consisting mostly of yellow flaggy sandstones, weathering brown. The whole thickness is 1,160 feet.* This is on the line with the Augusta locality.

Beyond the Greenbrier river, owing to the rapid development of faults, the Pocono extends farther eastward than it does at the north, and the area of Carboniferous reaches to East or Peters mountain, while toward the southeast is the narrow strip along Brushy mountain, in Bland, Smyth, and Washington counties; the similarly narrow strip along Little Walker mountain, in Montgomery, Pulaski, Wythe, and Smyth counties, as well as some petty outliers within the Great valley in Catawba and Price mountains of Montgomery and in Pulaski and Wythe counties. The information respecting Monroe county of West Virginia beyond East mountain is very scanty, as is also that respecting Catawba mountain.

Fontaine made a careful study of Price mountain, where he measured 1,090 feet of red shales above his middle division, but made no detailed measurement of the lower divisions. The greater part of this mass belongs to the Mauch Chunk, which here has no limestone. Two coal beds, 2 and 6 feet respectively, are mined here.† Stevenson visited Price mountain, as well as the little area east from Wytheville, on the Norfolk and Western railway, but made no measurements. His conclusions respecting the shales agree with those of Fontaine.

Little Walker mountain is known as Brush mountain in Montgomery county. There Professor Fontaine assigned 930 and 670 feet to his lower and middle divisions, but did not obtain any measurement for the upper division. Stevenson succeeded in making a section on New river at 4 or 5 miles southwest from Fontaine's locality. He cuts off most of the lower division, placing it in the Devonian, and practically draws the line under the conglomerate sandstone, 30 to 80 feet thick,

* W. M. Fontaine: *Am. Jour. Sci.*, vol. xiii, pp. 44-48.

† W. M. Fontaine: *Op. cit.*, p. 119.

which underlies the middle or coal-bearing division. The section shows only shales and sandstones for about 1,700 feet, as determined from the dip, of which the bottom 700 feet are assigned to the Pocono.* Coal beds have been opened at many places along little Walker, in Montgomery, Pulaski, and Wythe counties. Thirteen beds are reported within a vertical distance of 400 feet in western Wythe, but only the lowest three become important economically. The thickness varies, as the beds have suffered much from compression, and in many cases the shales have been thrust into the coal. The dying of this fault throws out the Mississippian at a little way over in Smyth county.†

The great Saltville fault has preserved the Mississippian in southern Bland (north from Wythe), as well as in Smyth and Washington, and beyond for several miles in Tennessee. The exposures in Bland were not such as to admit of measurement. The coals continue into Smyth and the hard sandstone, the "Quarry" of Wythe county, the 80-foot rock of Lewis tunnel, underlies them. The thickness in Smyth was estimated at 500 feet, but in this were included rocks which afterward were referred to an earlier period. A noteworthy change begins in eastern Smyth, for there impure limestones appear in the shales and the passage to the overlying limestones is very gradual.‡ This change is very rapid toward the southwest, for when one has reached the middle of Washington county, adjoining Smyth, he finds the Pocono so linked with the great limestone mass that the separation can be made only with great difficulty.

It is possible that the lowest coal bed may be persistent thus far, for coal is said to have been dug at low water in the Holston river, near Mendota. The Pocono here is the Protean or lower division of Safford's Silicious group and the lower division, the great sandstone, is evidently a part of the Grainger shales of Mr M. R. Campbell, which carry Devonian fossils. In Wise county, about 40 miles west, the Pocono is about 150 feet thick on the waters of Powell river, where it consists of more or less calcareous sandstones with some shale.§ At probably 15 or 20 miles northwest in Whitely county, of Kentucky, where the Pine Mountain fault brings these rocks up, the thickness is estimated at fully 150 feet by Professor Crandall.||

* J. J. Stevenson : A geological reconnaissance of Bland, Giles, Wythe, and parts of Pulaski and Montgomery counties of Virginia. Proc. Amer. Phil. Soc., vol. xxiv, 1887, pp. 105, 106.

† J. J. Stevenson : Op. cit., pp. 78, 79.

‡ J. J. Stevenson : Notes on the geological structure of Tazewell, Russell, Wise, Smyth, and Washington counties of Virginia. Proc. Amer. Phil. Soc., vol. xxii, 1884, pp. 135, 143.

§ J. J. Stevenson : A geological reconnaissance of parts of Lee, Wise, Scott, and Washington counties, Virginia. Proc. Amer. Phil. Soc., vol. xix, 1881, pp. 242, 259.

|| A. R. Crandall : Geological Survey of Kentucky, Geology of Whitely county and part of Pulaski county.

The Pocono under West Virginia.—The oil-well records preserved in Doctor White's report on the geology of West Virginia exhibit the variations of the Pocono under cover in that state.

The northern tier of counties consists of Monongalia and Marion at the east, Wetzel and Tyler at the west along the Ohio river. In northern Monongalia near the border of Greene county, Pennsylvania, the section is in contrast with records from the latter county, for a well shows

	Feet
Sandstone.....	150
Shale and sandstone	160
Sandstone.....	100

a total of 410 feet, the middle containing 125 feet of shale. In a neighboring well the upper sandstone is 173 feet, with another sandstone of 55 feet at 55 feet below it. The records in Marion county are mostly incomplete, usually giving only the upper plate, which varies from 142 to 168 feet, but in one well the driller reports 50 feet of limestone below this plate, while at 40 feet lower there begins a mass of shale and sandstone 195 feet thick. In western Marion the thickness of the sand is given as 140 feet, but just over the line in Wetzel it is reported to be 250 feet, while elsewhere in that county it varies from 127 to 192 feet. The complete record of one well shows, however, that these variations may be due in some degree to the caprice of the driller, who may end the record for the "Big Injun" at the base of the upper plate or may continue it until the first thick bed of shale has been reached; for in that well the driller reports two beds of sandstone, 151 and 150 feet, separated by 4 feet of shale. There is, however, a distinct individuality about the upper plate, that known in West Virginia oil districts as the "Big Injun." In complete records of wells in Marion, Monongalia, Wetzel, and counties of the northern "panhandle" of the state, a shale of varying thickness separates this upper plate from one below, known in some localities as the "Squaw sand." In Monongalia the upper plate is from 150 to 173 feet, the shales from 55 to 57 feet, and the lower plate from 35 to 100 feet. In Marion the upper plate is 130 to 140 feet; one record gives 30 feet for the shale, and there is no record for the "Squaw."

Northward from Wetzel, in the northern "panhandle," which is west from Greene, Washington, Allegheny, and Beaver counties of Pennsylvania, one finds the two sandstones differentiated in most of the records. At Moundsville, in Marshall county, the Big Injun is 165 feet, resting on 50 feet of shale; at Wheeling, in Ohio county, 139 feet, with 45 feet of black shale between it and the Squaw, 25 feet thick; at Wellsburg, Brooke county, one finds Big Injun 140 feet; Shales, 50 feet; Squaw, 50

feet; but near New Cumberland, in Hancock county, the Big Injun is 95 feet thick, with 350 feet of shale below it. Here one is so far north, alongside of Beaver county, Pennsylvania, that it is difficult to resist the conclusion that the section represents the Shenango-Logan sandstone resting on the Cuyahoga shales; so that the upper plate is evidently the Shenango sandstone of White; the Shale, his Meadville, and the Squaw his Sharpville.

In this connection it may be well to introduce for comparison the record of a well at McDonald's station, in northern Washington county, Pennsylvania, about midway between Pittsburg and Wellsburg, on a west-southwest line. The record is exceptionally satisfactory, in that the measurements were made at intervals of 1 to 3 feet, and additional precautions were taken to confirm rope measurements by tape measurements at intervals of 15 to 60 feet. At each measurement the drillings were tested with acid. The grouping by Doctor White is

	Feet
"Big Injun sand," all sand except in 17 feet near bottom, no trace of limestone.....	237
Shales, white, gray, black, a little sandstone.....	88
"Squaw sand," 9 feet of shale near middle.....	42
Shales, black and gray, some sandy beds.....	201
Sand.....	29
Total.....	617

From the "Squaw" to the first Venango sand in this record is 333 feet. This section is greatly in contrast with those at Pittsburg and Wellsburg. At the former the upper sandstone is 140 feet, separated by 10 feet of shale from the lower bed of 20 feet, which rests on 115 feet of shale; at the latter the Big Injun is 140 feet, the Shales 50 feet, the Squaw 50 feet, resting on 400 feet of blue shale. It is equally in contrast with the section at Mount Pleasant, a few miles south from McDonalds, where the Big Injun may be taken as 133, slate 22 feet, Squaw 11 feet, shales and irregular sandstones 367 feet, and the total distance from the bottom of the Mauch Chunk to the first Venango sand is 671 feet as against 720 feet at McDonalds. The chief concern for us, as will be seen in the second section of this chapter, is with the Big Injun or upper plate, but it is noteworthy that the Crawford County section is recognizable as far south as southern Pennsylvania.

Returning to the south and crossing Wetzel county, one reaches Tyler. Here, as in several other counties, the lower portion of the Greenbrier (Mauch Chunk) limestone is absent, while the sandstone overlying it is persistent, and therefore rests directly on the Shenango, from which it can not be separated easily. This is the "Keener" sand of the drillers,

to which more detailed reference will be made in chapter ii. At Alva, in Tyler county, the two sandstones are 161 feet, with no record above or below for many feet. Few of the Tyler records go below the Shenango or Big Injun, as that is the oil-bearing rock in the Hebron and Sisterville pools of that county. In one well near Little Mills the Big Injun is 79 feet, separated by 20 feet of black shale from the Squaw, which is 20 feet. The Keener varies from 15 to 19 feet.

In Pleasants county, which extends along the Ohio river beyond Tyler, the Mauch Chunk is wanting and the Pocono is continuous with the overlying Pottsville, the records showing from 330 to 375 feet of sandstone for the two formations.*

The next tier of counties at the south consists of Harrison, Doddridge, Ritchie, and Wood, the last reaching the Ohio river.

The records in Harrison begin on the western side, almost on the strike from Mannington, in Marion county, and show a condition not easily explained. It is true that near Mannington limestone is reported below the Big Injun, but in Harrison the sandstone is very thin, 20 to 40 feet, with a great thickness of limestone below it within the Sardis Pool district. The same condition is reported from the Ten-mile district, a few miles southwest from the last; but in southern Harrison, within the Jarvisville district, the records give no information beyond the fact that the Big Injun is still thin, 47 to 80 feet, the underlying rocks being unrecorded. Doctor White lays emphasis on this change in the Big Injun as explaining the absence of oil and gas.

In Doddridge county, near Sedalia, only 10 miles west from Sardis, the Big Injun is sandstone, 102 feet, with underlying rocks unrecorded. Three or four miles northwest, at Center Point, the Keener is separated occasionally and is given in one record as 13 feet, but as it is separated from the Shenango only by a very thin shale, the two rocks are recorded usually as a continuous sandstone. As thus constituted, the Shenango in northern Doddridge averages about 115 feet and is separated from the Squaw or Sharpsville sandstone by 34 to 40 feet of shale, reported in one record as black. The conditions observed in Tyler, Wetzel, and the northern counties are reproduced here, though the Shenango is thinner. Farther south, in eastern Doddridge, near the Baltimore and Ohio railroad, the Shenango is but 79 feet, with only "shales, sand, and shells" below it for 148 feet. In south central Doddridge, 8 miles from the railroad, the thickness is given as 195 feet, with unrecorded rocks for 583 feet below; but at Oxford, 8 miles farther west, near the line of Ritchie

* I. C. White: *Geology of West Virginia*, vol. 1, 1900. Monongalia county, p. 235; Marion county, pp. 245, 347; Wetzel county, pp. 339-349; Panhandle, pp. 362-369; Tyler county, pp. 336, 338, 355-360; Pleasants county, p. 353; McDonalds, p. 228.

county, one finds evidence that the Shenango is breaking down, for the sandstone is but 24 feet, with unrecorded rocks for 342 feet below it.

In southern Ritchie, about 3 miles south from Oxford, the Big Injun is given as 47 feet, while at 12 miles northwest, on the railroad and nearly 25 miles west from Long Run, eastern Doddridge, the sandstone is 54 feet, with no record below for 347 feet. In north central Ritchie, within the Whiskey Run district, about 5 miles southwest from the Hebron district, in Tyler county, the sandstone is thinner than in the latter district and much thicker than in southeastern Ritchie, though still much as in northern Doddridge, two wells giving 70 and 73 feet, the Keener being included in both. The records are nearly complete in central Ritchie, near Harrisville and Cairo. Midway between Whiskey run and Cairo the Big Injun is reported as 140 feet, with 222 feet of shales below it; but at Cairo, on the railroad, 4 miles southwest from the last, it is only 97 feet, while at Harrisville, 3 miles east from Cairo, it is 102 feet. No records in southwest Ritchie pass through the Shenango, but a record at Burning spring, in Wirt county, 12 miles south-southwest from Cairo' gives the Big Injun as 50 feet, with 385 feet of gray shale below it. This locality is barely 10 miles farther south than is Oxford, in Doddridge county. On the western side of Ritchie, north from the Baltimore and Ohio railroad and not more than 15 miles due north from Burning spring, the Big Injun is given as varying from 121 to 147 feet, in each case resting on a great mass of shale. In the former well the mass is white sand throughout, but in the latter the bottom 34 feet of sandstone is separated from the upper plate by 14 feet of shale. Doctor White identifies the lower plate with the Squaw. This increase northward accords with the Tyler conditions.

Passing over into Wood county, one finds in the Hendershot district 200 feet of Big Injun, with limestone below it. Doctor White suggests that some of the sandstone may belong to the Pottsville, as the Mauch Chunk is absent westward. Be this as it may, a record obtained a little farther eastward in the same district shows 222 feet of sandstone underlying the Mauch Chunk and resting on a great mass of shale. At Parkersburg, on the Ohio, the thickness is 205 feet, with apparently no shale division. At Marietta, on the Ohio side of the river, according to Professor Orton, the sandstone is 335 feet thick, resting on the Cuyahoga shales; but much of this sandstone must be referred to the Pottsville, as the Mauch Chunk is absent. At Macksburg, Noble county, Ohio, 20 miles north from Marietta, 214 feet of pebbly sandstone overlie the Cuyahoga shales.* Professor Orton says that the Logan (Shenango)

*I. C. White: *Op. cit.* Harrison county, pp. 248-254; Doddridge county, pp. 321-333; Ritchie county, pp. 300-321; Wirt county, p. 262; Wood county, pp. 285-298.

sandstone is usually about 200 feet thick in southeastern Ohio, as shown by well records.*

The next tier of counties consists of Lewis and Braxton at the east, Gilmer, Calhoun, Roane, Jackson, and Mason, the last extending along the Ohio river beyond Wood.

Lewis is south from Harrison. Here are two records, one at the eastern edge at about 25 miles west from the Pocono outcrops in Rich mountain of Randolph county, West Virginia, and the other about 20 miles west on the western line of the county. In the eastern well one finds underlying the greatly thickened Greenbrier (Mauch Chunk) limestone and separated from it by 50 feet of shale, 215 feet of sandstone, which in view of the conditions on Rich mountain must be regarded as the Shenango. At Vadis, on the western edge of the county, the thickness is 196 feet, while immediately over the Doddridge line it is 152 feet, considerably more than in northern Doddridge, but less than in the south central part of that county. A well bored near Sutton, in Braxton county, 30 miles south-southwest from that in eastern Lewis, shows no sandstone whatever at the Shenango horizon, there being for 800 feet below the Mauch Chunk limestones nothing but shale except 5 feet of sandstone about midway in the mass. Glenville, in Gilmer county, is 10 miles west of south from Vadis, in Lewis county, and 20 miles west of north from Sutton. Evidently no sandstone occurs here below the limestone, for the driller found nothing worthy of record until he had gone 629 feet below it; so that the conditions here are most probably the same as at Sutton, and very much such as one should expect from the southward decrease of the Shenango in Ritchie county, for at Glenville one is about 23 miles south from Oxford, where the Shenango sandstone is but 47 feet thick.

No records are given for Calhoun county, the next west from Gilmer; but one may recall the measurement at Burning spring, northwest from Glenville, where the sandstone is but 50 feet. This locality is 15 miles north from Spencer, in Roane county, which is 30 miles south of west from Glenville. There the sandstone is missing, being either gone or more probably replaced by shale, but at 11 miles southwest from Spencer, in the same county, it reappears, clean, white, and 45 feet thick. This locality is about 40 miles west from the Sutton well. The next record is at Ravenswood, † on the Ohio river, in Jackson county, where the sandstone is 147 feet, and the underlying shales are more or less sandy. At Letart, on the Ohio, in Mason county, 12 miles west from Ravenswood,

* Edward Orton : Ohio Survey reports, vol. vii, p. 379.

† Ravenswood is 25 miles from Spencer, 30 from Burning spring, and 25 miles west from Parkersburg.

159 feet of sandstone underlie 65 feet of shale and sandstone and rest on 270 feet of Cuyahoga shale. The same condition is found opposite Gallipolis, 12 miles southwest from Letart, where the sandstone beds begin at 10 feet below the Mauch Chunk.*

Kanawha county is south from Roane. A well at Burning spring, 40 miles south from Spencer and somewhat more than 50 miles southwest from Sutton, has no sandstone under the Mauch Chunk (Greenbrier) limestone for more than 1,000 feet, aside from a 2-foot layer at 237 feet, showing the continuance of the shale southward; but on the Ohio river, at Central City, in Cabell county, 50 miles west from Burning spring and 30 miles south from Gallipolis, the Shenango-Logan is 177 feet, separated from the Mauch Chunk above by 28 feet of shale and resting on 370 feet of Cuyahoga.†

A well in southern Lincoln county at about 35 miles southwest from the Burning spring and the same distance southeast from Central City, shows no sandstone for 260 feet below the Mauch Chunk limestones. Near Dingess, 10 miles southwest from the last, the more or less sandy red rock observed below the limestone at the Burning spring, as well as in Lincoln county, has become a hard, red sandstone, 94 feet thick, while at 10 miles farther southwest, on the Sandy river, opposite Warfield, Kentucky, only shale underlies the limestone; so also in another well at a few miles farther south only shale occurs for more than 400 feet below the limestone. The consolidation near Dingess appears to be merely local.‡ Evidently the area in which the Pocono is represented only by shale is broad and far-reaching southward.

The eastern outcrops in Tennessee and Alabama.—The Pocono is followed with difficulty by means of lithological characters in the southeasterly outcrops southward from the Virginia line, but the conditions along the edge of the Cumberland plateau become clearer as the outcrop is followed south, for the Pocono is in part the Protean division of Safford's Silicious group. The lower portion of the Pennsylvania Pocono, that below the coal beds in Virginia, decreased rapidly in the southwestern part of that state until it disappeared or was merged into the Grainger shales of M. R. Campbell.

Details are wanting in northern Tennessee; Safford's work there was incomplete, and the investigations of the United States geologists have been published in very small part; but midway in the state Mr Hayes describes the lower part of the Great Limestone mass as very cherty,

* I. C. White: Op. cit. Lewis county, pp. 255, 258; Braxton county, p. 270; Gilmer county, p. 260; Wirt county, p. 262; Roane county, pp. 264, 268; Jackson county, p. 284; Mason county, pp. 274, 282.

† I. C. White: Op. cit. Kanawha county, p. 272; Cabell county, p. 275.

‡ I. C. White: Op. cit. Lincoln county, p. 280; Mingo county, pp. 276-279.

enabling us to recognize the Protean of Safford as distinguished from the more calcareous Lithostrotion bed above. This Protean is traceable easily into Alabama, where it is the Lauderdale of McCalley and extends far southward beyond the Grainger, resting for a great part of the distance on the still lower Chattanooga shales. In the southeasterly exposures it becomes very thin and disappears before southern Shelby county of Alabama has been reached. But much farther north it seems to have been lost in the overlying Tuscumbia, equivalent to Safford's Lithostrotion. The Lauderdale is sharply defined along Wills valley in front of the Cumberland plateau as well as in Browns valley, within that plateau. It consists almost wholly of chert and disappears south, so that it is recognizable only with doubt in Bibb county of central Alabama.

The western outcrops in Alabama, Tennessee, and Kentucky.—On the west side of the plateau, the Lauderdale is practically the newest formation exposed in the northwestern three counties of Alabama, where it contains much limestone with much bedded chert, in this respect differing from the overlying Tuscumbia, in which the chert is usually nodular, rarely bedded. Its thickness varies from 175 to 225 feet.*

In Tennessee, Mr Hayes does not separate the Protean from the overlying Lithostrotion, but includes them both under the term Fort Payne, but his reference to the abundance of chert in the lower portion enables one to recognize the Lauderdale near the Alabama border.† Farther north, in White county, Professor Safford gives a section of the Protean, thus:

	Feet
Limestone, cherty.....	100
Limestone, without chert.....	30
Shaly rock.....	20
Limestone and chert.....	127
Total.....	277

Chert increases downward, so that in the bottom 100 feet there is merely a succession of chert beds separated by thin layers of crinoidal limestone. Northeastward from White county a marked change occurs, for in the next county the section is

	Feet
Sandstone.....	8
Blue limestone, coarse, fetid.....	45
Interval, much chert.....	216
Total.....	265

* For references to Mr McCalley's Alabama reports, see chapter ii, where the whole series as it occurs in that state is described. This is necessary because at many localities the separation of Lauderdale and Tuscumbia will remain impossible until after much closer study has been made. † C. W. Hayes: U. S. Geol. Survey folios. Sewanee, 1894; McMinnville, 1895.

resting on the black Chattanooga shale. Farther north, near the Kentucky line, these rocks weather almost wholly into shale.* This statement agrees with that of Mr Campbell, who, near the Kentucky line, finds 350 feet of "Waverly" shales and limestones.†

The Protean covers much of Tennessee west from the Great Central valley. In a great part of the southern and western counties of this area it "is a stratified leached mass of soft pale yellowish or orange gray porous sandstone, which can be easily sawn or cut with an axe." In many places toward the center and south it is a pale blue fetid calcareous silicious shale carrying chert, but the chert is not persistent. This shale reaches into Lauderdale county of Alabama. In Hickman county and in the northwestern portion of the area the Protean is sometimes an almost continuous limestone, 150 feet thick.‡ This area is continuous with that of central Kentucky and of Indiana and its features have only an indirect bearing on the Appalachian.

The Waverly of the Second Geological Survey of Kentucky is the same with the Knobstone of Joseph Lesley and includes the Protean of Safford. It is the same with the Waverly of Ohio, and its lower beds cover a narrow space extending southwardly from the earlier beds rounding the southerly point of the Cincinnati uplift. The whole series is shown in a narrow strip eastward, continuous with that of Ohio.

At one locality in Clinton county, near the Tennessee line, Doctor Loughridge obtained the following Waverly section :

	Feet
1. Sandstones, more or less calcareous.....	95
2. Shaly rock.....	50
3. Sandstone with geodes.....	40
4. Green shale.....	4
5. Crinoidal limestone with flints.....	25
6. Shale with flint layers.....	49
Total.....	272

and resting on the black (Chattanooga) shale; but the section varies much, for elsewhere in this county Doctor Loughridge measured 376 feet.§ In these sections the whole interval from the Mauch Chunk to the Black shale is regarded as belonging to the Lower Carboniferous and as equivalent to the Waverly of Ohio. Mr Joseph Lesley in his general description of the formation says that it is separable into two divisions;

* J. M. Safford: *Geology of Tennessee*, 1869, pp. 339, 354, 356.

† M. R. Campbell: *Standing Stone* folio, U. S. Geol. Survey, 1899.

‡ J. M. Safford: *Op. cit.*, pp. 339, 340, 341.

§ R. H. Loughridge: *Report on geology of Clinton county*. Geological Survey of Kentucky, 1890, p. 18.

the lower or larger portion is an olive mud rock, while the upper, also olive colored, is very largely a fine grained sandstone, many layers of which are excellent for building purposes, while others have been used for grindstones. The upper portion is characterized by a *Spirophyton* resembling that of the New York Cauda-galli grit.* The upper or sandy portion is the protecting cover of the "knobs" of eastern Kentucky. Professor Crandall's notes on Greenup and Rowan counties confirm Mr Lesley's statement, for he describes the Waverly as upward of 500 feet thick, consisting of fine grained sandstones and shales, with layers of good building stone at the bottom and at other horizons. This accords with Professor Andrews's description of the formation as it exists in southern Ohio and the adjacent portion of Kentucky. The Kentucky geologists did not think that the Ohio subdivisions can be recognized in their state. Professor Herrick's work, however, has removed much of the difficulty.

In Kentucky the mass grows more and more sandy northward, and all trace of limestone seems to be wanting near the Ohio river. It is evident that on this westerly side of the basin the conditions are like those described on the easterly side, and that the change from merely land detritus to calcareous rock begins in middle Kentucky as at the east it begins in southern Virginia, with little difference in the latitude.

GEOLOGICAL RELATIONS OF THE POCONO

We have followed the variations of the Pocono around the Appalachian basin and, by means of the oil-well records, under much of the interior, where the formation lies deeply buried. The characters are distinct throughout except in the northern outcrops of eastern Tennessee, where for 100 miles detailed information is wanting, though on both sides of that space the conditions are clear, the features at the south being those foreshadowed by the changing structure and composition in southwest Virginia.

We have seen that the great mass, as observed in Pennsylvania, retains its general characteristics and thickness into Virginia, in which state its upper portion becomes less coarse and more shaly until within 60 or 70 miles of the Tennessee border, where calcareous deposits appear, and the formation becomes closely related to the overlying limestone mass, while the lower portion, which has retained its detrital character, seems to be merged into the Upper Devonian, the Grainger shales of M. R. Campbell. The change continues southward in the upper portion, and the deposit becomes mixed calcareous and silicious, often chert. Along the

* Geology Lesley: Fourth report on the geology of Kentucky, 1861, pp. 451, 452.

northern outcrop the thickness decreases rapidly westward from the area east of the Allegheny mountains, apparently in part from loss of the lower beds, until it becomes approximately 400 feet in Clinton and the adjacent counties, whence to the northwest outcrop in Pennsylvania the variation is insignificant. The character of the rock changes slowly in that direction. It is mostly sandstone, often coarse, along the north-easterly outcrop and easterly outcrop, though in the central east shales occur, one of which, midway in the mass, was found by Dr I. C. White to be richly fossiliferous. An impure limestone makes its appearance in the same relative position near Ralston, in the second basin of Rogers. Hodge describes it in Tioga county of the third basin, and speaks as though it were widely distributed, while later observers have found limestones in the adjacent counties of Elk, Warren, and McKean. Doctor Chance has shown clearly how the Pocono, after reaching its minimum Pennsylvania thickness of about 400 feet in the third basin, changes in composition westwardly, becoming more and more shaly below the Shenango sandstone, so that Doctor White's section, giving for the Pocono of Crawford and Erie a series of shales and sandstones with several thin limestones, is what one might expect to find in northwest Pennsylvania. The Pocono holds an impure limestone in the Chestnut Hill gaps of southwest Pennsylvania and northern West Virginia, where the mass is once more a sandstone.

Along the westerly outcrop in Ohio one finds the same general conditions as in northwest Pennsylvania, the sandstone on top with shales and irregular limestones below. Southwardly the limestones disappear and do not reach into northern Kentucky, but midway in that state calcareous beds appear, as at the southeast in southern Virginia, increasing southward until they become important in Tennessee, while in northwest Alabama one finds only limestone and chert. The thickness diminishes southward from nearly 500 feet at the Ohio river to 175 feet in northern Alabama, and the whole disappears finally before one reaches the middle of that state. Apparently the thinning toward the south is due to the gradual loss of the lower members—a continuation of the conditions observed in the upper Devonian.

The physical geography is discussed later on; here must be considered only the place of the Pocono in the geological column.

The Pocono of Pennsylvania, Ohio, Kentucky, and Virginia has been regarded by most geologists as Lower Carboniferous throughout. The Pocono of the eastern outcrops in Pennsylvania has been accepted as the equivalent of that in the western counties, as though the westward decrease were due merely to lessened thickness in each of the subdivisions.

It must be clear, however, to the reader who has followed the preceding summary that the loss in thickness is due very largely to disappearance of the lower members of the section, as is the case also southward from central Kentucky and southern Virginia, so that in Alabama and much of Tennessee only the uppermost beds remain. A new correlation appears to be necessary.

As already stated, Dr I. C. White's work first made clear the relations of the Pocono divisions in northwest Pennsylvania. His Shenango shales, Shenango sandstone, and Meadville shales, down to and including the upper Meadville limestone, are undoubtedly Lower Carboniferous, while the underlying divisions—the lower part of the Meadville shales, the Sharpsville sandstones, the Orangeville shales, and the Oil Lake group—are evidently later Devonian. Doctor White obtained from the upper Meadville limestone an abundant fauna, vertebrate and invertebrate, which was submitted to Professors Worthen and St. John. The invertebrate fauna has a Kinderhook facies, though some of the species are allied to Burlington and Keokuk forms. The vertebrate fauna, though in some respects resembling the Chester, is more nearly related to that of a lower horizon, probably Kinderhook. The fossils from the Shenango sandstone are unlike those from the Shenango shales, which are Chester.

In the Sharpsville sandstones is the lower Meadville limestone, which has been recognized in Crawford, Mercer, Warren, and Venango counties by Doctor White, and in McKean and Elk by Mr Ashburner; farther east is the impure limestone of Tioga and Lycoming counties, while on the eastern outcrop, at much the same horizon, allowance being made for thickening in that direction, are the somewhat calcareous, fossiliferous shales described by Doctor White in the report on Huntingdon county. This limestone, hard and flinty at the northwest, is almost non-fossiliferous in Crawford county, but is rich in fossils within Warren and Venango, where the most characteristic fossil is a *Spirifer* very near to *Sp. disjunctus*. Devonian forms occur in the lower divisions, and the Oil Lake group rests on the Riceville shales, which are rich in typical Chemung forms and extend downward to the first Venango oil-sand, the Allegrippus of White in eastern Pennsylvania, the upper Chemung conglomerate of Stevenson.

Closely following this work by Doctor White came that by Professor C. L. Herrick upon the Waverly of central Ohio, which was developed gradually in several publications and took final form in the discussion published in volume vii of the Ohio Reports.

Professor Herrick's investigation was one of the most painstaking ever performed in our country. The "Waverly problem," as it was termed

by Professor H. S. Williams, had been a torment for many years and the conclusions of observers were mutually contradictory. The first result of Professor Herrick's study was the discovery that most of the trouble had arisen from faulty methods of collecting, whereby differentiation of horizons was ignored and fossils from all parts of the series were labeled Waverly.

Underlying the Berea grit of Ohio is the Bedford shale, whose fossils are closely related to those of the New York Hamilton. The Berea grit, evidently the same with the upper part of White's Oil Lake group, is exceedingly poor in fossils, but overlying it is the Berea shale containing characteristic forms, among which are two which occur in the Bedford. This shale is paleontologically similar to the Orangeville of White. On the Berea shale rests the mass known in Ohio as the Cuyahoga and represented in Pennsylvania by the Sharpsville sandstones and possibly by the lower portion of the Meadville. The Sharpsville sandstones are persistent in Ohio as the Buena Vista sandstone, but the great overlying mass of the Cuyahoga seems to have almost disappeared eastward at the Pennsylvania line in the north. The Cuyahoga in Ohio was thought formerly to be very poor in fossils, but Professor Herrick found an abundant fauna at various horizons. The lower portion in northern Ohio contains a fauna which is related to that of the Berea, while the upper portion for 90 to 100 feet below the Logan conglomerate contains a very different and characteristic fauna. The lower shales disappear southward and the true Cuyahoga fauna is found at a few feet above the Buena Vista flags near the Ohio river. The forms characterizing this horizon were collected by Professor Herrick at many localities from the Cuyahoga valley near lake Erie southward to the Ohio river. In the discussion of this fauna he says that "the fossils which have been referred to Carboniferous species seem in every case to have been incorrectly identified," and he concludes with the statement that "enough has been said to show that the Cuyahoga shales are Devonian and lie above the Hamilton." The fauna is Chemung, but not specifically the same as that of New York.

In central Ohio there underlies the Logan sandstone a shale which Herrick named "The Waverly shale."* Here he obtained the fauna described in earlier days as "Waverly," and he shows its unmistakable resemblance to Kinderhook. This fauna passes upward into the Logan conglomerate, which becomes shaly southward, though still retaining the fauna. The Burlington and Keokuk are found in the upper portion of the Logan, from which Professor Herrick made collections at several

* C. L. Herrick : Bull. Geol. Soc. Am., vol. ii, 1891, p. 37.

localities in central Ohio and on the Ohio river, in the southern portion of the state; 250 feet of shales and flags belonging to the Logan remain near Portsmouth, on the Ohio. The lower portion yields a Burlington fauna, while the Keokuk is found in a variable band of red sandstone at the top.*

Paleontological details for Kentucky are wanting, but the Upper Knobstone or Logan is recognizable almost all the way across the state, the underlying Devonian becoming thinner, until in northern Tennessee it seems to disappear. Safford's lists † show that in Tennessee the fossils of the Protean group are Keokuk, though two forms of Burlington affinity are mentioned. In view of the southward disappearance of Kinderhook in Ohio, there is no room for surprise when one finds the Burlington practically missing in Tennessee, and he is quite prepared for the reference of the Alabama Lauderdale to the Keokuk by both Professor Smith ‡ and Mr McCalley.§

It is possible to make an approximate correlation for the several parts of the Appalachian basin, as follows:

Lower Carboniferous:

Shenango and Upper Meadville.....	Northwestern Pennsylv- ania.....	} Keokuk, Bur- lington, and Kinderhook.
Logan, including Waverly shales.....	Ohio.....	
Upper 400 feet of Bedford and Hunt- ingdon.....	Eastern Pennsylvania...	
Coal-bearing shales and sandstone...	Virginia.....	
Upper plate of Big Injun.....	West Virginia.....	
Upper Knobstone of.....	Kentucky.....	} Keokuk and Burlington.
Protean of Safford.....	Tennessee.....	} Keokuk.
Lauderdale of McCalley.....	Alabama.....	
Lowest Fort Payne of Hayes.....	Georgia and eastern Ala- bama.....	} Undeter- mined.
Lowest Newman of Campbell.....	Tennessee and Virginia.	

Devonian:

- I. Lower Meadville, Sharpsville, Orangeville, and Oil Lake of White..... Northwestern Pennsylvania.
 Cuyahoga and Berea..... Ohio.
 Rest of Pocono, Bedford, and Hunt-
 ington counties..... Eastern Pennsylvania.
 Lower Pocono of..... Virginia.
 Upper Grainger of..... Southwestern Virginia.

*C. L. Herrick: Ohio Reports, vol. vii, pp. 495-515.

†J. M. Safford: Geology of Tennessee, p. 342.

‡E. A. Smith: Geological map of Alabama, Exp. chart, 1894.

§Henry McCalley: Geol. Survey of Alabama, Valley regions of Alabama, part i, 1896, p. 35.

- Squaw sandstone, etcetera.....West Virginia.
 Lower Knobstone.....Kentucky.
 Absent in most of.....Tennessee and Alabama.
- II. Catskill (of Vanuxem)..... Eastern Pennsylvania.
 Hampshire of Darton.....Virginia.
 Absent in Western Pennsylvania, Ohio, Kentucky, most of West Virginia,
 Tennessee, and Alabama.
- III. Chemung and Chemung-Catskill of } Eastern Pennsylvania, Maryland, and
 I. C. White, Chemung of Steven- } Virginia.
 son, Jennings of Darton..... }
 Riceville and Venango of I. C. White. Northwestern Pennsylvania.
 Erie shale of Newberry.....Ohio.
 Absent.....Tennessee and Alabama.
 Grainger shale of M. R. Campbell..Southwestern Virginia and Northern
 Tennessee.

The correlation is not exact; the details available thus far enable one to make but approximation. Of the names applicable to the upper part of the Pocono, perhaps Logan is the best, as it is the most comprehensive and is the oldest, having been used by Professor Andrews in 1870.* No one of the terms used for the upper division of the Devonian can be taken as a name for the whole, as each one of them has been applied to a definite portion. The limits of the Catskill were set definitively by Vanuxem, but the name had been used earlier by Mather to cover rocks extending from the upper Silurian to the top of the Devonian; it has been used since to designate a condition, and wherever red rocks have been found in the upper Devonian they have been regarded, for this reason, as Catskill. The name has led to serious confusion stratigraphically as well as paleontologically, so that the fishes *Holoptychius* and *Bothriolepis* and the plant *Archeopteris jacksoni* have been spoken of as Catskill fossils, whereas they belong far down in the true Chemung. Mr N. H. Darton's term Hampshire will have to be employed instead of Catskill. There is less objection to retention of the name Chemung, yet it has been used with indefiniteness. Perhaps the slate may be as well rubbed off to begin anew with the name Jennings, offered by Mr Darton and already accepted by the United States and Maryland surveys.

The chief defect of the correlation is in respect to the Catskill or Hampshire; yet correction is extremely difficult, at present impossible. The lowest member of Doctor I. C. White's Oil Lake group in northwest Pennsylvania is the Cussewago sandstone, a flat pebble conglomerate resting on his Riceville shales, which are Chemung. This conglomerate

* E. B. Andrews: Report of Progress, Ohio Geol. Survey, 1870, p. 62.

is present in southern Pennsylvania and northern West Virginia; it is recognizable at more than one locality along the northern outcrop, while along the eastern outcrop a conglomerate often occurs at about the same horizon. At the east this is above the Catskill; in western Pennsylvania it rests on the Chemung.

The Catskill of Vanuxem, consisting of blood-red shales and green to red sandstones, was deposited in a narrow trough very deep at the east and shallowing rapidly westward. In southern Pennsylvania the thickness is 3,700 feet in Fulton county; 1,980 feet in western Bedford, 35 miles away; 10 feet in western Somerset, 35 miles farther west, and nothing in eastern Fayette, 5 miles farther, where the bottom conglomerate of the Pocono (White's Cussewago) rests directly on the equivalent of the Riceville shales. Nowhere in western Pennsylvania is there any deposit answering to the enormous mass of Catskill found on the Alleghanies and eastward. The lowest portion of Dr White's Crawford County Pocono is evidently equivalent to some portion of the transition beds of eastern Pennsylvania. Whether or not any portion of this should be included in the Catskill can not be determined now.

The conditions to which the red beds were due began in New York, within the Catskill region, toward the close of the Hamilton. During the Chemung the influence of these conditions extended westwardly, and especially southwestwardly, spreading red rocks over constantly increasing area, until rocks of that type covered the whole region of the eastern outcrops in Pennsylvania, Maryland, and Virginia to beyond the New river. The conditions were fatal to most forms of animal life, so that we find the fauna surviving for a longer period the farther it was away from the Catskill Mountain area. Occasionally, when the conditions were interrupted, the fauna found its way, at one horizon at least, into the Catskill region itself, near which Professor Prosser found it in the Delaware flags.

In New York the typical Chemung fauna was cut off by the Catskill conditions, while farther west it disappeared with the narrowing of the trough of sedimentation following the deposit of the Riceville and Erie shales. Whether or not there was any sedimentation in Ohio during the Catskill is very uncertain, but the fauna survived somewhere in the northwest portion of the basin and underwent changes during that long period; so that when the Cuyahoga sedimentation occurred in Ohio and northwest Pennsylvania the fauna spread eastward, no longer specifically identical with the old Chemung fauna, but related to it and retaining the Devonian facies.

With the next great change in topographical conditions, that introducing the Mississippian, this fauna disappeared and another took its

place. The discussion of this matter, however, must be deferred until the Mauch Chunk has been described.

THE MAUCH CHUNK OF LESLEY; UMBRAL OF ROGERS

DISTRIBUTION AND CHARACTERISTICS OF THE ROCKS

Range of the Mauch Chunk.—The Mauch Chunk embraces the rocks from the top of the Logan to the base of the Pottsville.

The anthracite strip.—Within the anthracite strip this series consists almost wholly of sandstones and red shale, with here and there thin calcareous beds which become more conspicuous toward the south. It is preserved around the anthracite fields of Pennsylvania, around the Broad Top bituminous area, in a petty area eastward within Fulton county, and at the northern end of the Mount Savage synclinal, which extends southward into Maryland and the Virginias, where the exposure becomes much more important. As the strike sweeps round toward the west in the anthracite fields, the southern field is the nearest to the old shoreline.

Mr Winslow's section near Mauch Chunk, at the easterly end of the southern field, shows a thickness of 2,168 feet, the upper 1,662 feet being red shale and sandstone, the lower portion almost wholly shale;* but at a little way farther north he finds 3,342 feet † almost wholly of red shale. I. C. White measured nearly 2,000 feet in the Catawissa valley, but in the southwest portion of the northern field near Shickshinny the thickness has diminished to only 1,200 feet. Eight miles farther eastward he found only 425 feet, the uppermost 100 being greenish sandstone, the rest red and green sandy shale. Thence northward in this basin the red shales disappear and the mass grows thinner, so that at Scranton the thickness is but 75 feet. ‡ Clearly in this region the Mauch Chunk did not extend into New York. H. D. Rogers, in summing up the character of the Umbral as it is shown around the anthracite fields, says that the more argillaceous portions of the red shale frequently contain some calcareous matter, bands of such matter being found occasionally in the upper portion, but becoming more numerous in the middle and lower portions. This calcareous matter is not in beds, but in nodules scattered through the shale. Twelve such beds were observed near Tamaqua, in the southern field, one of them 6 and another 3 feet thick, in which the nodules are very abundant. This description refers especially to the southern and middle fields. In the northern field the calcareous matter

* J. P. Lesley: A summary description of the geology of Pennsylvania (final report), 1895, p. 1815.

† Final report, p. 1635.

‡ I. C. White: Geology of the Susquehanna region (G 7), 1883, pp. 44-46.

occurs chiefly in the sandstones and becomes more abundant* north-eastwardly. P. J. P. Lesley calls attention to the presence of calcareous layers near Ashley, in the upper third of the section.† There is practically no information respecting the western extension of the southern field beyond Professor Claypole's statement that the thickness of shale spared from erosion is at least 1,500 feet in Perry county, and that some of the beds contain enough of calcareous matter to make well water hard.‡

The Broad Top coal field may be regarded as in a line with the Northern Anthracite field and the area in Fulton county as corresponding to the Middle field. Only the lower portion of the Mauch Chunk remains in the Fulton area, but the surface is littered with fragments of limestone, always sandy, sometimes red, often bluish. This is the most eastern locality in Pennsylvania at which any of the limestones of the Mauch Chunk are well defined.§ The conditions around the Broad Top field have been studied by I. C. White, Ashburner, and Stevenson. Ashburner's section on the eastern side within Huntingdon county showed a thickness of 1,100 feet, thus:

	Feet
Sandstone and shale.....	910
Limestone.....	49
Shale and sandstone.....	141

The writer was inclined formerly to regard the lowest member as belonging to the Pocono (Logan), but in view of the conditions along the northern border, he now regards it as equivalent to the shale underlying the limestone mass in the oil wells of western Pennsylvania. The limestone is sandy and much of it red. Mr Ashburner discovered a fossiliferous bed containing *Terebratula romingeri*, *Grammysia*, *Strophodonta*, *Rhynchonella*, while lower down is another from which he obtained a *Centronella*.|| This grouping of forms is so well nigh impossible in the upper Mississippian that one must place these identifications in the same list with those which led to recognition of middle Devonian fauna in the Lower Barren Coal Measures of western Pennsylvania. Stevenson found the same type of limestone on the eastern side in Fulton county, where, however, the limestone appears to be somewhat thicker. On the western side, in Huntingdon county, I. C. White reports 1,050 feet, with the limestone 50 feet broken into alternate bands of limestone and shale and practically non-fossiliferous. In addition to this mass, he discovered

* H. D. Rogers : Geology of Pennsylvania, 1858, vol. ii, p. 10.

† J. P. Lesley : Final report, p. 1823.

‡ E. W. Claypole : Prelim. report on paleontology of Perry county (F 2), 1885, p. 79.

§ J. J. Stevenson : Geology of Bedford and Fulton counties (T 2), 1882, p. 68.

|| C. A. Ashburner : Aughwick valley and east Broad Top district, in vol. F, 1878, pp. 194-195.

two beds of impure limestone, 2 and 3 feet thick, at 175 and 500 feet respectively below the Pottsville, in which he sees the representative of the upper limestone, which becomes so important beyond the Allegheny mountains.* These upper limestones were not seen in Bedford county by Stevenson, but the lower limestone is persistent there and is present at the northern end of the Mount Savage synclinal, where it shows distinctly the curious current bedding which characterizes it at all exposures farther west.†

Little information is available for localities along the easterly front of the Allegheny plateau in Pennsylvania. R. H. Sanders's section, in Blair county, gives the thickness as 283 feet and shows no trace of limestone, ‡ a condition difficult of explanation in view of observations on all sides. Edward Miller found near the Old Portage, in the same county, 30 feet of limestone, containing "so large a proportion of silex that it forms good mortar without any admixture of sand," which can be no other than the lower Mauch Chunk limestone, the silicious limestone of southwestern Pennsylvania. § Where the Potomac issues from the Alleghanies in Maryland, one has C. C. O'Harra's section, which shows

	Feet
Mauch Chunk shales.....	800
Greenbrier limestone.....	227

a total of 1,107 feet. The Mauch Chunk is mostly red shale, but above the middle is a greenish, soft, flaggy sandstone about 100 feet thick, and at the base a brecciated sandstone 4 feet. The Greenbrier is limestone, with thin shales, 70 feet; shales and sandstones, 113 feet, and a silicious limestone, 38 feet, which rests directly on the Pocono.¶ Evidently the section varies notably, for within a short distance Rogers reported from Westernport:

	Feet	Inches
1. Red sandstones and shales.....	650	
2. Limestone, conglomerate, fossiliferous.....	4	6
3. Red shale, with a little sandstone.....	184	11
4. Silicious limestone, oolitic bands.....	46	7
5. Red shale sandstone, some limestone.....	15	5
6. Silicious limestone, diagonally bedded weathers like coarse freestone.....	14	4
7. Limestone.....	7	
Total.....	918	9

* I. C. White: *Geology of Huntingdon county* (T 3), 1885, pp. 75-76.

† J. J. Stevenson, vol. T 2, p. 102.

‡ R. H. Sanders, cited by Franklin Platt: *Geology of Blair county* (T), 1881, p. 13.

§ Edward Miller: *Transactions of the Geological Society of Pennsylvania*, 1835, vol. i, p. 254.

¶ C. C. O'Harra: *Maryland Geological Survey, Allegany county*, pp. 110-113.

This recalls Doctor White's Huntingdon County section, as number 2 is very near the place of the lower impure limestone.*

Eastern counties of the Allegheny plateau.—Returning now to the north and following the eastern tier of counties on the Allegheny plateau, embracing at the south the great anticlinals of the Viaduct, Laurel, and Chestnut ridges, one finds a succession which was to be expected in view of Miller's discovery in Blair county.

Mauch Chunk rocks decrease in thickness rapidly along the northern border. Shales and sandstones only are reported from Bradford, Tioga, and Sullivan counties. In the last, Franklin Platt assigns but 25 to 140 feet to the whole series; but this estimate is indefinite, including, as it does, only the red shales and ignoring the greenish sandstones as well as the underlying red shale which contains a limestone. In the Barclay coal field of Bradford county the thickness is about 200 feet, shales and greenish gray sandstones, † while in the Blossburg coal field of Tioga I. C. White finds 245 feet of shales and sandstones. Passing over into Lycoming county, west from Sullivan and south from Tioga, one finds Mr Platt's measurement of 75 feet at McIntyre, but this includes only the red shales, and his line of separation differs from that drawn by Doctor White; so that we may regard the thickness in the two counties as the same, taking the larger estimate as preferable. A. Sherwood asserts that the thickness in Lycoming county varies from 271 to 415 feet. Professor Lesley quotes in detail the observations of Abram Meyer in northern Lycoming, according to which the thickness is variable and the section differs extraordinarily from that obtained by other observers. According to Mr Meyer, the thickness sometimes becomes 353 feet, though usually much less. The succession is

	Feet
Shales.....	20 to 150
Limestone and shale.....	50 to 75
Shales.....	80 to 120

A section very similar to that already found in Bedford and Fulton counties, the limestone being somewhat thicker, while the upper shales have lost much. The middle portion of the limestone is silicious, massive, and non-fossiliferous, the only fossils found occurring just below this in a yellow ferruginous bed crowded with encrinal discs.‡

Clinton county adjoins Lycoming at the west. There, at Lock Haven, Doctor Chance finds below the Pottsville 100 feet of red shale, 15 feet of white and gray sandstone, and 3 feet of mixed limestone and sandstone,

* W. B. Rogers: Annual report Geol. Survey of Virginia, 1839, p. 91.

† Franklin Platt: Report of Progress in Bradford and Tioga (G), 1878, p. 127.

‡ A. Meyer, cited by J. P. Lesley: Final report, p. 1803.

but he places only the upper shales in the Mauch Chunk. The limestone was not observed at any locality north or west from that locality; the shales grow thinner northward, so that in northwest Cameron, and even at some localities within western Clinton, they appear to be absent. Doctor Chance is inclined to doubt whether the shales ever reached the western side of Elk county, west from Cameron. Shale is present in Center county, south from Clinton, at Snowshoe, where it is at least 100 feet thick.* The condition in Potter county, north from Clinton, is not sharply defined, and Ashburner was unwilling to draw the line between Pocono and Mauch Chunk, giving for the whole interval of Mauch Chunk and upper Pocono only 70 feet.† Franklin Platt also hesitated to mark any boundary and contented himself with the remark in many places that the Mauch Chunk is very thin. Clearly the upper shale has disappeared.

Ashburner reports 40 to 50 feet of Mauch Chunk in Cameron county and in the greater part of Elk, but at the western side of the latter county the thickness is but 10 to 15 feet, with no red shale. In Forest county, west from Elk, he finds some red shale in the 70 feet below the Pottsville, but in McKean, north from Elk, he finds the Mauch Chunk 50 feet thick on the Cameron border and decreasing northward until it becomes a dark, often coaly shale, varying from 5 to 10 feet.‡

Returning southwardly and entering Clearfield county from the southwestern side of Clinton, one finds few exposures. Doctor Chance in this county and W. G. Platt in the adjoining county of Jefferson were unable to make any satisfactory measurements. Doctor Chance gives 125 feet as probably the extreme thickness for Clearfield.§ The anticlines, which rise so high farther south, are too gentle here to bring up much of the Mississippian.

Cambria lies south from Clearfield and west from Blair, extending eastward to the crest of the Alleghenies. Mr Platt observed the Mauch Chunk beds on the Allegheny slope, but reached the bottom only where the Conemaugh river cuts the Viaduct axis in the south central part of the county, where he estimated the total thickness at 200 feet. A partial section shows ||

	Feet
Red and olive shales and sandstone.....	96
Silicious limestone, exposed	10

* H. M. Chance: *Geology of Clinton county* (G 4), 1880, pp. 94-96, 125.

† C. A. Ashburner: *Geology of Potter county* (G 3), 1880, p. 104.

‡ C. A. Ashburner: *Geology of McKean county* (R), 1880, pp. 63-64.

§ H. M. Chance: *A revision of the bituminous Coal Measures of Clearfield county* (H 7), 1884, p. 14.

|| W. G. Platt: *Report of progress in Cambria and Somerset district, part i* (H 2), 1877, p. 46.

The same conditions prevail in the Conemaugh gap through the Laurel Hill axis, where the whole of the limestone is brought up and seen to be much thicker. In the Conemaugh gap through Chestnut hill, within Westmoreland county, J. J. Stevenson found along the Pennsylvania railroad this succession :

	Feet
1. Shales.....	82
2. Fossiliferous limestone.....	6
3. Shales and sandstone.....	60
4. Calcareous shale.....	3
5. Interval.....	37
6. Silicious limestone.....	40 to 50

The same section is shown on the Indiana side of the river.* In that county limestone is present in Chestnut hill almost midway from the Conemaugh to the Clearfield line. In this region one finds for the first time along the lines thus far followed full exposures of this limestone, as farther north and east the deposit is much thinner. It may be well to introduce here a detailed description of it as given originally by Stevenson :

“The upper portion is a conglomerate sandstone of varying thickness, in which are great numbers of more or less angular fragments of the silicious limestone. This passes down imperceptibly into the silicious limestone proper, which in its turn passes into the Pocono sandstone below. The fragments in the conglomerate portion are so clearly free in most cases from all traces of aqueous action that they may have been stripped off by some abrading agent while the limestone bed was above water level.

“The limestone itself is an exceedingly fine grained rock, with a delicate blue color, and on the fresh surface it shows no lines of bedding. It has a flint like fracture and no definite cleavage. On the long exposed surface the color is dull brown and the rock resembles a loose sandstone. Under such circumstances the structure of the rock is perfectly distinct, and it shows curious cross-bedding.

“At first glance this rock is hardly to be taken for a limestone, and the silica evidently predominates at all localities. At the same time lime is present in considerable quantity, for when the rock is burned it becomes snow white, slakes readily, and forms a mortar without the addition of sand.”†

The upper fossiliferous limestone is shown in the Conemaugh gap through Chestnut hill, and its thickness suggests that the beds ought to be found at some distance farther north, but Mr Platt appears to have found no traces of it in Black Lick gap of Indiana county. It was not observed in the gap through Laurel hill. The section recalls that obtained by Doctor White in Broad Top, for here one has the upper shales

* J. J. Stevenson : Report of progress in the Fayette and Westmoreland district, part ii (K 3), 1878, p. 48.

† J. J. Stevenson, vol. i (K 3), p. 52. The statement on page 53 respecting the distribution of this deposit is wholly erroneous.

with the impure limestone and the lower or sandy limestone, but the upper shales are very thin and the lower shales are wanting.

A difficulty is encountered in reference to the upper shales, counted here as part of the Mauch Chunk. The lower member of the Pottsville, as shown in northwestern Pennsylvania, evidently disappears southwardly, so that the Sharon coal group is continuous with the Mauch Chunk shale. Stevenson, in his Pennsylvania reports, included that group in the Mauch Chunk, but afterward,* in the light of I. C. White's studies in the northern counties, transferred it to the Pottsville. The Sharon is certainly present in the Conemaugh gap through Chestnut hill, for an insignificant coal bed was seen there directly under the Pottsville; but the group is so thin that no rearrangement of the section is necessary. Farther south, however, the Sharon becomes thicker and its relations will be discussed in a later chapter.

Southward from the Conemaugh the upper limestone quickly becomes important. W. G. Platt does not appear to have found it on the west flank of the Allegheny mountains, in Somerset county, or under the Viaduct axis, though he found the silicious limestone on the Allegheny near Ashtola; but Stevenson found on the west side of Laurel hill, at 20 miles south from the Conemaugh, 16 feet of limestone, separated by about 50 feet of red shale from the silicious limestone below, and thence south he reports frequent exposures to the Youghiogheny gap through Laurel hill, where the two limestones are present on both sides of the anticline. Along Chestnut hill the upper limestone increases rapidly south from the Conemaugh. The two beds of the Conemaugh gap were seen in the Loyalhanna gap, both thin, silicious, and fossiliferous. On Jacobs creek, the boundary between Westmoreland and Fayette, the upper limestone is exposed for 40 feet, the top portion for 18 feet very pure and the lower portion very argillaceous and with abundant fossils. The section does not reach down to the silicious limestone.† Both limestones are present in the Youghiogheny gap, where the silicious limestone is about 40 feet thick. Stevenson has given recently a section on the National road in Fayette county, which shows shales, 100 feet, and limestone and shale, 150 feet, the latter having at the base 35 feet of silicious limestone, with 35 feet of shales separating it from the main mass of limestone above. There is a concealed space of 23 feet in the lower part of the upper limestone, and the character of the slope suggests that it is filled with readily yielding material, possibly very calcareous sandstone or very sandy limestone, of which a little is shown just above it.‡ Dr I. C. White's studies carry the

* Notes on the Lower Carboniferous groups, etcetera. Amer. Jour. Sci., vol. xxxiv, p. 37.

† J. J. Stevenson: Report on Fayette and Westmoreland district, part I, 1877 (K 2), p. 262.

‡ Notes on the Mauch Chunk of Pennsylvania. Amer. Geologist, vol. xxix, p. 244.

measurements across Preston county of West Virginia, which adjoins Fayette and Somerset of Pennsylvania, where he measured the Mauch Chunk in Chestnut, Laurel, and Briery mountains, the last being the continuation of the Pennsylvania viaduct. Here the order may be reversed and his measurements may be followed southeastwardly, that comparisons may be made with measurements on the Potomac in Maryland.

The Cheat River gap through Chestnut hill is about 20 miles south from the National Road locality just referred to. There Doctor White found shales and sandstones, 299 feet; limestones, 110 feet; silicious limestone, 30 feet; the upper shales containing 10 feet of impure limestone at 40 feet above the base. The silicious limestone varies greatly, being only 5 feet, with 10 feet of overlying sandstone at a little distance from the measured section. The sandstone contains fragments of the limestone as at many localities in southwestern Pennsylvania. Under the Laurel Hill axis, on the west side, at 30 miles south-southwest from the Youghiogheny gap, the section is

	Feet
Shales and sandstones.....	220
Limestone.....	94
Silicious limestone.....	8

with the 10 feet of impure limestone persistent in the shales; but the silicious limestone is as variable as under Chestnut hill, for on the east side of the fold it is 35 feet thick, and the upper part of the Pocono sandstone is calcareous for 10 or 15 feet. At this last exposure the shales are 295 feet, with a thin coal bed within the top 25 feet, while the upper limestone has become 120 feet, an increase eastwardly.* On the west side of the Briery axis, 15 miles south from the last and about 30 miles west from Westernport, in Maryland, the whole mass is thickened greatly, for there the section is

	Feet
Shales and sandstones.....	370
Limestone and thin shales.....	227
Silicious limestone.....	105
Shale.....	10

No limestone appears here in the upper shales, as the impure limestone of the Cheat river sections has become 20 feet thick, and is included in the limestone mass. The limestone division is less pure than in the Cheat sections, and is broken up into eight beds, aggregating 124 feet 6 inches, separated by beds of red and green shales from 4 to 20 feet thick, so that while there has been an increase in thickness of limestone, that in detrital matter has been still greater. No sandstone occurs in the

* I. C. White: Proc. Amer. Phil. Soc., vol. xx, 1882, pp. 484, 486, 491, 492.

limestone division except near the top. That, however, is the same with that which in the other sections was taken as the bottom of the shales. The silicious limestone is massive except 10 feet at the bottom.* These measurements were made at about 40 miles southwest from the Somerset County exposures under the Viaduct axis.

Western counties of Pennsylvania.—Returning now to the north, one finds in Crawford county of Pennsylvania the Shenango shales of Doctor White, which there vary from 35 to 60 feet and consist of gray to brown and blue shales. The thickness becomes 45 feet near Kinzua in Warren county, east from Crawford, while southward it is 60 feet near Tidioute in Venango and 47 feet near Sharon in Mercer.† Mr Carll gives 50 feet for Warren, northwest from the Allegheny river, but from 120 to 150 feet in the southeastern part of the county.‡ Fossils occur occasionally within Crawford and Erie counties, which, according to White, belong to types characterizing the Chester group. No limestone appears in these shales and they evidently represent the whole sedimentation for the Mississippian in this area.

The relations in the southern counties of western Pennsylvania are shown in the tabulated series of well records given by Mr Carll in his report for 1886. In Crawford county, the Shenango shales are 50 feet; in Venango, 60 feet; in Clarion, east from Venango, 172 feet; in Butler, 90 to 194 feet, increasing southwardly; thus far no limestone. The series is thickening and evidently we have here the upper and the lower shales, between which the limestone should make its appearance. At Pittsburg, about 30 miles west from the Conemaugh gap, through Chestnut hill, the succession differs in some respects from that seen in the gap; the lower shales are here, 44 feet, underlying the silicious limestone, 56 feet, on which rests the upper limestone, which is shaly and 23 feet thick, but the upper shales are absent, so that the Pottsville sandstone is let down directly on the limestone. A similar section is shown at Murrysville, about midway between Pittsburg and the gap, where, however, the upper shale is present, the thicknesses being, shale, 30 feet; limestone, 30 and 90 feet; shale, 60 feet. In Mount Pleasant township of Washington county, about 20 miles southwest from Pittsburg, the lower shale is still present, 27 feet, the upper shale, only 10 feet, while the limestones have diminished to 13 and 29 feet. This, clearly, is not far from the western limit of the limestones, for at the S. B. Phillips well number 1, near McDonald station, 10 miles northwest, no limestone is present and the whole interval from Pottsville to Pocono is but 39 feet.

* I. C. White: *Catalogue of West Virginia University*, 1882-'3, p. 50.

† I. C. White: *Geology of Erie and Crawford counties* (Q 4), 1881, p. 78.

‡ J. F. Carll: *Geological report on Warren county* (I 4), 1883, p. 193.

The record of this well was kept with extreme care and the drillings were tested with acid.* Southward the conditions observed in Chestnut hill prevail, for at Washington, 12 miles south from Mount Pleasant, the lower shales have disappeared, the upper shales are 95 feet, while the limestones are 27 and 58 feet, dark and light respectively. The same condition exists in Greene county, south from Washington, where the upper shale is 55 feet, 20 feet of it being red rock, while the limestones are 55 feet of dark and 110 feet of white, the latter being the silicious. †

This thinning out of the Mauch Chunk across Allegheny and Washington counties is precisely what one should expect in view of the conditions shown by oil-borings within the West Virginia panhandle. Doctor White tells us that in Beaver county of Pennsylvania the thickness is not more than one foot; at Wellsburg, in Brooks county of West Virginia, west from McDonalds, the whole Mauch Chunk consists of but 31 feet of shale and sandstone, while at Wheeling, in Ohio county of the same state, the Pottsville and Pocono are in contact. The western limit of the limestone, passing southwest through Washington county of Pennsylvania, crosses the Ohio river not far below Wheeling, for in Marshall county both shale and limestone occur at Moundsville, the reported succession being: ‡

	Feet.
Slate and shells.....	82
Big limestone.....	85
Slate.....	25

Northern and western outcrop in Ohio.—Returning to the north and passing over into Ohio, one finds difficulty in tracing the Shenango shales, for the Pocono becomes shaly in its upper portion and the differentiation between the two divisions has not been carried far beyond the state line. Where the Logan becomes distinctly recognizable in north central Ohio, one finds the conditions as at Wheeling, it and the Pottsville are in contact, so that the Mauch Chunk must be absent; but in the central part of the state, in Muskingum county, the Maxville limestone appears somewhat abruptly. It is the equivalent of the upper or fossiliferous limestone of southwestern Pennsylvania. Professor Orton's general section, given in volume vii of the Ohio reports, marks shale as intervening between the Logan and the Maxville. Professor Andrews, in his description of the Maxville, speaks of 12 feet of clay or soapstone between the limestone and the Logan; but this shale seems to be of very uncertain distribution, for in some localities the limestone

* I. C. White: West Virginia Geol. Survey, vol. i, 1899, p. 227.

† J. F. Carrl: Annual report Geol. Survey of Pennsylvania for 1886, pp. 636-660.

‡ I. C. White: West Virginia Geol. Survey, vol. i, pp. 363, 366, 367.

and the Logan sandstone are in contact. The presence of the upper shales is very doubtful, for the coal series begins at 5 to 20 feet above the limestone; so that the upper shales may be regarded as absent, unless indeed some part of the coal-bearing series be taken as their equivalent.

The Maxville limestone was discovered by Professor Andrews in 1869, and was described by him in the Ohio annual report for that year, where he identified it with the Lower Carboniferous limestone of Kentucky. He observed it in western Muskingum and eastern Perry, where it is 17 feet thick, with 4 feet of sandy shale between it and the underlying Logan; it evidently extended across Perry, for it is at least 10 feet thick in Fairfield; in Hocking county, 9 feet were seen at one locality, with the bottom not reached; in Vinton, where it is 16 feet and rests directly on the Logan, it is partly brecciated; 8 feet were seen in Jackson county at 12 feet above the Logan; no exposures were found in Scioto county, but in northeast Greenup county of Kentucky, opposite Scioto of Ohio, he obtained this section: *

Coal measures:	Feet
Sandy clay with Coal Measures plants.....	8
Limestone, pure, fossiliferous.....	31
Limestone, highly sandy.....	15
Concealed.....	10
Waverly sandstone.....	215

Here the limestone shows its full characteristics, for above is the fossiliferous division and below the silicious limestone, as in Pennsylvania. These are conspicuous farther south. The extent of the Maxville east and northeast from central Ohio is not great, for in southern Noble, the county adjoining Muskingum at the southeast, a record shows it absent at Macksburg, where 21 feet of black shale intervene between the Logan and Pottsville.† Professor Orton states that it is reported in some of the well records in Jefferson, Noble, Monroe, and other counties in eastern Ohio. This is perplexing, for the limestone is absent on the Ohio opposite Steubenville, in Jefferson county, and at Macksburg, in Noble county.

Doctor Newberry states that in northwest Holmes county the Pottsville conglomerate "contains, mingled with its quartz pebbles, rather rudely rounded masses of chert, generally 1 to 3 inches in diameter, which contain Lower Carboniferous fossils." The presence of these fragments, he thinks, shows that the Maxville limestone reached at one time nearly

* E. B. Andrews: Ohio Reports, vol. iii, 1878, pp. 816-822.

† Geol. of West Virginia, vol. ii, p. 299.

to the northern border of the basin, and that it had been broken up and removed by the agencies which transported the materials of the conglomerate.* Mr Read, in his report upon Holmes county, says that the conglomerate contains "large quantities of broken angular fragments of white and yellow chert, with a profusion of fossils identified by Mr Meek as belonging to the Carboniferous formation."† The writer has been unable to find any published statement by Mr Meek in reference to this matter, and the remarks in the reports give no information respecting the horizon to which the fossils belong. In any event, the Maxville limestone in Ohio, as described by Andrews, is not cherty, and no trace of it appears north from Muskingum county, so that it can hardly be the source of the fragments; but the Lower Carboniferous limestone of Michigan, as described by A. Winchell, is cherty, as is also much of the same limestone in Kentucky, so that the presence of these chert fragments points either to Michigan or to Kentucky as the source from which they came. It suggests also an elevation of the land prior to the deposit of the Pottsville, whereby the Lower Carboniferous was exposed to subaerial erosion.

Eastern outcrop in Virginia and West Virginia.—Returning now to the easterly outcrops, we may follow the Mauch Chunk southward to the New river by the aid of the folios published by the United States Geological Survey.

In Pendleton county of West Virginia, at say 30 miles south-south-west from Westernport, Maryland, and at about the same distance south-east from the locality of Doctor White's section, on the Baltimore and Ohio railroad, Mr Darton finds

	Feet
Shales (Canaan).....	1,250
Limestone (Greenbrier).....	325 to 400

The Canaan (equivalent to Mauch Chunk of Maryland) shales contain gray and brown sandstones as well as red shale; the limestone is double, the upper division containing much calcareous shale, while the lower division is mostly massive with numerous silicious beds.‡ The deposit retains its characteristics. Messrs Taft and Brooks found on Rich mountain, in Randolph county, of the same state, at say 18 miles west from the last

	Feet	
Canaan shales.....	600 to	700
Greenbrier limestone.....		350

* J. S. Newberry: Ohio reports, vol. ii, 1874, p. 104.

† M. C. Read: Ohio reports, vol. iii, 1878, p. 545.

‡ N. H. Darton: U. S. Geol. Survey, Franklin folio, 1896.

the shales thickening southward.* The thickness of the limestone is much less than that reported by Stevenson from this region. He found a continuous exposure of 400 feet on the Staunton pike, and at 200 feet lower some calcareous shale; these measurements by barometer and without allowing for the dip. This correction would make the thickness, including the concealed space, upward of 600 feet. The same observer found remarkable variation in the shales. They are wholly absent at a few miles south from the Staunton pike, where a continuous exposure of 30 feet shows the Pottsville in contact with the limestone. Elsewhere they are present, though in at least one locality as thin as 50 feet. A thin coal bed is said to occur on Rich mountain in some shale at about 250 feet below the top of the limestone.† The shales are thicker in the southern portion of the Buchhannon quadrangle than in the northern. Everywhere the lower portion is more sandy than the upper. The lower portion of the limestone is silicious, sometimes containing a conglomerate of quartz pebbles.‡

The Rich Mountain locality is practically on the strike with White's Briery-Viaduct locality, as the Pendleton locality is very nearly on the line with Westernport. The limestone division has increased from 332 feet on the Baltimore and Ohio railroad to at least 600 feet in Randolph, and from 227 feet at Westernport to an average of 350 feet in Pendleton. The thickness of the limestone division in this area should be borne in mind during the study of the apparently perplexing conditions shown by oil-well records within some of the West Virginia counties.

Stamping creek, in Pocahontas county, West Virginia, about 40 miles south from the area of the Buchhannon folio, descends the east slope of Greenbrier mountain. Its line is perhaps 10 miles nearer the old shore than is Rich mountain and not quite so far east as the Pendleton Alleghany. The section on Stamping creek as given by Rogers is

	Feet
Sandstone and shales (Canaan, Mauch Chunk)	1,260
Limestone (Greenbrier)	822
Red shale	50

Unlike those in Randolph county, the upper shales are more sandy above, the sandstones being always fine in grain, red to gray; the shales, for the most part of "rich brownish red color," are crumbly and contain a little calcareous matter; the limestones are described as blue and gray, with argillaceous bands, and contain a cherty layer near the top.§

* J. A. Taft and A. H. Brooks: U. S. Geol. Survey, Franklin folio, 1896.

† J. J. Stevenson: Proc. Amer. Phil. Soc., vol. xiv, 1875, p. 389.

‡ J. A. Taft and A. H. Brooks: U. S. Geol. Survey, Buchhannon folio, 1896.

§ W. B. Rogers: Report of progress of Geol. Survey of Virginia for 1839, p. 92.

In 1873 Professor Fontaine made some studies in Greenbrier county, adjoining Pocahontas at the south, where he secured the following measurement:

	Feet
Shale.....	1,310
Limestone.....	822

But he gives no details, further than the shales consist of red, green, and brown sandstones and shales. At a later date he obtained at Quinimont, in Raleigh county, on New river, some characteristic Lower Carboniferous fossils from the upper part of the shales. In Summers county, southwest from Greenbrier, Fontaine estimated the shales at Richmond falls on New river as 1,450 feet, dividing them into

	Feet
Upper, red and variegated.....	310
Middle, gray shale and sandstone.....	820
Lower, red shale and sandstone.....	320

He made no estimate of the limestone further than the statement that it is evidently thicker than at the northern locality in Greenbrier.*

This brings the line to the New river of Virginia. Southward the increasing strength and number of the faults have preserved narrow strips of lower Carboniferous farther and farther east, some remaining even in the Great valley. Before continuing farther along this line, it may be best to turn to the great basin under West Virginia, so that the relations of shales and limestones along the outcrop be not forgotten. For our knowledge respecting this region we are indebted wholly to Dr I. C. White, who has preserved and tabulated a great number of well records.

West Virginia basin.—In crossing Monongalia, Marion, and Wetzel, the northern tier of counties, one notes an abrupt decrease in thickness of the Mauch Chunk. In Monongalia, at barely 20 miles from Cheat River gap through Chestnut hill, the whole interval from Pottsville to Pocono is but 210 feet, filled with "slate, shells, and red rock," 172 feet, and limestone 38 feet. The upper limestone, apparently, is wanting. At Fairview, 15 miles southwest in Marion county, the interval is given as varying from 235 to 255 feet; a detailed section in one well shows shale, mostly red, 195 feet, and limestone 70 feet; but below the latter are sand, red, soft, 5 feet, and sand, limy, yellow, hard, 22 feet, below which comes the Big Injun or Logan. This lower red sand may be the "Keener" of the drillers, which has been regarded in the previous portion of this paper as belonging to the Mauch Chunk. At ten miles farther south-

* W. M. Fontaine: Amer. Jour. Sci., vol. vii, p. 577; *ibid.*, vol. xi, p. 278.

west, near Mannington, in the same county, Doctor White's well shows the interval between Pocono and Pottsville to be 316 feet, thus:

	Feet
Shale, in great part red	191
Blue shale and limestone	28
Red rock	5
Gray limestone	92

The upper limestone is present also at 3 miles north from Mannington, where two limestones are reported at 5 and 22 feet above the silicious limestone, which is 85 feet thick. At Mannington one finds the Fairview condition, for there a white limestone, 17 feet, is found below the thin sandstone, which is marked in the driller's record as the top of the Big Injun. In northwestern Marion the interval is given in one record as 320 feet, with 5 feet of red rock and 68 feet of limestone at the bottom, the upper beds being unrecorded. It may be noted here that in very many wells there occurs, overlying the silicious or lower limestone, several feet of soft rock termed the "Pencil cave."

Great variation appears in Wetzel county, for in the northeast, near the Pennsylvania line, the thickness of Mauch Chunk is 205 feet, which is approximately that of southern Marshall in the "Panhandle," while at 12 miles south it is 257 feet, with 50 feet of silicious limestone at the bottom; but at Smithfield, 4 or 5 miles farther south, it is given as 133 feet, with the silicious limestone 88 feet, while at 2 miles northeast it is said to be 396 feet, with the lower limestone 71 feet, separated by 5 feet of "Pencil" from 20 feet of limestone above. The extreme thinness of Pottsville in this last record suggests that of the unrecorded 200 feet above the limestone much should be referred to the Pottsville. In Marion county, near the Wetzel border, 6 or 7 miles east from Smithfield, everything has disappeared except 50 feet of limestone, which lies between Pottsville sandstone, 105 feet, and Big Injun, 132 feet.

There is great dearth of detail in Tyler, which lies south from Wetzel, there being no complete record of any well in the county. In the northern part, at 20 miles west from Smithfield of Wetzel and 5 miles east from the Ohio river, the interval is given as 255 feet, with the silicious limestone, 68 feet; 5 miles west, on the Ohio river, the limestone is 97 feet, but at 2 miles farther west-southwest it is only 40 feet, while near Hebron, 12 miles farther south, the whole interval is said to be 360 feet, with the limestone 100 feet. No details are available for the little county of Pleasants, adjoining Tyler along the Ohio river, but Doctor White states that the shales disappear.*

*Geol. of West Virginia, i, pp. 236, 240, 243, 245, 343, 345, 348, 349, 356, 357, 360.

The upper division of the limestone is apparently persistent, though irregular as far westward as Wetzel county, while the distribution of the shales is very irregular; the silicious limestone is clearly persistent through the four northern counties to the Ohio river, and in such thickness that it ought to be present in eastern Monroe and northeast Washington of Ohio; but the western limit is not far away in Ohio, for a record in Pleasants county, near Eureka, on the Ohio river, appears to show that the Mauch Chunk is absent, as it gives 375 feet of continuous sandstone for Pottsville and Pocono, with no limestone for more than 300 feet above or below, and this is confirmed by the record of another well farther down the river.*

The next tier of counties consists of Harrison, Doddridge, Ritchie, and Woods, the last extending along the Ohio river farther west than Pleasants.

Sardis district is in the northwestern corner of Harrison. There, at say 10 miles southwest from Mannington, in Marion county, a well was drilled for Doctor White, and the record was kept with such scrupulous accuracy as to give a standard not only for this tier of counties, but also for that next at the south, where a record is available much farther east. The writer, in view of the conditions along the outcrops, ventures to draw the boundary between Mauch Chunk and Pocono at a somewhat lower horizon than has been done by Doctor White; but this is rather a matter of detail, as affording a more convenient mode for the comparisons to be made in later portions of this paper. The section below the Pottsville, as rearranged, is

	Feet
1. Slate and shells.....	8
2. Limestone and slate.....	10
3. Limestone, hard.....	30
4. Red rock.....	15
5. Black slate.....	37
6. Limestone, hard, blue.....	6
7. Limestone and shells.....	12
8. Red rock.....	5
9. Black shale ("Cave"?).....	11
12. Limestone.....	49
13. Sandstone, gray.....	7
14. Limestone, gray.....	32
15. Black shale.....	4
16. Limestone, gray.....	14

below which comes sandstone, 45 feet, to bottom of the well. This last may be taken as the Logan, so that the interval is 240 feet. Reference

*I. C. White: Op. cit., p. 353.

to the Marion County records shows a notable change in the upper part of the section, for the shales and sandstones have disappeared, while the upper limestones of the Mannington well have increased greatly. The general structure of the silicious limestone, numbers 12 to 16, is that observed at both Fairview and Mannington. The thickness varies, being 97 at Fairview, 146 at Mannington, and 106 at Sardis, but the extreme thickness at Mannington is due mostly to the local increase of the sandstone, number 13, which there is 37 feet. A record in the southern part of the county shows the sandstone still present, with 96 feet of limestone below it.

Near Center Point, in Doddridge county, about 10 or 12 miles west from the White well, the section is similar, though differing somewhat in detail. It is given in full:

	Feet
1. Slate.....	9
2. Limestone.....	40
3. Red rock.....	36
4. Limestone.....	13
5. Red rock.....	11
6. Slate.....	9
7. Limestone.....	31
8. Slate ("Pencil").....	15
9. Limestone.....	58
10. Sandstone.....	13
11. Shale.....	2

resting on 72 feet of sandstone to bottom of well. Here, as at Sardis, the upper shales are probably wanting, for the Pottsville rests on number 1. The limestone of the upper division has increased, as has also the upper part of the silicious limestone. The "Keener" persists, but the lower part of the limestone seems to have disappeared. Another well near by shows no shale, but a great increase in the upper limestones, which are, descending, 56, 39, 30, while the silicious has become 69 feet. Ten miles south from this locality the Mauch Chunk interval is given as 310 feet, with slate shells and limestone 230 feet; slate, 10 feet; limestone, 77 feet. This appears to show that the upper shales are present. A notable change in conditions appears in south central Doddridge, where at 8 miles east from the Ritchie county line the whole interval is but 105 feet, not including the "Keener," and the silicious is but 25 feet. The rocks above the latter are unrecorded.

Passing over into Ritchie county, one finds the records abundant and interesting. In southeastern Ritchie, about 8 miles from the last-mentioned locality in Doddridge, a record gives limestone, 18 feet; "Dark lime, shale, and hard shell," 82 feet—practically the same interval as the

last; the shales are absent and the limestones cannot be differentiated. Four miles west the record gives 69 feet of limestone, but says nothing of the overlying rocks. In northern Ritchie, at about 15 miles north from the last and about 10 miles west from the Doddridge line, the interval varies within a few feet from 20 to 75 feet, the limestone being 20 and 67 feet. There can be no doubt respecting these records, as they are given on the authority of Mr J. F. Carl. It is sufficiently clear that in this portion of Ritchie only the silicious limestone remains. At Harrisville, in the center of the county, shale, 8 feet, and limestone, 91 feet, are reported, while at Cairo one finds in the 90 foot interval 16 feet of "Pencil" resting on the limestone, which at 50 feet from the top shows a 12-foot sandstone; but the shale is absent from a well near by. Four miles northeast from Cairo no shale is present and a 10-foot sandstone is at 5 feet from the top of the limestone; but 8 miles south from Cairo the interval is 67 feet, filled with limestone. Doctor White states that the upper shales are wanting throughout Ritchie, Tyler, Pleasants, Wirt, Wood, and counties along the Ohio. In western Ritchie the interval is from 16 to 44 feet and is filled with limestone. In the Hendershot field, within central Wood county, the thickness of Mauch Chunk varies from 0 to 90 feet, the last being in the southerly part and 5 miles from the other. Near the last the record gives the interval as 48 feet, with limestones 15 and 18 feet, separated by 15 feet of shale; but at Parkersburg, on the Ohio, at 5 miles southwest, the limestone has disappeared, and between the Logan and the Pottsville one finds 65 feet of less massive rocks, which may belong to either one or the other. The limestone is absent from central and southern Washington county of Ohio, adjoining Pleasants and Wood of West Virginia.*

The western limit of the silicious limestone is along the Ohio river from north Washington county of Ohio to a little below Waverly in Wood county. It passes east from Parkersburg.

The next tier of counties consists of Lewis and Braxton at the east, then Gilmer, Calhoun, Wirt and Roane adjoining Calhoun, Jackson, and Mason along the Ohio river.

Lewis adjoins Harrison at the south. Here one finds a record of great value for the proper interpretation of the Harrison County records, for the boring was made at the extreme eastern border of the county and barely 25 miles from the exposures in Rich mountain of Randolph county. The succession is

*The references for this tier of counties are Geol. of West Virginia, vol. i, pp. 250, 253, 285, 287, 294, 296, 297, 300, 301, 303, 306, 309, 314, 315, 318, 320, 322, 325, 329, 330.

	Feet.
1. Shales.....	100
2. Sandstone.....	65
3. Limestone.....	95
4. Sandstone.....	5
5. Limestone, white.....	30
6. Sandstone.....	10
7. Red rock ("Pencil").....	5
8. Limestone.....	55
9. Sandstone.....	10
10. Limestone.....	20
11. Shale.....	50

resting on the Pocono sandstone, 215 feet. We have here the upper shales, 165 feet; the upper limestone, 140 feet; the "Pencil," 5 feet; the silicious limestone, 85 feet, and the lower shale, 50 feet; in all, the limestone is 230 feet. Comparing this with the measurements on Rich mountain by Taft and Brooks, one observes a decrease in the shales from 600 to 165 feet, which is what might be expected, since Mr Darton gives 1,250 feet for the shales farther east in Pendleton county. The limestone has decreased, though not to the same extent, there being, according to Messrs Taft and Brooks, 350 feet in Rich mountain. If Stevenson's figures for Rich mountain be accepted, the decrease in the limestone would be comparable with that in the shale. From what has been learned of conditions in the western counties, it is probable that the decrease is mainly in the upper limestone, for thus far the silicious limestone tends to hold its own. At this locality one is on the east side of the Chestnut Hill anticlinal, which has become so gentle that it is crossed by the Pittsburg coal bed. The section may be compared with that obtained by Doctor White under this axis on Cheat river. There the shales are 299 feet and the limestone 140 feet, including the silicious limestone; the shale has decreased, while the limestone has increased.

With this Lewis record may be compared that of a well drilled near Sutton, in Braxton county, about 35 miles southwest of the last and about an equal distance northwest from the Stamping Creek locality in Pocahontas county. It is very nearly on the strike with the well in Lewis county. The succession is

	Feet
1. Slate.....	30
2. Limestone.....	35
3. Red rock.....	15
4. Black shale.....	10
5. Limestone.....	50
6. Slate.....	20
7. Sand.....	15
8. Limestone.....	290

resting on a great mass of shales, the Logan having lost its massive character and assumed the shaly phase characterizing it farther south. No differentiation of the limestone is given in the record, so that one can not recognize the silicious portion; but the great increase is in the lower portion, for in Braxton, as in Lewis, the sandstone is at 130 feet below the top, while above the sandstone there is decrease of calcareous matter. The most notable feature as compared with Stamping creek is the decrease in the shales, which here are barely one-fortieth of what they are at the easterly locality and one-fifth of what they are in Lewis. The thickness of limestone is more than one-half that on Stamping creek and nearly double that in eastern Lewis, showing that while the thickness diminishes in general direction of dip, it increases southwardly along the strike.

No other record is available for Lewis until Vadis is reached, on the western border of the county, about 20 miles west from the eastern line, 30 miles due north from Sutton, and 20 miles south-southwest from the well in southern Harrison county. The succession at Vadis is

	Feet
1. Shale.....	10
2. Limestone.....	20
3. Slate.....	30
4. Limestone.....	30
5. Slate.....	75
6. Sand.....	15
7. Limestone.....	30
8. Red rock ("Pencil").....	2
9. Limestone.....	18
10. Sandstone.....	15
11. Red rock.....	5
12. Limestone.....	35

resting on the Logan sandstone, 195 feet. There is an increase in the upper limestone division, but it is due to detrital matter, for in crossing the county the limestone above the "Pencil" has decreased from 125 to 80 feet, and the upper bed of 95 feet has become two, respectively 20 and 30 feet. The decrease of the shales continues westwardly, and shows the approach of the conditions observed in Doddridge immediately west from Vadis, where within a short distance the shales, as well as most of the upper limestone and its shale, has disappeared. The change becomes more notable in the record of a well near Glenville, in Gilmer county, 10 miles west of south from Vadis and nearly on the strike with it. The record is

	Feet
1. Blue shale	25
2. Red rock	30
3. Blue shale and lime shells.....	15
4. Red rock.....	20
5. Limestone and sand shells.....	39
6. Black limestone... ..	23
7. "Pencil".....	6
8. Limestone, silicious, blue.....	57

but below the last the rock is described as "broken and limy," so that the full thickness of the silicious limestone is not given in the record. An unexpected feature is the practical disappearance of the topmost limestone of eastern Lewis, 95 feet thick, which is represented at Vadis by 50 feet of limestone and 30 feet of shale. The red rock has increased greatly, and of the upper limestones there remains only the lowest bed. Meanwhile there has been a decrease in thickness of the section and the sandstones are represented only by fine material; the Logan, as a sandstone, has disappeared, and the driller found nothing worthy of record for 639 feet below the limestone.

Doctor White gives no record for wells in Calhoun county, that adjoining Gilmer at the west, but a record at Burning Springs, in Wirt county, 28 miles northwest from Glenville, shows under the Pottsville 115 feet of limestone, "very hard, and lower half mixed with sand." Burning Springs is but 10 miles south from the locality in southern Ritchie, where 67 feet of limestone represents the whole series. Spencer, in Roane county, is 30 miles south of west from Glenville and barely 15 miles south from Burning Springs. There the limestone is 75 feet, the lower 45 feet being "gritty;" 20 feet of shale and sandstone intervene between it and the Pottsville sandstone above, and it rests on the blue shales of the Logan. In another well, 11 miles southwest from Spencer, the limestone is 86 feet, the lower portion for 25 feet being "gritty, very white," while the upper part is gray. This well is about 40 miles west from that at Sutton; within this distance the limestone has decreased 360 feet.

Jackson county lies west from Wirt and Roane. The record is at Ravenswood, on the Ohio river, 25 miles from Spencer, 30 from Burning Springs, and 25 south of west from Parkersburg, in Wood county. The succession is

	Feet
1. Shale.....	42
2. Limestone and sand.....	38
3. Black shale.....	12
4. Limestone.....	68
5. Limestone and sand.....	50

resting on the mass of Logan shale. The 118 feet at the bottom may be taken to represent the silicious limestone; the black shale, the "Pencil" of wells farther east. In that case number 2 would represent the upper limestone and number 1 would be either the upper shales or continuous with the upper portion of the limestone. That these are the proper assignments appears very probable from the record of a well 25 miles southwest from Ravenswood, in Mason county, opposite Gallipolis, Ohio; for there the driller reports shale 45 feet, limestone 165 feet, separated from the hard Logan below by 10 feet of shale. The limestone is not differentiated in the record. Gallipolis is less than 30 miles east from Maxville exposures in Ohio. At Letart, in northern Mason, on the Ohio, and 12 miles west from Ravenswood, the condition is sufficiently clear, for there one finds

	Feet
1. Limestone.....	60
2. Hard sand and gray shale.....	4
3. Limestone....	10
4. Gray sand and limestone.....	24

Number 1 is the Maxville limestone as exposed in central Ohio, and numbers 3 and 4 are the silicious limestone, which is becoming thinner in this direction, to disappear before the Maxville outcrop has been reached. It will be remembered that Andrews discovered this portion of the limestone in Kentucky.*

Kanawha county lies south from Roane. At the Burning spring, 40 miles south from Spencer, blue limestone, 300 feet thick, underlies the Pottsville and rests on shales of apparently great thickness. The lower portion of the limestone is more or less silicious, but the driller did not differentiate the portions, so that their respective thicknesses can not be given. This locality is about 50 miles south-southwest from Sutton, in Braxton county, and probably 10 miles westward off the line of strike from that place. The limestone is considerably less than at Sutton, but detrital beds appear to form a very small part of the mass. At Central City, in Cabell county, 50 miles west from the Burning spring and 30 miles south from Gallipolis, the limestone is 150 feet, with 28 feet of shale between it and the Logan below. Andrews's section, in Greenup county, Kentucky, is less than 30 miles west from Central City.

Lincoln county is southeast from Cabell and southwest from Kanawha. In its southern portion, on the border of Mingo county, a record gives 235 feet of limestone divided at 75 feet from the bottom by 2 feet of sandstone. This is 35 miles south-southwest from the Burning spring

*The references for this tier of counties are Geol. of West Virginia, vol. i, pp. 255, 258, 260, 262, 264, 268, 270, 274, 282, 284.

and about 10 miles off the strike westward. Mingo county, adjoining Lincoln at the south, extends to the Kentucky line at the Big Sandy river. Near Dingess, 10 miles west-southwest from the last locality, a record gives

	Feet
1. Black shale.....	22
2. Gray limestone.....	6
3. Red rock.....	4
4. Gray limestone.....	2
5. White shale.....	4
6. Red rock.....	2
7. White shale.....	34
8. Gray shelly limestone.....	51
9. White hard limestone.....	125

resting on the Logan sandstone. The shaly upper portion, 72 feet, is about the same as in Lincoln county, but contains limestones. The shales thicken westwardly, for, at 10 miles away on the Big Sandy, opposite Warfield, Kentucky, they are 153 feet, with 4 feet of limestone separating them from 60 feet of shale and sandstone, while at a little farther south they are 195 feet, resting directly on 40 feet of sand, with no intervening limestone. The main limestone thickens southwardly, being 205 feet at the last locality, where the whole thickness is 440 feet. It is easy to recognize in this Mingo County section the Chester and Saint Louis limestones of the Kentucky geologists.*

Along the eastern and southern outcrops.—Returning now to the outcrops at the east, south from the New river and eastward into the Great valley, information is wanting respecting the counties of Highland, Bath, and Alleghany, Virginia, which are east from Pocohontas and Greenbrier of West Virginia, as well as respecting Monroe of West Virginia, south from the New river. The numerous faults beyond the Alleghany mountains of Virginia, beginning near the Greenbrier river, have led to the preservation of narrow strips of Mississippian farther toward the Great Valley than at the north, so that in Montgomery, Pulaski, Wythe, and Smyth counties small areas remain even in the valley itself.

In the petty areas of Mississippian within the Great Valley, already referred to in the previous pages on the Pocono, the Mauch Chunk is represented almost wholly by shale. No measurements are known for the Catawba Mountain area, but in the Price mountain of Montgomery Professor Fontaine measured 1,090 feet of shale, which he regards as in part contemporaneous with the Greenbrier limestone.* The shales are present in the little area along the Norfolk and Western railroad west

* The references for these counties are Geol. of West Virginia, pp. 272, 275, 277, 278, 279, 280.

* W. M. Fontaine: Amer. Jour. Sci., vol. xiii, p. 119.

from Pulaski, but they have suffered so severely from erosion that the writer made no effort to estimate their thickness. The silicious limestone is there, but very thin, less than five feet.

The Brush-Cloyd-Little Walker Mountain strip, forming the northerly boundary of Montgomery, Pulaski, and Wythe counties and extending a little way over into Smyth county, shows no limestone in Montgomery, according to Fontaine and Stevenson. The latter found no limestone in Pulaski county, and only the silicious limestone 7 or 8 feet thick in western Wythe. The thickness of the shales in New River gap, through Little Walker mountain, was estimated at 996 feet, the boundary between Mauch Chunk and Pocono being drawn arbitrarily, there being no limestone present; but the limit as given accords with the place of the silicious limestone in Wythe and Bland. The silicious limestone, still very thin, was seen in southern Bland county, north from Wythe, along the foot of Brushy mountain, where also a streak of coal occurs in the overlying shales. The shoreward boundary of the silicious limestone extended along the strike within the valley little farther than the eastern border of Wythe county. It may have reached as far as the line of the Blue Ridge, for the fragment on the Norfolk and Western railroad is within 12 miles of the pre-Cambrian rocks. The limestone mass, so thick at only a few miles west and northwest, appears to be represented in Wythe and Bland only by a few feet of the silicious limestone and to be wholly wanting in Pulaski and Montgomery.*

The fault of Walker mountain diminishes westwardly, so that its Mississippian area is cut off suddenly at a little way beyond the Smyth County line; but the great Saltville fault increases in that direction, and its Brushy Mountain exposures continue through Smyth and Washington counties into Tennessee. Along this line the limestone increases in thickness, so that in central Smyth county it becomes a notable feature, attaining its greatest thickness in Washington where the Holston river breaks through Brushy mountain. There Stevenson estimated the shales at 1,000 feet, the upper limestone at 1,270 feet, and the lower at 755 feet. These were merely estimates made during a preliminary reconnaissance, and they are doubtless excessive. The shales consist of red shales, fine grained sandstones, and grits, with some thin limestones, the

*J. J. Stevenson: Proc. Amer. Phil. Soc., vol. xxiv, pp. 75, 76, 100. Mr M. R. Campbell visited this region several years after the publication of results obtained by Fontaine and Stevenson. He came to very different conclusions respecting the relations of the Price Mountain shales, as well as of those along Little Walker mountain. He does not regard them as contemporaneous with the Greenbrier limestone, as he recognizes that limestone in Wythe county, where he finds a thickness of about 1,500 feet, as opposed to the practical absence of limestone asserted by Stevenson. It is impossible to reconcile these figures, and nothing can be done now further than to state the case. For the present, however, the writer prefers to accept his own observations as apparently in accord with conditions in similar petty areas farther south.

whole becoming more or less calcareous in the lower portion. The upper limestone is not wholly exposed, there being a concealed space, estimated at 250 feet, beginning at 105 feet from the top and containing in its upper portion a thick bed of sandstone. Apparently at least one-half of the total thickness is shale, of which one bed, estimated at 150 feet, is almost midway in the section. Many of the limestone layers are very impure. The fossils from beds as far down as to within 80 feet from the bottom are similar to those obtained from the upper limestones in southwest Pennsylvania. The lower limestone is very distinct from the upper. Chert is present in almost every bed. Some shales are present, but limestone predominates throughout. The fossils differ from those in the upper limestone.* Mr Campbell has named the shales Pennington and the whole limestone Newman. Along the same line in Scott county of Virginia and in northern Tennessee the thickness of the Newman limestone is estimated by Mr Campbell as at least 1,500 feet, but he makes no estimate there of the Pennington, as it has suffered much from erosion.†

A space 15 or 20 miles wide intervenes between the Brushy Mountain strip of Mississippian and the next at the northwest, the latter being not very far off the strike with the Alleghany of Pendleton, Alleghany, and Greenbrier counties. No information is available at present for Monroe county of West Virginia, but observations are recorded for Summers and Mercer counties, those lying next to Monroe on the dip. These observations are somewhat at variance.

Professor Fontaine, as already stated, found near Hinton, in Summers county, shales 1,450 feet resting on the limestone. Mr Maury gives 3,500 feet as the aggregate thickness of the whole Mississippian in the neighborhood of Hinton, which, after deducting 1,160 feet for the Pocono, as measured by Fontaine, would give somewhat more than 2,200 feet for the limestone and shales.‡ Messrs Campbell and Mendenhall describe the Hinton formation, the upper portion of the shales, as a "heterogeneous mass of variegated shales and sandstones of varying character and impure limestones, ranging in thickness from 1,050 to 1,100 feet." The lowest bed is a heavy sandstone, which is above the river bed at Hinton. They call especial attention to the conglomerate character of this sandstone, the pebbles consisting of dark slightly sandy shale. They see evidences of local erosion in the finer portions of the sandstone, the eroded portions being filled up with the conglomerate.§ Apparently

* J. J. Stevenson: Proc. Amer. Phil. Soc., vol. xxii, p. 135; the same, vol. xix, p. 258 et seq. The measurement given for the lower limestone in the latter paper should be diminished by 100 feet, as the lowest portion should be referred to the Granger shales of Campbell, which are Devonian.

† M. R. Campbell: U. S. Geol. Survey, Estillville folio, 1894.

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

§ M. R. Campbell and W. C. Mendenhall: Seventeenth Annual Report U. S. Geol. Survey, 1896, pp. 487-489.

the Hinton formation includes the upper and middle portion of Fontaine's Umbral shales.

Beyond New river, in Summers and Mercer counties, Mr Campbell finds the Hinton about 1,200 feet, very largely red shales, resting on the Bluefield, 1,200 feet thick, mostly blue shale and very calcareous at the bottom. The latter must be the equivalent of Fontaine's lower division, and the whole is equivalent to the Pennington shale of Campbell, in Scott county of Virginia. Above the Hinton is a mass of sediment, which Mr Campbell placed at one time in the Mississippian, but in the paper just quoted it is transferred to the Pottsville.* There is substantial agreement respecting the thickness of the Hinton formation, Fontaine making it 1,130 feet on the Chesapeake and Ohio railroad, where Campbell finds 1,050 to 1,100 feet. Stevenson gives for southern Summers 973 feet down to the top of the great sandstone at Hinton, while Campbell gives as the average of the Hinton for Summers and Mercer about 1,200 feet. The especial difficulty is in the extraordinary thickening of the lower portion of the Fontaine section, the Bluefield of Campbell, an increase of 400 per cent within a few miles from New river. The Greenbrier limestone, in northeast Tazewell, adjoining Mercer, is given by Campbell as about 1,200 feet, but it decreases westwardly so as to be only 900 feet in the western portion of that county, where the lower beds are very cherty. Northeast Tazewell is barely 25 miles north from the Little Walker locality, in Wythe, where only the lowest part of the limestone remains.

The weakening of the faults in west-southwest direction soon cuts off the narrow strips observed in Tazewell and Scott counties, and the next exposures are found in Wise and Lee counties of Virginia, the latter on the Tennessee border, along the edge of the Cumberland plateau. It will be remembered that Mr Campbell estimated the thickness of the Newman limestone in Brushy mountain near the Tennessee line at not less than 1,500 feet. This is in Scott county. Barely 25 miles northwest one comes to Big Stone gap, in Wise county, where Mr Campbell finds 829 feet of Newman limestone and 1,025 feet of Pennington shale. The latter is shown at 10 or 15 miles farther northwest, in Hurricane gap, through Pine mountain, in Kentucky, with a thickness of 890 feet.† The Pennington consists of shales, sandstones, and a few thin limestones, one of which, near the middle, is fossiliferous. There is a similar bed at this horizon in the Hinton. The lower third consists almost wholly of sandstone. The limestone section as given by Mr Campbell is separable into an upper division of 451 feet and a lower of 378 feet. The

* M. R. Campbell: U. S. Geol. Survey, Pocahontas folio, 1896; Tazewell folio, 1897.

† Professor Crandall, of the Kentucky Geological Survey, represents the Pottsville as in contact with the limestones in Hurricane gap.

upper contains only 155 feet of limestone in nine beds, all of them impure and many of them apparently approaching calcareous shale. Of the rest, 81 feet are described as calcareous shales or calcareous sandstones. The important sand deposits are at about 90 feet from the top. It is evident that in this direction the mass is not only thinner, but less calcareous than in the Brushy Mountain region. The lower division is described as "heavy blue limestone, becoming cherty toward base."* This must be kept in mind during the study of the Bangor limestone farther south. At Pennington gap, in Lee county, Stevenson estimated the lower part of the Pennington shales at 350 feet and the limestone at 765 feet. The characteristics of the several portions resemble those given by Mr Campbell. Heavy sandstones are at the bottom of the shales, and the lower part of the Newman is a massive limestone. The conditions suggest that the lower part of the New River section has disappeared in the shales, and that there remains here only the Hinton of Campbell, the upper and middle portions of Fontaine's grouping.

Eastern outcrops in Tennessee.—The Brushy Mountain strip of Newman (Greenbrier) limestone extends into Tennessee not more than 15 miles, as the Saltville fault loses strength. The thickness remains about the same as in Virginia, 1,500 feet, but, excepting 100 feet of massive limestone at the bottom, it consists of shales and shaly limestones. Farther westward, in Claiborne county, along the face of the Cumberland plateau, it has 700 feet of solid limestone, strangely in contrast with the condition in Lee and Wise counties of Virginia along the same line.

A petty area like those of Wythe and Montgomery counties of Virginia remains in Blount county on the Chilhowie mountains, not more, according to Safford's map, than 15 miles from the pre-Cambrian rocks. There the thickness of the Newman is about 600 feet, with limestone at the bottom, rich in fossils, but the greater portion above consisting of shales carrying a little limestone. The thickness increases somewhat northwestwardly, so as to become 700 feet, with the lower portion containing much chert. Along the face of the Cumberland plateau the condition observed in Claiborne county continues southwestwardly through Campbell and Anderson, the Newman limestone varying from 600 to 700 feet, mostly limestone, and with few beds of shale. Near Big Spring gap it shows 130 feet of cherty limestone at the bottom, which is not equally conspicuous elsewhere. The Pennington shale, like the Newman limestone, increases southwardly, and varies from 160 to 400 feet; but the whole series decreases westwardly, for in Morgan county

* M. R. Campbell: *Geology of Big Stone Gap coal field*. Bull. U. S. Geol. Survey, no. 111, 1893, p. 39.

the limestone becomes 400 feet, while in the northern part of that county the Pennington shales disappear. The limestone contains a 10 to 30 foot sandstone at 150 feet from the top.*

The eastern portion of the Cumberland plateau is known as Waldens ridge in Roane, Rhea, and Hamilton counties, the last extending to the Alabama-Georgia line. The Newman limestone of Mr Campbell is divided by Mr Hayes into Bangor limestone above and Fort Payne chert below—a distinction more or less exact for the whole eastern outcrop. Mr Hayes finds the Fort Payne 75 feet thick in Roane, but at a little way farther east it is hardly distinguishable from the overlying limestone. It thickens southwestwardly until it becomes 150 feet in Hamilton; at the bottom it consists almost wholly of heavy beds of chert with little shale or limestone, while higher up it is more calcareous and passes gradually into the limestone above. This is the silicious group of Safford, † and Mr Hayes's description enables us to recognize here both divisions of that group, the Protean or Logan below the more calcareous Lithostrotion above. The Bangor of Hayes, equivalent to the Mountain limestone of Safford and the upper Newman and Pennington of Campbell, attains great thickness along this eastern side of Waldens ridge, being apparently nowhere less than 800 feet, while in Hamilton it is reported as 1,100 feet, which, added to the 150 feet of Fort Payne, makes nearly twice the thickness reported from the Chilhowie mountains. In the White Oak mountains, about 15 miles east from Chattanooga and very near the Georgia line, a condition begins which becomes more noteworthy in Alabama. The upper part of the Fort Payne becomes a calcareous sandstone and is separated from the Bangor limestone by from 600 to 800 feet of mostly black carbonaceous shale, the Floyd shale of Mr Hayes. This he recognizes as contemporaneous with the lower portion of the Bangor farther west, for the limestone is but 600 feet thick. The Floyd shale contains a few streaks of impure limestone. A narrow strip of Mississippian is shown on the west side of Waldens ridge in Cumberland, Bledsoe, Sequatchie, and Marion counties, about 12 miles from the east face of the ridge. It is known as the Sequatchie valley and extends for many miles into Alabama. The Bangor is from 800 to 1,100 feet thick in this valley, and a hard sandstone, 15 to 20 feet thick, is seen at many places about 280 feet from the top ‡

Outcrops in Georgia.—Somewhat isolated areas of the Mississippian remain in northwestern Georgia, west from the Oostanoula and north

* Arthur Keith: U. S. Geol. Survey folios—Morristown, 1896; Knoxville, 1895; Loudon, 1896; Briceville, 1896; Wartburg, 1896.

† J. M. Safford: *Geology of Tennessee*, pp. 332-339.

‡ W. C. Hayes: U. S. Geol. Survey folios—Kingston, 1892; Chattanooga, 1892; Pikeville, 1895.

from the Coosa river. The White Oak Mountain area of Tennessee, extending into Catoosa county, may be regarded as on the strike with Taylors ridge in Catoosa, Walker, and Chattóoga counties, which may be taken as the westerly boundary of the Valley outcrops. The area in Catoosa is insignificant, 1 to 2 miles wide, but southward its width becomes fully 12 miles and the eastern edge is in Whitfield, Gordon, and Floyd, or about as far toward the old land as the Chilhowie area in Blount county of Tennessee. The condition observed in the White Oak mountains within Tennessee becomes more marked. The Fort Payne appears to be about 75 feet thick, very cherty below, and showing coarse, cherty sandstones above, which Mr Hayes thinks were originally more or less calcareous. The Floyd shale, synonymous with the Oxmoor sandstone of the later Alabama reports, is mostly sandstone in the White Oak mountains of Catoosa county, but mostly black carbonaceous shale in Floyd and Chattooga, becoming rather more calcareous westward toward Taylors ridge. A thin-bedded sandstone is in the upper portion. The Floyd is from 1,350 to 850 feet, decreasing northwestwardly. The Bangor is found east from Taylors ridge and 500 feet thick, so that it must have extended at one time eastward into Floyd county. Westward, in Walker and Dade counties, around the northern end of Lookout mountain and along the easterly face of Sand mountain (Waldens ridge of Tennessee), the Floyd shale is wanting, the Fort Payne becomes 200 feet, and the Bangor 750 feet.*

Eastern outcrops in Alabama.—From Georgia there passes into Alabama the narrow strip on the east side of Lookout mountain, the broader strip between Lookout and Sand mountains; from Tennessee, the Sequatchie valley, known in Alabama as Browns valley. The earlier work by Mr Hayes, which gave the structure and set forth the succession, has been superseded by Mr McCalley's detailed work for the Alabama survey, so that the latter must be the guide in tracing the formations through this state.

The extreme southeastern exposures are in an irregular but almost continuous area, crossing Calhoun, Saint Clair, Talladega, and Shelby counties, which may be regarded as lying a little farther eastward than the Floyd-Gordon area of Georgia. Here the Fort Payne diminishes southwardly and southwestwardly, the thickness varying from 275 to 0 feet. It disappears in southern Shelby and southwestern Talladega; along the southeasterly side of the area in Calhoun it is not more than 25 feet; but in Saint Clair it becomes 275 feet, and with increasing thickness shows an increase of calcareous matter. The Bangor limestone is

* W. C. Hayes: Geol. Survey of Alabama, Bull. no. 4, 1892, pp. 44-48; U. S. Geol. Survey, Ringgold folio, 1894.

absent throughout, being represented by the Oxmoor sandstone, which includes the Floyd shale of Hayes. This contains irregular beds of nodular limestone, occasionally some chert, and usually has at the bottom one or two beds of massive sandstone, one of which sometimes becomes conglomerate at the extreme southeast exposures in Talledega and Shelby; but for the most part it is made up of black shale. The thickness is from 1,000 to 1,500 feet, being greatest at the southeast.*

The next line of exposures enters northern Cherokee county, Alabama, from Chattooga of Georgia. The conditions in these petty areas are practically the same with those in the southeasterly face of Lookout mountain, a few miles farther north. The Fort Payne is very thin, 25 feet at the southeast, but becomes 250 feet on Lookout mountain, not more than 12 miles away toward the west-northwest. Along this latter line it shows a limestone at the top, very pure, though containing rows of nodular chert. The Bangor is represented by the Oxmoor, which shows no limestone along Lookout mountain, though some irregular but rather persistent beds are seen farther southeast. Sandstones occur at various horizons, but the persistent beds are at the bottom. The thickness varies from 1,000 to 1,900 feet, the increase being toward the northwest. This line of exposures ends near Gadsden, in Etowah county.†

A third line of exposures enters De Kalb county from Dade of Georgia, about 6 miles northwest from the last. It is on the northwest side of Lookout mountain, which it separates from Sand mountain, the continuation of Waldens ridge. This is Wills valley, whence a series of irregular strips extends southwestwardly through De Kalb, Etowah, Saint Clair, Jefferson, Tuscaloosa, and Bibb counties. The Fort Payne varies with some irregularity. It is 200 to 300 feet in De Kalb, 150 to 275 feet in Etowah and Saint Clair, 250 to 300 feet in Jefferson and Tuscaloosa, but diminishes rapidly to 50 feet in Bibb, where, however, the little patches lie somewhat to the southeast of the principal line of exposures. The lower portion is largely chert, with some crinoidal limestone, but the upper portion contains some pure limestone, especially in the northern counties. The Bangor limestone, 500 to 600 feet thick, is present in the northern counties, with massive sandstones at the bottom, but is wanting in Jefferson, where the Oxmoor is present, 800 to 1,200 feet thick, and showing the massive sandstone at the bottom overlying a pure limestone. The condition is the same in Tuscaloosa, except that the limestones seem to be absent. In Bibb county the thickness of the mass

* Henry McCalley: Geol. Survey of Alabama, the Valley regions, vol. ii, pp. 292, 300, 304, 526, 528, 530, 531, 643, 645, 740, 746.

† Henry McCalley, vol. ii, pp. 249, 809 to 812.

‡ Henry McCalley, vol. ii, pp. 172, 183, 184, 245, 249, 300, 304, 410, 422, 476, 478, 504.

diminishes to 600 feet, and some irregular streaks of limestone are shown.

The next important strip is in Browns valley, the continuation of Sequatchie valley of Tennessee, which enters Jackson from Marion of that state. This lies beyond Sand mountain and extends southwestward through Jackson, Marshall, and Blount counties, about 20 miles northwest from Wills valley ; but in Blount county is Murphrees valley, about midway between Browns and Wills, to which reference must be made, as it marks the transition between conditions at the east and those so well marked at the west.

The Fort Payne chert is about 300 feet thick in Murphrees valley, The rather pure limestone already mentioned as occurring at several localities in the upper part of the Fort Payne, here becomes so well marked that Mr McCalley has divided the Fort Payne into the Tuscumbia above, about 175 feet, and the Lauderdale chert below, about 125 feet, these corresponding closely to the Lithostrotion and Protean of Safford in southern Tennessee, the latter being that regarded in the former chapter as equivalent to the upper portion of the Pennsylvania Pocono. Here also the sandstones of the Bangor become so well defined that Mr McCalley sets them off from the Bangor under the name of Hartselle sandstones. Eastward one finds massive sandstones at the base of the Bangor and Oxmoor and at one locality a limestone below them. In this valley sandstones are at the top of the Hartselle, while below them are limestones, shales, and sandstones. The Bangor limestone, as defined by McCalley, is about 300 feet, consisting of interstratified limestones and shales, while the Hartselle is not far from 150 feet.*

Within Jackson and Marshall, in Browns valley, the Fort Wayne is from 225 to 300 feet thick, and the two divisions can be distinguished, though not so sharply as in Blount county where the mass is thicker, the Lauderdale being 175 to 225 feet, and the Tuscumbia 125 to 150 feet. Throughout this valley the Lauderdale is almost wholly chert, while the Tuscumbia consists of cherty limestone. The total thickness of the Bangor is 600 to 800 feet in Jackson and 500 to 600 feet in Marshall, but the sandstone at the base is very irregular. The sandstones may not be the upper but the bottom sandstones of the Hartselle, for in Dorans cove, in northeastern Jackson, there is a 25-foot sandstone at 75 feet below the top of the limestone. In Blount county the Bangor has 300 to 350 feet of limestone and calcareous shale, while the Hartselle is from 150 to 225 feet, with massive sandstones 5 to 80 feet on top,

* Henry McCalley, vol. i, pp. 395 to 407.

a thin sandstone at the bottom, with shales and limestones in the interval. The limestones diminish southwardly. This valley terminates in southwest Blount, nearly 100 miles farther north than the exposures in Bibb county.*

Here one has reached the southern extremity of the eastern exposures; farther southward the Carboniferous is buried under the Cretaceous and later deposits, so that the final conditions in that direction can not be ascertained. On the westerly side of the Plateau area exposures are almost continuous in Alabama, the rocks forming a broad band across the northwestern seven counties of the state and reaching a little way over into Mississippi, the breadth of exposure being due to absence of disturbance. The deep trenching by the Tennessee river near the northern line of the state has removed the upper beds, so that north from that river, in Madison, Limestone, and Lauderdale counties, one finds practically only the equivalents of the Fort Payne, while south from the river, in Morgan, Lawrence, Franklin, and Colbert, only the equivalents of the Bangor occur, underrunning the Coal Measures near the southern border of the first three and the Cretaceous in the last.

Western outcrops in Alabama.—Some deep valleys in western Jackson (on the Tennessee line) reach the Bangor, which shows at from 160 to 200 feet from the top an apparently persistent sandstone, which is probably the upper Hartselle, the limestone below it being cherty. In Madison, just west from Jackson, both divisions are shown fully; the Bangor exhibits abrupt variations, being 200 feet in the northeastern part of the county, but only 100 feet at a little way southeast from Huntsville, while it is 200 feet at the Tennessee river in the southeastern corner of the county, beyond which it passes under the Coal Measures. These abrupt changes and the condition in western Jackson lend countenance to the suggestion that the Dorans Cove sandstone of northeastern Jackson may be the upper Hartselle. The Hartselle in Madison is 150 to 225 feet thick, with a persistent sandstone on top and a thin flaggy sandstone at the bottom, the interval being filled mostly with more or less cherty limestone. All of the sandstones decrease eastwardly, but the upper one persists. In Morgan, south from Madison and west from Blount, the Bangor is thicker, 400 to 425 feet, and portions are as cherty as the Lauderdale, while the Hartselle is from 200 to 300 feet. The sandstones of the latter are thin at the east, but thicken westwardly, the upper bed becoming 100 feet, and the limestones are cherty everywhere. The Bangor is slightly thicker in Lawrence, sometimes reaching 450 feet, while the Hartselle is 300 to 350 feet, the upper sandstone becoming 150 feet and the bottom sandstone 15 feet. In Franklin, west from

* Henry McCalley, vol. i, pp. 307, 309, 320, 360-367, 402, 407, 409, 410.

Lawrence, the Bangor is 350 to 400 feet. In Colbert, north from Franklin, the Hartselle shows unexpected variations; the upper sandstone is apparently 150 feet at La Grange, but it becomes thinner westwardly, for midway in the county are two sandstones, 50 and 25 feet, separated by 25 feet of limestone and overlying 75 feet of sandstone, limestone, and shale; limestone predominates on the Mississippi border, for there the upper sandstones are 30 to 40 feet and 25 feet respectively, separated by 35 to 40 feet of limestone, while lower down are 60 feet of limestone. The bottom sandstones vary from 5 to 15 feet.*

The Fort Payne is very clearly separable into the Lauderdale and Tuscumbia. In Madison both are very cherty and both contain beds of limestone, but the chert of the Tuscumbia is nodular, not bedded. In Limestone the Lauderdale is 175 to 225 feet, and the Tuscumbia 150 to 200 feet, while in Lauderdale the lower division is 175 to 250 feet, with, in the northwest, a thick shale toward the bottom, which disappears southeastwardly. In these counties the Lauderdale becomes more and the Tuscumbia less cherty as one follows them westward.†

Western outcrops in Tennessee.—Professor Safford's notes on the Mississippian of central Tennessee are full and one has in addition, for the southern counties, the résumé of Mr Hayes's observations, and for the extreme northern counties those of Mr Campbell. The exposure with which this chapter has to do forms a broad band crossing the state from south to north through Lincoln, Franklin, Coffee, Warren, De Kalb, Putnam, Overton, and Pickett counties, with extensions eastward into valleys within the Cumberland plateau. This band is separated by the Central Basin of Tennessee from the western area of Mississippian in the state, which is continuous at the south with Lauderdale and Limestone counties of Alabama, and at the north with the western area in Kentucky. The division in Tennessee is wholly due to erosion, and the areas are very nearly united at both the northern and the southern border of the state. As the western area is part of the Mississippi region, which farther north lies west from the Cincinnati peninsula, only incidental reference will be made to it after description of the west side of the Cumberland plateau.

Mr Hayes does not separate the Lauderdale and Tuscumbia—the Protean and Lithostrotion of Safford—using only the term Fort Payne, which includes both. He mentions that the Fort Payne is very silicious at the bottom, often only chert, while calcareous matter increases upward so as to make a gradual transition to the Bangor. The thickness

* Henry McCalley, vol. i, Jackson county, 323, 327; Madison, 140, 144; Morgan, 250, 251, 252, 258, 261, 266; Lawrence, 224, 230, 234; Franklin, 190, 197; Colbert, 154, 157, 161, 166, 176.

† Henry McCalley, vol. i, Madison, 125, 126; Limestone, 115, 119; Lauderdale, 92, 103.

in Franklin and Grundy is not far from 200 feet, but at the north it becomes 225 feet. The Bangor (embracing Hartselle and Bangor of McCalley) is 800 to 900 feet thick at the south, but becomes thinner northward in Grundy and Warren. The upper portion is described as argillaceous and as weathering to bright argillaceous shales—a feature frequently referred to by Mr Hayes in description of the Bangor along the eastern outcrops in this state. No mention is made of any sandstone in Franklin, but in Grundy and Warren a sandstone 15 to 20 feet thick was found at from 150 to 180 feet below the top.*

The work by Mr Hayes enables us to make more intelligent use of Professor Safford's detailed statements. That geologist obtained the following section in Franklin county, near Cowan :

	Feet
1. Shale and some limestone.....	85
2. Limestone.....	32
3. Shale and some limestone.....	70
4. Limestone.....	214
5. Shales and limestone.....	26
6. Shale.....	26
7. Sandstone.....	8
8. Shale.....	31
9. Limestone.....	13
10. Shale.....	27
11. Limestone.....	196
Total.....	704

below which he found about 110 feet of the Tuscumbia (Lithostroton). The sandstone is here 437 feet below the top as compared with 280 feet in the Sequatchie valley only a few miles eastward. Number 11 shows cherty layers at 80 feet from the bottom, and the Tuscumbia is apparently chert-bearing limestone throughout. The sandstone of the section may be one of the lower Hartselle.†

In White county, northeast from Warren, where Mr Hayes found 700 feet of Bangor, Professor Safford found 601 feet, which shows that the rate of decrease indicated by Mr Hayes continues. The character of the deposit is changing, as appears from the section, which is condensed from the original :

	Feet
1. Limestone.....	40
2. Mostly shales.....	115
3. Shales and limestones.....	70
4. Limestone.....	123

* W. C. Hayes: U. S. Geol. Survey folios—Sewanee, 1894; McMinnville, 1895.

† J. M. Safford: Geology of Tennessee, pp. 357-358. The section as given is condensed from the original.

5. Sandstone.	Feet 40
6. Limestone.....	123
Total.	601

The sandstone has become thicker and it forms a well defined bench. The limestone is disappearing from the upper portion. The Lithostrotion is 244 feet thick at one locality in this county and contains much chert, which, however, is mostly nodular and much of it is fossiliferous.*

Mr Campbell, in Putnam, Overton, and Pickett counties, northeastward from White to the Kentucky line, finds the conditions similar to those on the east side of the plateau, and reports

Pennington shales.....	Feet 90 to 300
Newman limestone....	400

About midway in the Newman he finds a sandstone, 40 to 60 feet, shown along the face of the plateau.†

Mr Campbell's average differs somewhat from the section obtained by Professor Safford in the southern portion of the area embraced in the Standing Stone quadrangle, and evidences the continued decrease northward. Professor Safford's measurements are:

1. Blue limestone.....	Feet 4
2. Shales, marls, etcetera.....	52
3. Limestones.....	154
4. Shales.....	6
5. Sandstone.....	48
6. Limestone.....	168
Total.....	432
7. Lithostrotion.....	203

Numbers 1 and 2 probably represent the Pennington shales, which thicken northward at the expense of the limestone, the upper part of number 3 being very largely argillaceous limestone. The sandstone is evidently one of those in the Hartselle, and it was identified by Professor Safford with that seam east from Huntsville in Alabama. The Lithostrotion contains much chert, but the bottom 75 feet is "an impure limestone of water lime aspect."‡

The Mountain limestone of Safford extends westward for only a few miles beyond the Cumberland plateau, so that one finds beyond the

* J. M. Safford: Op. cit., pp. 355-356.

† M. R. Campbell: U. S. Geol. Survey folio, Standing Stone, 1899.

‡ J. M. Safford: Op. cit., pp. 353-354.

Central Basin only the silicious group as in Lauderdale, Limestone, and most of Madison in Alabama. The whole area is bounded at the west practically by the Tennessee river, and the Tuscumbia or Lithostrotion is confined almost wholly to the region north from the Cumberland river. At Clarksville, in the northern part of the area, the Lithostrotion bed shows :

	Feet
1. Not exposed..	30
2. Limestone, slightly cherty.....	15
3. Limestone, no chert, lower third, oolite.....	120
4. Limestone, more or less cherty.	30

The extreme thickness in the northwest corner is about 250 feet, and the limestones contain nodular chert. There is a contrast with the Overton County section, for there the upper 128 feet is largely cherty, while in this western area the chert is insignificant.*

Western outcrops in Kentucky.—In northern Kentucky the Appalachian and Mississippian areas are separated by the Cincinnati peninsula, beyond whose southern termination to the Tennessee line the separation continues, as erosion has removed all rocks newer than the Devonian.

Unfortunately not much of detail is available with reference to Kentucky. The early survey under Doctor Owen ended abruptly with his death, in 1860. Up to that time the work had been very largely that of reconnaissance, and such detailed work as had been done was almost wholly economical, so that the references to Lower Carboniferous deposits are little more than incidental. The same remarks apply almost equally to the second survey, which was prosecuted with much energy to determine as rapidly as possible the coal and iron resources of the state. There is lack of information respecting the limestone, so that one finds difficulty in carrying forward to the Ohio river the differentiation of formations seen so clearly in Alabama and Tennessee. Enough, however, is afforded by the scattered observations in the several counties to make the general conditions clear.

Clinton county of Kentucky adjoins Pickett of Tennessee. Mr Loughridge's section in this county shows the groups as in Tennessee, but with decreasing thickness of the Bangor. His section on Poplar mountain, in the eastern portion of the county, shows—the subdivision and the nomenclature being ours :

1. Bangor:	Feet
Shales and marls.....	130
Limestone.....	73

*J. M. Safford : Op. cit., pp. 340, 345.

2. Hartselle:	Feet
Sandstone.....	25
Limestone.....	164
3. Tuscumbia:	
Limestone, cherty.....	140

The upper portion of the Bangor, as here given, is evidently the Pennington shale of Campbell. Mr Loughridge places the Bangor and the sandstone of the Hartselle in the Chester and the rest of the section in the Saint Louis; but the cherty limestone at the bottom is distinctly the Lithostrotion bed of Tennessee, containing that fossil in abundance, so that it is separated here in order to follow the northward variation more easily.*

Pulaski is northeast from Clinton. There Professor Crandall finds the Chester well exposed in the northern and central parts of the county, where it varies from 25 to 40 feet of earthy limestone with greenish reddish shales. He does not refer to the presence of any sandstone, and gives the Saint Louis as 250 feet thick in the western part of the county, including under this term the equivalents of the Hartselle and Tuscumbia.†

Rockcastle is northeast from Pulaski. Mr Lesley in his notes does not divide the limestone, but gives simply total thicknesses at several localities. He finds it increasing southeastwardly, the measurements being 115, 145, 152, and in the center of the county 182 feet. He suggests that it may reach 220 to 240 feet in the southeast corner, and notes that geodes occur above the lower third, which consists almost wholly of white limestone.‡

Mr Sullivan says that in eastern Rockcastle the "Saint Louis" is from 200 to 210 feet, and his notes seem to show that the "Chester" is absent; but in Jackson county, the next east, he reports the "Chester" as 15 to 30 feet of reddish to greenish shales and argillaceous limestone, separated by 10 to 20 feet of shaly sandstone from the "Saint Louis" below, which is from 225 to 250 feet thick. The upper 25 to 50 feet of the Saint Louis has many flint concretions, but the rest is close-grained whitish limestone.§

Estill county is northeast from Rockcastle. Mr Lyon obtained here a detailed section at about 5 miles from the Kentucky river:

* R. H. Loughridge: Geol. Survey of Kentucky, Report on geology of Clinton county, 1890, pp. 13, 14.

† A. R. Crandall: Geol. Survey of Kentucky, Geology of Whitely county and part of Pulaski county (no date), p. 7.

‡ Joseph Lesley: Fourth Annual Report on Geology of Kentucky, 1861, pp. 482-483.

§ G. M. Sullivan: Geol. Survey of Kentucky, Geology of parts of Jackson and Rockcastle counties, pp. 6, 7, 18.

	Feet
1. Place of ore beds.....	
2. Shales.....	2
3. Limestone.....	93
4. Limestone with chert.....	46
5. Earthy limestone.....	94

The limestone number 3 is mostly earthy, and it might well be described as calcareous shale, if seen only on weathered slopes. Here the "Chester" or Bangor appears to be wanting and the Hartselle and Tusculumbia are sufficiently distinct.*

In Powell county, northeast from Estill, Mr Lesley found a total thickness of 161 feet of limestone. But the limestone quickly decreases, becoming from 30 to 70 feet in Menifee county, according to Mr Crandall, and showing an extreme thickness of 65 feet, according to Mr Linney, in Bath county, where that observer places the whole section in the Saint Louis. Rowan, east from Bath, shows, according to Lesley, only 30 feet of limestone, which is flinty in the lower portion.

Carter county is northeast from Rowan. Mr Crandall's summary notes for this and Greenup county are practically our only source of information, aside from Professor Andrews's fragmentary observations along the Ohio. Mr Lesley's notes are too incomplete to be of service. In southwestern Carter the whole thickness of limestone is 75 feet, while in southeastern Rowan, only a few miles away at the west, it is but 25 feet, showing the rapid decrease westward, which continues until the mass is represented by only a few feet of cherty rock. It increases eastward in Carter county, being 140 feet at Carter's caves, in the central part of the county, though it decreases again eastward, becoming only 40 feet within a few miles. It must increase southeastwardly and be persistent under Boyd and Lawrence counties, for oil-well records in the latter county show a considerable thickness of limestone, as do also those on the West Virginia side of the Big Sandy. Northward from western Carter the decrease is very rapid; 80 to 100 feet of limestone were seen near Boone furnace, in northern Carter, but at Kenton, in west central Greenup, only 10 feet. Farther north the limestone is represented by a few feet of chert or cherty limestone from Schultzes run to the Ohio, in the northwest corner of the county. Eastwardly from this line the distribution is very irregular, for opposite Portsmouth, in Ohio, in the extreme northern part of the county, limestone is wholly wanting, while in the eastern portion, along the Ohio, the limestone is seen again at 5 or 6 miles below Greenupsburg and soon becomes 35 feet, which, however, decreases quickly, so that before the mouth of Little Sandy

*S. S. Lyon: Fourth Annual Report on Geology of Kentucky, p. 528.

has been reached near Greenupsburg it has disappeared. The detailed section obtained by Professor Andrews below Greenupsburg has been given.*

THE CORRELATION

The Mauch Chunk is represented only by shales, or by shales and sandstones, along the northerly border in Pennsylvania, but southward limestone is found with shale above and below it. This limestone, in the Allegheny Mountain region, reaches to within 30 miles of the northern outcrop, while traces of it are present still farther north in the anthracite region. In southern Pennsylvania it is double, with a silicious division below and a more or less argillaceous division above. The former is the more persistent at the north and in the central part of the basin, but it is wanting in Ohio except in the extreme southeast. Both divisions persist in Virginia, Tennessee, and Alabama, as well as in the greater part of West Virginia and Kentucky. The lower shales become indefinite southward and the upper shales extend as shales little beyond the northern line of Tennessee.

The whole series has been termed Mauch Chunk in Pennsylvania and no special geographical term has been applied there to any of the subdivisions except in the northwestern part of the state, where Dr I. C. White gave the name Shenango to the shale which there is the sole representative of the Mauch Chunk. In Maryland the upper shales have been termed Mauch Chunk and the limestone Greenbrier; in Virginia Professor W. B. Rogers used the names Greenbrier shale and limestone; the United States geologists in that state have applied the names Canaan and Pennington to the shales, Greenbrier and Newman to the limestone; Professor Safford in Tennessee divided the limestone into Mountain limestone above and the Silicious group below, the latter into the Lithostrotion and the Protean, of which the former belongs to the Mauch Chunk; to Professor Safford's divisions Mr Hayes applies the designations Bangor and Fort Payne, with, in the southeastern areas, Floyd as equivalent to the lower portion of the Bangor; in Alabama the limestone is divided by Smith and McCalley into Bangor, Hartselle, and Tuscumbia; in Kentucky the divisions are Chester and Saint Louis, and in Ohio, Andrews termed it the Maxville.

The reader who has followed the details given in the preceding section has seen that the Alabama divisions are traceable northward for a long distance.

*A. R. Crandall: Geol. Survey of Kentucky, Report on the geology of Greenup, Carter, and Boyd counties and a part of Lawrence. Reprint of reports, vol. C, 1884, p. 6

Beginning at the south on the western outcrop, one finds, ascending, the Tuscumbia, limestone and markedly silicious; the Hartselle, sandstone with shales and limestones; and the Bangor, limestones more or less argillaceous. These three divisions retain their characteristics across Tennessee into Kentucky, the Bangor meanwhile becoming more argillaceous in northern Tennessee, where its upper portion has been identified with the Pennington shale. In Kentucky the Tuscumbia and Hartselle are taken together as the Saint Louis, but they retain the Tennessee features, one of the Hartselle sandstones being persistent. The Bangor becomes very shaly, and, like the Tuscumbia, thins out northward more rapidly than the Hartselle, so that the last alone is present in central Ohio, where Professor Andrews called it the Maxville.

Along the eastern outcrop, one finds greater variation, for outlying areas toward the southeast reveal something of the conditions existing along the old shoreline. But those areas may be neglected in this connection. Following the border of the principal areas, one finds the Tuscumbia, Hartselle, and Bangor sharply defined in Alabama, with the same features as on the western side. In Tennessee the Tuscumbia is easily recognized in the upper portion of Mr Hayes's Fort Payne, while at least one of the Hartselle sandstones is persistent into southern Virginia; but the Bangor, the upper portion of Mr Hayes's Bangor limestone, becomes increasingly argillaceous northward, so that frequent reference is made to its tendency to weather into shale. Toward the Virginia line it becomes almost wholly shale and sandstone, while it increases greatly in thickness, so that Mr Campbell has separated the Pennington shale from the limestone which he calls Newman. The enormous increase in thickness of the section, due to increase of land detritus, renders exact tracing difficult for a little way in southwest Virginia, the more so since detailed descriptions have not been published. The Bangor evidently becomes wholly shale and sandstone before New and Greenbrier rivers are reached, where Fontaine and Campbell found so great a mass of shales with insignificant streaks of limestone. The persistence of the Hartselle sandstone at the bottom of the shales or near the top of the limestone is shown by many of the oil records and along the outcrops almost into Pennsylvania. The upper limestone of Virginia, Maryland, and Pennsylvania is the Hartselle. The Tuscumbia retains its silicious character throughout, though losing its chert in Virginia and becoming merely a silicious limestone; this feature, along with a curiously current-bedded structure and a peculiar whiteness when crushed, characterizes it thence into Pennsylvania, where by several of the geologists it was termed the Silicious limestone.

The correlation seems to be :

Shenango.—Bangor of McCalley in Alabama; upper portion of Bangor of Hayes in Tennessee; upper portion of Safford's mountain limestone in Tennessee; Chester of Kentucky geologists (second survey); Pennington and top of Newman of Campbell in Tennessee and southwest Virginia; Umbral shales of Fontaine; Canaan shales of Darton; Greenbrier shale of W. B. Rogers; Mauch Chunk shale of Maryland; Mauch Chunk of Pennsylvania in part; absent from most of Ohio; Shenango shale of I. C. White in northeast Ohio and northwest Pennsylvania.

Maxville.—Hartselle of Alabama; greater part of Bangor in Tennessee; lower part of mountain limestone in Tennessee; greater part of upper Newman and of upper Greenbrier in Virginia; upper Umbral and upper Mauch Chunk limestones in Pennsylvania; Maxville of Ohio; upper Saint Louis of Kentucky.

Tuscumbia.—Tuscumbia of McCalley in Alabama; Lithostrotion of Safford in Tennessee; upper part of Fort Payne in Tennessee; lower part of Saint Louis in Kentucky; lower Newman and Greenbrier in Virginia; lower of Greenbrier in Maryland; silicious limestone of Pennsylvania; absent in Ohio except at Kentucky border.

The term Shenango is the earliest applied definitely to the latest division. Though Doctor White's Shenango shales have been spoken of as representing the whole of the Mauch Chunk sedimentation, it will be shown in the next chapter that they represent practically only the sedimentation of the closing epoch. The name Maxville was given by Professor Andrews in 1870, and therefore antedates Hartselle by many years. Tuscumbia, being a geographical term, will have to replace the much older Lithostrotion of Professor Safford.*

The fossils from the Shenango appear to be those characteristic of the Chester of the Mississippi basin. Forms belonging to that epoch have been collected in Pennsylvania, Virginia, Kentucky, and elsewhere. Fossils collected by Andrews in 1869 from the Maxville localities in Ohio and by Stevenson in 1870 from the same limestone in West Virginia were submitted to Mr F. B. Meek, who pronounced them distinctly Chester. Professor R. P. Whitfield afterwards figured and described the Ohio forms, referring them practically to the same horizon. Still later,

*In the preceding chapter the writer has given reasons for rejection of the name Catskill, and he has conceded that owing to confusion in the use of Chemung, that name also might be discarded. In the latter case, however, he entertains some misgivings, as the difficulty lies rather in disagreement respecting boundary lines, and he can not grant that because a term has been used to designate two formations which are consecutive it should be cast aside, any more than he could grant that a generic term in biology should be rejected because in the original description it included forms which proved afterwards to belong to several genera. This has been conceded by those who are apparently urgent in introducing new names without any regard to priority, for Greenbrier and Mauch Chunk have been retained, both of which have been used as comprehensively as either Hamilton or Chemung. In the immediate instance Shenango is definite. Its boundaries are clear, and it should be retained in preference to the cacophonous Mauch Chunk, which, if retained at all, should be used merely as equivalent to the Genevieve of Professor H. S. Williams.

in 1901, Stevenson collected carefully at a locality in Fayette county of Pennsylvania and submitted the specimens to Mr Weller, who found that the fauna contains some Saint Louis as well as the Chester forms. There is, however, practically no change in the fauna from the bottom to the top of this locality, the same forms, with two or three exceptions, being found throughout. The Chester forms predominate, and of those belonging to the Saint Louis some lived on into the Chester at typical localities within the Mississippi basin. The same fauna occurs in Randolph county of east central West Virginia and in Washington county of Virginia at the Tennessee border. In Tennessee and Alabama the Maxville (Hartselle) is clearly Chester. The Kentucky geologists of the second survey make the Maxville the upper part of their Saint Louis, but it overlies the *Lithostrotion* bed, the lower part of their Saint Louis. No list is given of the fossils which lead to classification of the limestone as Saint Louis.

The Tuscumbia is practically non-fossiliferous at most localities in Pennsylvania. In Tennessee and Alabama, as well as in Kentucky, *Lithostrotion canadensis* is the characteristic fossil, and it is associated with other forms belonging to the Saint Louis.

PHYSICAL CHANGES DURING THE MISSISSIPPIAN

THE LATER DEVONIAN

The several deposits have been traced throughout the basin in such detail as available observations permit. It remains to ascertain, if possible, what geographical changes and stratigraphical disturbances took place during the Mississippian, but it is necessary first to make reference to conditions existing during the later Devonian.

During the Chemung (Jenning) the area of sedimentation extended from the Appalachian shore westward across Pennsylvania into northern Ohio; across Virginia and West Virginia, evidently to the Ohio river; southward from the line of central Virginia the area contracts. There appears to be no Chemung in Kentucky, none in Tennessee, except on the eastern side of the basin, while in Georgia it is confined to a narrow strip following the old shoreline. The Chemung basin was very broad at the north, reaching far into New York and crossing into northeastern Ohio, but it tapered southward, the contraction being on the westerly side, until it disappeared in Georgia. The area of more rapid subsidence, lying near the old shoreline, was narrow throughout, reaching north, from New river of Virginia, to only a few miles beyond the Alleghany region. The vast thickness observed along the eastern border decreases so quickly in southern Pennsylvania that before the

Alleghenies of that state have been reached the mass has become diminished one-half, while in central western Pennsylvania the section is barely one-fifth as thick as in Fulton county of the same state; and in Ohio the deposit becomes thin and recognizable only with difficulty. Southward from New river the rate of subsidence decreased and the trough became narrower. At 125 miles beyond that river the great mass has become only a few hundred feet thick even on the edge of the Great valley, and the deposits appear to reach not very far into Tennessee; but outlying areas show that the rapidly tapering trough continued into northwestern Georgia and possibly into Alabama.

The material of the Chemung deposits is fine grained throughout, with the exception of two conglomerates, very persistent along the eastern border to beyond New river in Virginia, but becoming somewhat finer westward, where they are the first and third oil-sands of Pennsylvania. The advent of the Catskill (of Vanuxem, Hampshire of Darton) was marked by physical changes which gave to that formation a good claim to recognition as a natural group. The area of sedimentation became contracted so as to coincide rather closely with the Chemung area of chief subsidence. Eastwardly it extended as far as did the Chemung, but westwardly it reached not more than 30 miles beyond the line of the Alleghenies of Pennsylvania, while southwardly it became shallower to the shoreline, which lay apparently in Montgomery county of Virginia. Western Pennsylvania, eastern Ohio, almost the whole of Kentucky, West Virginia, and Tennessee received no deposits, so that there was land or water too shallow to receive any deposit all the way from the Cincinnati peninsula almost to the line of the Pennsylvania Alleghenies. That the basin was wholly landlocked southward is not probable, for the writer obtained *Spirifer disjunctus* from the upper beds near Salem, Virginia, not very far from the last traces of Catskill toward the south. Throughout the Catskill the deposit is fine grained, mostly mud and muddy sandstones, with red and green as the prevailing colors. Toward the close a conglomerate appeared at the northeast, which, however, extends but a short distance southwestwardly.

The Chemung conditions were restored and exceeded at the close of the Catskill, and deposits belonging to the later Devonian (Lower Pocono, Cuyahoga, etcetera,) show that the area of sedimentation gradually encroached upon the land, west and south, so that they finally covered the whole basin north from the Tennessee line, thus overlapping the Chemung at the west and northwest. Southward from the Tennessee line the basin contracted on the westerly side and very quickly was confined to the area of eastern Tennessee and northwest Georgia where there seems to have been a deep arm of the sea during the Chemung and latest De-

vonian. The deposits are in contrast with those of the Chemung and Catskill; at the east they are for the most part sands, often very clean, at times coarsely conglomerate. The lowest bed is conglomerate, most markedly so along the easterly outcrops, but more or less so at localities in western Pennsylvania and northern West Virginia. The transition from the Catskill is abrupt but not absolute, for red beds occur at many localities in eastern Pennsylvania, while in the north central part of that state green is the characteristic color of many sandstone beds. The material grows finer westward, the thickness varying slightly beyond the Alleghenies, and in northwestern Pennsylvania thin calcareous beds make their appearance, one of which may have been persistent southward in West Virginia.

Throughout the Chemung and Catskill the land must have been subsiding at the east; the streams were approaching nearly to baselevel and only fine material was brought down. Two interruptions occurred, during which were formed the Chemung conglomerates.

The extreme subsidence had been reached in New York as early as the beginning of the Chemung, and the streams brought down mud and fine sand, in great part containing so much iron as to be colored red or green. As the subsidence of the mainland became marked farther and farther south, the red and green beds covered a greater area, and in the Catskill one finds those beds to the southern limit of the formation. It is worthy of note that the *Amnigenia catskillensis*, which in the Catskill Mountain region began its existence in the lower Chemung, gradually moved southward, so that before the close of the Catskill it had reached the southern border of Pennsylvania. As the change in Chemung rocks had become complete at the end of that period, one may imagine that some relation may have existed between the great sinking of the Appalachian land and the elevation of land on the western side, by which the Catskill trough was narrowed.

The Catskill was closed by an elevation in the Appalachian region, rendering the streams more or less torrential, so that the last period of the Devonian was opened by the deposit of coarse rocks. Answering to the eastern elevation was the western depression, so that the subsidence and amount of deposit was almost as great in Ohio and Kentucky as in Pennsylvania and the most of Virginia. Southward the subsidence continued far beyond the limits of the Catskill and possibly beyond that of the Chemung.

As already stated, the Catskill may have been almost landlocked. The absence of salt in the beds, which otherwise recall in many ways the Salina of New York, and the almost total absence of marine life seem to suggest that during the greater part of the Catskill sentimenta-

tion most of the area was covered with a shallow depth of fresh water; but marine conditions returned during the latest Devonian.

THE LOGAN

At the beginning of the Logan the Appalachian land north from Tennessee is rising and the whole basin, except along the northern border, is subsiding gently, so that the sea encroaches on the land westward and southward.

East from the Alleghenies of Pennsylvania the Logan conditions are shown imperfectly, for even the anthracite outliers are at a long distance from the old shoreline. The rocks for the most part are coarse sandstones, with thin shales and very thin coal beds. This is the condition in northern Virginia, but southward in that state the outliers are found still farther eastward, some of them even in the Great valley and within a few miles of pre-Cambrian. There the rocks are finer and the coal beds thicker, so as to be of local importance, though the coal is usually very impure. Still farther south the coal beds disappear, calcareous rocks appear, and eventually the silicious matter is in the form of chert beds, interstratified with thin limestones.

Beyond the Pennsylvania Alleghenies sandstone with no coal is the prevailing rock in the most of Pennsylvania, as well as in West Virginia, to probably 30 miles south from the Baltimore and Ohio railroad, meanwhile becoming replaced by shale below until at last, in central West Virginia, the whole interval is occupied by shales, extending downward into the Devonian for hundreds of feet, a condition continuing even into Kentucky. This change in character takes place at practically the same latitude as on the eastern outcrop. In Tennessee and Alabama, within this central part of the basin, the conditions resemble those on the eastern outcrop. In northwestern Pennsylvania the lower portion is shale and contains an impure limestone. No trace of this limestone appears in oil-well records of western Pennsylvania, but the records of wells in portions of Harrison and adjoining counties in north central West Virginia note the local development of limestones directly under the "Big Injun" or Logan sandstone.

Still farther westward, along the outcrops in Ohio and Kentucky, as well as under cover in those states, the conditions are strikingly in contrast with those of the Devonian. The mass thickens rapidly southward and southwestward in Ohio. For about one hundred miles from the Pennsylvania border it is fine grained above and coarse below, but along the western outcrop for many miles it is distinctly and almost constantly conglomerate, though evidently thinner than at the north. The pebbles are flat, small, and nearly uniform in size. Irregular limestones occur,

very thin, but persisting for considerable distances. The massive structure and great thickness characterize the Logan under cover in southeastern Ohio and eastward to Roane county of West Virginia, where it is replaced by the shales to which reference has been made. In southern Ohio, however, the coarseness diminishes, and in the upper Knobstone of Kentucky one finds only fine grained sandstone, which in turn grows finer and more shaly until in Tennessee the Lauderdale character is assumed, which prevails in western middle Tennessee and in northwestern Alabama. There is, then, a sandstone deposit crossing the northern portion of the basin, extending southward almost to the central line of West Virginia; on the west side this extends southward into Tennessee, but on the east side hardly any farther than in West Virginia; the south central portion of the basin almost to Tennessee is occupied by shales. From both sides the deposit grows finer toward the central line of the basin.

The form of the area of sedimentation differs from that of the latest Devonian. It seems hardly possible that the Logan extended northward into New York except at the extreme northeast; its limit in northern Ohio is far south from that of the Cuyahoga, while its western limit in that state could hardly have been very far beyond the present line of outcrops; but southwardly the area widened until beyond the Cincinnati peninsula it became broadly continuous with sediments of the Mississippi area. On the eastern side the boundary can have been little different from that of the Devonian as far south as the Tennessee line. Southward the latest Devonian overlaps the Catskill by many miles and is in turn overlapped by the Logan, which reaches into central Alabama, overlapping even the Chattanooga black shale, which may represent the Hamilton of New York. The southward expansion of the area was very gradual; for while Kinderhook, Burlington, and Keokuk occur in northwest Pennsylvania and Ohio, the lower members disappear southwardly in succession, so that in northwestern Alabama only the Keokuk appears to be present. The rate of subsidence must have been practically the same in by far the greater part of the area, contrasting in this respect notably with prior times, for from Cambrian almost to the close of the Devonian a great trough of subsidence lay along the old shoreline at the east.

The source of material found along the westerly outcrop is very uncertain. The rocks of earlier periods on that side are fine grained, very largely calcareous or argillaceous; even the Berea sandstone is very fine; yet for a long distance the Logan is largely conglomerate and the sandy deposit continues much farther southward on the west than on the east side. The pebbles of quartz are small and flat, as though chafed

long on a low shore. They can hardly have come from the north, for there the upper Logan, Reid's Olive shales, is very fine in grain, while farther south it becomes coarse as it is in northwest Pennsylvania, east from Reid's localities. It is equally improbable that the pebbles came from the east, for the deposits become finer eastward toward the central line of the basin, beyond which they become coarser. The sands must have come from the western side.

THE TUSCUMBIA

The Tuscumbia is represented in the northern portion of the basin by shale and the overlying silicious limestone.

The limestone is present, though indefinite, within the anthracite fields and is distinct in the Broad Top and Fulton County outliers. According to Mr Meyer, quoted by Professor Lesley, it is present in the Allegheny area as far north as Lycoming county; only a trace remains in Clinton, the next west, and there appears to be none in Center, south from Lycoming. The boundary passes westwardly from Blair across Indiana into Allegheny; thence across northern Washington into West Virginia; crosses the Ohio river below Wheeling into Ohio; reenters West Virginia near Saint Mary's and passes a little way east from Parkersburg; there bending, it crosses southeast Ohio to the Ohio river and enters Kentucky just beyond the western border of Greenup county and continues thence irregularly southwestwardly until it curves around the Cincinnati peninsula. East and southeast from this irregular line, which is very nearly the original shoreline, it is persistent in the main area as well as in outlying areas, except those of Montgomery county, Virginia, though very attenuated in those of Pulaski and Wythe in the same state.

It is difficult to determine, by means of available observations, whether or not the Fort Payne of the extreme southeasterly areas embraces any Tuscumbia. For the most part the features are those of the Lauderdale (Logan), there being an almost total absence of limestone in the upper part; but in Calhoun county of Alabama, very near the extreme southeast exposure, one finds the Tuscumbia clearly present. One may conjecture that as the Lauderdale is practically without limestone nearer the shoreline the Tuscumbia would undergo the same change, so that the thin Fort Payne on the border would represent both. This is in accordance with the conditions in this region, as each of the Mississippian formations apparently overlaps its predecessor; but for the present the question must remain unanswered.

The Tuscumbia limestone is absent from the whole of northwestern Pennsylvania, about 15,000 square miles; from almost the whole of eastern Ohio, and is very irregular in distribution within eastern Ken-

tucky, where, however, the available observations suffice for an approximation.

A shale underlies the limestone in some portions of the basin. It appears to be persistent in the Anthracite strip, but in the Allegheny region its presence is doubtful except in Lycoming county. It is absent in the greater part of that region in Pennsylvania as well as under the Laurel and Chestnut anticlinals; but oil-well records prove its presence in western Pennsylvania along a narrow strip southward from Butler county almost to the West Virginia line. It is present in Pocahontas county of West Virginia and is recorded occasionally in wells of that state. Usually it is overlapped by the limestone, but in the strip within western Pennsylvania it evidently extends farther north; the shale may have had greater eastward extension in the anthracite fields, but no positive assertion can be made, for in those fields the results of the first and second geological surveys are not wholly in accord respecting the limestones or, better, the calcareous beds.

It is very evident that at the close of the Logan the trough of sedimentation was greatly contracted on the north and west, and that in some portions of Pennsylvania, where the limestone is present, there was dry land at the beginning of the Tuscumbia, for in a large area within the central portion of the state the shales are wanting. Local foldings of slight extent must have been very numerous, as shown by the absence of the shales in so many localities within West Virginia.

The most northerly point of the basin during deposition of the limestone was apparently midway in the northern anthracite field. The rate of subsidence increased southwestwardly, as in that direction the thickness increases, being greatest in the Cumberland Plateau region—equivalent closely to the Alleghenies of Pennsylvania, which shows also that as in the Logan the axis of greatest subsidence lay somewhat west from that for the Devonian. Whether or not the encroachment of sea on the land continued at the southeast can not be ascertained at present. Tuscumbia is clearly present in Calhoun county, Alabama, within 3 or 4 miles of the extreme Fort Payne outcrop at the southeast. Tuscumbia appears to be recognizable at the extreme southern exposures in central Alabama.

Almost as far south as Tennessee, in the eastern and middle portions of the basin, the Tuscumbia limestone is very arenaceous, weathering to a sand. Fossils are extremely rare, but those which have been found are marine. The continuity of the calcareous deposit was interrupted for a short time, during which a sandstone, very coarse at one locality but ordinarily very fine, was laid down over a great area. The peculiar current bedding of the limestone, thoroughly characteristic, is suggestive

of shallow water. The irregularities in thickness, as shown in the West Virginia records, seem to show that the subsidence was associated with petty crumplings of the beds.

THE MAXVILLE

In the Anthracite strip of Pennsylvania the Maxville has not been recognized north from the Broad Top area, where the impure limestones above the main deposit have been taken as its representative. As these limestones thicken southwardly at the expense of the shales, the latter to some distance above the impure beds should be taken as Maxville. Such shales make up a great part of the section in the southern and middle anthracite fields, but in the northern field it is doubtful if they extend as far north as Scranton, for the deposits there and northward are of the Shenango type. There is not much reason to suppose that Maxville deposits of any sort extend northward beyond the central line of Pennsylvania in the Allegheny region, since in Blair county the whole of the Mauch Chunk is but 283 feet, while in Center county it is estimated at not more than 150 feet, whereas in Broad Top, only 30 miles east, the Shenango and Maxville are 910 feet. In western Pennsylvania, as shown by exposures under Laurel and Chestnut hills, as well as by oil-well records, the northern limit is not far beyond the line of the Conemaugh gaps, considerably south from that of the Tuscumbia. It is barely possible that the western boundary crosses into the Panhandle of West Virginia, but in any event it lies near the Pennsylvania line and passes southwardly across Wetzel county of West Virginia, through western Doddridge into Gilmer, where it turns westwardly into Wirt, central Wood, and Jackson, from which it passes into Ohio. No well records in the latter state have been published, but the line evidently bends northwardly, for the Maxville limestone outcrops in Perry, and it has been found in eastern Muskingum, whence Andrews followed it into Kentucky, where it is the upper part of the Saint Louis. Thence southward it is recognized easily as the lower part of Safford's Mountain limestone and as McCalley's Hartselle.

Along the eastern outcrop in the Allegheny region the Maxville limestone increases slowly southward to beyond the Potomac; but farther west, under the great anticlinals of southwest Pennsylvania and West Virginia, it increases rapidly, becoming important commercially before reaching the line between those states. The mass thickens and becomes more calcareous southwardly, attaining its greatest thickness in the region of the Virginia Alleghanies or even farther eastward—that is, in the equivalent of the Pennsylvania Anthracite strip. One must remember, however, that the Maxville is hardly to be considered as limestone

in by far the greater part of this area. It is very calcareous, but it contains few beds pure enough for lime, the most of it being calcareous shale or argillaceous limestone, with varying beds of sandstone. The greatest mass of comparatively pure limestone appears to be in the Cumberland Plateau region of Tennessee, approximately on the line of the Pennsylvania Alleghenies.

The outlying areas in Virginia, Tennessee, Georgia, and Alabama show the influence of near-shore conditions. The Virginia areas, within the Great valley, have no limestones, only shales and sandstones being present; whether or not any portion of these represent the Maxville could not be determined. The Maxville is certainly present in the Chilhowie mountains of east Tennessee, in the most easterly exposures within Georgia, as well as in those of Alabama to the last exposure at the south; but in all of these it is no longer an impure limestone with sandstones and shales, but a mass of shales and sandstones, the former often carbonaceous, with occasional thin beds of limestones; and this mass attains great thickness where it overlaps the Tuscumbia. Even on the western side in Alabama the same condition exists, for there the sandstones and shales predominate in the Hartselle. It is possible that some of the overlying Bangor limestone belongs to the Maxville.

The conditions during the Maxville differed in some respects from those during the Tuscumbia. The area of sedimentation was more contracted on the northern and western sides, for no deposits were made in northwestern West Virginia. It is altogether probable that in the early part of the period much of central Pennsylvania received no deposit, for there and in adjoining part of West Virginia one often finds a breccia above the silicious limestone, consisting chiefly of fragments of that rock. But while so much of the area was above water at the beginning and so remained throughout the period, there was a subsidence in southeastern Ohio, gradually extending northward, forming a bay reaching into Muskingum county, so that along the outcrop from Muskingum southward one finds lower beds appearing until the Tuscumbia is shown before the Kentucky line has been reached, and in like manner, under cover, before the West Virginia line has been reached. Under cover in West Virginia the oil records show great irregularities within the counties bordering on the shore area—sometimes apparently only the upper beds, at others only the lower beds are present—and one is led once more to suggest local crumplings and disturbances as the only explanation.

At the east one finds evidence of continued lowering of the mainland and of continued advance of the sea upon a low shoreline. The deposits at the north were of fine material even to the Allegheny line, with very little calcareous matter; and this continued all the way to

the last exposures; but the landward advance was much more marked at the south, where the thickness of the sandstones and shales is very great, even where the Tuscomb and Logan have almost disappeared, while in Alabama the advance was so great as to push the shore evidently almost to the fall-line of the streams, for there the sands are coarser and in such quantity as to be the characteristic feature from central Alabama northward to within 50 miles of the Tennessee border on the western side of the area; which leads to the supposition that the land area southward and westward was much greater than has been supposed. The outlet to the ocean may have been in Tennessee.

The water area at the close of the Maxville extended farther south and west than at any time after the middle of the Upper Silurian, for the Maxville overlaps the whole Devonian and even the earlier members of the Mississippian. The greatest thickness is in the equivalent of the Pennsylvania Anthracite strip, though it does not coincide with that of the Devonian. Apparently the depth of water was not considerable in any portion, except possibly in the Cumberland plateau of Tennessee, for at most localities the limestone is very impure and the deposit was interrupted several times by sandstones.

THE SHENANGO

The Shenango overlaps the Maxville in Pennsylvania and reaches northward, almost to the line of New York. At the west it barely crosses the Ohio line and the boundary lies but little beyond Pennsylvania to the southern line of that state. In West Virginia the Shenango is wanting in Wetzel, Tyler, Pleasants, Ritchie, most of Doddridge and Wood counties, is very thin in the northern Panhandle, and is very irregular in many other counties of the state. The Maxville underlies the Coal Measures directly in Ohio, and in Kentucky the western limit of Shenango is at some distance east from that of the Maxville. In western Pennsylvania, as shown by oil-well records, the Shenango is very thin, rarely exceeding 100 feet and often wanting. Even in the Allegheny area of that state it is insignificant, the whole Mauch Chunk section varying from 75 feet in Tioga to 300 feet in Blair, and apparently not much more in Somerset county; but farther south, under the Briery Viaduct axis, White found 370 feet, while on the Potomac it is not less than 650 feet. In the Anthracite strip it is 75 feet at Scranton, and increases southwardly to about 600 feet or more in the southern field.

Under West Virginia, along the line of the Pennsylvania Alleghenies and westward it decreases rapidly, but along a line somewhat farther

east, that of the Alleghenies of Virginia, it increases, being 1,250 feet in Pendleton, 1,260 feet in Greenbrier, and 2,500 feet in Summers, the greatest thickness being apparently in the vicinity of New river. In the Great valley of Virginia and on the border of the Cumberland plateau, in the southern part of the state, it is about 1,100 feet. Westward it thins rapidly along the whole line, and everywhere to the northern border of Tennessee it is shale or sandstone with a little limestone; but in Tennessee, on both sides of the main area, the shales become thinner, more calcareous, and at length become limestone, so as to be included in the Bangor limestone of Mr Hayes. The upper beds persist as shale much farther than do the lower.

The outlying areas in Georgia show the limestone of the later Maxville (?) and Shenango extending far to the southeastward, overlapping the Floyd shales or Oxmoor sandstone of that region; but at the south it appears to be replaced wholly by sandstone, the Oxmoor there being regarded by the Alabama geologists as representing both Maxville (Hartselle) and Shenango (Bangor).

So, toward the close of the Shenango, the water-covered area occupied Pennsylvania, Maryland, Virginia, central Tennessee, northwestern Georgia, and northern Alabama west from the Blue Ridge line, but practically none of northwest West Virginia, of Ohio, and in Kentucky less than during the Maxville. The subsidence in Pennsylvania and West Virginia west from the Alleghenies was insignificant and very slow, the main trough of sedimentation lying eastward from the Allegheny region. The subsidence extended southward so as to permit the Shenango to overlap the Maxville in Georgia and Alabama as it does at the north. The character of the sediment north from Tennessee, almost invariably red shale or muddy sandstone, shows a continued depression of the mainland at the east, while the same condition for the south is shown by the overlapping of the earlier members of the series.

The four subdivisions of the Mississippian—the Logan, the Tuscumbia, the Maxville, and the Shenango—are characterized by definite boundaries, due to physical changes, involving for each the whole basin.