UPPER MISSISSIPPIAN STRATIGRAPHY
OF SOUTHWESTERN VIRGINIA,
SOUTHERN WEST VIRGINIA,
AND EASTERN KENTUCKY

by

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Dissertation submitted to the Graduate Faculty of the
Virginia Polytechnic Institute
in candidacy for the degree of

DOCTOR OF PHILOSOPHY

in the

Department of Geological Sciences

September, 1959
Blacksburg, Virginia

TABLE OF CONTENTS

LIST OF ILLUSTRATIONS

LIST OF TABLES

INTRODUCTION

In the western fold belts of the Appalachians in southwestern Virginia, southern West Virginia, and eastern Kentucky the Mississippian system is characterized by a succession of three major lithologic types. The lower part of the section is composed of sandstones and maroon mudstones. The middle division of the Mississippian system is a thick succession of limestones, the top of which marks the base of beds studied in this investigation. The upper clastic division of the Mississippian, studied in detail for this paper,, consists of sandstones, mudstones, coaly beds, and a single limestone member. The area studied extends from Pocahontas County, West Virginia, southwestward through Tazewell County, Virginia, to Harlan County, Kentucky, in a belt ranging from twenty to fifty miles wide (Pl. 1).

Field work during the summer of 1958 included detailed measurement of a number of stratigraphic sections (locations shown on Plates 1 and 2) and examination of scattered outcrops. Field studies were supplemented by petrographic examination of rock samples and identification of faunal collections from a number of horizons. Outcrops studied are located in two general areas (Pl. 1): (1) both sides

PLATE I.- REGIONAL MAP SHOWING LOCATIONS OF GEOLOGIC SECTIONS AND MAJOR STRUCTURAL FEATURES

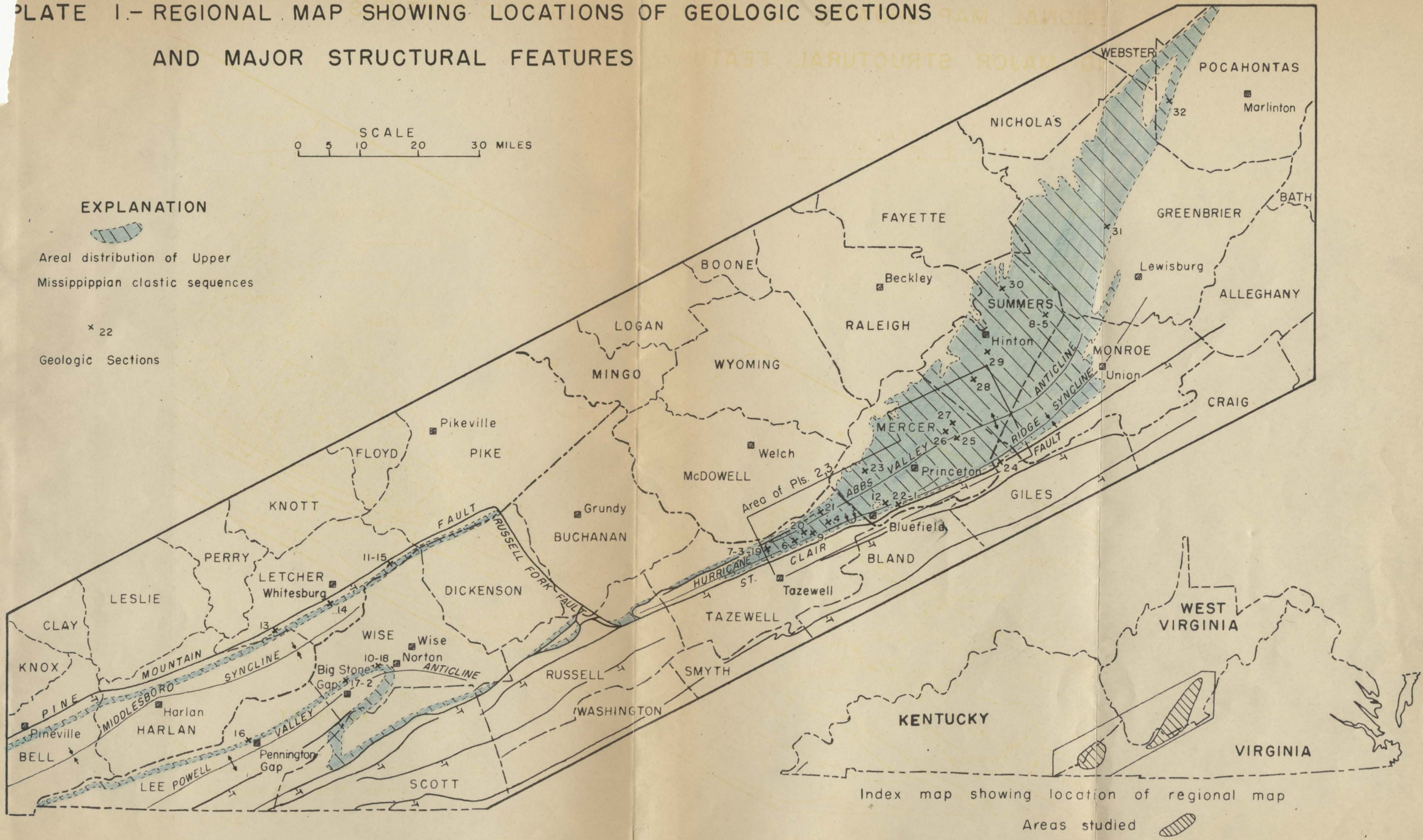
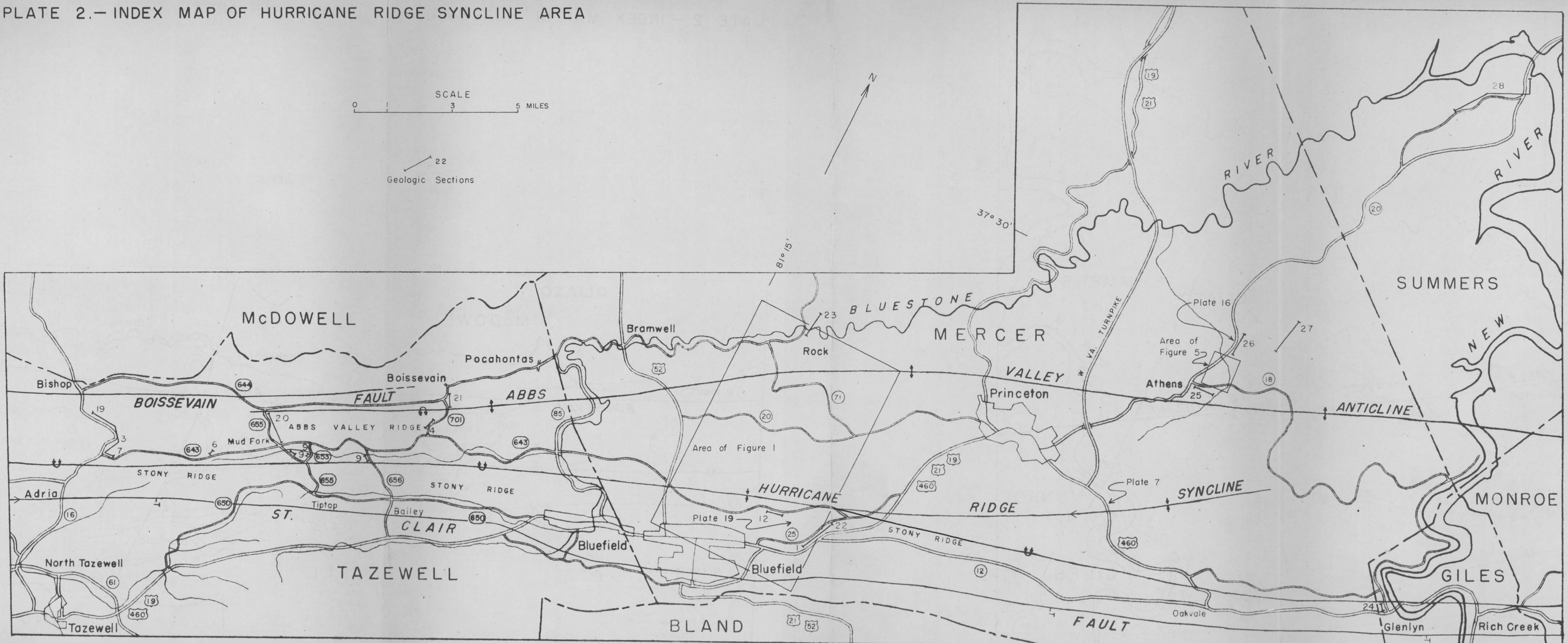


PLATE 2.— INDEX MAP OF HURRICANE RIDGE SYNCLINE AREA

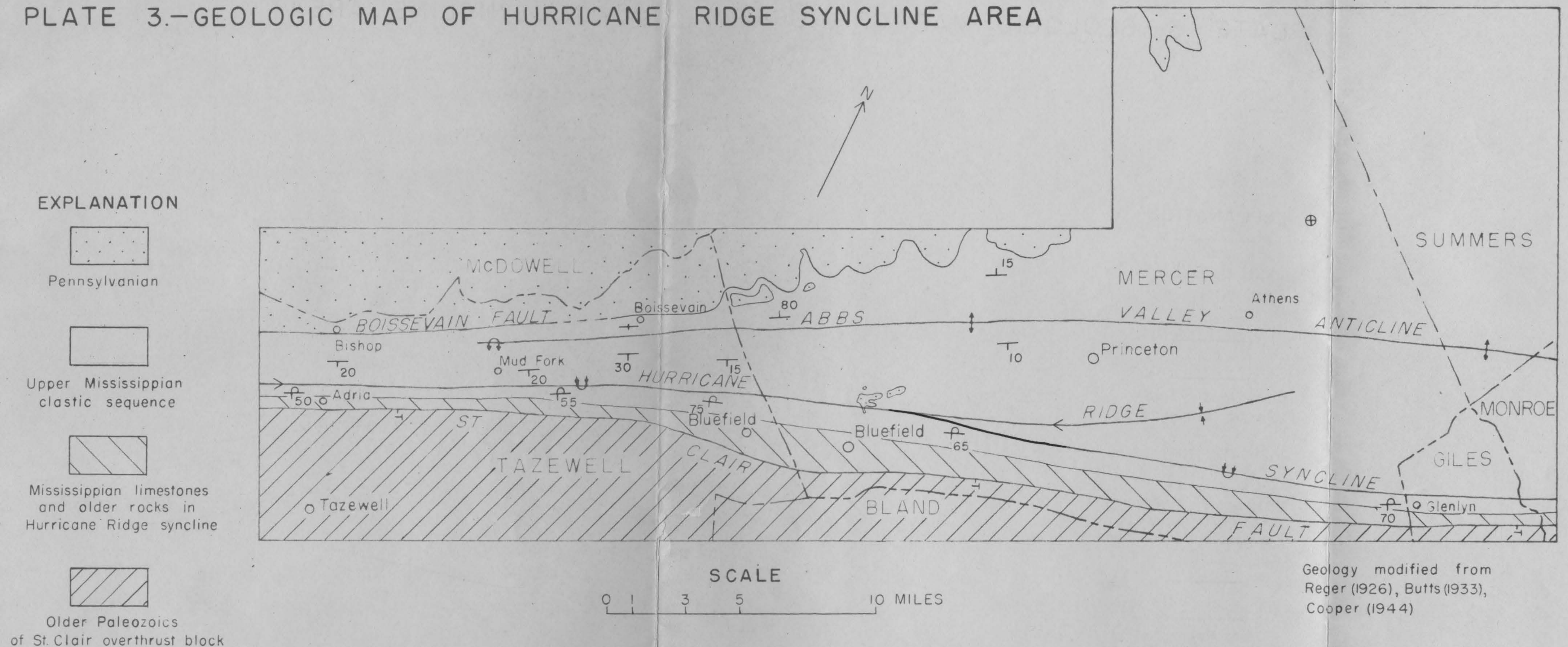


of the Middlesboro syncline, and (2) the Hurricane Ridge syncline, Abbs Valley anticline, and adjacent folds in West Virginia.

In north-central Pennsylvania the Mississippian clastic sequence consists of about 1000 feet of Pocono sandstone overlain by 3000 feet of Mauch Chunk red beds. In southwestern Pennsylvania the Pocono and Mauch Chunk are separated by a thin limestone unit, the Loyalhanna, which has been regarded as a thinned equivalent of part of the Greenbrier limestone (Butts, 1924; Cooper, 1948). Toward the southwest in West Virginia the upper part of the Pocono gives way to a red bed facies, the Maccrady formation, which in its upper part is supplanted by a limestone facies (Cooper, 1948). Similarly the lower part of the Mauch Chunk grades southward into a limestone facies. Farther south in West Virginia sandstone members become increasingly important in the upper part of the Mauch Chunk. In the Bluefield area of Virginia-West Virginia the Mississippian is composed of the Price sandstone (500 feet), the Maccrady red beds (250 feet), the Greenbrier limestone (1500 feet), and an Upper Mississippian clastic sequence (3500 feet) of maroon mudstones, sandstones, calcareous beds, and coal (Reger, 1926). The Mississippian section thins toward the southwest in southwestern Virginia; and the lower part of the Lower Mississippian clastic unit gives way to black shale, and the upper clastic sequence becomes more sandy. Thus in southwestern Virginia and eastern Kentucky the Mississippian consists of black shale at the base, a lower red and green shale and sandstone unit (100 feet), the St. Louis, Ste. Genevieve, and Gasper limestones (700 feet), and the upper clastic sequence (1500 feet) of the Mississippian (Butts, 1940).

Between Pocahontas and Mercer counties, West Virginia, Upper Mississippian rocks, gently warped into a series of northeast-southwest trending folds, crop out in a relatively wide belt along the eastern margin of the Pennsylvanian coal fields (Pl. 1). These beds dip to the west under the Coal Measures and thin down dip in the subsurface in West Virginia (Martens, 1945). In Mercer County, West Virginia, and Tazewell County, Virginia, Upper Mississippian strata are preserved in the Hurricane Ridge syncline and on the flanks of the Abbs Valley anticline (Pl. 3). The northwest limb of the Abbs Valley anticline dips steeply to the northwest and in Tazewell County, Mississippian beds at the crest of the structure are faulted over Pennsylvanian rocks; thus immediately northwest of the Abbs Valley anticline Mississippian strata are deeply buried (Pl. 3). The Hurricane Ridge syncline plunges northeastward toward northeastern Tazewell County, and Upper Mississippian beds are not preserved in the trough of the syncline in

PLATE 3.—GEOLOGIC MAP OF HURRICANE RIDGE SYNCLINE AREA



the western part of the county. Cambrian and Lower Ordovician rocks have been thrust over Silurian, Devonian, and Mississippian strata comprising the overturned southeast limb of the Hurricane Ridge syncline along the St. Clair fault in Tazewell County (Pl. 3). Between Tazewell and Scott counties, Virginia, Lower Paleozoic strata of the overthrust block of the St. Clair fault rest on Devonian, Mississippian, and Pennsylvanian rocks which dip northwestward into the Middlesboro syncline. However, along this belt Mississippian strata are not well exposed. Upper Mississippian rocks crop out around the northeastward plunging nose of the Powell Valley anticline in Scott and Wise counties, Virginia (Pl. 1). In Wise and Lee counties, Virginia, Mississippian rocks on the northwest limb of the Powell Valley anticline dip to the northwest beneath the Pennsylvanian into the Middlesboro syncline. Along Pine Mountain between Pike and Bell counties, Kentucky, and southwestward into Tennessee, the Mississippian on the northwest limb of the Middlesboro syncline is brought to the surface by the Pine Mountain overthrust.

Acknowledgments

Professor Byron N. Cooper, who supervised the project, has been interested for a number of years in the problem of contemporaneous downwarp and deposition in the folded Appalachians, and he has contributed many helpful ideas and suggestions both in field work and in preparation of the manuscript. Appreciation is expressed to Professors W. D. Lowry, C. G. Tillman, J. A. Redden, and B. W. Nelson for advice in laboratory work and for helpful criticisms. Thanks are due to and who served as field assistants. The writer is also grateful to his wife, , for assistance in field work and in preparation of the manuscript. The field work for this investigation was made possible by a grant from the Penrose Bequest of the Geological Society of America. A National Science Foundation Fellowship has permitted uninterrupted work on the project.

UPPER MISSISSIPPIAN STRATIGRAPHY

General Lithologic Succession

The general vertical distribution of lithologies is constant throughout the region; however, in overall aspect the Upper Mississippian clastic sequence in the Middlesboro syncline is distinct from that in the Hurricane Ridge syncline area. The lower part of the succession is composed of gray calcareous and non-calcareous shales and limestone interbeds in both areas. Above the lower shales in the Middlesboro syncline sandstones make up most of the succession; however, interbeds of gray clay shale and a few thin units of maroon mudstone are present. In contrast, the succession in the Hurricane Ridge syncline area is predominantly a maroon mudstone sequence. A basal sandstone and a number of sandstones near the middle of the succession are interbedded with the maroon mudstones. A single prominent limestone member occurs in the upper part of the clastic sequences in both areas. The succession of lithologies in the two areas is generalized in the following sections (Table 1):

TABLE 1

GENERALIZED UPPER MISSISSIPPIAN CLASTIC SEQUENCES

Middlesboro Syncline Area	Hurricane Ridge Syncline Area
	150 ft.—gray claystone and siltstone; thin coals
	500 ft.—maroon mudstone and thin sandstones
250-800 ft.—gray clay shale; thin coals; brown sandstones; conglomerate at base	100-300 ft.—dark-gray clay shale and siltstone
	10-165 ft.—yellowish-brown orthoquartzite and quartz-pebble conglomerate
	250-450 ft.—gray and brown sandstones, locally conglomeratic; maroon mudstones
0-50 ft.—blue-gray argillaceous limestone	0-60 ft.—blue-gray argillaceous limestone
100-300 ft.—brown sandstone and siltstone; thin maroon mudstones	350-850 ft.—maroon mudstone; thin maroon siltstones and sandstones; thin green mudstones; very thin nodular limestones; gray claystone in lower part of thicker sections
150-300 ft.—light-brown orthoquartzite; interlaminated and interbedded gray clay shale	20-450 ft.—light-brown orthoquartzite; gray clay shales and maroon mudstones in sections thicker than 150 feet
200-550 ft.—gray clay shale with limestone interbeds in lower part	100-800 ft.—gray clay shale; thin sandstones; thin coals; maroon mudstones near top
	200-400 ft.—argillaceous limestone and calcareous mudstone grade upward to noncalcareous shales
Mississippian limestones	Mississippian limestones

History and Derivation of Stratigraphic Names

W. B. Rogers (1837) described the stratigraphic succession west of the Blue Ridge in Virginia and designated each member of the sequence by a number expressing its position in the series, the lowest being indicated by No. 1. He considered the thick limestone (the Mississippian limestone) and the overlying gray and red fine clastics as a single unit which he called No. 11 and to which he assigned a Mid-Carboniferous or Upper Sub-Carboniferous age (Pl. 4). Rogers noted the marked thickening of the limestone toward the southwest and he also described the red color and crumbly nature of the upper shales. In a later report Rogers (1838) used the designation No. XI for this unit.

In <u>MacFarlane's Geological Railway Guide</u>, W. B. Rogers (1879) called the same succession No. 13b and supplied the name Greenbrier limestones for the lower part and the name Greenbrier shales for the upper part of the unit. He also noted the correlation of No. 13b with the Umbral of H. D. Rogers' <u>The Geology of Pennsylvania</u> (1858).

In the New River valley southeast of Charleston, West Virginia, Fontaine (1876) placed all of the massive quartzose conglomerates in the lower part of the Coal

PLATE 4.—CORRELATION CHART SHOWING DERIVATION OF STRATIGRAPHIC NAMES USED FOR UPPER MISSISSIPPIAN STRATA

Rogers, W. B. 1837 Virginia	Rogers, H. D. 1858 Pennsylvania	Rogers, W. B. 1879 Virginia	Fontaine, W. M. 1876 West Virginia	Campbell, M. R. 1893 Big Stone Gap Coal Field, Virginia	Campbell, M. R. and Mendenhall, W. C. 1896 West Virginia	Campbell, M. R. 1896 Pocahontas Folio, Virginia-West Virginia	Reger, D. B. 1926 Mercer, Monroe, and Summers Counties, West Virginia	Butts, Charles 1940		Cooper, B. N. 1944 Burkes Garden Quadrangle, Virginia	Wilpolt, R. H. and Marden, D. W. 1949 Southern West Virginia, Southwestern Virginia, and Eastern Kentucky	THIS REPORT	
								Southwestern Virginia	Bluefield Area, Virginia			Southwestern Virginia and Eastern Kentucky	Southern West Virginia and adjacent counties of Virginia
			Conglomerate series coal-bearing beds		Royal formation coal-bearing beds	Pocahontas formation (Pennsylvanian)							
No. 12	Seral	14a. Great Conglomerate	red and gray shales		red and green shales	Bluestone formation	Bluestone group Bent Hunt Bratton Belcher Mud Glady Fork Pipestem Pride	hiatus	Bluestone formation	Bluestone formation Bent Mountain member Hunt member Bratton member Belcher member Mud Fork member Glady Fork member Pipestem member Pride member	Bluestone formation Upper member Red member Gray shale member	Pennington formation Upper Pennington	Bluestone formation
			conglomerate		Princeton conglomerate	Princeton conglomerate	Princeton conglomerate		Princeton conglomerate	Princeton conglomerate	Princeton conglomerate		Princeton formation
			Transition series										
No. 11	Umbral shales	13b. Greenbrier shales	Umbral	Pennington formation	Hinton formation (base of outcrop)	Hinton formation	Hinton group Terry Pluto Falls Mills Five Mile Tallery Low Gap Avis Payne Branch Hackett Tophet Goodwyn Bellepoint Stony Gap	Pennington formation	Pennington formation	Pennington formation Falls Mills member Avis limestone member Stony Gap sandstone member	Hinton formation Upper red member Avis limestone of Reger Middle red member Stony Gap sandstone member	Pound Gap member Middle Pennington Blackwood member	Hinton formation Abbs Valley Ridge member Avis member Adria member Stony Gap sandstone member
				Newman limestone		Bluefield formation	Bluefield group Coney Clayton Graham Bertha Bradshaw Indian Mills Raines Corner Possumtrot Droop Talcott Ada Reynolds Bickett Webster Springs Glenray Lillydale	Glen Dean limestone	Bluefield formation	Bluefield formation	Bluefield formation	Bluefield formation	Bluefield formation
	Umbral limestones	13b. Greenbrier limestones				Greenbrier limestone	Greenbrier series	Gasper limestone	Gasper limestone	"Gasper" limestone	Greenbrier limestone	Gasper limestone	Greenbrier limestone

Measures into a single unit, which he named the Conglomerate series. He considered the lowest conglomerate in the section to be the base of the Conglomerate series, although he noted several hundred feet of red beds between the lowest conglomerate and the continuous sequence of thick-bedded conglomeratic sandstones of the coal-bearing strata above. Below the base of the Conglomerate series Fontaine recognized a thin Transition series of gray sandy shales and a lower unit of red shales and limy beds which he called Umbral series, indicating correlation with the Pennsylvania section.

The initial names employed by Campbell (1893) for the Upper Mississippian rocks in the Big Stone Gap coal field of Virginia are still in use in that area (Pl. 4). The Newman limestone as named by Campbell included the calcareous shale and argillaceous limestone sequence as well as the underlying thick limestone unit. The top was placed at the base of the lowest prominent sandstone bed. The overlying sequence of sandstone units and interbedded red and gray shales was named Pennington formation from Pennington Gap, Lee County, Virginia. The top of the Pennington was placed at the base of the first thick-bedded sandstone above the highest red bed.

In the sections along the New and Kanawha rivers in West Virginia, Campbell and Mendenhall (1896) defined three formations. The conglomerate bed at the base of the Conglomerate series of Fontaine (1876) was named Princeton conglomerate from the town of Princeton, Mercer County, West Virginia. Below the Princeton conglomerate the succession of red shales, sandstones and limestones was named the Hinton formation from Hinton, Summers County, West Virginia, where the beds are well exposed. The strata above the Princeton conglomerate were referred to as the Royal formation, which included two distinct members—a red and green shale unit overlain by a coal-bearing predominantly sandy sequence. Campbell and Mendenhall noted that the red beds in the lower part of the Royal were an upward continuation of the Hinton and that a significant change in the section was marked by the top of the red beds. They also mentioned that the highest red beds were probably not the same age everywhere.

Another significant contribution to regional stratigraphic nomenclature was made by Campbell (1896) in the Pocahontas Folio of the United States Geological Atlas. The red beds above the Princeton conglomerate were named Bluestone formation from exposures along the Bluestone River in Mercer County, West Virginia. The base of the formation was marked by the Princeton conglomerate, and the highest red unit was taken as the top of the Bluestone. The Princeton conglomerate and Hinton formation were used as defined in the report on the New-Kanawha River valley (Campbell and Mendenhall, 1896). The base of the Hinton was marked by the prominent sandstone near the horizon of the lowest red beds. The term Bluefield formation was proposed for the calcareous shales and argillaceous limestones between the top of the major Carboniferous limestones and the base of the Hinton. The formation was named from exposures east of Bluefield, Mercer County, West Virginia.

Reger (1926) raised the Bluefield, Hinton, and Bluestone formations to group status and recognized several formations within each of these groups in Mercer, Monroe, and Summers counties, West Virginia (Pl. 4). Most of these formations may be distinguished only in local areas where the strata are nearly horizontal; however, a few of the units may be traced as much as 100 miles. The beds are almost perfectly horizontal in Summers County and in all of Mercer County except the southern part, and the thicknesses of the formations are consistent (Reger, 1926). Hence, Reger was able to trace his relatively thin formations for considerable distances and to study them in detail. Many of the formations could not be recognized in southern Mercer County and in adjacent parts of Tazewell County, Virginia, because of complicated structure and less extensive exposures. Facies changes and greatly increased thicknesses in the same area further obscured the distinguishing features of the thin stratigraphic units. Reger pointed out the correlation of the combined Bluefield, Hinton, Princeton, and Bluestone formations with the Mauch Chunk series (Ashburner, 1877) of Pennsylvania. He (Reger, 1926) also noted that Campbell (1896) in his original subdivision of these sequences failed to relate these beds to the Mauch Chunk, but mentioned only that the Bluefield represented the "upper portion of Rogers' No. XI".

Charles Butts (1940) used Campbell's (1896) units as formations with certain modifications. He (Butts, 1940) extended the name Glen Dean limestone (Butts, 1917) into this area to be applied to the upper formation in the limestone division of the Mississippian in southwestern Virginia, and he correlated his Glen Dean with the Bluefield formation of the Pocahontas quadrangle. Butts considered the Pennington formation to be the exact equivalent of the Hinton formation; and, because the former name had priority, he used it exclusively. The base of the Pennington was marked everywhere by the Stony Gap sandstone member, a unit defined as a formation in the Hinton group by Reger (1926). The Princeton and Bluestone formations in southwestern Virginia were represented by a hiatus which placed Pennsylvanian strata immediately on the Pennington formation.

In the Burkes Garden Quadrangle, Tazewell County, Virginia, B. N. Cooper (1944) employed the same formation names as Butts (1940). Cooper dropped to member rank in the Pennington formation three units of the Hinton defined as formations by Reger (1926): the Stony Gap sandstone member at the base of the Pennington, the Avis limestone member, and the Falls Mills sandstone member. Similarly Cooper reduced the formations of Reger's Bluestone group to member status.

Wilpolt and Marden (1949) correlated the Pennington formation with the combined Hinton, Princeton, and Bluestone; and by recognizing the Princeton conglomerate within the Pennington sequence in southwestern Virginia and eastern Kentucky they were able to use Hinton, Princeton, and Bluestone as formations from southern West Virginia to Cumberland Gap, Kentucky. They used the term Bluefield for the shaly limestones and shales that Butts (1940) referred to the Glen Dean; and this enabled the exclusive use of the term Bluefield for the shales immediately above the Mississippian limestones. Following Cooper (1944) they recognized the Stony Gap sandstone member and the Avis limestone member; however, they also noted that the term Avis was preoccupied (Plummer and Moore, 1922) and it was qualified as "Avis limestone of Reger". Wilpolt and Marden distinguished other members of the Hinton and

Bluestone formations by means of gross color characteristics.

In the present study it was discovered that two distinct sequences are present in the region (Table 1). Hence it is proposed to use two sets of formation terms; the Pennington formation is used in southwestern Virginia and eastern Kentucky, the area wherein it was defined, and the Hinton, Princeton, and Bluestone formations are distinguished in the Bluefield area, where they were defined (Table 2). Because the calcareous shale sequence below the Pennington more closely resembles the Bluefield formation (Campbell, 1896) than the Glen Dean limestone of Kentucky (Butts, 1917), the writer uses the term Bluefield exclusively for this part of the sequence. Members of these formations are defined in the following generalized sections (Table 2):

TABLE 2

GENERALIZED STRATIGRAPHIC SECTIONS OF

UPPER MISSISSIPPIAN ROCKS

<table>
<tr><th>Southwestern Virginia and
Eastern Kentucky</th><th>Southern West Virginia and
Tazewell County, Virginia</th></tr>
<tr><td rowspan="3">Pennington formation
(675-1300 ft.)
Upper Pennington
(240-800 ft.)
gray clay shale, coal, maroon mudstone, sandstone, local conglomerate at base

Pound Gap member
(0-50 ft.)
fossiliferous limestone and calcareous mudstone

Middle Pennington
(130-325 ft.)
mudstone, sandstone

Blackwood member
(140-300 ft.)
sandstone, gray clay shale</td><td>Bluestone formation
(120-800 ft.)
gray clay shale, coal, maroon mudstone, sandstone, siltstone</td></tr>
<tr><td>Princeton formation
(10-165 ft.)
quartz-pebble conglomerate and sandstone</td></tr>
<tr><td>Hinton formation
(640-1625 ft.)
Abbs Valley Ridge member
(250-450 ft.)
sandstone, maroon mudstone

Avis member
(0-60 ft.)
fossiliferous limestone and calcareous mudstone

Adria member
(340-850 ft.)
maroon mudstone, siltstone, sandstone

Stony Gap member
(20-450 ft.)
sandstone</td></tr>
<tr><td>Bluefield formation
(180-575 ft.)
clay shale, argillaceous limestone, fossiliferous</td><td>Bluefield formation
(300-1300 ft.)
clay shale, calcareous mudstone, argillaceous limestone, fossiliferous</td></tr>
</table>

Bluefield Formation

The Bluefield formation (Campbell, 1896) consists of calcareous and non-calcareous mudstones and argillaceous limestones which represent a transition from the Mississippian limestones to the overlying Hinton and Pennington formations. The writer places the lower contact of the Bluefield at the base of the lowest thick shaly argillaceous limestone above the Mississippian limestone division; however, this contact is probably not everywhere the same age. The Gasper limestone (Butts, 1940) in the Middlesboro syncline and the Greenbrier limestone (Reger, 1926) in the Hurricane Ridge syncline area are conformably overlain by the Bluefield formation. The Bluefield is conformably overlain by the Stony Gap sandstone member of the Hinton formation in the Hurricane Ridge syncline area and by the Blackwood sandstone member of the Pennington formation in the Middlesboro syncline.

The formation attains its maximum thickness of about 1300 feet in Mercer, Monroe, and Summers counties, West Virginia. The thickness decreases regularly to the northeast, north, west, and southwest; and minimum thicknesses observed are about 300 feet in Pocahontas County, West Virginia, and slightly less than 200 feet on Pine Mountain in eastern Kentucky.

The lower part of the Bluefield is predominantly blue-gray, fine-grained shaly argillaceous limestone and blue-gray calcareous mudstone[1]. Beds of blue-gray, medium-grained fossiliferous limestone occur throughout this part of the succession but are more common near the base of the Bluefield. Gray non-calcareous claystones occur in the upper part of this unit. At or near the base of the formation in Pocahontas County, West Virginia, is a thin, irregular, brown, fine-grained sandstone with interbeds of oolitic limestone, both of which have festoon cross-bedding. At the middle of the formation in sections in West Virginia is a yellowish-brown, fine-grained, thin-bedded sandstone with interlaminated clay. The sandstones characteristically have current ripple marks; and in southern Mercer County interference ripple marks are present.

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1. The terms mudstone and claystone are employed throughout this report in the sense defined by Pettijohn (1948, p. 341). Claystone is indurated clay which may be laminated. If the rock is fissile parallel to bedding, it is a clay shale. The term mudstone is applied to claystones which are neither laminated nor fissile but are blocky or massive. However, a shale or mudstone may contain 50 or more per cent silt sized particles.

The upper part of the Bluefield is generally non-calcareous and grades into the overlying formations. Light- to dark-gray and yellow-brown soft laminated claystones make up most of this part of the sequence. Locally there are a few minor sandstones and beds of blue-gray argillaceous limestone. Very thin clayey coal beds are restricted to the eastern fringes of outcrop of the Bluefield and are found only in Tazewell County, Virginia, and Mercer County, West Virginia. These are black, highly carbonaceous, soft, shaly layers with scattered unidentified plant remains. Beds of maroon-drab, blocky mudstone also are present near the top of the formation northward from Tazewell County. The maroon mudstone interbeds increase in number and thickness farther to the north in southern West Virginia.

The character of the Bluefield formation is indicated by the following geologic sections. The type section of the Bluefield formation (Campbell, 1896) is located in the Hurricane Ridge syncline 2 miles northeast of Bluefield, West Virginia, and was measured as follows:

Geologic Section 1.—Bluefield formation at Stony Gap along State Highway 25, 2 miles northeast of Bluefield, Mercer County, West Virginia.

	Thickness (Feet)
Hinton formation (Geologic Section 22)	
Bluefield formation (1280 feet)	
44. Clay shale, gray and maroon, fissile . . .	80
43. Sandstone, light-gray to brown, fine to medium grained; in even beds as much as 1 foot thick	4
42. Clay, dark-gray, carbonaceous; fragments of plant fossils	12
41. Mudstone, maroon-drab, blocky	9
40. Claystone, light-gray, fissile	17
39. Sandstone, grayish-yellow, very fine grained; thin shaly beds	4
38. Mudstone, maroon-drab, blocky	37
37. Sandstone, gray-brown, fine grained; thin shaly beds	26
36. Clay shale, olive-drab, fissile	10
35. Siltstone, maroon, micaceous; thin shaly beds	3
34. Clay shale, light-gray to dark-gray, finely fissile	15

33. Mudstone, maroon-drab, blocky; thin shaly interbeds of maroon, very fine-grained sandstone; unit is about 80 per cent mudstone	26
32. Mudstone, olive-brown, blocky	38
31. Clay shale, light-gray to dark-gray, finely fissile	24
30. Coal, black, clayey	1
29. Clay, red-brown, carbonaceous; fragments of plant fossils	2
28. Coal, black, clayey	1
27. Clay, red-brown, carbonaceous; fragments of plant fossils	4
26. Coal, black, clayey	2
25. Clay, red-brown, carbonaceous; fragments of plant fossils	4
24. Clay shale, light-gray, finely fissile	3
23. Clay, red-brown, carbonaceous; fragments of plant fossils; 2-inch bed of black clayey coal at top	2
22. Clay shale, light-gray, finely fissile	2
21. Coal, black, clayey; 2-inch bed of gray clay at base	1

20. Sandstone, light-gray, very fine grained; in uneven beds as much as 2 feet thick at top, thin shaly beds in lower part, gradation from thick beds above to shaly beds below; thin partings of carbonaceous clay with fragments of plant fossils . . .	11
19. Clay shale, light-gray to dark-gray, finely fissile	54
18. Sandstone, yellowish-brown, very fine grained; thin shaly beds, with a prominent 1-foot bed at base	5
17. Clay shale, light-gray to dark-gray, finely fissile	16
16. Covered	89
15. Limestone, gray, fine grained, argillaceous; shaly	11
14. Covered	42
13. Sandstone, pinkish-gray to white, fine grained; thin shaly beds; thin partings of gray clay	12
12. Sandstone, yellowish-gray to white, fine grained; in slightly uneven beds 2 inches to 1 foot	

	thick; interference ripple marks	6
11.	Sandstone, pinkish-gray to white, fine grained, friable; in even beds as much as 2 inches thick; interbeds of gray fissile clay shale; unit is about 80 per cent sandstone	40
10.	Covered	232
9.	Claystone, yellow-brown; thin bedded	8
8.	Mudstone, blue-gray, slightly calcareous, blocky to shaly	124
7.	Clay shale, olive-drab, fissile; few claystone concretions in lower 30 feet	169
6.	Limestone, dark blue-gray, fine grained, argillaceous; shaly	37
5.	Limestone, blue-gray, coarse grained; in even beds about 8 inches thick; _Diaphragmus elegans_, _Spirifer_ sp., _Pentremites brevis_, _Amplexizaphrentis spinulosum_, _Michelinia_ sp., _Archimedes symmetricus_	6
4.	Limestone, blue-gray, fine grained,	

argillaceous; shaly	29
3. Limestone, dark blue-gray, medium grained; in two even beds	3
2. Limestone, blue-gray, fine grained, argillaceous; shaly	50
1. Limestone, light-gray, very fine grained, argillaceous; shaly	9

Greenbrier limestone

A typical section of the Bluefield formation in southwestern Virginia is the following, measured at Big Stone Gap, Wise County:

Geologic Section 2.—Bluefield formation along Southern Railroad at Big Stone Gap where the Powell River cuts through Little Stone Mountain, Wise County, Virginia.

	Thickness (Feet)
Pennington formation (Geologic Section 17)	
Bluefield formation (455 feet)	
31. Claystone, dark-gray; thin bedded	5
30. Sandstone, maroon, very fine grained; thin shaly beds	2
29. Clay shale, dark-gray to black, fissile; thin lenses of maroon, very fine-grained sandstone	7
28. Sandstone, light-gray, very fine grained, micaceous; single bed	3
27. Siltstone, light-gray to dark-gray; thin shaly beds	19
26. Mudstone, gray, blocky	7
25. Claystone, gray; thin bedded	4
24. Siltstone, light-gray; in even	

	beds as much as 2 feet thick	7
23.	Clay shale, dark-gray to black, fissile; coaly layers; fragments of plant fossils	11
22.	Sandstone, gray, very fine grained; thin shaly beds, lenses; current ripple marks; interlaminated dark-gray clay; unit is about 60 per cent sandstone	40
21.	Limestone, light-gray, fine grained, argillaceous; shaly; small fragments of brachiopod shells	3
20.	Claystone, dark-gray; thin bedded	4
19.	Limestone, dark blue-gray, fine grained with scattered medium crystals of calcite; single bed; (crinoids?) *Spirifer* sp., *Orthotetes kaskaskiensis*	2
18.	Clay shale, dark blue-gray, calcareous, fissile; thin interbeds of blue-gray fine-grained argillaceous limestone; unit is about 75 per cent clay shale	29

17.	Limestone, dark blue-gray, fine grained; in even beds as much as 3 feet thick	23
16.	Covered	100
15.	Limestone, blue-gray, medium grained; thin shaly beds; _Spirifer_ sp., _Composita_ sp., _Chonetes chesterensis_, _Amplexizaphrentis spinulosum_	5
14.	Limestone, light-gray, fine grained; thin shaly beds; _Spirifer_ sp., _Archimedes_ sp.	5
13.	Limestone, dark blue-gray, fine grained, argillaceous; thin shaly beds; thin interbeds of blue-gray fine-grained limestone; _Orthotetes kaskaskiensis_	26
12.	Limestone, dark blue-gray, medium grained; single bed	2
11.	Limestone, dark blue-gray, fine grained, argillaceous; shaly; _Spirifer_ sp., _Amplexizaphrentis spinulosum_	16
10.	Clay shale, blue-gray, fissile	2
9.	Limestone, light-gray, fine grained,	

argillaceous; thin shaly beds; oscillation ripple marks 2

8. Limestone, blue-gray, fine grained, oolitic; single bed 2

7. Clay shale, blue-gray, fissile 4

6. Limestone, blue-gray, fine grained with scattered crystals of calcite; in even beds as much as 2 feet thick; Archimedes sp. 17

5. Mudstone, olive, slightly calcareous, blocky 5

4. Mudstone, dark-gray, slightly calcareous, blocky 20

3. Limestone, blue-gray, fine grained, argillaceous; shaly 12

2. Limestone, blue-gray, fine grained, argillaceous; shaly; Spirifer sp., Diaphragmus elegans, Chonetes chesterensis, Archimedes sp. 25

1. Covered 46

Gasper limestone

Hinton Formation

The Hinton formation (Campbell, 1896) consists of a sequence of maroon mudstones and interbedded sandstones. The thickness of the formation ranges from 640 feet in Pocahontas County, West Virginia, to 1600 feet in northeastern Tazewell County, Virginia. The Hinton formation is subdivided into four members: Stony Gap sandstone member, Adria member, Avis member, and Abbs Valley Ridge member.

The name Hinton formation is restricted by the writer to areas in and north of Tazewell County, Virginia. The Upper Mississippian clastic sequence in southwestern Virginia and eastern Kentucky is stratigraphically distinct from the sequence exposed in southern West Virginia and adjacent counties of Virginia (Table 1). For this reason it is proposed that the name Hinton be used in the latter area and that the name Pennington be used in southwestern Virginia. However, these two formations are at least partially equivalent.

Stony Gap sandstone member.—The Stony Gap sandstone member (Reger, 1926) marks the base of the Hinton formation. The type section is at Stony Gap, 2 miles east of Bluefield, West Virginia (Pl. 5, fig. 1). It is generally a white to light-brown medium-grained thick-bedded orthoquartzite from 20 to 120 feet thick. Cross-bedding is fairly common and some of the beds have ripple marks. Locally in the structurally lowest part of the Hurricane Ridge syncline the member is as much as 450 feet thick and is composed of gray clay shale and sandstone.

North of Mercer County, West Virginia, the Stony Gap is a light-colored medium-grained thick-bedded orthoquartzite from 50 to 75 feet thick. However, shaly beds and interlaminated clays are common locally, north and west of Hinton, Summers County, West Virginia.

The Stony Gap extends as a single unit from Summers County into the Hurricane Ridge syncline a few miles west of Bluefield. The Stony Gap member at Bluefield, on the overturned southeast limb of the Hurricane Ridge syncline, is closer to the trough of the syncline than any other measured section. At this locality the member is a light-brown orthoquartzite 120 feet thick. The section at Glenlyn, east of Bluefield, is higher on the overturned southeast flank of the syncline and there the Stony Gap is

PLATE 5

TOPOGRAPHIC EXPRESSION OF UPPER MISSISSIPPIAN SANDSTONES

Figure 1.—Type locality of Stony Gap sandstone member of Hinton formation at Stony Gap, Mercer County, West Virginia. Stony Ridge, into which the gap is cut, is held up by overturned Stony Gap sandstone.

Figure 2.—Characteristic outcrop of the lower sandstone unit of the Abbs Valley Ridge member of the Hinton formation, near Mud Fork, Tazewell County, Virginia.

Figure 1

Figure 2

a fine-grained sandstone 23 feet thick. The member consists of 60 feet of white orthoquartzite west of Bluefield near Bailey, Tazewell County, Virginia, which is somewhat higher on the southeast flank of the syncline than the section at Bluefield. The Stony Gap is a light-brown medium-grained orthoquartzite about 25 feet thick on the northwest flank of the Hurricane Ridge syncline northwest of Bluefield in the vicinity of Boissevain, Tazewell County, Virginia.

The orthoquartzite of the Stony Gap in the vicinity of Bluefield is composed almost entirely of subround grains of quartz, but about 3 per cent of the grains are detrital fragments of a fine-grained quartz-mica rock[1]. Rounded

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1. The detrital lithic grains in the Upper Mississippian are commonly less than 0.3 millimeter in diameter and are composed of very small (less than 0.1 millimeter) angular grains of quartz and very small flakes of mica. The small flakes of mica in the detrital grains and the larger detrital grains of mica in the sandstones were originally derived from a primary source, but they have been recycled. The parent rock of the lithic fragments may be shaly sandstones or quartzose shales which are common in the Upper Devonian and Lower Mississippian of the western belts of the folded Appalachians; however, schists or phyllites of the Blue Ridge metamorphic terrain may be the source of these fragments.

grains of tourmaline and zircon, fragments of magnetite, apatite, and small flakes of muscovite make up a small part of the rock. A trace of limonite cements some of the quartz grains.

Southwest of Bluefield in the vicinity of Bishop and Mud Fork, Tazewell County, the Stony Gap member loses its identity. In exposures of the lower Hinton nearest to the structurally lowest part of the Hurricane Ridge syncline a 450-foot succession of gray clay shales at the approximate position of the Stony Gap contains three to six separate light-brown, fine- to medium-grained sandstones ranging in thickness from 5 to 45 feet. This entire sequence of sandstones probably represents the thinner Stony Gap of the Bluefield vicinity, which occurs as a single orthoquartzite unit. The member is about 375 feet thick on the north side of Stony Ridge along State Highway 16, 4 miles north of Adria, Tazewell County, Virginia. Five sandstone units are present and these total about 80 feet. The remainder of the member is composed of gray clay shales and a single unit of maroon clay shale. A typical sandstone of this group contains about 80 per cent quartz, 6 per cent biotite, 10 per cent detrital grains of a fine-grained quartz-mica rock, and traces of muscovite, magnetite, and limonite.

<u>Adria member</u>.—As much as 1000 feet of gray and maroon mudstones containing interbeds of maroon-brown very fine-grained sandstone overlie the Stony Gap sandstone member and are named the Adria member of the Hinton formation by the writer. The name is taken from the village of Adria on State Highway 16, 3 miles north of Tazewell, Tazewell County, Virginia. The type section is on the northwest side of Stony Ridge on the northwest flank of the Hurricane Ridge syncline 3 miles north of Adria (Geologic Section 3).

In the thicker sections, which are located in the structurally lowest part of the Hurricane Ridge syncline, in Tazewell and Mercer counties, the lower half of the Adria member is made up of gray fissile clay shales and gray and brown sandy claystones with thin interbeds of yellow-brown fine-grained sandstone and maroon-drab mudstone. Maroon mudstones increase in abundance upward in the section and the upper half of the member is composed almost entirely of this type of rock. North of Hinton, Summers County, West Virginia, the Adria member is essentially all maroon mudstone and contains interbeds of maroon fine-grained sandstone, which have very limited lateral extent (Pl. 6, fig. 1). Thin layers of green mudstone are common in the maroon mudstone sequence. The contact between green mudstones and underlying maroon mudstones is irregular and gradational; however, the contact between green mudstones and overlying maroon mudstones is sharp and even (Pl. 6, fig. 2). Very thin nodular beds of black limestone overlie some of the green mudstone layers.

In the structurally lowest part of the Hurricane Ridge syncline in Tazewell County, Virginia, the upper part of the Adria member consists of alternating maroon mudstones and maroon very fine-grained sandstones. The sandstones, which are in beds as much as 6 feet thick, break into large blocks because of widely spaced joints; but the sandstone is sufficiently resistant to make prominent ledges. The top and bottom of each bed is remarkably smooth; however, shallow groove casts are common on the undersides of most of the sandstone beds.

A number of small folds and faults (Pl. 21, fig. 1) occur in thin sandstone interbeds in the maroon mudstone sequence of the Adria member on the northwest flank of the Hurricane Ridge syncline in the vicinity of Rich Creek and Glenlyn, Giles County, Virginia. These structures, which have dips steepened toward the trough of the Hurricane Ridge syncline, are limited to a few feet of beds and have very small lateral extent.

PLATE 6

LITHOLOGY OF ADRIA MEMBER

'igure 1.—Middle part of Adria member, west of
Iarlinton on Kennison Mountain, Pocahontas County,
lest Virginia. The small resistant bed of maroon
'ine-grained sandstone, which decreases in thickness
'rom 3 feet to a pinch-out within 200 feet laterally
left to right in photograph), in a maroon mudstone
equence is typical of the Adria member.

igure 2.—Adria member on northwest side of Stony
idge on State Highway 16, Tazewell County, Virginia.
he thin nodular bed of limestone (head of hammer)
ests on greenish-gray mudstone, which grades downward
o maroon-drab mudstone. The typical blocky character
f the Upper Mississippian mudstones is shown.

Figure 1

Figure 2

Avis member.—The Avis member (Reger, 1926), which conformably overlies the Adria member, is generally a blue-gray fine-grained argillaceous limestone with thin interbeds of calcareous mudstone. It is everywhere abundantly fossiliferous and is locally as much as 60 feet thick. A more or less regular lateral transition occurs between a relatively clean limestone which comprises the Avis along the western side of the outcrop in West Virginia and a brown non-calcareous mudstone in the vicinity of Bluefield, West Virginia.

A 1- to 3-foot blue-gray limestone containing fragments of brachiopod shells probably represents a greatly thinned northern extension of the Avis in Pocahontas and Greenbrier counties, West Virginia. In Mercer and Summers counties, West Virginia, the Avis is typically a blue-gray argillaceous limestone between 30 and 60 feet thick. In northern Summers County—in the most westerly section observed—the Avis is a blue-gray fine-grained limestone. In the trough of the Hurricane Ridge syncline in Tazewell County, Virginia, the Avis consists of interbedded calcareous mudstone and argillaceous limestone; the thickness ranges from 20 to 50 feet. The only exposures on the southeast flank of the Hurricane Ridge syncline are on Stony Ridge in the vicinity of

Bluefield, West Virginia, where the Avis is composed of 20 feet of brown mudstone.

Abbs Valley Ridge member.—The uppermost part of the Hinton formation is composed mainly of a number of light-colored sandstones with interbedded units of maroon-drab mudstone and gray fissile clay shale. The name Abbs Valley Ridge member is proposed for this unit from excellent exposures on Abbs Valley Ridge about 3 miles south of Boissevain, Tazewell County, Virginia (Geologic Section 4). One to six light-brown, fine- to medium-grained sandstones are present and one—the Falls Mills sandstone of Reger (1926)—attains a maximum thickness of 60 feet. The sandstones locally have foreset bedding and current ripple marks. A number of conglomerates occur locally at various horizons in this part of the section. Locally one to two thin limestones in the middle part of the member contain abundant fossils; and one to two beds of brown thin-bedded claystone in the upper part contain limonitic casts of fossils. The member is apparently conformable on the underlying Avis member.

The Abbs Valley Ridge member contains a single important sandstone about 40 feet thick in sections in and north of northern Summers County, West Virginia. The number of sandstones increases southward and in southern Summers County two sandstones are present. In Mercer County, West Virginia, and Tazewell County, Virginia, along the northwest flank of the Hurricane Ridge syncline three to five sandstones are present. However, in the trough and on the southeast flank of the syncline only one sandstone occurs in the Abbs Valley Ridge member (Pl. 5, fig. 2). In the structurally lowest part of the Hurricane Ridge syncline a typical sandstone is composed of about 75 per cent quartz, 15 per cent detrital grains of a fine-grained quartz-mica rock, 6 per cent biotite, 2 per cent muscovite, a few grains of magnetite, and a trace of limonite cement. In contrast a typical sandstone in the Summers County area contains about 90 per cent quartz, 4 per cent detrital grains of a fine-grained quartz-mica rock, 4 per cent biotite, and a few grains of magnetite. A trace of limonite cements some of the grains. In all of these rocks the grains are subangular and are in close contact. The aggregate thickness of the several sandstones on the northwest flank is between 80 and 90 feet; and the single sandstone in the axial portion and on the southeast flank of the Hurricane Ridge syncline is about 45 feet thick. The latter is very fine grained but the sandstones to the northwest are fine to medium grained.

In the vicinity of Athens, Mercer County, West

Virginia, the lowermost sandstone of the Abbs Valley Ridge member (Avis sandstone of Reger, 1926) changes abruptly in both thickness and lithologic character. In exposures along Laurel Creek north of Athens, the unit changes from a 70-foot sandstone and limestone-pebble conglomerate to a 20-foot sandstone within 0.5 mile. The top of the unit is essentially a plane and the local 50-foot increase is added at the base. The conglomerate is restricted to the lower 20 feet of the thickest sections and occurs in elongate lenses a few feet thick and several tens of feet wide. The typical gray to brown, fine- to medium-grained sandstone is composed of about 60 per cent quartz, 5 per cent rounded detrital grains of calcite, and 35 per cent calcite cement. A few rounded grains of tourmaline and zircon are present. Rounded pebbles as much as 0.5 inch in diameter composed of blue-gray fine-grained limestone make up the bulk of the conglomerate; however, a few pebbles are of black pyritic carbonaceous claystone, maroon siltstone, and maroon mudstone. Compound foreset bedding is common throughout the unit; however, the dominant orientation of foreset inclination is toward the locus of the thickest sections (Fig. 5).

A small lobate lens of maroon mudstone-pebble conglomerate is exposed in a road cut along U. S. Highway 460, 4 miles southeast of Princeton, Mercer County, West

Virginia. The mudstone pebbles are subround to round and are contained in a matrix of maroon mudstone. The conglomerate bed is within a sequence of maroon mudstones which weather into small blocks as much as 0.5 inch in maximum dimension; the rounded pebbles in the conglomerate are of comparable size. The single bed of conglomerate, which is located on the northwest flank of the Hurricane Ridge syncline only a few hundred feet from the trough of the structure, extends for several tens of feet transverse to the strike of the syncline. The maximum thickness of the bed is 3 feet and it pinches out in a lobate front down the dip. Other occurrences of similar material are noted along the New River northwest of Glenlyn, Giles County, Virginia.

A small asymmetric syncline of limited lateral extent occurs in a thin limestone in the middle of the Abbs Valley Ridge member in the vicinity of Athens, Mercer County, West Virginia (Pls. 16, 17). The limestone is truncated by a sandstone and limestone-pebble conglomerate. Minor undulations in bedding occur in shaly sandstones in the vicinity of Athens, West Virginia, and on Kennison Mountain, Pocahontas County, West Virginia (Fig. 6-A).

__Geologic sections of Hinton formation.__—A typical section of the Hinton, which includes the type section of the Adria member, in the structurally lowest part of the Hurricane Ridge syncline in Tazewell County, Virginia, is described in detail as follows:

Geologic Section 3.—Hinton formation on north side of Stony Ridge along State Highway 16, Tazewell County, Virginia.

	Thickness (Feet)
Princeton formation (Geologic Section 7)	
Hinton formation (1587 feet)	
Abbs Valley Ridge member (455 feet)	
80. Covered	165
79. Clay shale, maroon and gray, fissile	20
78. Clay shale, blue-gray, fissile	11
77. Mudstone, maroon-drab, blocky	42
76. Covered	26
75. Sandstone, yellowish-gray, very fine grained; thin shaly beds	3
74. Mudstone, maroon-drab, blocky	11
73. Covered	90

72. Sandstone, light gray-brown, fine grained, micaceous; in slightly uneven beds 1 inch to 3 feet thick, uniform foreset bedding dips northwest; current ripple marks 42

71. Covered 45

Avis member (43 feet)

70. Limestone, blue-gray, fine grained, argillaceous; interbeds of blue-gray calcareous mudstone; shaly; Dictyoclostus inflatus, Composita subquadrata, Orthotetes kaskaskiensis, Reticulariina spinosa, Sulcatopinna missouriensis, Amplexizaphrentis spinulosum 43

Adria member (type section, 713 feet)

69. Mudstone, maroon-drab, blocky 5

68. Mudstone, mottled maroon and gray, calcareous; nodules of gray fine-grained limestone 2

67. Sandstone, light-gray, fine grained, micaceous; single bed, smooth top and bottom; distally jointed, breaks into

large blocks	4
66. Clay shale, maroon-drab, fissile; interbeds of maroon, very fine-grained sandstone as much as 2 feet thick	7
65. Sandstone, gray-brown, fine grained; single bed, smooth top and bottom, groove casts on under surface; distally jointed, breaks into large blocks	5
64. Clay shale, maroon-drab, fissile	7
63. Sandstone, light-gray, fine grained; two beds parted by 6 inches of maroon fissile clay shale; beds smooth with groove casts on under surfaces	5
62. Mudstone, maroon-drab, shaly to blocky, calcareous	20
61. Limestone, mottled maroon and gray, fine grained, argillaceous; shaly	2
60. Covered	4
59. Siltstone, maroon; beds as much as 1.5 feet thick, shaly; interbeds of maroon-drab fissile clay shale	7

58. Clay shale, maroon-drab, fissile	4
57. Sandstone, light-brown, fine grained; single bed	2
56. Covered	12
55. Clay shale, maroon-drab, fissile	5
54. Siltstone, pinkish-gray, fine grained, calcareous; single bed	2
53. Mudstone, maroon-drab with intercalations of greenish-gray, blocky; interbeds of maroon siltstone as much as 0.5 foot thick	20
52. Sandstone, gray, very fine grained; in even beds as much as 5 feet thick; uniform foreset bedding dips southeast; distally jointed, breaks into large blocks	13
51. Mudstone, maroon-drab, blocky, calcareous; gray calcareous nodules as much as 1 inch in diameter	5
50. Siltstone, maroon, coarse grained, calcareous; two beds with thin parting of maroon-drab mudstone	2
49. Mudstone, maroon-drab with	

	greenish-gray layer at top, blocky	13
48.	Siltstone, maroon, coarse grained; thin shaly beds; groove casts on under surface	5
47.	Mudstone, maroon-drab with thin layers of greenish-gray, blocky to fissile, calcareous	17
46.	Sandstone, maroon, very fine grained; single bed, smooth top and bottom; distally jointed, breaks into large blocks	4
45.	Covered	12
44.	Limestone, gray to red, fine grained, argillaceous; shaly	11
43.	Sandstone, maroon, very fine grained; single bed	1
42.	Clay shale, maroon-drab, fissile; interbeds of maroon fine-grained siltstone; shaly, beds as much as 1 foot thick	9
41.	Sandstone, maroon, very fine grained; single bed	2
40.	Clay shale, maroon-drab, fissile, calcareous	5
39.	Sandstone, gray, very fine grained;	

thin interbeds of maroon fissile clay shale; beds as much as 2 feet thick; groove casts on under surfaces of lower beds 7

38. Clay shale, maroon-drab with layer of greenish-gray at top, fissile to blocky, calcareous 3

37. Limestone, dark-gray, fine grained, argillaceous; single bed 1

36. Mudstone, maroon-drab with layer of greenish-gray at top, calcareous, blocky; calcareous nodules in lower 3 feet 10

35. Sandstone, gray-brown, fine grained; in beds as much as 2 feet thick with partings of maroon-drab mudstone; groove casts on under surfaces of lower beds 12

34. Mudstone, maroon-drab with layer of greenish-gray at top, fissile to blocky; calcareous nodules in lower part 13

33. Sandstone, maroon, very fine grained; two beds 2 feet thick,

parted by 4 feet of maroon clay shale; lower bed has current-bedding (Pl. 13, fig. 2) 8

32. Mudstone, greenish-gray, blocky 6

31. Sandstone, maroon, very fine grained; thin shaly beds with partings of maroon fissile clay shale 8

30. Mudstone, greenish-gray at top grades down to maroon-drab within 8 feet, blocky, calcareous; thin interbeds of maroon siltstone 41

29. Sandstone, maroon, very fine grained; in uneven beds as much as 3 feet thick, partings of maroon fissile clay shale; groove casts on under surfaces of lower beds 21

28. Mudstone, maroon-drab, blocky; 1 foot thick at top; underlain by 2-inch bed of black fine-grained limestone; the limestone is underlain by a layer of greenish-gray mudstone which is underlain by maroon-drab mudstone; minimum

	thickness of the greenish-gray mudstone is 1 inch, pendants of greenish-gray mudstone extend down into the underlying maroon-drab mudstone as much as 10 inches (Pl. 6, fig. 2)	2
27.	Mudstone, maroon-drab, blocky	18
26.	Covered	17
25.	Clay shale, maroon mottled with greenish-gray, fissile; thin interbeds of maroon siltstone	34
24.	Clay shale, olive, fissile	38
23.	Sandstone, greenish-gray, very fine grained; single bed	4
22.	Covered	5
21.	Limestone, dark-gray, fine grained, argillaceous; nodular beds	2
20.	Clay shale, dark-gray to black, fissile; carbonaceous layers, fragments of plant fossils	76
19.	Limestone, gray, fine grained, argillaceous; single bed	1
18.	Sandstone, gray, fine grained, calcareous; single bed	3
17.	Clay shale, gray, fissile	4

16. Covered	14
15. Sandstone, grayish-brown, fine grained; single bed	1
14. Clay shale, gray to olive-drab, fissile	44
13. Clay shale, light-gray, fissile to thin bedded; thin interbeds of gray, very fine-grained sandstones near top and bottom; <u>Aviculopecten</u> sp., <u>Nuculana</u> sp.	106
Stony Gap sandstone member (376 feet)	
12. Sandstone, light-yellow, medium grained; in even beds as much as 2 feet thick	7
11. Covered	32
10. Sandstone, brownish-yellow, very fine grained; in even beds 2 inches to 2 feet thick	7
9. Clay shale, gray, fissile	24
8. Clay shale, maroon mottled with greenish-gray, fissile	24
7. Covered	40
6. Sandstone, brownish-yellow, medium grained; in even beds as much as 1 foot thick	4

} in "switchback"

5. Covered	40
4. Sandstone, light brownish-gray, fine to medium grained, micaceous; in uneven beds as much as 4 feet thick	39
3. Clay shale, gray, fissile	5
2. Covered	133 – Rte 644 turnoff
1. Sandstone, light-gray, fine grained; in even beds as much as 2 feet thick; interbeds of shaly sandstone . . .	21

Bluefield formation (Geologic Section 19)

The section of the Hinton formation at the type locality of the Abbs Valley Ridge member is described as follows:

Geologic Section 4.—Hinton formation on the crest of Abbs Valley Ridge on State Secondary Road 702, near Boissevain, Tazewell County, Virginia.

	Thickness (Feet)
Princeton formation (20+ feet)	
29. Orthoquartzite, white to salmon, medium grained; in even beds as much as 2 feet thick	20
Hinton formation (570+ feet)	
Abbs Valley Ridge member (type section, 345 feet)	
28. Covered	20
27. Clay shale, dark-gray to black, fissile	6
26. Claystone, olive-drab; thin bedded; Dictyoclostus inflatus, Reticulariina spinosa, Punctospirifer transversa	4
25. Clay, light-gray, lumpy, limonite streaks	10
24. Covered	6

23. Sandstone, brownish-yellow to salmon, fine grained, micaceous; in even beds as much as 4 inches thick	48
22. Mudstone, maroon-drab, blocky	36
21. Orthoquartzite, yellowish-gray, medium grained; single bed	2
20. Covered	17
19. Sandstone, salmon, fine to medium grained; in even beds as much as 3 feet thick	20
18. Covered	49
17. Siltstone, dark-gray, fine grained, micaceous; thin shaly beds	3
16. Clay shale, olive-drab, fissile	16
15. Orthoquartzite, gray to brownish-gray, medium grained; in even beds as much as 2 feet thick	18
14. Mudstone, olive-drab, blocky	18
13. Siltstone, maroon, fine grained, micaceous; in even beds as much as 8 inches thick	6
12. Mudstone, maroon-drab, blocky; thin interbeds of maroon siltstone	19

11. Siltstone, maroon, fine grained; thin shaly beds	10
10. Clay shale, greenish-gray, fissile	7
9. Clay shale, gray to blue-gray, calcareous	30
Avis member (43 feet)	
8. Limestone, light blue-gray, fine grained, argillaceous; shaly; *Dictyoclostus inflatus*, *Composita subquadrata*, *Schizophoria* sp., *Orthotetes kaskaskiensis*	34
7. Clay shale, dark gray-brown, calcareous, fissile; small lenses of blue-gray medium-grained limestone; *Orthotetes kaskaskiensis*, *Composita subquadrata*, *Eumetria costata*, *Reticulariina spinosa*, *Amplexizaphrentis spinulosum*, *Agassizocrinus conicus*, *Allorisma* sp.	9
Adria member (182+ feet)	
6. Mudstone, maroon-drab, blocky	13
5. Siltstone, maroon, fine grained, micaceous; thin shaly beds	4
4. Covered	8

3. Mudstone, maroon-drab, blocky	31
2. Siltstone, maroon, fine grained, micaceous; thin shaly beds; thin partings of maroon-drab fissile clay shale	17
1. Mudstone, maroon-drab with thin layers of greenish-gray, blocky; thin interbeds of maroon siltstone in upper 20 feet	109

End of exposure.

The character of the Hinton formation north of the Hurricane Ridge syncline is typified by the following section:

Geologic Section 5.—Hinton formation on southeast spur of Keeney Mountain along dirt road in vicinity of Clayton Village, Summers County, West Virginia.

	Thickness (Feet)
Princeton formation (Geologic Section 8)	
Hinton formation (907 feet)	
Abbs Valley Ridge member (301 feet)	
36. Clay, light-gray, lumpy	21
35. Clay shale, dark-gray, fissile	17
34. Claystone, light-gray, thin bedded	5
33. Covered	23
32. Sandstone, yellowish-brown, very fine grained; thin shaly beds	8
31. Mudstone, greenish-gray, blocky	34
30. Covered	17
29. Sandstone, white, very fine grained; single bed	1
28. Mudstone, maroon-drab, blocky	29
27. Siltstone, greenish-gray; thin shaly beds	11

26. Orthoquartzite, light-brown, fine to medium grained; in even beds as much as 3 feet thick, uniform foreset bedding dips southwest (Pl. 13, fig. 1)	51
25. Covered	5
24. Sandstone, brownish-yellow, fine to medium grained; thin shaly beds	3
23. Claystone, brown, sandy; thin bedded	2
22. Mudstone, olive-drab, blocky	10
21. Mudstone, maroon-drab, blocky	14
20. Mudstone, maroon-drab with thin layers of greenish-gray, calcareous, blocky	10
19. Mudstone, maroon-drab, blocky	23
18. Limestone, yellowish-gray, fine grained, argillaceous; single bed	2
17. Mudstone, maroon-drab mottled with greenish-gray, calcareous, blocky	15

Avis member (40 feet)

16. Limestone, light blue-gray, fine grained, argillaceous; in uneven beds as much as 3 feet thick, shaly; Reticulariina spinosa,

<u>Composita</u> <u>subquadrata</u>, <u>Dictyoclostus</u> <u>inflatus</u>, <u>Allorisma</u> sp.	40
Adria member (526 feet)	
15. Mudstone, greenish-gray, blocky to fissile	6
14. Limestone, yellowish-gray, fine grained, argillaceous; single bed	1
13. Mudstone, maroon-drab with thin layer of greenish-gray at top, blocky	45
12. Covered	65
11. Siltstone, maroon; thin shaly beds	10
10. Mudstone, maroon-drab, blocky	61
9. Mudstone, olive to yellowish-brown, blocky to fissile	17
8. Mudstone, maroon-drab, blocky	60
7. Siltstone, maroon, micaceous; thin shaly beds	11
6. Mudstone, olive, blocky	22
5. Mudstone, maroon-drab, calcareous, blocky	14
4. Mudstone, maroon-drab with layers of greenish-gray, blocky	55
3. Sandstone, maroon, very fine grained; thin shaly beds	15

2. Covered; few small widely scattered outcrops of maroon-drab blocky mudstone 144

Stony Gap sandstone member (40 feet)

1. Orthoquartzite, light-gray, fine to medium grained; in slightly uneven beds as much as 2 feet thick 40

Bluefield formation

Princeton Formation

The Princeton formation (Campbell and Mendenhall, 1896) conformably overlies the Hinton formation and underlies the Bluestone formation. Its average thickness is about 25 feet; the maximum observed is 165 feet in northeastern Tazewell County, Virginia, in the structurally lowest part of the Hurricane Ridge syncline. The Princeton is a light-brown, medium- to very coarse-grained orthoquartzite locally containing rounded pebbles of quartz as much as 1 inch in diameter. In some sections the Princeton contains rounded pebbles of various kinds of sedimentary rocks, the most common of which are dark mudstones and argillaceous limestones. Interbeds of dark-gray fissile carbonaceous shale are common in the thickest sections of the Princeton.

The Princeton is lithologically distinct from other sandstones in the Upper Mississippian in and north of Mercer County, West Virginia. In Tazewell County, Virginia, the Princeton is similar to sandstones in the upper Hinton and lower Bluestone formations; however, in that area it can be identified by its position in the sequence.

In and north of Summers County, West Virginia, the

Princeton is a yellow to white, medium- to very coarse-grained orthoquartzite which contains rounded pebbles of quartz as much as 1 inch in diameter. The size and number of pebbles decrease regularly toward the south and west. The rock is composed of more than 95 per cent subround quartz grains; detrital grains of a fine-grained quartz-mica rock, rounded grains of tourmaline and zircon, and a trace of magnetite make up the remainder of the rock. The thickness of the unit ranges from 25 to 35 feet. Locally in Pocahontas County, West Virginia, the lower 10 feet of the Princeton is a conglomerate composed of rounded pebbles of blue-gray limestone and gray mudstone as much as 0.5 inch in diameter. Fragments of plant fossils occur in this section. The most westerly section studied, in northern Summers County, West Virginia, contains a brown fine-grained sandstone that is probably equivalent to the conglomeratic orthoquartzite of the eastern part of the area.

In southern Mercer County, West Virginia, along the southeast side of the Hurricane Ridge syncline, the Princeton is a brown medium-grained orthoquartzite about 35 feet thick. However, on the northwest flank of the syncline the orthoquartzite contains scattered pebbles of quartz as much as 0.5 inch in diameter.

About 4 miles southeast of Princeton, West Virginia, a few hundred feet northwest of the trough of the Hurricane Ridge syncline, the typical 35-foot thick sandstone bed of the Princeton is overlapped by three distinct lenses of sandstone (Pls. 7, 8). Shallow channel-fillings occur at the base of the thick Princeton sandstone. The three lenses above the main sandstone bed are composed of light-brown medium-grained sandstone. The lenses pinch out up dip and thicken down dip by truncation of underlying beds of mudstone. The lenses are asymmetric and grade laterally into mudstones down dip toward the trough of the syncline. The largest of the three lenses has a maximum thickness of 15 feet and extends across the strike of the syncline for about 100 feet. The bedding in these lenses is thick and somewhat irregular.

The thick sandstone unit of the Princeton in this locality, 4 miles southeast of Princeton, contains three irregular beds of conglomerate, each having a thickness of about 4 feet. Similar beds of conglomerate occur in the Princeton on the southeast flank almost in the trough of the Hurricane Ridge syncline at the point where State Highway 85 crosses the Bluestone River between Bluefield and Pocahontas, Tazewell County, Virginia. These conglomerates are part of a thick-bedded sandstone unit. Most of the rock consists of angular to subround pebbles of gray and brown fine-grained limestones as much as 2 inches in

PLATE 7.—CROSS SECTION SHOWING LENSES OF SANDSTONE ABOVE THICK SANDSTONE IN PRINCETON FORMATION

PLATE 8

LENSES OF SANDSTONE ABOVE THE MAIN BED

OF PRINCETON SANDSTONE

Figure 1.—Lens of sandstone above thick bed of Princeton formation, on U. S. Highway 460, 4 miles southeast of Princeton, Mercer County, West Virginia.

Figure 2.—Lenses of sandstone above thick bed of Princeton formation, on U. S. Highway 460, 4 miles southeast of Princeton, Mercer County, West Virginia.

Figure 1

Figure 2

diameter. Dark-gray to black carbonaceous shales occur in flat chips as much as 0.75 inch across. A very few pebbles of maroon mudstone and red sandstone as much as 0.25 inch in diameter are present. The matrix is a medium- to coarse-grained quartz sand with a few grains as much as 0.2 inch in diameter.

The light-brown medium-grained orthoquartzite typical of the Princeton of Mercer County, West Virginia, persists along the northwest flank of the Hurricane Ridge syncline into northeastern Tazewell County, Virginia. The orthoquartzite, which is composed entirely of closely packed subangular quartz grains, is about 25 feet thick. The Princeton in this belt contains no conglomerate or conglomeratic beds.

Southwest of Bluefield down the plunge in the axial portion of the Hurricane Ridge syncline the thickness of the Princeton increases markedly. Two miles west of Mud Fork on State Road 643, Tazewell County, Virginia, the formation has a maximum thickness of about 165 feet; it is 90 feet thick about 3 miles to the southwest in the vicinity of Bishop. The section where the maximum thickness was observed is located near the trough of the structure in the structurally lowest part of the doubly plunging Hurricane Ridge syncline. In the vicinity of Bishop and Mud Fork the formation is composed of light-brown fine-grained sandstone containing 90 per cent quartz and 10 per cent limonite and clay matrix. Dark-gray to black carbonaceous fissile shale in units as much as 10 feet thick are present in the thickest sections. The sandstone occurs in thick even beds; however, in the Mud Fork section two narrow channel fills each with about 3 feet of relief are exposed near the top of the formation (Pl. 9).

The thickest observed section of the Princeton occurs near Mud Fork, Tazewell County, Virginia, and is described as follows:

PLATE 9

CHANNEL FILLS IN PRINCETON FORMATION

Figures 1 and 2.—Small channel fill in upper part of Princeton formation 2 miles west of Mud Fork, Tazewell County, Virginia.

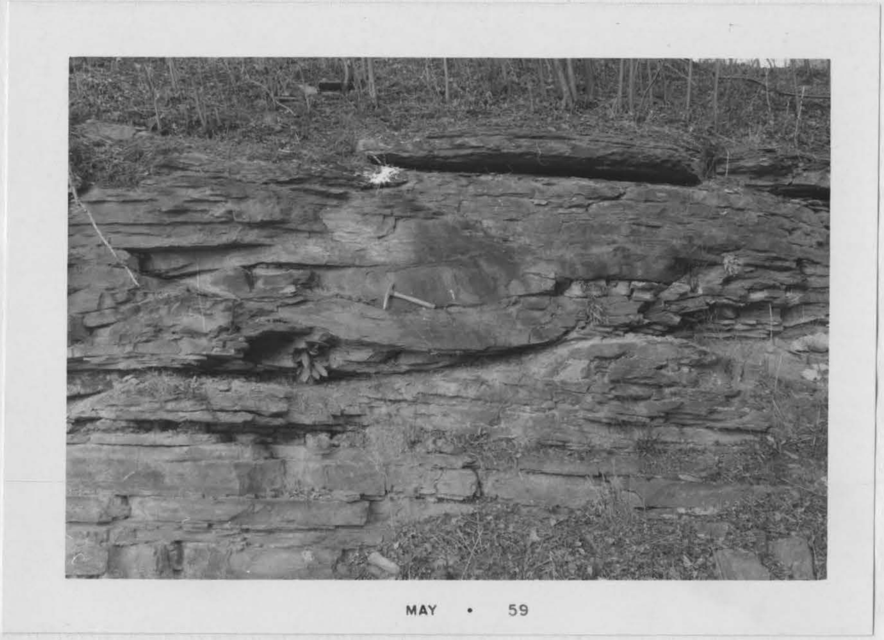


Figure 1

Figure 2

Geologic Section 6.—Princeton formation exposed at large cliff along State Road 643, 2 miles west of Mud Fork, Tazewell County, Virginia.

	Thickness (Feet)
Bluestone formation	
Princeton formation (165 feet)	
4. Orthoquartzite, gray-brown, medium grained; in even beds as much as 1 foot thick; two channel fills with about 3 feet of relief near top (Pl. 9)	32
3. Sandstone, gray, fine grained; in beds as much as 6 inches thick; interbedded dark-gray to black carbonaceous shale in beds as much as 6 inches thick; unit is about 50 per cent sandstone	17
2. Covered	56
1. Sandstone, yellowish-brown, fine grained; thick bedded; quartz-pebble conglomerate 1 foot thick 30 feet above base, rounded quartz pebbles as much as 0.25 inch in diameter	60
Hinton formation	

Another section showing the character of the Princeton in the structurally lowest part of the Hurricane Ridge syncline at the crest of Stony Ridge, north of Tazewell, Tazewell County, Virginia, is as follows:

Geologic Section 7.—Princeton formation exposed in old quarry at crest of Stony Ridge, 0.25 mile northeast of State Highway 16, Tazewell County, Virginia.

	Thickness (Feet)
Princeton formation (89 feet)	
5. Orthoquartzite, yellowish-brown, fine grained, contains small chips of carbonaceous shale in lower part; in slightly uneven beds as much as 3 feet thick	58
4. Carbonaceous shale, black, fissile; lenses of yellowish-brown fine-grained sandstone as much as 0.25 inch thick and 3 inches wide	1
3. Orthoquartzite, yellowish-brown, fine grained; in slightly uneven beds as much as 1 foot thick	4
2. Carbonaceous shale, black, fissile;	

wavy laminae of light-gray, very fine-grained sandstone as much as 0.25 inch thick	9
1. Orthoquartzite, light-gray, very fine grained; in uneven beds as much as 3 feet thick	17

Hinton formation (Geologic Section 3)

The section of Princeton on the south end of Keeney Mountain in Summers County is typical of the area northeast of Princeton, Mercer County, West Virginia:

Geologic Section 8.—Princeton formation on southeast spur of Keeney Mountain along unpaved road in vicinity of Clayton, Summers County, West Virginia.

	Thickness (Feet)
Bluestone formation (covered, chips of gray clay shale in soil)	
Princeton formation (30 feet)	
1. Orthoquartzite, yellowish-brown, medium to very coarse grained, rounded pebbles of quartz as much as 1 inch in diameter; thick bedded	30
Hinton formation (Geologic Section 5)	

Bluestone Formation

The Bluestone formation (Campbell, 1896), which conformably overlies the Princeton, is composed mainly of dark-gray mudstones above and below a thick unit of maroon mudstones. Where the Princeton cannot be recognized it is nearly impossible to separate the Bluestone from the underlying Hinton formation. Both Campbell (1896) and Reger (1926) gave the maximum thickness of the Bluestone as 800 feet, which agrees with the sections measured by the writer in Tazewell County, Virginia, and Mercer County, West Virginia.

The formation is poorly exposed because of its non-resistant nature. In northeastern Tazewell County, Virginia, and southwestern Mercer County, West Virginia, it is exposed in the trough of the Hurricane Ridge syncline but is folded so that a continuous section is difficult to obtain. The Bluestone is largely concealed along the Allegheny Front in West Virginia because it is bordered by two important ledge-makers, the Princeton formation below and the basal Pennsylvanian sandstones above.

The lower part of the Bluestone is composed of dark-gray or brown siltstones and clay shales. West of Princeton in Mercer County, West Virginia, and Tazewell County, Virginia, the lower unit is a dark-gray fine-grained thin-bedded calcareous siltstone, which weathers into pencil-like slivers. North and east of Princeton it is a dark-gray or brown silty thin-bedded claystone. Thin brown fine-grained sandstones are present locally at the top of this part of the Bluestone. In the trough of the Hurricane Ridge syncline in Tazewell County, Virginia, the sandstone is 22 feet thick and contains thin partings of carbonaceous clay shale in the lower few feet. The rock consists of about 85 per cent angular quartz grains, 7 per cent rounded grains of detrital calcite, and 18 per cent calcite cement. Chips of carbonaceous clay shale as much as 0.3 inch across are present in the lower few feet of the sandstone.

The middle 500 feet of the Bluestone is largely composed of blocky maroon-drab mudstones with layers of greenish-gray mudstone. Thin units of buff very fine-grained sandstone, having a high content of clay-sized matrix, are common throughout this part of the formation. Zones of calcareous mudstone and layers of calcareous nodules as much as 1.5 inches in diameter are present locally in different parts of the succession. Thin coaly shale beds are present locally in this part of the formation.

The upper part of the Bluestone is composed of dark-olive and dark-gray claystones with interbeds of dark-gray siltstone and fine-grained sandstone. Beds of black fissile claystone are common in the upper part.

Along the Allegheny Front in West Virginia the upper Bluestone is composed of maroon mudstones, which are conformably overlain by Pennsylvanian sandstones. A coal bed of questionable Pennsylvanian age occurs about 100 feet above the highest exposed Bluestone in the structurally lowest part of the Hurricane Ridge syncline, 3 miles east of Mud Fork, Tazewell County, Virginia. Locally, on the overturned southeast flank of the Hurricane Ridge syncline in the vicinity of Bluefield, an angular unconformity separates the Bluestone from overlying Pennsylvanian sandstones; however, in the adjacent axial portion of the syncline the Pennsylvanian rests conformably on the Bluestone.

A number of minor structures, which have dips steepened toward the trough of the Hurricane Ridge syncline, occur in the upper part of the Bluestone formation on both flanks of the syncline in the vicinity of Bluefield (Pls. 19, 20). These structures are of limited extent and occur in sandstone interbeds in the mudstone sequence of the upper Bluestone.

Sections of the Bluestone formation measured in the trough of the Hurricane Ridge syncline in Tazewell County, Virginia, are typical of the formation. A composite section of several isolated exposures on the northwest side of

Stony Ridge north of Bailey, Tazewell County, Virginia, is as follows:

Geologic Section 9.—Composite section of Bluestone formation on the northwest side of Stony Ridge along State Roads 656 (Units 53-16), 655 (Units 19-1), and 653 (Units 24-11), Tazewell County, Virginia.

	Thickness (Feet)
Bluestone formation (777+ feet)	
53. Mudstone, buff to olive, blocky	15
52. Sandstone, buff, fine grained; thin shaly beds	9
51. Claystone, olive-drab; thin bedded	24
50. Siltstone, yellowish-brown, fine grained; in even beds as much as 1 foot thick, thin shaly partings	40
49. Covered	8
48. Clay shale, black, carbonaceous, fissile	14
47. Claystone, buff, thin bedded	2
46. Sandstone, brown, fine grained; in uneven beds as much as 6 inches thick, thin shaly partings	2
45. Mudstone, buff and maroon-drab,	

blocky to fissile; layer of calcareous nodules 15 feet above base	30
44. Sandstone, yellowish-brown, fine grained; thin bedded	4
43. Mudstone, olive-drab, blocky to fissile	14
42. Mudstone, maroon-drab mottled with greenish-gray, blocky	31
41. Sandstone, olive-drab, fine grained, soft; thin shaly beds	36
40. Mudstone, buff, silty, blocky	3
39. Mudstone, maroon-drab, blocky, calcareous	14
38. Siltstone, yellowish-green, soft; thin shaly beds	4
37. Mudstone, maroon-drab, blocky to fissile	24
36. Siltstone, yellowish-green, soft; thin shaly beds	1
35. Mudstone, maroon-drab, blocky	28
34. Claystone, yellowish-brown; carbonaceous layer with fragments of plant fossils 6 feet below top; thin bedded to shaly	19

33. Mudstone, maroon-drab, fissile to blocky	11
32. Sandstone, bright-olive, fine grained; thin shaly beds	7
31. Siltstone, maroon and buff; thin bedded	13
30. Sandstone, gray, fine grained; single bed	1
29. Mudstone, maroon-drab and olive, blocky to fissile; few thin interbeds of gray fissile carbonaceous clay shale with fragments of plant fossils	27
28. Sandstone, yellowish-brown, very fine grained; thin shaly beds	2
27. Mudstone, maroon-drab mottled with greenish-gray, blocky to fissile	8
26. Clay, gray; fragments of plant fossils	2
25. Sandstone, yellow, very fine grained, soft; single bed	4
24. Mudstone, maroon-drab, blocky, calcareous	14
23. Sandstone, yellow, very fine grained, soft; single bed	6

22. Mudstone, maroon-drab, blocky	10
21. Limestone, dark-gray, fine grained, argillaceous; single bed	1
20. Covered; chips of maroon-drab mudstone in soil	22
19. Sandstone, gray, medium grained; single bed	6
18. Mudstone, olive and gray at top grades to maroon at base, blocky	25
17. Sandstone, olive-drab, fine grained; thin shaly beds	3
16. Mudstone, olive-drab, blocky to fissile	17
15. Sandstone, gray-brown, fine grained; thin shaly beds; interbedded dark-gray to black fissile carbonaceous shale in layers as much as 6 inches thick; fragments of plant fossils; unit is about 75 per cent carbonaceous shale	8
14. Clay shale, gray, fissile; few thin interbeds of gray blocky siltstone	5
13. Clay shale, black, carbonaceous, fissile	7

12. Sandstone, gray-brown, fine grained; single bed	1
11. Mudstone, maroon-drab mottled with gray, blocky	32
10. Sandstone, gray, fine grained; single bed	1
9. Mudstone, maroon-drab mottled with gray, blocky	17
8. Sandstone, gray-brown, fine to medium grained; in even beds as much as 2 feet thick; parting of gray clay shale 6 inches thick, 3 feet below top	9
7. Sandstone, gray, fine to medium grained, calcareous; in even beds as much as 2 feet thick; thin partings of gray clay shale	9
6. Clay shale, gray-brown, fissile; lenses and thin beds of gray-brown fine-grained sandstone; fragments of plant fossils; thin coaly layer at top	1
5. Sandstone, gray-brown, fine grained, calcareous; fragments of carbonaceous plant fossils and carbonaceous clay	

shale as much as 0.3 inch in diameter; single bed	1
4. Sandstone, gray, medium grained, calcareous; single bed	2
3. Clay shale, gray-brown, silty, fissile	10
2. Siltstone, dark-gray, fine grained, calcareous; thin shaly beds; weathers into pencil-like slivers	126
1. Covered	25

Princeton formation

Pennington Formation

The Pennington formation (Campbell, 1893), which includes all Mississippian rocks above the Bluefield in southwestern Virginia and eastern Kentucky (Table 2), is primarily a sandstone sequence. The maximum thickness measured for the formation is 1314 feet at Little Stone Gap in Wise County, Virginia, and the minimum is 680 feet on Pine Mountain, near Whitesburg, Letcher County, Kentucky.

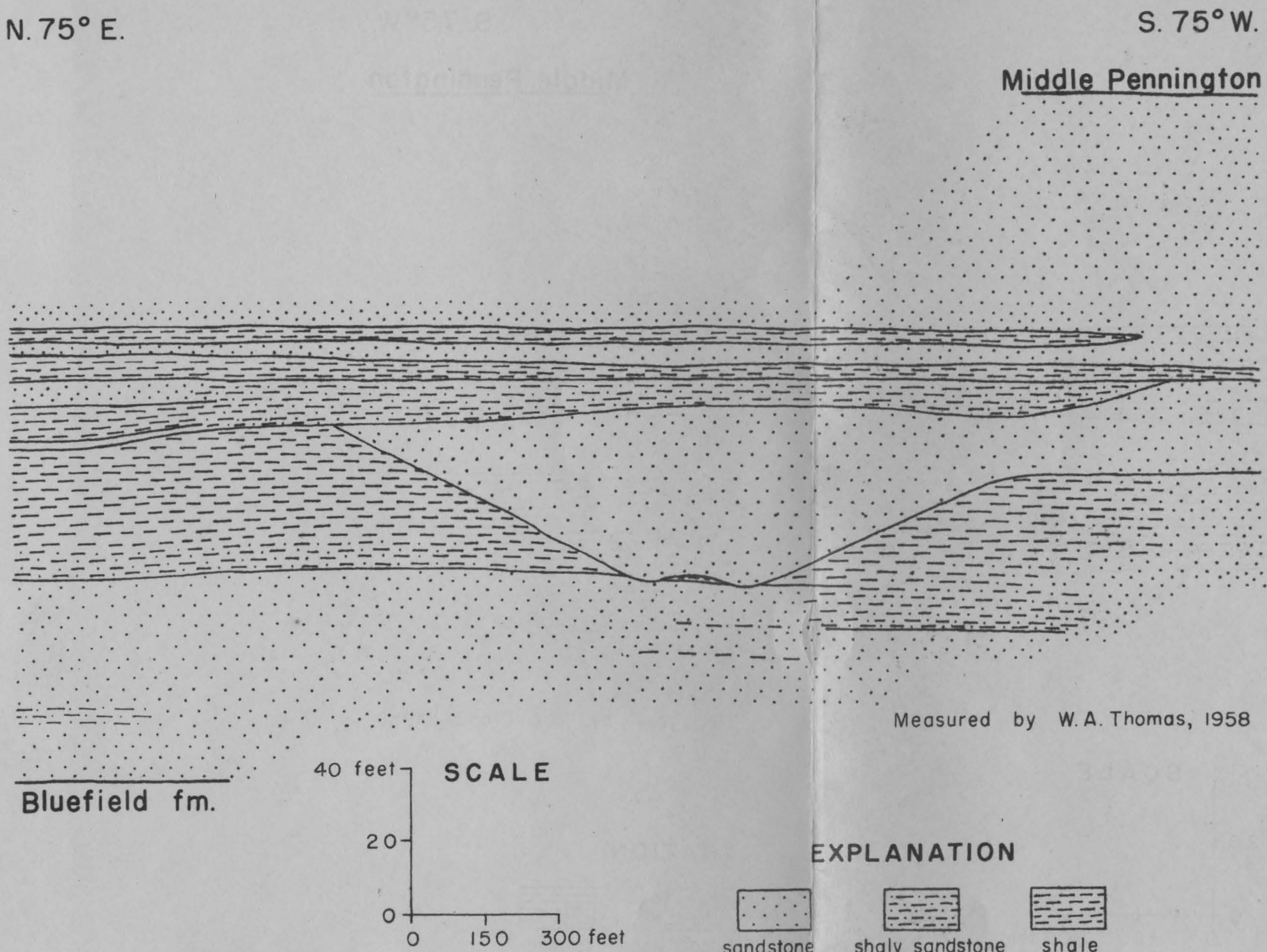
The Blackwood sandstone member at the base of the Pennington is a thick sandstone unit which in some sections contains clay shale interbeds. The middle part of the Pennington consists mostly of gray and brown sandstones and mudstones, and it contains interbeds of maroon mudstone. The Pound Gap member is an argillaceous limestone, which is locally fossiliferous. The upper part of the Pennington has a basal sandstone, which is locally conglomeratic, and contains gray shales, sandstones, thin shaly coals, and thin interbeds of maroon mudstone.

<u>Blackwood</u> <u>sandstone</u> <u>member</u>.—The lower part of the Pennington formation is a thick sandstone unit which is named the Blackwood sandstone by the writer. This unit has been called the Stony Gap sandstone member (Butts, 1940; Wilpolt and Marden, 1949). However, the term Stony Gap member is applied to the basal sandstone of the Hinton formation in the Bluefield area, and extending its usage into the southwestern part of Virginia as the basal sandstone member of the Pennington is not advisable. Such terminology would imply that the basal sandstone of the Pennington is identical to that of the Hinton and would also imply that both formations are more or less identical in character. The Hinton and Pennington are in general clearly different lithologic successions and the same member name should not be applied to similar parts of the two formations.

The name Blackwood sandstone member is proposed, therefore, for the basal sandstone member of the Pennington formation. The name is taken from the village of Blackwood on U. S. Highway 23 between Norton and Appalachia, Wise County, Virginia. The type section of the member is along State Road 610 in Little Stone Gap on Little Stone Mountain, Wise County, Virginia. At Little Stone Gap and at Big Stone Gap on the northwest flank of the Powell Valley anticline the Blackwood member is composed entirely of thick-bedded orthoquartzite. It consists of an alternating succession of thick-bedded orthoquartzites and shaly sandstones at Pennington Gap on the northwest flank of the Powell Valley anticline and in all sections on Pine Mountain. At Little Stone Gap, the type section, the member consists of 225 feet of white to yellow-brown, fine- to medium-grained orthoquartzite composed almost entirely of subround grains of quartz and less than 1 per cent of detrital grains of fine-grained quartz-mica rock. Southwestward along the same strike belt on the southwest side of the Powell Valley anticline the Blackwood is 200 feet of yellow-brown medium-grained orthoquartzite at Big Stone Gap.

Other sections range in thickness from 140 to 300 feet and the orthoquartzite member contains two to three units of brown to white very fine-grained shaly sandstone with closely spaced very thin wavy laminae of dark-gray carbonaceous clay. Each of the alternating units of orthoquartzite and shaly sandstone is between 20 and 40 feet thick. These individual units are local in extent and irregular in thickness. Abrupt lateral facies changes and channel fillings are visible in the extensive exposures on Pine Mountain in the vicinity of Whitesburg, Letcher County, Kentucky (Pl. 10). A channel filling is also

PLATE 10.—CROSS SECTION SHOWING FACIES AND CHANNEL FILL IN BLACKWOOD SANDSTONE MEMBER



Section in road cuts on U. S. Highway 119, on Pine Mountain 4 miles south of Whitesburg, Letcher County, Kentucky exposed within the Blackwood member at Pound Gap on Pine Mountain. The orthoquartzite on Pine Mountain is about 95 per cent quartz and 4 per cent detrital grains of fine-grained quartz-mica rock. Rounded grains of zircon, both rounded and euhedral grains of tourmaline, and grains of magnetite make up the remainder of the rock.

<u>Middle Pennington</u>.—The middle part of the Pennington is composed of a heterogeneous succession of sandstones and mudstones. Brown fine-grained soft sandstone beds make up most of the sequence, and a few yellow-brown medium-grained sandstones are present. Blocky maroon-drab mudstones and brown and gray sandy mudstones are common throughout the succession.

Pound Gap member.—A thin, but relatively persistent, limestone marks the approximate middle of the Pennington formation, and the writer proposes the name Pound Gap member for this unit. Wilpolt and Marden (1949) called this limestone the Avis limestone of Reger (1926), but it is not considered advisable to use that name for the same reason that the term Stony Gap member was not used for the lower sandstone unit of the Pennington. The new name is taken from Pound Gap on Pine Mountain in Letcher County, Kentucky, where the type section is located.

At the type section the member is 33 feet thick and is composed of light blue-gray argillaceous limestone and dark blue-gray medium-grained limestone with interbeds of blue-gray calcareous mudstone. The unit is abundantly fossiliferous. At Hurricane Gap the member consists of 30 feet of calcareous mudstone which contains nodules of crystalline limestone. In the vicinity of Whitesburg, Letcher County, Kentucky, the Pound Gap member is absent; and a limestone-pebble conglomerate at the base of the upper Pennington rests on the middle part of the Pennington.

The Pound Gap member is variable in thickness and character along the southeast flank of the Powell Valley anticline. At Pennington Gap, Lee County, Virginia, it is represented by 15 feet of non-fossiliferous blue-gray calcareous mudstone. At Big Stone Gap, Wise County, Virginia, the member is a fossiliferous blue-gray fine-grained argillaceous limestone 40 feet thick. On the northeast end of the Powell Valley anticline the Pound Gap member at Little Stone Gap, Wise County, Virginia, is represented by 25 feet of yellow-brown non-calcareous mudstone which contains abundant fossils.

Upper Pennington.—On both sides of the Middlesboro syncline a sandstone and conglomerate unit occurs immediately above the Pound Gap member of the Pennington formation. The sandstone is a light-brown, fine- to medium-grained rock which composes most of the unit; conglomerate beds occur locally at the base. The thickness of the sandstone ranges from 50 to 100 feet along the Powell Valley anticline and from 10 to 20 feet along Pine Mountain. The thicker sections along both belts are at the southwest end of the outcrop.

At Little Stone Gap the conglomerate at the base of the upper Pennington is 10 feet thick and contains a variety of relatively large pebbles. Subround pebbles as much as 1.5 inches in diameter make up about 50 per cent of the rock; the matrix is a coarse-grained sandstone. Pebbles of quartz predominate; pebbles of light-brown coarse-grained sandstone similar to the matrix and of bright-red hematitic claystone are less common. At Big Stone Gap a conglomerate of similar composition but with pebbles less than 0.75 inch in diameter occurs immediately above the Pound Gap member. On Pine Mountain in the vicinity of Whitesburg, Kentucky, the sandstone is a dark-brown fine-grained rock with a coating of hematite on each grain. Angular boulders of yellow-brown mudstone as much as 1 foot in diameter are included in the conglomerate; and the rock weathers pitted suggesting the removal of pebbles of limestone. Impressions of fenestrate bryozoans, crinoid columnals, and fragments of brachiopod shells are preserved. The Pound Gap member is absent in the Whitesburg section; and the conglomerate rests on maroon mudstones of the middle Pennington.

Above the basal sandstone and conglomerate of the upper part of the Pennington the section is composed mainly of light- to dark-gray fissile clay shales. Several thin units of yellow-brown fine-grained sandstone are present throughout the upper Pennington. Coaly clays and thin shaly coal layers are present locally near the top of the formation. A relatively thin zone of blocky maroon-drab mudstones occurs near the top of the Pennington.

The contact with the overlying Pennsylvanian rocks, based on an abrupt lithologic change, is placed at the base of the lowest massive conglomeratic quartzose sandstone above the highest maroon mudstone. Abrupt, relatively local, changes in thickness in the Pennington are most marked in the upper part of the formation; and this variation suggests an erosional unconformity between the Pennington and the overlying Pennsylvanian sandstone.

Geologic sections of Pennington formation.—The thickest section of Pennington measured is at Little Stone Gap, Wise County, Virginia. This section, containing the type section of the Blackwood sandstone member, is as follows:

Geologic Section 10.—Pennington formation at Little Stone Gap in Little Stone Mountain on State Road 610, Wise County, Virginia.

	Thickness (Feet)
Lee formation (Pennsylvanian)	
45. Orthoquartzite, brown, medium grained, rounded quartz pebbles as much as 0.5 inch in diameter; thick bedded	
Pennington formation (1314 feet)	
Upper Pennington (780 feet)	
44. Covered	40
43. Mudstone, brown, sandy; thin bedded; interbeds of brown fine-grained sandstone as much as 6 inches thick; unit is about 50 per cent sandstone	23

42. Sandstone, light-gray, fine grained; thin shaly beds; thin partings of black carbonaceous shale	7
41. Mudstone, yellow-brown, blocky	8
40. Sandstone, greenish-gray, fine grained; single bed	6
39. Clay shale, dark-gray to black, fissile, carbonaceous in lower part; shaly coal layer, 3 inches thick, at base	16
38. Claystone, light-gray; thin bedded	4
37. Covered	13
36. Sandstone, yellow-brown, fine grained; in even beds as much as 3 feet thick	17
35. Covered	52
34. Mudstone, olive-drab, fissile to blocky	36
33. Sandstone, yellow-brown, very fine grained; thin shaly beds	9
32. Claystone, light-gray, soft	11
31. Siltstone, yellow-brown, soft; single bed	4
30. Claystone, light-gray to yellow	12

29.	Mudstone, maroon-drab, blocky	3
28.	Sandstone, olive, very fine grained; thin shaly beds	7
27.	Mudstone, maroon-drab, blocky	3
26.	Covered	25
25.	Mudstone, maroon-drab mottled with greenish-gray, blocky	15
24.	Covered	185
23.	Sandstone, brown, very fine grained; in even beds as much as 1 foot thick	24
22.	Covered	11
21.	Sandstone, gray-brown, medium grained; in slightly uneven beds as much as 1 foot thick	29
20.	Covered	49
19.	Clay shale, light-gray, fissile, soft	62
18.	Sandstone, yellow-brown, fine grained; in even beds as much as 2 feet thick	21
17.	Sandstone, white, fine grained; thin shaly beds; very thin wavy interlaminations of light-gray clay	24

16. Covered	12
15. Orthoquartzite, yellow to white, medium grained; in even beds as much as 3 feet thick	44
14. Conglomerate, white, very coarse grained quartz sand matrix (50 per cent); rounded pebbles as much as 1.5 inches in diameter—quartz (40 per cent), orthoquartzite (8 per cent), mudstone (2 per cent)	8
Pound Gap member (25 feet)	
13. Mudstone, yellow-brown, blocky to thin bedded; *Diaphragmus elegans*, *Orthotetes kaskaskiensis*, *Punctospirifer* sp., *Sargentina allani*, *Paraconularia* sp., *Archimedes* sp., *Fenestrellina* sp., *Polypora* sp.	25
Middle Pennington (286 feet)	
12. Covered	40
11. Mudstone, gray to yellow-brown, blocky to fissile	29
10. Sandstone, yellow-brown, fine grained; in even beds 4 inches to 3 feet thick	35

9. Claystone, yellow-brown; thin bedded	3
8. Covered	9
7. Sandstone, yellow-brown, fine grained, soft; single bed	8
6. Covered	16
5. Sandstone, yellow-brown, fine grained; single bed	5
4. Covered	21
3. Sandstone, reddish-brown, very fine grained; thin shaly beds	35
2. Covered	85
Blackwood sandstone member (type section, 223 feet)	
1. Orthoquartzite, white to yellow-brown, medium grained; in even beds as much as 2 feet thick	223
Bluefield formation (Geologic Section 18)	

The section at Pound Gap, including the type locality of the Pound Gap member, was measured as follows:

Geologic Section 11.—Pennington formation on west slope of Pine Mountain at Pound Gap along U. S. Highway 23, Letcher County, Kentucky.

	Thickness (Feet)
Pennington formation (798 feet)	
Upper Pennington (306 feet)	
37. Covered	34
36. Sandstone, light-brown, fine grained; in even beds 2 inches to 4 inches thick, thin partings of gray clay	4
35. Mudstone, maroon-drab mottled with greenish-gray, blocky	13
34. Sandstone, light-gray, fine grained; thin wavy beds as much as 0.25 inch thick; thin laminae of dark-gray clay; interbeds of dark-gray clay shale as much as 6 inches thick; unit is about 50 per cent sandstone	28

33. Mudstone, dark-gray, blocky	2
32. Sandstone, greenish-gray, fine grained; in uneven beds as much as 8 inches thick; base uneven	24
31. Sandstone, light-gray, fine grained; thin wavy beds as much as 0.25 inch thick; thin laminae of dark-gray clay; interbeds of sandstone as much as 4 inches thick; unit is about 50 per cent sandstone	31
30. Clay shale, black, fissile, carbonaceous	10
29. Sandstone, light-gray, fine grained; thin wavy beds as much as 0.25 inch thick; thin laminae of dark-gray clay; interbeds of sandstone as much as 6 inches thick; unit is about 75 per cent sandstone	38
28. Covered	44
27. Clay shale, dark-gray to black, fissile, carbonaceous; layers of claystone concretions throughout	64
26. Sandstone, light-gray, fine	

grained; in uneven beds as much as 3 feet thick; partings of dark-gray carbonaceous clay shale in upper part; limestone-pebble conglomerate, pebbles as much as 0.25 inch in diameter, 1 inch thick, at base 13

Pound Gap member (type section, 33 feet)

25. Limestone, dark blue-gray, medium grained; nodular beds as much as 4 inches thick; interbeds of dark blue-gray calcareous mudstone; unit is about 50 per cent limestone; _Dictyoclostus_ _inflatus_, _Linoproductus_ _ovatus_, _Orthotetes_ _kaskaskiensis_, _Composita_ _subquadrata_, _Amplexizaphrentis_ _spinulosum_, _Polypora_ sp., _Fenestrellina_ sp. 23

24. Limestone, blue-gray, fine grained, argillaceous; thick bedded; _Diaphragmus_ _elegans_, _Spirifer_ _increbescens_, _Orthotetes_ _kaskaskiensis_, _Reticulariina_ _spinosa_, _Composita_ _subquadrata_, _Agassizocrinus_ _conicus_,

Amplexizaphrentis _spinulosum_	5
23. Mudstone, blue-gray, calcareous, blocky; _Dictyoclostus_ _inflatus_, _Spirifer_ _increbescens_	5
Middle Pennington (317 feet)	
22. Mudstone, maroon-drab, blocky, calcareous	14
21. Limestone, light-gray, fine grained, argillaceous; thin nodular beds, partings of blue-gray calcareous mudstone	2
20. Sandstone, brownish-gray, very fine grained, soft; single bed	9
19. Mudstone, maroon-drab, blocky	12
18. Covered	191
17. Sandstone, light-brown, fine grained; upper part thin bedded, lower part thick bedded	17
16. Clay, gray; fragments of plant fossils	4
15. Coal, black, clayey	1
14. Clay, gray; fragments of plant fossils	5
13. Sandstone, yellow-gray, very fine grained; thin shaly beds;	

interbeds of yellowish-gray sandy mudstone; unit is about 60 per cent sandstone 6

12. Mudstone, maroon-drab mottled with gray, blocky 11

11. Siltstone, dark-gray; thin shaly beds 7

10. Claystone, gray; thin bedded; fragments of plant fossils 4

9. Mudstone, gray, silty, fissile to blocky; base fills channel cut into underlying unit, relief 5 feet 17

8. Clay shale, gray, fissile; lenses of light-gray fine-grained sandstone as much as 0.25 inch thick; interbeds of sandstone as much as 3 inches thick; unit is about 75 per cent clay shale 17

Blackwood sandstone member (142 feet)

7. Orthoquartzite, white, medium grained; in slightly uneven beds as much as 4 feet thick 32

6. Sandstone, yellow, fine grained; thin shaly beds; thin laminae of

gray sandy clay shale	7
5. Orthoquartzite, white, medium grained; in even beds as much as 3 feet thick	16
4. Clay shale, gray, fissile; thin discontinuous interbeds of light-gray fine-grained sandstone; unit is about 80 per cent clay shale	17
3. Orthoquartzite, white, fine grained; thick bedded; base fills channel cut into underlying unit, maximum depth of channel 10 feet, width observed 60 feet	33
2. Clay shale, dark-gray to black, carbonaceous, fissile	15
1. Orthoquartzite, white, medium grained; in even beds as much as 4 feet thick	22

Bluefield formation (Geologic Section 15)

Mississippian—Pennsylvanian Boundary

Introduction.—In the western Appalachians deposition proceeded more or less uninterruptedly during the time which elsewhere marks the Mississippian—Pennsylvanian boundary; and the well defined unconformity between these systems in the Central Interior of the United States is not a feature of the Appalachian sequences. The contact has been placed at the marked change in lithologic character from the maroon mudstones below to the coal-bearing sandstone sequence above. Changes in conditions of deposition, which resulted in the rather abrupt change in lithology in the Appalachian sequences, may also have caused the erosional unconformity in the Mississippi Valley sections.

Campbell and Mendenhall (1896) indicated that the most important break in the Carboniferous sequence in the New-Kanawha River Valley occurred within the Royal formation (Pl. 4). The upper Royal was composed of thick-bedded sandstones with shale and coal units, which was considered to be typical of the Pottsville. The lower Royal was made up of red shales like those of the Hinton formation. Campbell and Mendenhall noted that the boundary between the red shale sequence and the coal-bearing sequence was not everywhere at the same stratigraphic horizon. They attributed this discrepancy to the probability that deposition of red shales in part of the area was contemporaneous with deposition of coal beds in other parts of the area.

Campbell (1896) defined the Bluestone and Pocahontas formations, using the top of the red mudstones as the top of the Bluestone formation. The Pocahontas formation, which marked the base of the Pennsylvanian system, was defined as a sequence of sandstones and shales with coal beds.

Reger (1926) noted a "striking unconformity" between the Pottsville series and the underlying Mauch Chunk series. The lower Pottsville was characterized by gray coarse-grained sandstones which were commonly conglomeratic. The upper Mauch Chunk was composed of red and green shales and greenish sandstones. Reger also noted the absence of commercial coals in the Mauch Chunk in contrast to the Pottsville. Although he described an important unconformity between the Mississippian and Pennsylvanian, Reger pointed out that the upper Mauch Chunk in Mercer County, West Virginia, was perhaps the youngest known Mississippian and that the lower Pottsville represented the earliest known Pennsylvanian.

Butts (1940) contrasted the marine origin of the latest Mississippian, Bluestone formation, with the nonmarine origin of the earliest Pennsylvanian, Lee formation, in western Virginia. In southwestern Virginia Butts noted an unconformity between the Lee formation and the Pennington formation, which he considered to be the exact equivalent of the Hinton formation. This unconformity represented the Princeton and Bluestone formations in the Hurricane Ridge syncline area.

<u>Southwestern Virginia and eastern Kentucky</u>.—In southwestern Virginia and eastern Kentucky the base of the Pennsylvanian is placed at the base of the lowest conglomeratic orthoquartzite above the highest red mudstone. The upper part of the Mississippian in this area is composed mainly of gray clay shales with local thin coaly layers. A few thin beds of blocky maroon mudstone, similar to those of the Hinton formation, occur in the upper part of the Mississippian. The basal unit of the Pennsylvanian is a brown, medium- to coarse-grained orthoquartzite which contains rounded pebbles of quartz as much as 0.5 inch in diameter; this unit is generally between 50 and 80 feet thick. Above the basal orthoquartzite the lower Pennsylvanian contains other orthoquartzites separated by coal-bearing gray carbonaceous shales. Changes in thickness of the Pennington are most abrupt in the upper part of the formation, and these thickness variations indicate an erosional unconformity between the Pennington and the overlying Pennsylvanian strata. It is not possible to show how much, if any, of the Bluestone formation is represented in the upper beds of the Pennington; therefore, the stratigraphic interval represented by the unconformity between the Pennington and the overlying Pennsylvanian is undetermined.

Allegheny Front in West Virginia.—Along the eastern side of the Allegheny Plateau in West Virginia the base of the Pennsylvanian is marked by a brown, medium-grained orthoquartzite which is generally less than 30 feet thick. In this area the uppermost Mississippian is composed almost entirely of maroon mudstones. A sequence of gray carbonaceous shales, brown sandstones, and coal beds makes up the lower Pennsylvanian. There is no evidence of an erosional unconformity between the Pennsylvanian and the Mississippian; and there is no indication of any break in deposition between these systems.

Hurricane Ridge syncline.—In the structurally lowest part of the Hurricane Ridge syncline in Tazewell County, Virginia, on the northwest side of Stony Ridge, a 5-foot bed of coal with a 2-foot clay parting occurs approximately 900 feet above the base of the Bluestone formation. The coal bed occurs in the trough of the overturned structure and crops out in two belts, one 75 feet above the other on Stony Ridge. The lower outcrop is right side up; the higher outcrop is overturned (Cooper, 1944). The few feet of beds, which are stratigraphically higher than the coal, in the trough of the syncline between the coal outcrops are not exposed. The upper Bluestone below the coal bed is made up of gray shales and siltstones; however, the nearest outcrop is about 100 feet stratigraphically below the coal. Plant fossils collected from the coal bed were identified by Dr. Sergius H. Mamay of the United States Geological Survey. In a letter dated May 7, 1959, Dr. G. Arthur Cooper of the United States National Museum states:

> Dr. Mamay . . . has determined them to be _Stigmaria_ (rootstock of arborescent lycopods). These are said to be common in the Pennsylvanian.

In view of the fact that the Mississippian in the Hurricane Ridge syncline is the latest Mississippian known in the Appalachian region, it is possible that _Stigmaria_ may have heretofore gone unidentified in the latest Mississippian. However, on the basis of present paleontologic knowledge the coal bed in the Hurricane Ridge syncline is assigned to the Pennsylvanian system. If the coal bed on Stony Ridge is Pennsylvanian in age, there is an apparent gradation from Mississippian to Pennsylvanian deposition within a sequence of gray carbonaceous shales and coaly units. However, about 100 feet of section is covered between the highest known Bluestone and the coal bed, and the character of the interval cannot be determined.

A distinct local angular unconformity occurs between the Bluestone formation and the Pennsylvanian on the overturned southeast limb of the Hurricane Ridge syncline on Hurricane Ridge 2 miles northeast of Bluefield, Mercer County, West Virginia. Relatively extensive Pennsylvanian sandstones conformably overlie nearly horizontal Bluestone beds in the trough of the Hurricane Ridge syncline (Figs. 1, 2). About 50 yards southeast of the main outcrop of Pennsylvanian sandstone a bed of identical sandstone rests on steeply dipping Bluestone beds (Fig. 2). The Bluestone dips 75° to the northwest and is apparently located on the steeply dipping southeast limb of the Hurricane Ridge syncline. The Pennsylvanian sandstone in angular discordance with the Bluestone dips 25° to the northwest. The small exposure of sandstone is identified as Pennsylvanian

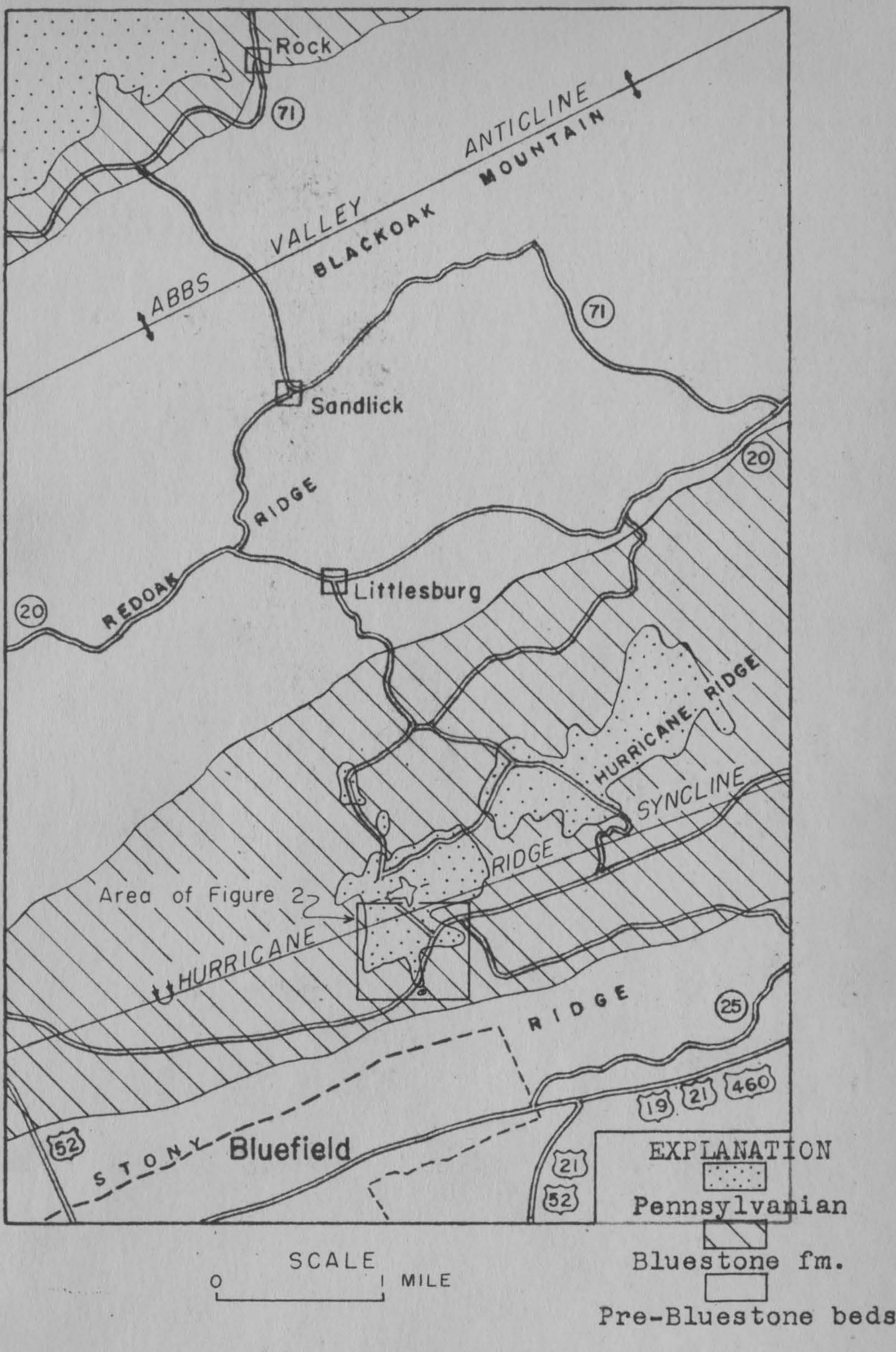


Figure 1.—Geologic map showing outcrop of Pennsylvanian sandstone in the Hurricane Ridge syncline north of Bluefield, Mercer County, West Virginia.

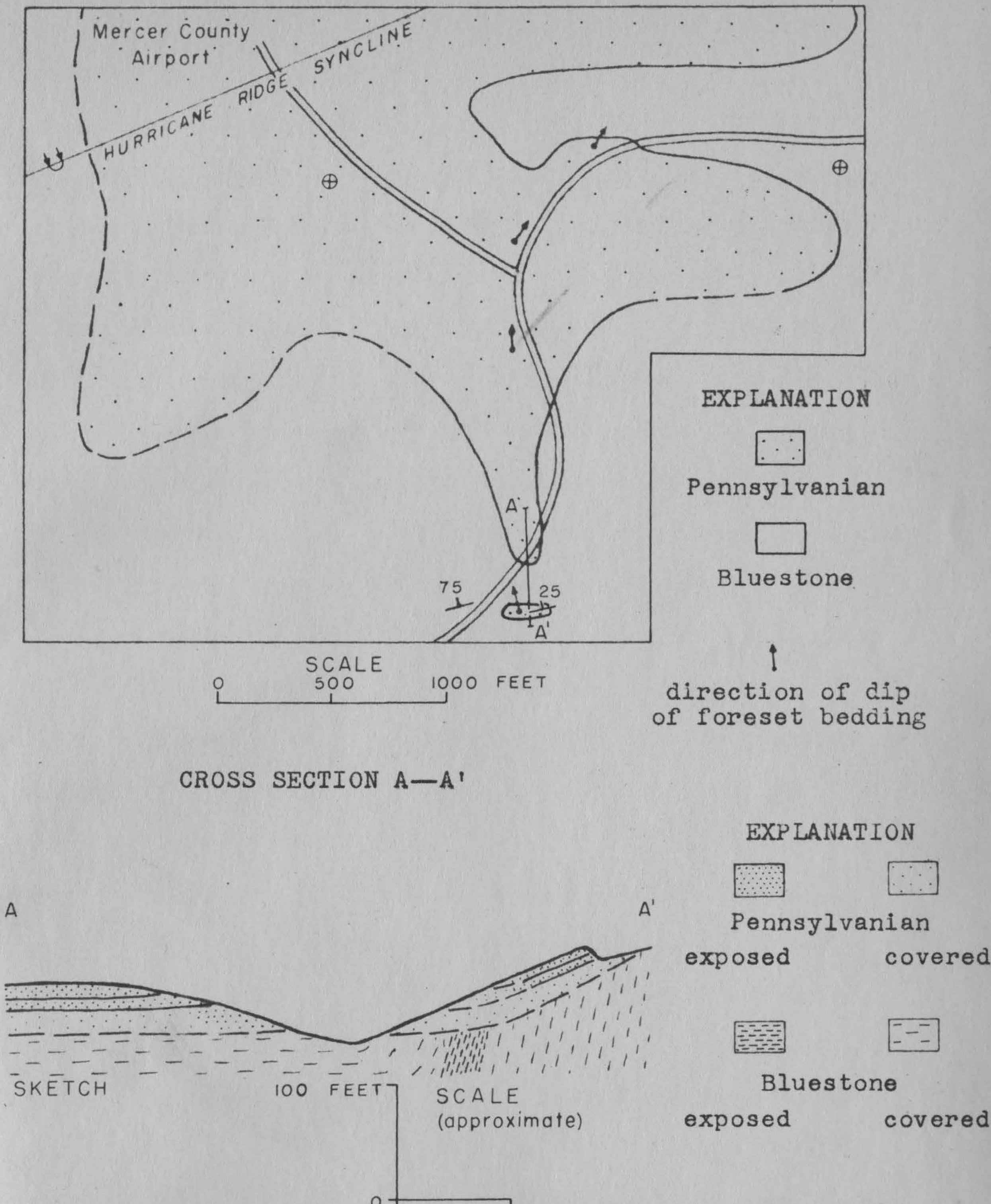


Figure 2.—Geologic map and cross section showing angular unconformity between Pennsylvanian sandstone and underlying Bluestone formation on southeast flank of the Hurricane Ridge syncline in the vicinity of the Mercer County Airport near Bluefield, West Virginia.

on the basis of its lithologic similarity to the main outcrop of Pennsylvanian sandstone and its position in relation to the larger outcrop. The local unconformity on the southeast flank of the Hurricane Ridge syncline probably has little time significance because the beds are conformable in the trough of the structure. However, the marked angular discordance below the Pennsylvanian indicates that considerable folding of the Bluestone had occurred on the southeast flank of the syncline before deposition of the Pennsylvanian. The stratigraphic relationships at this locality in the Hurricane Ridge syncline are similar to those described by Spieker (1946) in Late Mesozoic and Early Cenozoic beds of central Utah. Spieker noted angular unconformities in some belts between beds which elsewhere were conformable, and these relationships were interpreted to indicate contemporaneous deformation and deposition.

The Pennsylvanian consists of about 120 feet of sandstones with foreset bedding, which dips to the north. The sandstone is conglomeratic in its lower part and contains rounded quartz pebbles as much as 2 inches in diameter and fragments of limonite concretions. Large fragments of Calamites are common in the lower part of the Pennsylvanian sandstones. A small lens of limestone-pebble conglomerate containing rounded pebbles of blue-gray medium-grained limestone occurs a few feet above the base of the sandstone. The limestone pebbles contain poorly preserved brachiopods which are questionably identified as <u>Diaphragmus elegans</u>; evidence of erosion of the Mississippian limestones during Pennsylvanian is thus recorded.

The Pennsylvanian sandstone extends about 1.5 miles northwest of the trough of the Hurricane Ridge syncline (Fig. 1). The sandstone on the southeast flank of the syncline has limited lateral extent, and the irregular contact with the underlying Bluestone suggests channeling. The width of exposure parallel to the strike of the syncline in the trough of the structure is about 3 miles. The foreset bedding of the sandstones and the shape of the outcrop indicate deposition by a northward moving current, which spread into the trough of the syncline.

The exposures of the upper part of the Bluestone formation and the conformably overlying Pennsylvanian sandstones in the trough of the Hurricane Ridge syncline were measured as follows:

Geologic Section 12.—Basal Pennsylvanian sandstone and Bluestone formation on un-numbered paved road east of Mercer County Airport in Hurricane Ridge north of Bluefield, Mercer County, West Virginia. Top of section is on hill top south of airport terminal building.

	Thickness (Feet)
Basal Pennsylvanian sandstone (117+ feet)	
15. Sandstone, yellow and red to gray, medium grained, micaceous, arkosic, friable, weathers to loose sand; foreset bedding dips northwest	65
14. Sandstone, gray with specks of black, medium grained, micaceous; small fragments of carbonaceous plant fossils; thick bedded	46
13. Conglomerate, brown; matrix of medium-grained sandstone; subround pebbles of quartz as much as 2 inches in diameter; fragments of limonite concretions as much as 3 inches in diameter; large fragments of plant fossils, <u>Calamites</u>; lens of limestone-pebble conglomerate	

3 inches thick and 2 feet wide, limestone pebbles as much as 2 inches in diameter contain fragments of brachiopod shells; single bed, base irregular 6

Bluestone formation (158+ feet)

12. Mudstone, dark-gray, blocky 54
11. Mudstone, olive-drab, blocky to fissile 4
10. Claystone, dark gray-brown; thin bedded; <u>Straparolus</u> sp., <u>Lingula</u> sp. . . . 8
9. Coal, black, clayey 1
8. Claystone, gray, soft 8
7. Mudstone, yellow, blocky 4
6. Mudstone, yellow mottled with maroon-drab, blocky 10
5. Mudstone, maroon-drab, blocky 17
4. Sandstone, yellowish-brown, very fine grained, soft; single bed, weathers spheroidal 7
3. Mudstone, maroon-drab, blocky 10
2. Covered 10
1. Mudstone, maroon-drab, blocky 25
0. Sandstone lens with discordant bedding (Pls. 19, 20).

Regional Correlation

The Upper Mississippian clastic sequence in southwestern Virginia and eastern Kentucky includes the Bluefield formation below and the Pennington formation above. The same interval in the Hurricane Ridge syncline is represented by the Bluefield, Hinton, Princeton, and Bluestone formations.

The Bluefield formation is considered to represent approximately the same time interval in both areas because of lithologic similarity and stratigraphic position. The base of this formation may not be the same age in both areas; however, faunal evidence is insufficient to prove this statement.

Above the Bluefield the Stony Gap sandstone member of the Hinton is probably correlative with part of the Blackwood sandstone member of the Pennington. These members are similar in character; and the earliest introduction of sandstone into the sequence, indicative of a regional change in depositional pattern, probably occurred at approximately the same time throughout the region. The Blackwood sandstone member makes up 40 to 60 per cent of the Pennington formation below the limestone member; and the Stony Gap member comprises 5 to 30 per cent of the

Hinton formation below the limestone member. Because the Blackwood makes up a relatively greater part of the succession, it is concluded that the Stony Gap is equivalent to only a part of the Blackwood.

Both the Hinton and Pennington formations contain similar prominent limestone members. On the basis of the apparent similarity of depositional conditions, which were markedly different from the prevailing conditions during the Late Mississippian, the limestone members are considered to be correlative.

If the Pound Gap member is equivalent to the Avis member then the upper part of the Pennington formation is equivalent in part at least to the upper Hinton, Princeton, and Bluestone formations. In the Pennington formation immediately above the limestone member a conglomerate and sandstone unit occurs. Above this unit a number of other sandstones are present in the sequence. Above the Avis limestone member of the Hinton the Abbs Valley Ridge member contains a number of sandstone units; and the Princeton formation—sandstone and conglomerate—is about 400 feet above the Avis limestone. Thus, a sequence of sandstone and conglomerate units succeeds the limestone members of both the Pennington and Hinton formations. The conglomerate above the Pound Gap member of the Pennington has been correlated with the Princeton formation (Wilpolt and Marden, 1949); and, although the two units are similar, there is no evidence that the Princeton actually descends in the section toward the southwest. The sandstones in the Upper Mississippian are not continuous over wide areas, and they lose their identity in relatively short lateral distances. For this reason it is not considered advisable to attempt direct correlation between individual sandstone units in different parts of the region. However, a general correlation between the upper Pennington sandstone-bearing succession and the Abbs Valley Ridge member of the Hinton and the Princeton formation is indicated. Thus, it is not possible to state the exact position in the Pennington which is equivalent to the Princeton formation.

Because the Princeton horizon cannot be established in the Pennington formation, the presence or absence of beds of Bluestone age within the upper Pennington cannot be determined. The Bluestone may be partly or wholly unrepresented in the Pennington formation. In the thickest sections of Bluestone in the Hurricane Ridge syncline there is apparently no significant break between the Bluestone and the overlying Pennsylvanian. The presence of an erosional disconformity between the Pennington and the overlying Pennsylvanian would suggest that at least the upper part of the Bluestone is not represented in the Pennington.

Correlation with the Standard Mississippian Section

The Upper Mississippian clastic sequence of the western Appalachians is of Chester and post-Chester Mississippian age. The top of the Mississippian limestone division of the Appalachians has been correlated with the top of the Gasper limestone of the Mississippi Valley (Butts, 1940). It has also been noted that the Pennington (Hinton) formation is probably correlative with the Menard and Clore formations of the type Chester (Butts, 1940). If this assignment is correct, and it is strongly supported by paleontologic evidence, the Princeton and Bluestone formations are younger than the top of the Chester in the type area in the Mississippi Valley.

Subdivision of Mississippian in type area.—The standard stratigraphic section of the Mississippian has been worked out in the Mississippi Valley in the states of Illinois, Iowa, Indiana, Kentucky, and Missouri. The major features of the type section of the Mississippian were defined in Iowa and Illinois by James Hall (Weller, and others, 1948). The Upper Mississippian was named the Chester group by A. H. Worthen in 1866 (Weller, and others, 1948). The assignment of the Chesterian to series rank has since been made; and the Chesterian has been divided into three groups (Weller and Sutton, 1940). Weller and Sutton defined in ascending order the New Design group, the Homberg group, and the Elvira group. A number of formations comprise each of these three subdivisions of the Chester series. The type section of the New Design group contains in ascending order the Aux Vases sandstone, Renault limestone, Bethel sandstone, and Paint Creek formation; the Gasper limestone of Butts (1917) represents the entire New Design group. The Homberg group is composed of the Cypress sandstone, Golconda formation, Hardinsburg sandstone, and Glen Dean limestone. The Elvira group consists of the Tar Springs sandstone, Vienna limestone, Waltersburg sandstone, Menard limestone, Palestine sandstone, Clore formation, Degonia sandstone, and Kinkaid limestone at the top.

Previous correlations.—Reger (1926) correlated the top of the Greenbrier series in southern West Virginia with the top of the Glen Dean limestone in the Mississippi Valley. This correlation, although generally related to fossils, was based mainly on lithologic characteristics. Reger reported _Sulcatopinna_, a pelecypod restricted to Menard and younger formations in the type region, from the lower part of the Bluefield. This occurrence has been questioned on the grounds that the horizon containing _Sulcatopinna_ was misidentified and was not actually lower Bluefield (Weller, and others, 1948). On the basis of lithologic similarity and position in the sequence Reger correlated sandstone members in the lower Bluefield with the Tar Springs and Palestine sandstones in the type section of the Mississippian. These assignments were further supported by the reported occurrence of _Sulcatopinna_. Reger concluded that the upper two-thirds of the Bluefield and the Hinton, Princeton, and Bluestone formations were entirely unrepresented in the type region of the Mississippian; and he concluded that the lower Bluefield was equivalent to the uppermost Chesterian.

Butts (1940) extended the terms Gasper and Glen Dean limestones from the type region into southwestern Virginia. This correlation was based on a few diagnostic guide fossils, the reliability of which was questionable. Butts correlated the Bluefield with the Glen Dean on the basis of guide fossils and position in the sequence. By these correlations Butts established a hiatus representing the Golconda of the type section between the Gasper and the Glen Dean-Bluefield. The occurrence of Sulcatopinna missouriensis in the upper part of the Pennington formation in the Greendale syncline in Washington County, Virginia, provided basis for correlation with the Menard and Clore limestones of the Mississippi Valley. Butts assumed that the Sulcatopinna missouriensis horizon in the upper Pennington of the Greendale syncline was near the top of the Pennington (Hinton) of the Hurricane Ridge syncline. He concluded that, if the upper Pennington formation were Menard and Clore in age, the Bluestone formation might be correlative with the Kinkaid limestone—the youngest Mississippian formation in the Mississippi Valley. Butts noted, however, that Sulcatopinna missouriensis had been reported from the Kinkaid.

The correlation chart prepared by the Committee on Stratigraphy of the National Research Council (Weller, and others, 1948) showed the Bluefield formation as equivalent to the Golconda-Glen Dean of the type Chester. The Pennington (Hinton) was correlated with the Vienna-Menard-Clore succession; and the Princeton formation was correlated with the Degonia sandstone. The lower part of the Bluestone was shown as equivalent to the Kinkaid limestone, and the upper part of the Bluestone was considered to be younger than the top of the type Chester.

Paleontology and correlation.—Specimens of all fossils in the faunal lists are on file in the Paleontology Museum in the Department of Geological Sciences, Virginia Polytechnic Institute, Blacksburg, Virginia. Museum reference numbers identifying the individual specimens are in the faunal lists.

The following fossils were collected from the uppermost beds of the Mississippian limestone division (Greenbrier-Gasper) in southern West Virginia, southwestern Virginia, and eastern Kentucky:

Corals:

Amplexizaphrentis spinulosum (Edwards and Haime) No. TC-4

Blastoids:

Pentremites godoni Ulrich No. TC-6

Pentremites pyriformis Say No. TC-7

Crinoids:

Agassizocrinus conicus Owen and Shumard No. TC-11

Agassizocrinus laevis (Roemer) No. TC-12

Pterotocrinus spatulatus Wetherby No. TC-15

Talarocrinus sp. No. TC-13

Bryozoa:

Archimedes swallovanus (Hall) No. TC-16

Brachiopods:

Composita subquadrata (Hall) No. TC-58

Diaphragmus elegans (Norwood and Pratten)
No. TC-31

Eumetria vera (Hall) No. TC-33

Trilobites:

Griffithides sp. No. TC-73

Most of these forms have a rather wide stratigraphic range and are common at least to the entire Chester series. The crinoid genus Talarocrinus is known only from the New Design group or Gasper limestone. The top of the Mississippian limestone division in the Appalachians is apparently correlative with the top of the Gasper limestone of the standard section.

Collections from the Bluefield throughout the region include the following fossils:

Corals:

Amplexizaphrentis spinulosum (Edwards and Haime)
No. TC-3

Michelinia sp. No. TC-5

Blastoids:

Pentremites brevis Ulrich No. TC-8

Crinoids:

Pterotocrinus spatulatus Wetherby No. TC-14

Bryozoa:

Archimedes meekanus (Hall) No. TC-17

Archimedes symmetricus McFarlan No. TC-18

Fenestrellina sp. No. TC-23

Glyptopora sp. No. TC-74

Polypora sp. No. TC-21

Brachiopods:

Brachythyris chesterensis Butts No. TC-37

Chonetes chesterensis Weller No. TC-46

Cleiothyridina sublamellosa (Hall) No. TC-40

Composita subquadrata (Hall) No. TC-57

Diaphragmus elegans (Norwood and Pratten) No. TC-30

Dictyoclostus inflatus (McChesney) No. TC-28

Linoproductus ovatus (Hall) No. TC-27

Orthotetes kaskaskiensis (McChesney) No. TC-44

Punctospirifer sp. No. TC-48

Schizophoria sp. No. TC-75

Spirifer increbescens Hall No. TC-36

Spirifer leidyi Norwood and Pratten No. TC-34

Stenocisma explanata (McChesney) No. TC-39

Pelecypods:

Allorisma sp. No. TC-62

Gastropods:

Straparolus sp. No. TC-68

Cephalopods:

Orthoceras sp. No. TC-69

Trilobites:

Griffithides sp. No. TC-72

All of the above forms occur in the Chester and many of them are restricted to the Chester series; some of the fossils listed have rather long stratigraphic ranges. A few are limited to narrow parts of the column and are most useful for correlation. Stenocisma explanata is not reported below the base of the Golconda; and Pterotocrinus spatulatus and Chonetes chesterensis are not reported above the top of the Glen Dean. All of the other forms present could by their stratigraphic ranges be present in the Golconda-Glen Dean. Pentremites maccalliei, which is very similar to P. obesus of the Golconda of the type section, has been reported from the lower Bluefield (Cooper, 1944). The faunal elements of the Bluefield bracket its age as Golconda and Glen Dean.

A single collection from the Adria member of the Hinton formation contained the pelecypods Aviculopecten sp. No. TC-64 and Nuculana sp. No. TC-65. These are long-ranging genera which are common to several geologic periods.

The following fossils were collected from the Pound Gap member of the Pennington formation:

Conularids:

Paraconularia sp. No. TC-70

Corals:

Amplexizaphrentis spinulosum (Edwards and Haime)

No. TC-2

Crinoids:

Agassizocrinus conicus Owen and Shumard

No. TC-10

Bryozoa:

Archimedes sp. No. TC-19

Fenestrellina sp. No. TC-22

Polypora sp. No. TC-20

Brachiopods:

Composita subquadrata (Hall) No. TC-56

Diaphragmus elegans (Norwood and Pratten)

No. TC-29

Dictyoclostus inflatus (McChesney) No. TC-26

Linoproductus ovatus (Hall) No. TC-32

Orthotetes kaskaskiensis (McChesney) No. TC-43

Punctospirifer sp. No. TC-47

Reticulariina spinosa (Norwood and Pratten)

No. TC-51

Spirifer increbescens Hall No. TC-35

Stenocisma explanata (McChesney) No. TC-38

Ostracods:

Sargentina allani Coryell and Johnson No. TC-71

Forms collected from the abundantly fossiliferous

Avis member of the Hinton formation include:

Corals:

<u>Amplexizaphrentis</u> <u>spinulosum</u> (Edwards and Haime) No. TC-1

Crinoids:

<u>Agassizocrinus</u> <u>conicus</u> Owen and Shumard No. TC-9

Brachiopods:

<u>Composita</u> <u>subquadrata</u> (Hall) No. TC-55

<u>Dictyoclostus</u> <u>inflatus</u> (McChesney) No. TC-25

<u>Eumetria</u> <u>costata</u> (Hall) No. TC-52

<u>Orthotetes</u> <u>kaskaskiensis</u> (McChesney) No. TC-42

<u>Reticulariina</u> <u>spinosa</u> (Norwood and Pratten) No. TC-50

<u>Schizophoria</u> sp. No. TC-45

Pelecypods:

<u>Allorisma</u> sp. No. TC-61

<u>Sulcatopinna</u> <u>missouriensis</u> (Swallow) No. TC-60

<u>Schizodus</u> sp. No. TC-66

As is true for the other faunal collections most of the forms range at least through the entire Chester series; however, a few restricted forms are particularly useful for correlation. <u>Eumetria</u> <u>costata</u> has been reported only from the Elvira group. <u>Sulcatopinna</u> <u>missouriensis</u> is abundant only in the Menard and Clore formations, but it has been reported from the other formations in the Elvira group. In the type area Sargentina allani is restricted to the Clore formation. The Avis and Pound Gap members are correlated with at least part of the Elvira group, probably the Clore formation, of the standard section for the Mississippian.

Fossils collected from two or three different units in the Abbs Valley Ridge member of the Hinton formation include the following:

Brachiopods:

Composita subquadrata (Hall) No. TC-54

Dictyoclostus inflatus (McChesney) No. TC-24

Orthotetes kaskaskiensis (McChesney) No. TC-41

Punctospirifer transversa (McChesney) No. TC-53

Reticulariina spinosa (Norwood and Pratten) No. TC-49

Pelecypods:

Cypricardella sp. No. TC-63

Sulcatopinna missouriensis (Swallow) No. TC-59

These forms are all common to the Elvira group, and by the stratigraphic position of the Abbs Valley Ridge member above the Avis member of the Hinton, it is concluded that the Abbs Valley Ridge probably represents the upper part of the Elvira group—the youngest Mississippian strata in the type area.

A single collection of fossils was obtained from the Bluestone formation. This collection contained the inarticulate brachiopod Lingula sp. No. TC-76 and the gastropod Straparolus sp. No. TC-67. The faunal evidence is insufficient to prove the Mississippian age of the Bluestone. The lithologic similarity of the Bluestone and Hinton in contrast to the dissimilarity of the Bluestone and overlying Pennsylvanian has led to the conclusion that the Bluestone is Mississippian (Campbell, 1896; Reger, 1926; Butts, 1940). Reger (1926) and Butts (1940) cited faunal evidence of the Mississippian age of the Bluestone. It is concluded that the Bluestone is Mississippian in age, but it is younger than the top of the type section of the Mississippian. The Bluestone is referred to the post-Elvira group part of the Chester series (Weller, and others, 1948).

PLATE 11

UPPER MISSISSIPPIAN FOSSILS

1. a-c. Dictyoclostus inflatus (McChesney). a-b, pedicle view; c, interior of brachial valve. Abbs Valley Ridge member; 1.0 mile north of Athens on State Highway 20, Mercer County, West Virginia. TC-24.
2. Linoproductus ovatus (Hall). pedicle view. Bluefield formation; Virginian Railway at Oakvale, Mercer County, West Virginia. TC-27.
3. a-b. Diaphragmus elegans (Norwood and Pratten). a, pedicle view; b, lateral view. Bluefield formation; Virginian Railway at Oakvale, Mercer County, West Virginia. TC-30.
4. Chonetes chesterensis Weller. Bluefield formation; Virginian Railway at Oakvale, Mercer County, West Virginia. TC-46.
5. Reticulariina spinosa (Norwood and Pratten). Abbs Valley Ridge member; 1.0 mile north of Athens on State Highway 20, Mercer County, West Virginia. TC-49.
6. Punctospirifer transversa (McChesney). Abbs Valley Ridge member; southeast side of Abbs Valley Ridge on State Road 701, 2 miles south of Boissevain, Tazewell County, Virginia. TC-53.
7. a-b. Spirifer leidyi Norwood and Pratten. a, brachial view; b, posterior view. Bluefield formation; Virginian Railway at Oakvale, Mercer County, West Virginia. TC-34.
8. Spirifer increbescens Hall. Bluefield formation; northwest side of Stony Ridge on State Highway 16, 1.5 miles south of Bishop, Tazewell County, Virginia. TC-36.
9. Brachythyris chesterensis Butts. Bluefield formation; Virginian Railway at Oakvale, Mercer County, West Virginia. TC-37.
10. Eumetria vera (Hall). Top of Gasper limestone; 0.5 mile south of Little Stone Gap on State Road 610, Wise County, Virginia. TC-33.
11. Eumetria costata (Hall). Avis member; northwest side of Abbs Valley Ridge on State Road 701, 1.5 miles south of Boissevain, Tazewell County, Virginia. TC-52.
12. Stenocisma explanata (McChesney). Pound Gap member; Southern Railroad 2.5 miles north of Big Stone Gap, Wise County, Virginia. TC-38.
13. a-d. Composita subquadrata (Hall). a-b, brachial view; c, pedicle view; d, lateral view. a, top of Gasper limestone; west side of Pine Mountain, 3.5 miles east of Jenkins on U. S. Highway 23, Letcher County, Kentucky. TC-58. b-d, Abbs Valley Ridge member; 1.0 mile north of Athens on State Highway 20, Mercer County, West Virginia. TC-54.
14. a-b. Orthotetes kaskaskiensis (McChesney). Pound Gap member; west side of Pine Mountain, 4 miles east of Jenkins on U. S. Highway 23, Letcher County, Kentucky. TC-43.

All specimens X1.

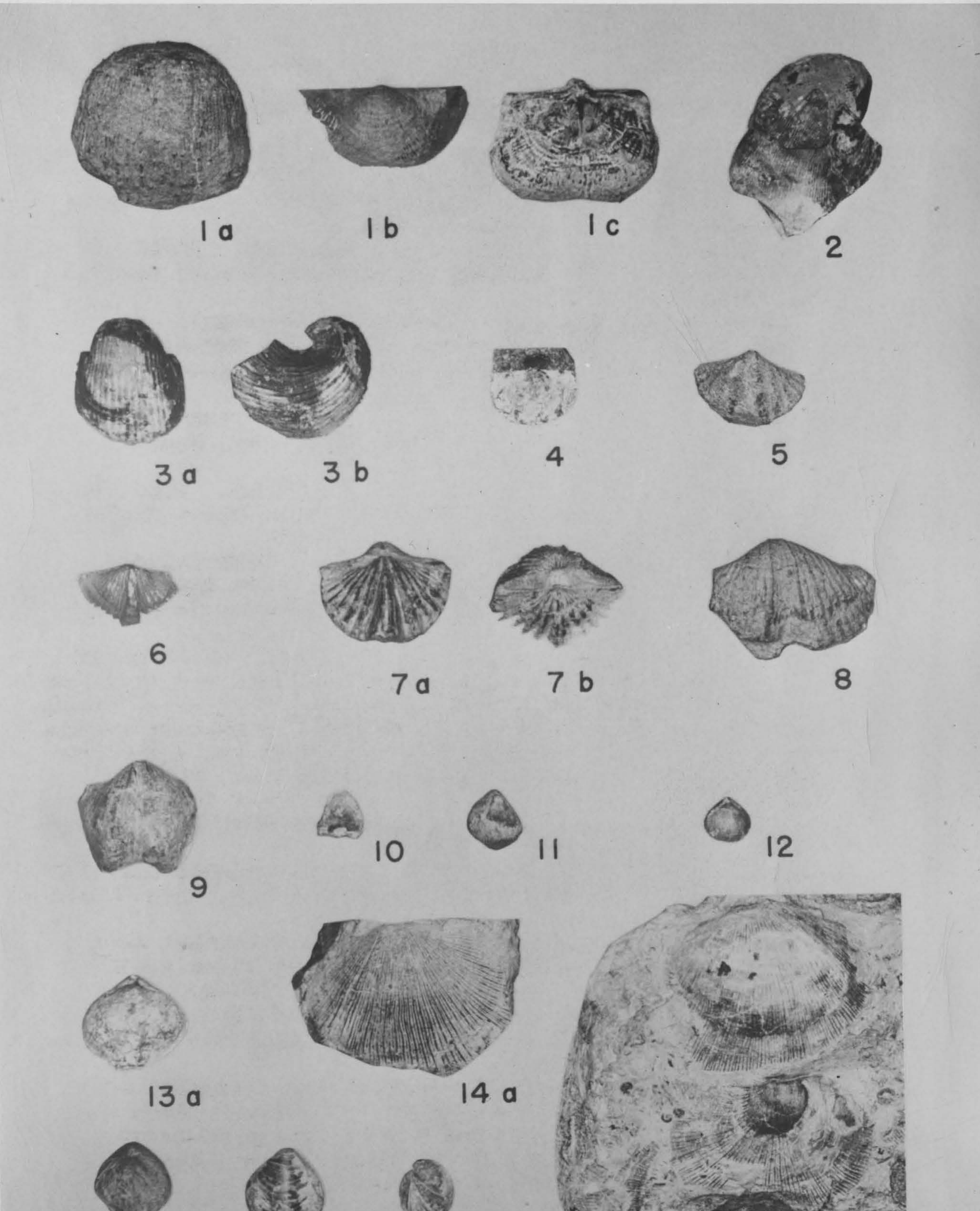
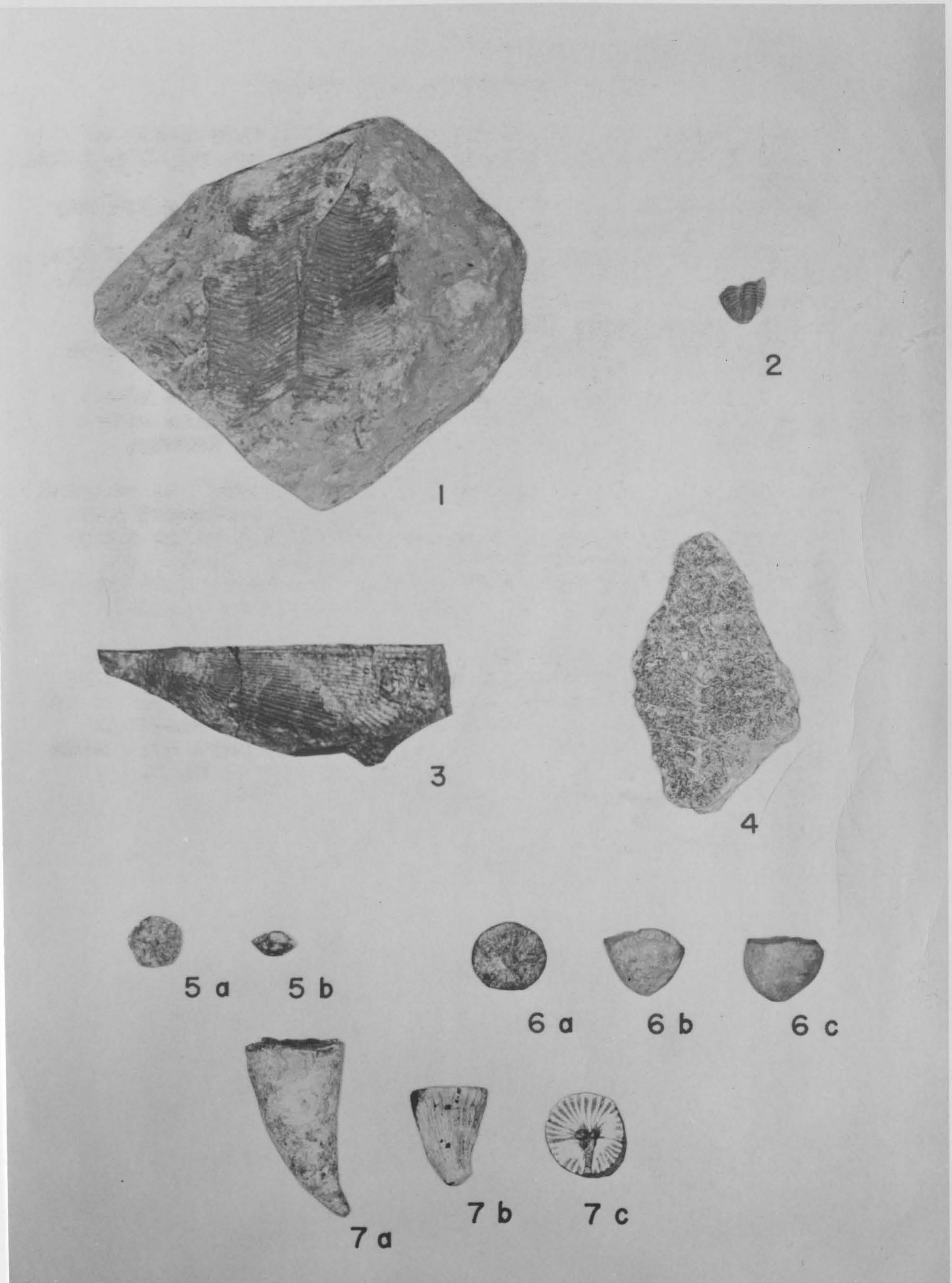

1a
1b
1c
2
3a
3b
4
5
6
7a
7b
8
9
10
11
12
13a
14a
13b
13c
13d
14b

PLATE 12

UPPER MISSISSIPPIAN FOSSILS

1. Paraconularia sp. Pound Gap member; 0.3 mile north of Little Stone Gap on State Road 610, Wise County, Virginia. TC-70.
2. Griffithides sp. Bluefield formation; Virginian Railway at Oakvale, Mercer County, West Virginia. TC-72.
3. Sulcatopinna missouriensis (Swallow). Abbs Valley Ridge member; 1.5 miles northeast of True on State Highway 18, Summers County, West Virginia. TC-59.
4. Archimedes meekanus (Hall). Bluefield formation; at intersection of State Roads 644 and 701, 0.5 mile south of Boissevain, Tazewell County, Virginia. TC-17.
5. a-b. Agassizocrinus laevis (Roemer). a, calical view; b, side view. Top of Gasper limestone; 0.5 mile south of Little Stone Gap on State Road 610, Wise County, Virginia. TC-12.
6. a-c. Agassizocrinus conicus Owen and Shumard. a, calical view; b-c, side view. a-b, Avis member; northwest side of Abbs Valley Ridge on State Road 701, 1.5 miles south of Boissevain, Tazewell County, Virginia. TC-9. c, Pound Gap member; west side of Pine Mountain, 4 miles east of Jenkins on U. S. Highway 23, Letcher County, Kentucky. TC-10.
7. a-c. Amplexizaphrentis spinulosum (Edwards and Haime). a-b, side view; c, calical view. a and c, Avis member; northwest side of Stony Ridge 100 yards west of crest on State Highway 16, 3.5 miles south of Bishop, Tazewell County, Virginia. TC-1. b, Pound Gap member; west side of Pine Mountain, 4 miles east of Jenkins on U. S. Highway 23, Letcher County, Kentucky. TC-2.

All specimens X1.



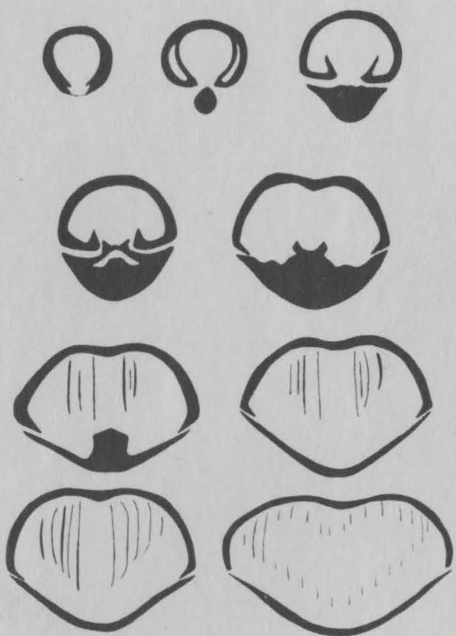


Figure 3.—Serial sections of Composita subquadrata. 2X TC-54, from limestone unit in middle part of Abbs Valley Ridge member of Hinton formation, on State Highway 20, 1 mile north of Athens, Mercer County, West Virginia.

<u>Conclusions</u>.—The top of the Mississippian limestone division of the western Appalachian sequence is correlated with the top of the New Design group of the standard section of the Mississippian. This correlation is based on the presence of Gasper fossils in the upper part of the Mississippian limestones in the Appalachians. The Bluefield is correlated with the Homberg group of the standard section on the basis of common occurrences of fossils which mark off the Golconda-Glen Dean sequence. The upper part of the Pennington-Hinton is correlated with the Elvira group of the standard section, and it is assumed that the lower part of the Pennington-Hinton belongs to the Elvira group. The Bluestone formation is younger than the Elvira group and it is not represented by beds in the type area of the Mississippian.

The Upper Mississippian clastic sequences in the western Appalachians are much thicker than the equivalent part of the standard section of the Mississippian in the Mississippi Valley. Continuous downwarp permitted uninterrupted accumulation of sediments in the Hurricane Ridge syncline and adjacent areas of the Appalachians. It is difficult to correlate the complete and much thicker Appalachian geosynclinal sequences with the standard section, which was deposited on the continental shelf area in the Central Interior of the United States. However, the position of the thinner units of the standard section could better be located in the Appalachian sequences. Perhaps the Hurricane Ridge syncline would have been a more fortunate choice for the type area of the Mississippian, because at a number of localities the entire system is exposed in a continuous section. Detailed work on the faunas of these beds would make this succession the most useful Mississippian reference section in the eastern United States.

PRIMARY SEDIMENTARY FEATURES

Cross-bedding

Both simple foreset and compound cross-bedding are relatively common in the hard clean sandstone units of the Upper Mississippian. Examples of foreset bedding occur in all parts of the area. Compound cross-bedding is essentially restricted to the lower sandstone unit of the Abbs Valley Ridge member in the area north of Athens, West Virginia, where the sandstone attains an abnormally great thickness.

Most of the foreset bedding dips to the northwest or west, and a few exposures have southeastward dips (Fig. 4). Foreset bedding inclined to the northwest is clearly defined, and the dips are in the range of 15 to 25 degrees (Pl. 13, fig. 1). In contrast the southeast dipping foreset beds are poorly defined, and the dips are less than 10 degrees. Southeastward dipping foreset beds are limited to the southeastern part of the outcrop in Mercer and Tazewell counties, and dips opposite the regional trend are probably the result of wave action on offshore bars. Wave deposition of southeast foresetting is also indicated by the occurrence of faint rill marks on the surface of southeastward dipping

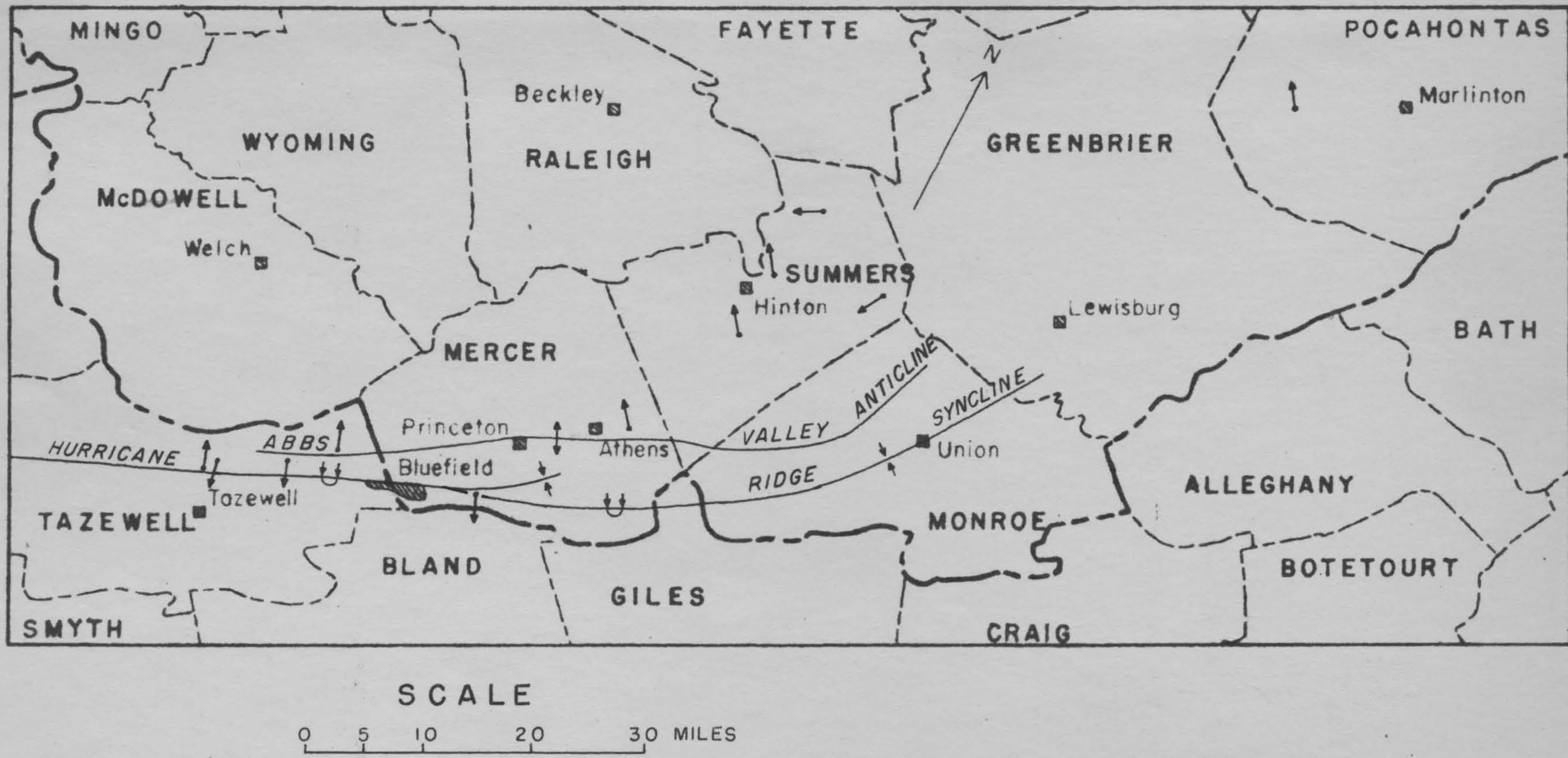


Figure 4.—Regional map showing orientation of foreset bedding of sandstones in the Hinton formation in southern West Virginia and Tazewell County, Virginia.

PLATE 13

PRIMARY SEDIMENTARY FEATURES

Figure 1.—Foreset bedding in lower sandstone unit of Abbs Valley Ridge member of Hinton formation, on unpaved road on south end of Keeney Mountain 1 mile northwest of Clayton, Summers County, West Virginia.

Figure 2.—Current-bedding in sandstone bed in upper part of Adria member of Hinton formation on northwest side of Stony Ridge, State Highway 16, Tazewell County, Virginia.

Figure 1

Figure 2

foresets in the Abbs Valley Ridge member on Abbs Valley Ridge in the vicinity of Mud Fork, Tazewell County, Virginia.

Compound foreset bedding in the lower sandstone unit of the Abbs Valley Ridge member occurs in the abnormally thick part of the sandstone in the vicinity of Athens, Mercer County, West Virginia (Pl. 14). The lower part of the unit contains beds of limestone-pebble conglomerate which was apparently derived from erosion of the underlying Avis limestone. This area may represent a site of breaking of marine currents, which would explain both the local erosion of the Avis limestone and the compound foreset bedding of the sandstone and conglomerate. The dominant orientation of dips of foreset beds is toward the sections of greatest thickness of the sandstone (Fig. 5).

PLATE 14

COMPOUND CROSS-BEDDING

Figures 1 and 2.—Compound cross-bedding in the lower sandstone unit of the Abbs Valley Ridge member of the Hinton formation on Laurel Creek, 0.5 mile north of Athens, Mercer County, West Virginia.

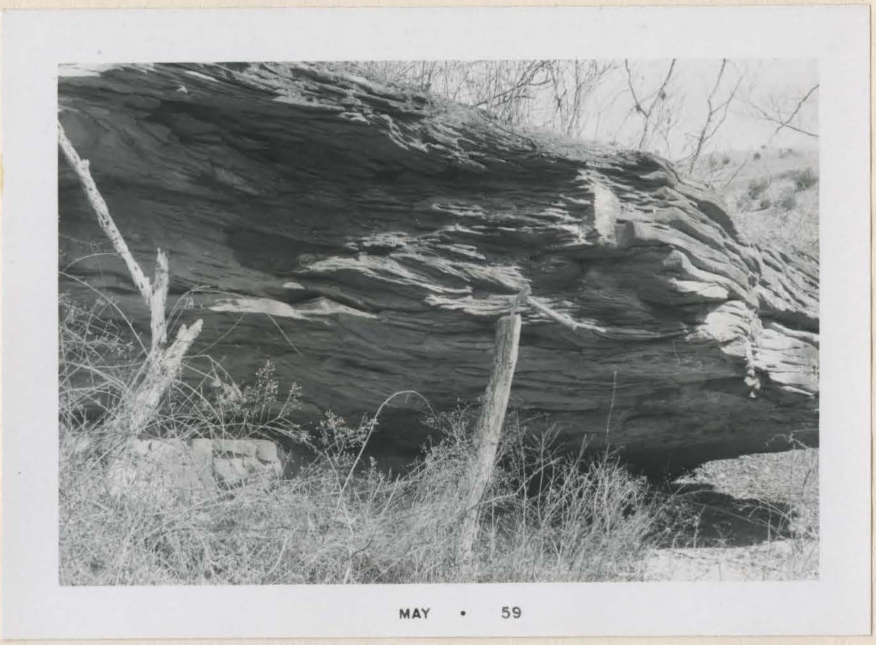


Figure 1

Figure 2

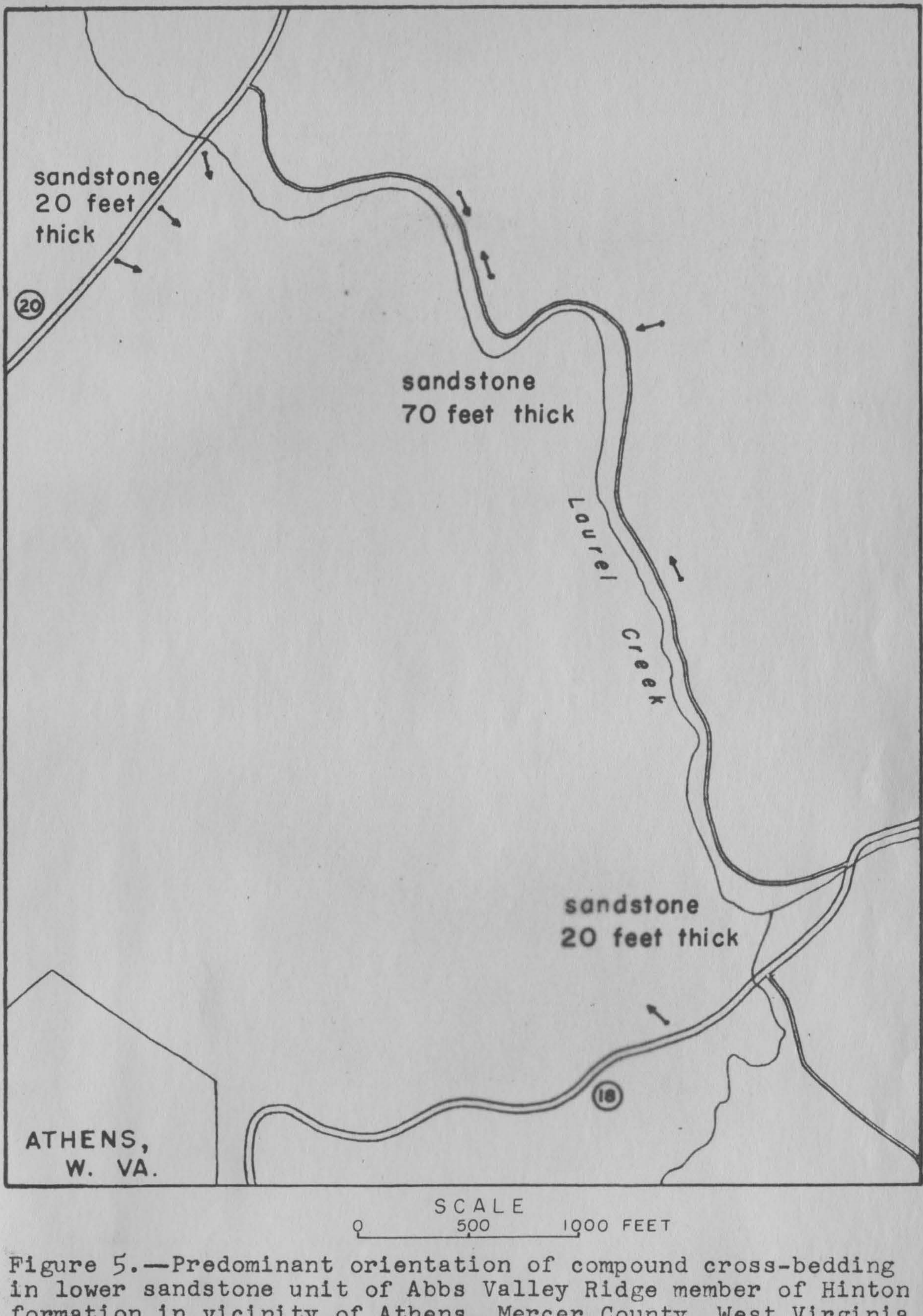


Figure 5.—Predominant orientation of compound cross-bedding in lower sandstone unit of Abbs Valley Ridge member of Hinton formation in vicinity of Athens, Mercer County, West Virginia.

Current-bedding

Current-bedding or cross-lamination is identical with small scale festoon cross-bedding. Formation of current bedding is attributable to rapid bottom currents in shallow water (Bailey, 1936). An example of well defined current-bedding occurs in a 2-foot sandstone bed in the upper part of the Adria member of the Hinton formation on the west side of Stony Ridge north of Tazewell, Tazewell County, Virginia (Pl. 13, fig. 2).

Groove Casts and Spatulate Markings

Rectilinear ridges on the bottom surface of sandstone beds are defined as groove casts (Shrock, 1948). These ridges represent sand fillings (casts) of elongate grooves in the surface upon which the sand was deposited. The origin of the grooves is in question; however, they seem to be related to current activity (Pettijohn, 1957). Groove casts are generally considered to be elongate parallel to direction of current movement. Spatulate markings (Pettijohn, 1957), or lobate rill marks (Shrock, 1948), are sometimes associated with groove casts. These marks, shaped like an inverted spoon, are also casts. They are elongated parallel to current direction and the broad end is upcurrent (Pettijohn, 1957).

Several examples of groove casts are exposed on sandstone beds in the upper part of the Adria member of the Hinton formation on Stony Ridge along State Highway 16 north of Tazewell, Virginia; they have not been found in other localities. These features are somewhat larger than the few millimeters of depth described by Shrock (1948); otherwise they conform to his description. The largest groove cast noted is tapered sharply but has a maximum depth of 4 inches and width of 16 inches. Spatulate markings associated with the large groove cast are elongate to the northwest and the broad deep part of the marks is to the southeast. The average size of the groove casts is about one inch deep and one inch wide. The average original azimuth of elongation is N. 20° W.; all of the groove casts are aligned between N. 5° W. and N. 35° W.

The presence of these features provides evidence that strong current action was a prominent influence on Upper Mississippian deposition. The orientation and configuration of the groove casts and spatulate markings is interpreted to indicate that currents moved from southeast toward the northwest.

Flow Casts

Lobate ridges and undulatory surfaces on the bottom of sandstone layers represent filling of negative features produced by flowage of soft underlying sediments; these are defined as flow casts (Shrock, 1948). Unequal loading of soft sediments with sand produces the flowage in the underlying materials which is reflected in the flow casts preserved on the under surfaces of sandstone beds.

Several examples of flow casts occur in the region. The best examples are in the area shown on Plate 10, one mile north of Athens, Mercer County, West Virginia. Several well developed flow casts occur in the under surface of a thin sandstone bed resting on gray clay shale beneath the unconformity (Pl. 15, fig. 1). Flow casts are present above a clay shale parting in a sandstone unit in the lower part of the Hinton formation 100 yards north of the entrance to Bluestone State Park on State Highway 20, Summers County, West Virginia. Flow casts occur on the under surface of a sandstone, which rests on brown clay shale in the lower Bluestone formation on State Highway 85, 1 mile south of Falls Mills, Tazewell County, Virginia.

PLATE 15

PRIMARY SEDIMENTARY FEATURES

Figure 1.—Flow casts on sandstone bed in middle part of Abbs Valley Ridge member of the Hinton formation, 1 mile north of Athens, Mercer County, West Virginia.

Figure 2.—Current ripples in middle sandstone unit in Bluefield formation, U. S. Highway 460 at Glenlyn, near Virginia-West Virginia boundary.

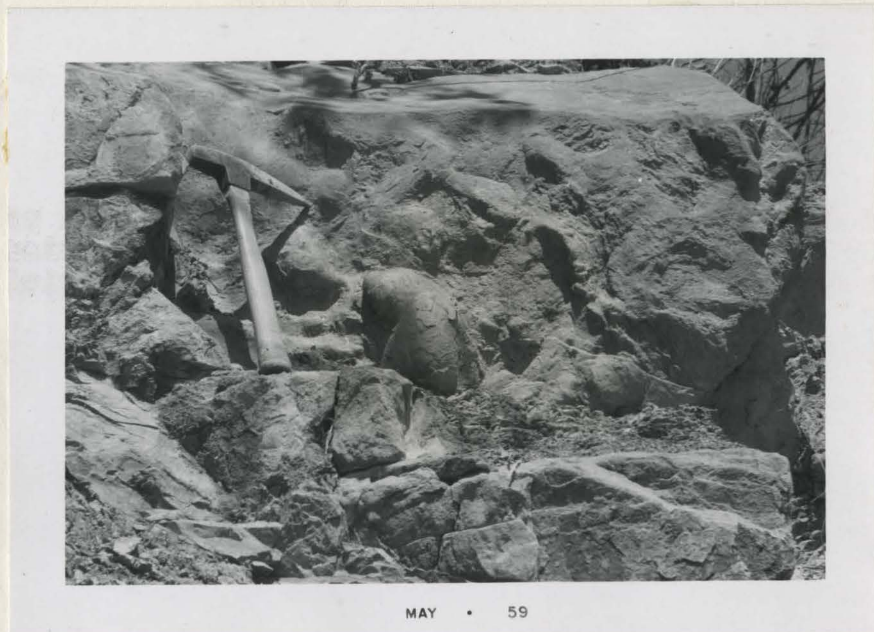


Figure 1

Figure 2

Ripple Marks

Several examples of ripple marks are known in the region; they occur through the section from middle Bluefield to upper Hinton (Pl. 15, fig. 2). These are generally small ripple marks with wave length as much as 4 inches and amplitude less than half an inch. Current ripples with a single orientation are the rule; however, on the sandstone in the middle Bluefield formation at Stony Gap near Bluefield, West Virginia, interference ripples are present. The orientation of the ripple marks is everywhere in a general northeast-southwest direction. The steep side of the ripples is consistently on the northwest, which indicates that the currents moved from southeast to northwest.

The ripple marks signify the importance of current action; however, because of their apparent sparse distribution conclusions regarding current direction based on ripple marks alone are unjustified. It is significant that current directions based on cross-bedding, groove casts, and ripple marks provide the same conclusion; that is, that the regional direction of prevailing currents was toward the northwest.

ADJUSTMENT STRUCTURES FORMED DURING EARLY DIAGENESIS

Introduction

A number of small folds and faults occur in the Hurricane Ridge syncline area in beds ranging from upper Bluefield up to the middle part of the Bluestone. The range of beds involved in any one of these minor structures is very limited, and the structures have very little lateral extent. The structures are associated with areas of relatively thicker sections, and most of these are in the axial portion of the Hurricane Ridge syncline.

Several lines of evidence indicate that the Upper Mississippian beds in the western Appalachians were lithified very soon after deposition. A number of local intraformational conglomerates are present, the pebbles of which were apparently eroded from beds that had just been deposited but were firm enough to be eroded as rock and transported as detrital fragments rather than being deflocculated in the water. Although the pebbles are generally rounded there is no evidence of distortion of shape; and the grains of the matrix are not impressed into the pebbles, which would be expected if the source beds had been soft when erosion and redeposition occurred.

The groove casts on the base of sandstone beds have sharply defined contacts and steep sides indicating that no soft sediment flowage occurred when these features were formed. Flow casts are present only on sandstone beds that rest on clay shales, which are the most plastic sediments in the succession; and only a small amount of flowage occurred in the most plastic materials. The adjustment structures were developed during a stage of partial lithification of the beds involved. The beds are sharply bent without fracturing, but there is no evidence of soft sediment flowage and each bed maintains its characteristic thickness and identity.

The origin of the structures associated with the locally thick accumulation of sediments is attributed to differential compaction generated, in part, by unequal loading. Compaction of materials beneath the local accumulations allowed for settling which caused folding of the beds. The structures associated with the thicker sections in the axial portion of the Hurricane Ridge syncline indicate shifting of sediments on the flanks toward the trough of the structure. Relatively greater compaction would necessarily occur in the thicker sections, because of the greater amount of material to be compacted. Continued active downwarp of the axial portion of the structure and possibly compaction of the thicker sections would have generated settling of the beds on the flanks and steepening of dips toward the trough of the Hurricane Ridge syncline.

Syncline and Angular Unconformity near Athens, West Virginia

A narrow asymmetric syncline in a thin limestone bed in the Abbs Valley Ridge member of the Hinton formation is exposed in a road cut along State Highway 20, 1 mile north of Athens, Mercer County, West Virginia (Pls. 16, 17). The strike of the syncline is N. 45° E.; the northwest flank dips 75° to the southeast, and the southeast flank dips 20° to the northwest. The limestone and associated clay shales in the syncline are truncated by a thick-bedded sandstone and limestone-pebble conglomerate. The regional dip is essentially horizontal in this vicinity.

Abrupt lateral changes in thickness and lithology of the limestone and associated beds are exhibited on opposite sides of the small syncline (Pl. 16). On the southeast limb of the structure the sequence in descending order is as follows:

	Thickness (Feet)
h. Conglomerate, rounded pebbles of limestone and claystone as much as 2 inches in diameter, matrix of brown medium-grained sandstone	

PLATE 16.—CROSS SECTION SHOWING SYNCLINE AND ANGULAR UNCONFORMITY WITHIN ABBS VALLEY RIDGE MEMBER

Section in road cut on State Highway 20, 1 mile north of Athens, Mercer County, West Virginia.

PLATE 17

SYNCLINE AND ANGULAR UNCONFORMITY IN

ABBS VALLEY RIDGE MEMBER

Figure 1.—Massive limestone-pebble conglomerate above angular unconformity in the Abbs Valley Ridge member of the Hinton formation, 1 mile north of Athens, Mercer County, West Virginia.

Figure 2.—Angular unconformity between a limestone and a sandstone in the Abbs Valley Ridge member of the Hinton formation, 1 mile north of Athens, Mercer County, West Virginia. The limestone (hammer) dips to the southeast at 75°; the overlying sandstone is essentially horizontal.

Figure 1

Figure 2

(Pl. 18)	10
g. Sandstone, brown, fine grained; single bed; flow casts on under surface	2
f. Clay shale, gray, fissile	4
e. Sandstone, brown, fine grained; single bed	2
d. Clay shale, gray, fissile; fragments of brachiopod shells	15
c. Limestone, blue-gray, fine grained, argillaceous; single bed; _Composita subquadrata_, _Dictyoclostus inflatus_	1
b. Clay shale, gray, fissile; fragments of brachiopod shells	4
a. Sandstone, light-brown, fine grained; in uneven beds as much as 4 inches thick, thin partings of gray clay shale	14

Only units b, c, and d of the section on the southeast flank are represented on the more steeply dipping northwest limb of the structure; the missing units are either cut out by the unconformity or are under cover. Each of the units is appreciably thicker on the northwest flank than on the southeast limb of the structure. The stratigraphic

PLATE 18

CONGLOMERATE ABOVE ANGULAR UNCONFORMITY

Figures 1 and 2.—Conglomerate from above the angular unconformity in the Abbs Valley Ridge member of the Hinton formation near Athens, Mercer County, West Virginia. The pebbles are mostly argillaceous limestone; the matrix is a fine- to medium-grained sandstone. (actual size)

Figure 1

Figure 2

section on the steep northwest limb of the syncline is:

	Thickness (Feet)
f. Conglomerate, rounded pebbles of limestone and claystone as much as 2 inches in diameter, matrix of brown medium-grained sandstone; lower surface of conglomerate is irregular, fills minor depressions in underlying units	25
— Angular unconformity —	
e. Clay shale, gray, fissile; Dictyoclostus inflatus, Orthotetes kaskaskiensis	22
d. Limestone, dark blue-gray, fine grained, argillaceous; shaly; Dictyoclostus inflatus, Orthotetes kaskaskiensis, Reticulariina spinosa, Composita subquadrata, Cypricardella sp.	4
c. Limestone, blue-gray, fine grained; single bed; Dictyoclostus inflatus, Orthotetes kaskaskiensis, Reticulariina spinosa, Composita subquadrata, Cypricardella sp.	2

b. Limestone, blue-gray, fine grained, argillaceous; shaly; Dictyoclostus inflatus, Orthotetes kaskaskiensis, Composita subquadrata 7

a. Clay shale, gray, fissile; fragments of brachiopod shells 20

The sequence on the northwest side of the structure shows a complete stratigraphic gradation from non-calcareous clay shale to calcareous mudstone, to limestone, and to clay shale. Such a gradation is also present on the southeast side; however, the most calcareous element of the sequence is a highly argillaceous limestone.

The conglomerates (Pl. 18) are composed of pebbles ranging from round to angular and exhibiting a wide variety of sizes up to 3 inches in diameter. The average size of pebbles is slightly less than 1 inch in diameter. A single block of argillaceous limestone, which is 2 feet by 3 feet in cross section and of undetermined length, is incorporated in the lower part of the conglomerate. No sorting either with respect to size or composition of pebbles is apparent. The bulk of the rock is made up of pebbles of blue-gray fine-grained argillaceous limestone; however, the pebbles range from light blue-gray highly argillaceous limestone to black fine-grained siliceous limestone. Pebbles of non-calcareous claystone and fragments of dark-gray calcareous claystone are relatively common. Yellow-brown and maroon mudstones are less abundant constituents. Few remarkably well preserved horn corals and fragments of other fossils are included. All of the pebbles could have been derived from the relatively narrow range of section exposed beneath the unconformity or from the immediate vicinity. The matrix of the conglomerate is a brown medium-grained sandstone.

Origin.—The trend of thickness change in the limestone unit suggests that it was deposited in a narrow, shallow basin, the deepest part of which probably was located at the present trough of the small syncline. Differential compaction of the clay shales beneath the limestone, perhaps induced by settling of the underlying units, could have created the small basin. Deposition of the limestone and overlying strata in the basin, giving rise to unequal loading on the partly lithified clays, may have produced continued compaction and slumping of the clays which led to the formation of the small asymmetric syncline in the limestone and related beds.

The upturned limestone and shale were rapidly fragmented by strong current action which carved irregular channels and produced the cross-bedding in the coarse clastic sediments along both sides of the limestone ridge formed by the steep side of the syncline. Sand was transported into the area and deposited with the debris from the local source area provided by the limestone ridge. The sand was deposited over a wide area and made up one of the prominent sandstone units in the Abbs Valley Ridge member. Pebbles mainly of limestone were incorporated in the sand for about 50 feet transverse to the strike on both sides of the nearly vertical limestone. The dimensions parallel to the strike are undetermined because of lack of exposure.

Small Fold Northeast of Athens, West Virginia

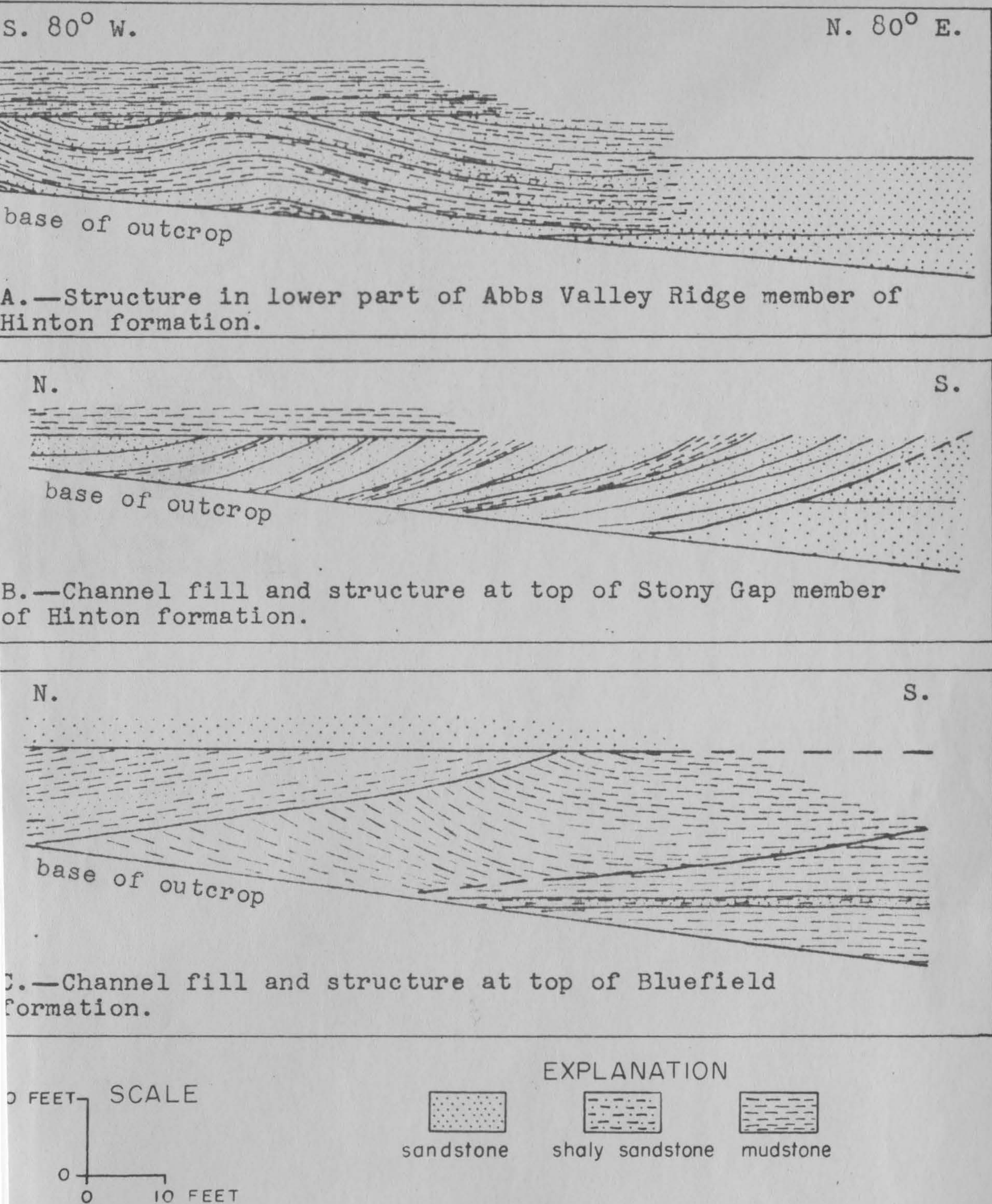
A small fold is exposed in a siltstone bed in the middle of the Abbs Valley Ridge member of the Hinton formation on State Highway 18 about 0.25 mile northeast of Concord College, Athens, West Virginia. The structure extends for about 100 feet along the outcrop and involves only about 10 feet of stratigraphic thickness. The bedding strikes N. 70° E. and dips 18° to the northwest. The orientation of ripple marks transverse to the strike of the bedding is interpreted to indicate folding rather than cross-bedding. The dip is toward the abnormally thick section of the lower sandstone unit in the Abbs Valley Ridge member and probably indicates settling toward the local basin.

Minor Folds on Kennison Mountain, Pocahontas County, West Virginia

Three examples of structures attributed to early post-lithification adjustments are exposed along State Highway 39 on Kennison Mountain, Pocahontas County, West Virginia. These structures are developed in thin-bedded sandstones and mudstones at different stratigraphic horizons.

One structure is located in the lower part of the Abbs Valley Ridge member of the Hinton formation (Fig. 6-A). The beds involved have only gentle highly localized angular discordance with other units in the sequence. About 10 feet of stratigraphic thickness is involved, and the structure extends about 60 feet laterally. The undulatory bedding has about 3 feet of structural relief. Differential compaction of the beds involved probably produced the structure which dies out with depth (10 to 15 feet) and is truncated at the top.

A shallow channel cut into the top of the Stony Gap sandstone member of the Hinton formation is filled by a relatively thin-bedded sandstone which dips toward the deepest part of the channel (Fig. 6-B). Most or all of the dip is attributed to primary foreset bedding.



A.—Structure in lower part of Abbs Valley Ridge member of Hinton formation.

B.—Channel fill and structure at top of Stony Gap member of Hinton formation.

C.—Channel fill and structure at top of Bluefield formation.

Figure 6.—Minor folds exposed along State Highway 39 on south end of Kennison Mountain, Pocahontas County, West Virginia.

Truncation of beds and lenses are common. However, the layers show gentle warping which forms a shallow syncline in the channel. Compaction of the channel sands may have emphasized the original dip.

The third structure is developed in beds immediately below the base of the Stony Gap sandstone member of the Hinton formation (Fig. 6-C). A very shallow syncline is restricted to about 12 feet of mudstones. These beds were apparently deposited in a broad shallow channel, and the gentle folding was produced by greater compaction in the thicker mudstones. These beds are overlapped with slight discordance by the Stony Gap sandstone member.

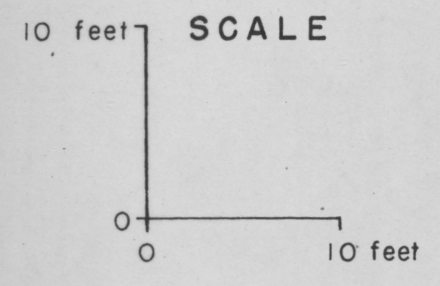
Discordant Bedding near Bluefield, West Virginia

Strongly discordant bedding in a sandstone lens in the Bluestone formation is exposed in a road cut 0.5 mile south of the Mercer County Airport near Bluefield, West Virginia (Pls. 19, 20). The sandstone lens, which has a great range in direction and degree of bedding attitude, is included within a sequence of horizontal maroon mudstones. The outcrop is located on the southeast limb of the Hurricane Ridge syncline between the trough and the sharp overturn of the structure to the southeast.

The sandstone lens is about 250 feet wide transverse to the strike of the regional structure; and it has a maximum thickness of about 20 feet. The sandstone extends about 300 feet parallel to the axis of the Hurricane Ridge syncline. At either end of the lens, where the sandstone pinches out, the beds are nearly horizontal. In the thicker middle part of the lens the sandstone beds dip as steeply as 70° to the northwest toward the trough of the Hurricane Ridge syncline. A general gradual change in degree of dip is expressed from the nearly horizontal beds at the margins of the lens to the steeply dipping layers in the middle part (Pl. 19). The individual sandstone beds are not continuous and generally grade laterally

PLATE 19.—CROSS SECTION SHOWING DISCORDANT BEDDING IN SANDSTONE LENS IN BLUESTONE FORMATION

Section in road cut near Mercer County Airport, 2 miles northeast of Bluefield, Mercer County, West Virginia.



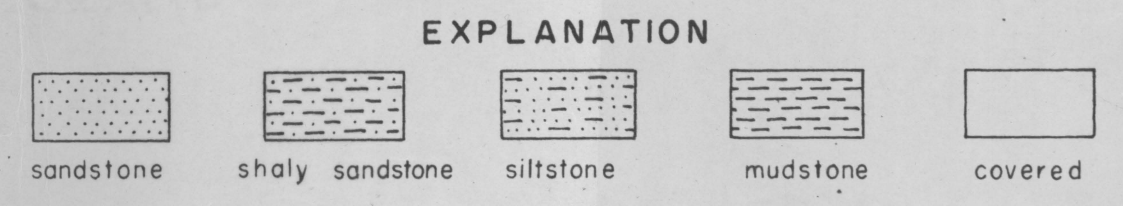


PLATE 20

ADJUSTMENT STRUCTURE FORMED DURING EARLY DIAGENESIS

Figure 1.—Discordant bedding in a sandstone lens in the Bluestone formation near Mercer County Airport, 1 mile north of Bluefield, Mercer County, West Virginia.

Figure 2.—Close-up of middle part of section shown in Plate 20, Figure 1.

Figure 1

Figure 2

in all directions into mudstone within a few feet. Sharp folding is recorded in some of the beds which turn as much as 70° in dip within a few feet and without fracturing or other disturbance of bedding continuity. A number of the beds are truncated by succeeding ones.

Sandstones near the margins of the lens are thick bedded and have small scale cross-bedding. The sandstone beds in the thicker part of the lens are relatively thin and are separated by layers of maroon mudstone.

Origin.—Development of the structure is attributed to two complementary processes. The sand was rapidly washed into a small depression and deposited with strong foreset bedding inclined to the northwest toward the trough of the Hurricane Ridge syncline. Continued active downwarp of the trough of the Hurricane Ridge syncline induced settling of the beds on the flanks and shifting toward the trough of the structure. Relatively greater compaction of the thicker sections in the trough of the Hurricane Ridge syncline may have contributed to settling of the beds on the flanks of the structure. This settling toward the northwest served to over-steepen the foreset dips in the sandstone lens on the southeast flank of the syncline. Settling prior to complete lithification of the sandstone served to increase the foreset dips and to produce the sharp folds exhibited by some of the layers.

Minor Structures in the Vicinity of Bluefield, West Virginia

A number of minor structures are exposed in the middle part of the Bluestone formation in road cuts on the un-numbered paved road approaching the Mercer County Airport, near Bluefield, West Virginia. The exposures are in the area 2 to 4 miles east of the airport. These structures are located on the northwest flank a few hundred feet from the trough of the Hurricane Ridge syncline. These features are developed in sandstone interbeds and lenses in a maroon mudstone sequence, and the structure is similar to that in a larger sandstone lens near the Mercer County Airport (Pl. 19). The structures are expressed as gentle undulations in the bedding, and the dips are generally less than 10 degrees to the southeast toward the trough of t he Hurricane Ridge syncline. All of the structures are limited to less than 20 feet of beds and less than 100 feet laterally. These structures indicate shifting of partly lithified sediments and over-steepening of dips toward the trough of the Hurricane Ridge syncline.

Fault at Rich Creek, Virginia

A small normal fault is exposed along U. S. Highway 460 in the northern part of Rich Creek, Giles County, Virginia (Pl. 21, fig. 1). The beds involved in the structure are in the upper part of the Adria member of the Hinton formation on the northwest flank of the Hurricane Ridge syncline almost in the trough of the structure. The strike of the fault is apparently parallel to that of the regional structure and the dip of the fault plane is 65° to the southeast toward the trough of the syncline. The down thrown side is on the southeast; the displacement is about 5 to 10 feet. Drag folding is exhibited on both sides of the fault. The possibility of several similar faults is indicated in more poorly exposed parts of the same outcrop.

The fault may have been developed during early diagenesis as a result of shifting of the beds on the flanks toward the trough of the actively downsinking Hurricane Ridge syncline. The displacement on the fault suggests movements similar to those which produced many small discordant folds during early diagenesis. However, the evidence is inconclusive and the fault may have formed during later structural development of the Hurricane Ridge syncline.

PLATE 21

ADJUSTMENT STRUCTURE FORMED DURING EARLY DIAGENESIS

Figure 1.—Small fault (hammer) in upper part of Adria member of Hinton formation in northern part of Rich Creek, Giles County, Virginia.

Figure 1

Minor Structures in the Vicinity of Glenlyn and Rich Creek, Virginia

Several small structures are present in the Adria member of the Hinton formation along the New River northwest of Glenlyn, Giles County, Virginia. These structures on the northwest flank of the Hurricane Ridge syncline have dips of less than 5° to the southwest toward the trough of the syncline. These features are limited to a few feet of beds, but they occur in several places in the vicinity.

A structure having dips as much as 10° is limited to a 20-foot sandstone in the Adria member of the Hinton formation along U. S. Highway 460 between Glenlyn and Rich Creek, Giles County, Virginia. The regional dip is to the southeast at a low angle toward the trough of the Hurricane Ridge syncline. A thick-bedded sandstone has local dips as steep as 10° toward the southeast, and the adjacent mudstones are somewhat contorted. Less than 100 feet laterally from the point of maximum dip the attitude of the sandstone conforms to regional dip.

The origin of these structures is attributed to settling and sliding of partly lithified sediments toward the axial portion of the Hurricane Ridge syncline. All of the minor structures are aligned parallel to the strike of the regional structure, and dips are inclined toward the trough.

TECTONIC FRAMEWORK OF DEPOSITION

Relation of Thickness to Structure

The thickness of the Upper Mississippian clastic sequence increases regularly eastward from the Cincinnati Arch across the broad foreland shelf of deposition in the subsurface of eastern Kentucky, southern West Virginia, and adjacent parts of Virginia (Wilpolt and Marden, 1949). The same general rate of thickness increase persists eastward as far as the western side of the Hurricane Ridge syncline. The eastward increase in thickness continues regularly across the axis of the Abbs Valley anticline, and there is no relation between the thickness of a section and its structural position. The Mississippian limestones (Wilpolt and Marden, 1949) and Upper Mississippian clastic sequence thicken markedly into the Hurricane Ridge syncline; however, the thickness decreases abruptly up the overturned southeast flank of the structure. The rate of thickening on the southeast flank is approximately parallel to that on the northwest flank of the syncline; however, the rate of thickness change in the syncline is markedly greater than the general regional change to the west (Wilpolt and Marden, 1949). Sections in the structurally lowest part of the doubly plunging syncline are 30 to 300 per cent thicker than those on the adjacent flanks for parts of the Upper Mississippian sequence. The thickness changes across the Middlesboro syncline show a regular eastward increase at a rate which is similar to that in the subsurface west of the Hurricane Ridge syncline. The succession in the Middlesboro syncline is markedly different from that in the Hurricane Ridge syncline (Table 1); but it is distinctly similar to that in the subsurface west of the Hurricane Ridge syncline (Wilpolt and Marden, 1949).

From the general distribution of thicknesses it is clear that the Hurricane Ridge syncline received more sediment than other parts of the depositional area. The close relationship of thickness to structure in the Hurricane Ridge syncline (Pls. 22, 23, 24, 25) is in marked contrast to the other structures where the thickness of the Upper Mississippian increases regularly toward the east regardless of position in the individual structures. These relationships indicate that the Hurricane Ridge syncline was undergoing active downwarp during Chester and post-Elvira time and that the Abbs Valley anticline and the Middlesboro syncline were developed after deposition of the Mississippian. The similarity of the succession in the Middlesboro syncline to the shelf area west of the

PLATE 22.– ISOPACHOUS MAP OF BLUEFIELD FORMATION, SHOWING RELATION OF THICKNESS TO STRUCTURE

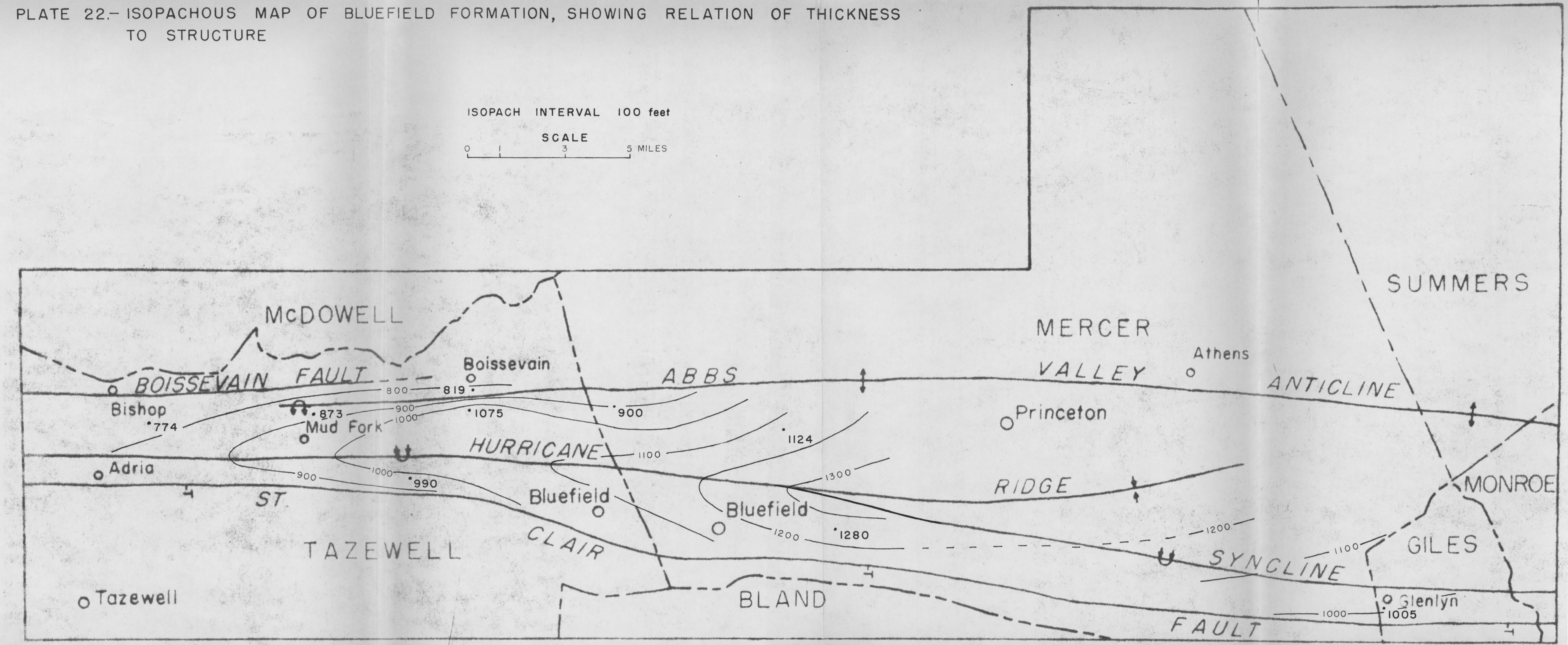


PLATE 23.—ISOPACHOUS MAP OF STONY GAP MEMBER, SHOWING RELATION OF THICKNESS TO STRUCTURE

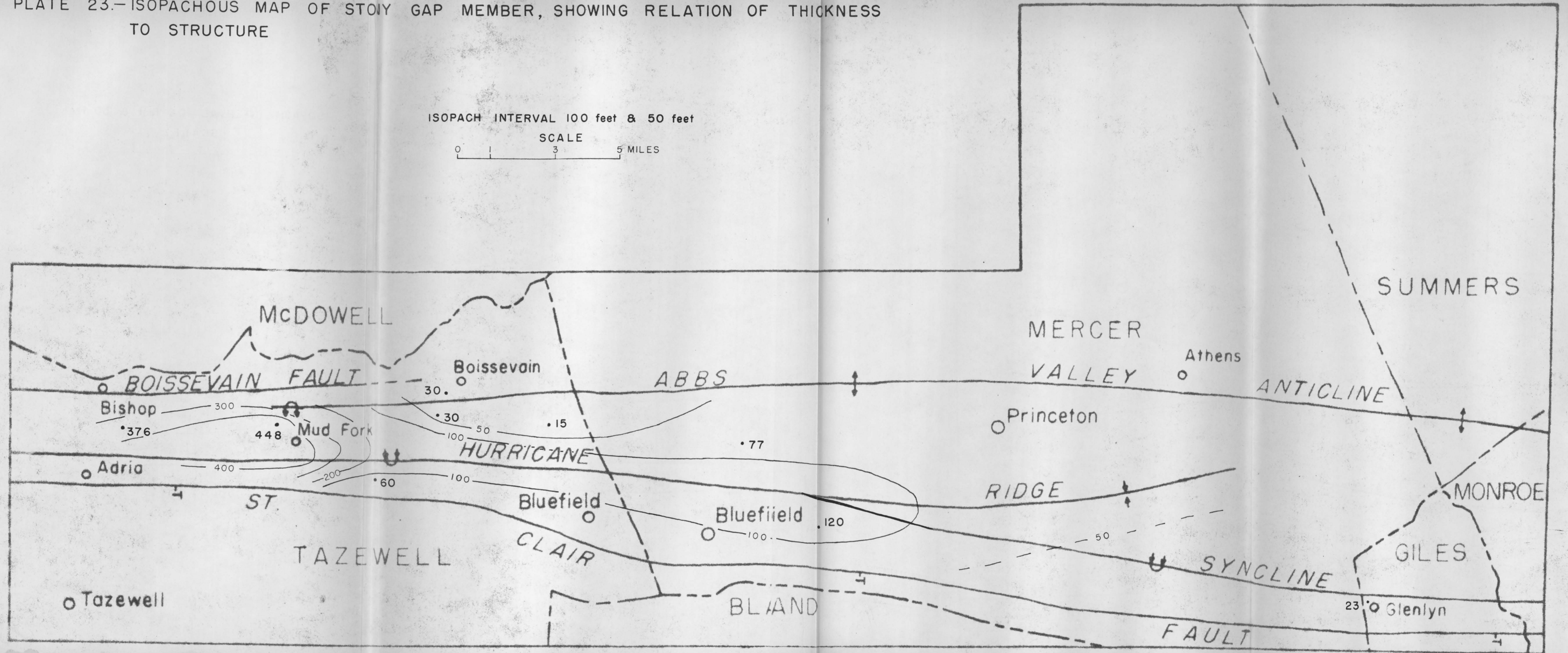


PLATE 24.—ISOPACHOUS MAP OF HINTON FORMATION, SHOWING RELATION OF THICKNESS TO STRUCTURE

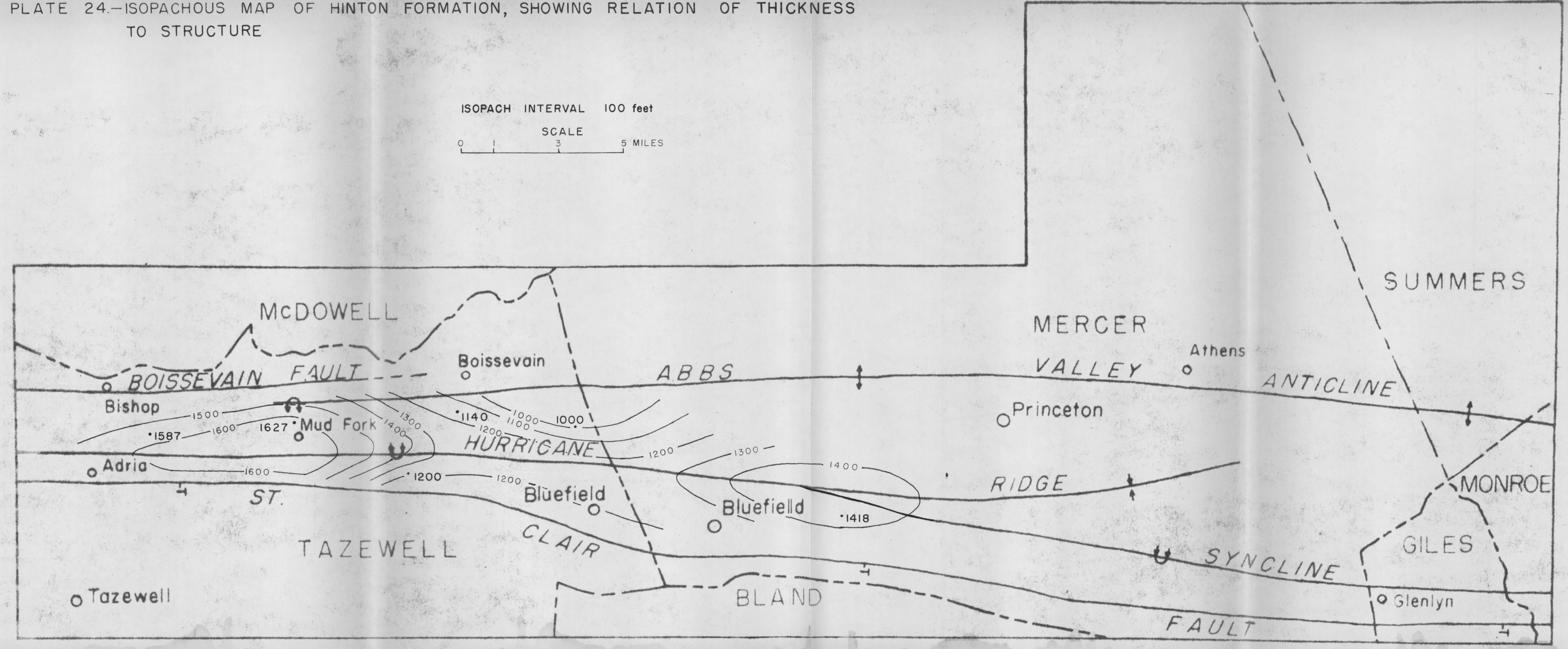
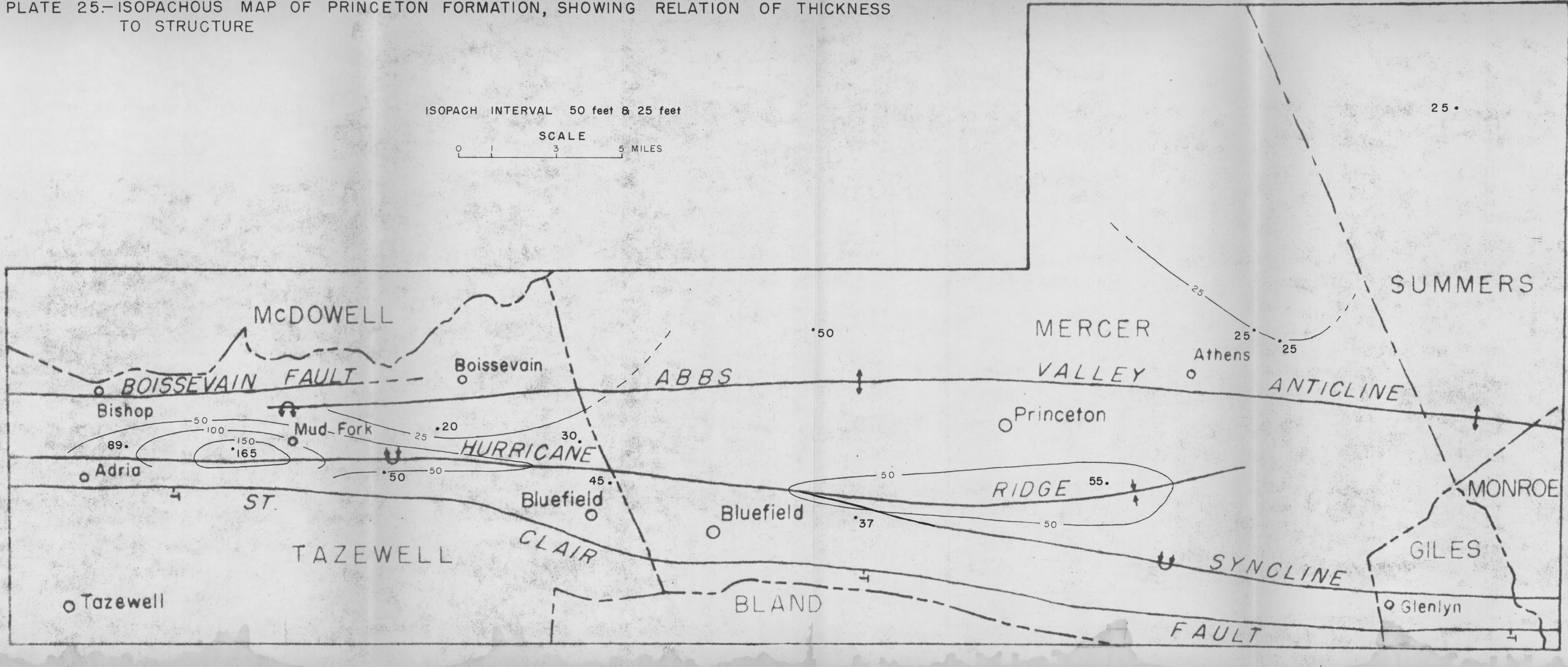


PLATE 25.- ISOPACHOUS MAP OF PRINCETON FORMATION, SHOWING RELATION OF THICKNESS TO STRUCTURE



Hurricane Ridge syncline indicates that the beds in the Middlesboro syncline were deposited on the foreland shelf. The Hurricane Ridge syncline served as a sediment trap during the Late Mississippian and a greater amount of material was tectonically induced to accumulate in that structure as a result of local, continuing differential downwarp which provided space for additional volume of sediments.

The isopachous maps of the Bluefield, Hinton, and Princeton formations and the Stony Gap sandstone member are patterned after those prepared by Wilpolt and Marden (1949); and the configuration of the isopach lines is partly based on information presented by Wilpolt and Marden (1949). The interpretation of thickness trends of the Bluefield formation is based partly on the thickness trends of the overlying units. Sparse thickness data on the Bluestone formation makes an isopachous map of this unit impractical.

Sedimentation and Source Areas

The red beds of the Mauch Chunk group extend from Pennsylvania along the western side of the folded Appalachians into southwestern Virginia; and by this continuity of distribution a common source for all of these red materials is suggested. This source was evidently not to the southwest of the Hurricane Ridge syncline because only a few thin interbeds of red mudstones are present in the succession southwest of the syncline. The red muds decrease in thickness toward the southwest away from the northeastern source area but thicken abruptly into the Hurricane Ridge syncline; however, they comprise an important part of the succession only as far southwest as Tazewell County, Virginia. Simultaneous with the accumulation of the red sediments washed into the Hurricane Ridge syncline area, local erosion of partly emergent western Appalachian anticlines was supplying a source of sand which was deposited in the basin along with the red muds. The Hurricane Ridge syncline must have been bordered on its southeastern side by a low, but rising, anticline whose crest lay southeast of the present trace of the St. Clair thrust. This anticline, whose northwest flank was the asymmetric southeast limb of the Hurricane Ridge syncline, has since been destroyed by thrusting of the St. Clair fault and subsequent erosion, as indicated by the fact that the present overthrust side of the fault is the southeast limb of an anticline. At the time of deposition of the Mississippian the present overturned southeast limb of the Hurricane Ridge syncline was shorter and possibly steeper than the northwest limb, but its dip was relatively low as indicated by the presence of Mississippian sediments.

Maroon muds carried from the northeast along the length of the Appalachian depositional trough were washed into areas of greater downwarp and accumulated there in greater thickness. Marine deposition of fossiliferous limestones and oolites preceeded deposition of the Bluefield. Two red mudstone interbeds, which represent elongate tongues of the Mauch Chunk, occur in the West Virginia sequence (Reger, 1926) and one of these extends into southwestern Virginia (Cooper, 1944, 1948; Wilpolt and Marden, 1949). Clay-sized clastic materials carried into the basin led to the formation of argillaceous limestones and calcareous mudstones which are common in the lower Bluefield; and later with a progressive supply of clays the marine calcareous sediments became more and more diluted higher in the Bluefield. In late Bluefield time tongues of Mauch Chunk red muds extended into the Hurricane Ridge syncline. At the end of Bluefield time sedimentation was dominated by the influx of red muds from the northeast, and sand was supplied from the southeast in significant quantities. Greatest accumulation of maroon muds was concentrated in the Hurricane Ridge syncline; and these materials disappear abruptly from sections to the southwest. Deposition of red muds continued throughout the remainder of the Mississippian as far southwest as the Hurricane Ridge syncline; and a few tongues of red mud extended into southwestern Virginia where they were deposited in a predominantly sandy sequence.

The color of the maroon muds was inherited from the source area which was probably in the vicinity of the thick succession of Mauch Chunk red beds in northeastern Pennsylvania. The red color is attributed to the oxidation state of the iron in the muds. The contact between maroon and overlying green muds is irregular and gradational; however, the contact between maroon and underlying green muds is regular and clearly defined. Thin pendants of green mud extend downward into underlying maroon muds (Pl. 6, fig. 2). Thin beds of black highly organic limestone, which rest on some of the green muds, must have been deposited in reducing environments. The red muds were washed into the Hurricane Ridge syncline and deposited in a reducing environment; however, before the red sediment was completely reduced it was buried by the rapid influx of additional sediment.

Deposition of sand in the Upper Mississippian occurred more or less simultaneously with the accumulation of the maroon muds. Most of the quartz sand was probably derived from a partly emergent anticline along the present trace of the St. Clair fault. Much of the erosion of materials from this structure was probably accomplished by wave action. Foreset bedding, groove casts, and ripple marks all indicate that the currents which transported these sands moved in a general northwestward direction.

The sand contains detrital grains of a fine-grained quartz-mica rock similar to those in the Lower Mississippian Price sandstone and there is a general resemblance to the Price composition. Erosion of the Mississippian Price sandstones may have provided much of the material for the Upper Mississippian sandstones. Possibly erosion of the Upper Devonian and even the Lower Silurian sandstones may have contributed materials to the Mississippian depositional basin. Most of the resistant minerals in the Upper Mississippian sandstones—tourmaline and zircon—occur in well rounded grains, which indicates erosion and redeposition of older sandstones. The rounding of these resistant minerals indicates reworking and shifting by current or wave action. Euhedral grains of tourmaline and zircon are less common than rounded grains.

The euhedral grains suggest a rapidly eroded and little reworked sandstone source or a primary source. The detrital grains of fine-grained quartz-mica rock could have been derived from the Lower Mississippian or Upper Devonian sandstones or from the primary source provided by the Blue Ridge metamorphic terrain. The sandstone source of these materials is favored because the Lower Mississippian and Upper Devonian sandstones were probably exposed at the margin of the sedimentary basin, and the Blue Ridge metamorphic terrain was separated from the depositional area by a number of fold belts across which the material would have necessarily been transported. However, the Blue Ridge probably served as the source of sedimentary rocks which supplied the Upper Mississippian sands.

The pebbles in the Princeton formation also suggest a source along the southeast side of the Hurricane Ridge syncline. The coarse sands and quartz pebbles in Mercer and Summers counties, West Virginia, were probably derived from the Lower Mississippian and Silurian sandstones and quartz-pebble conglomerates in the western fold belts of the Appalachians. The variety of pebbles in the Princeton in the area between Princeton and Bluefield was probably derived from erosion of exposed beds ranging from the Mississippian down to the Silurian along the eastern margin of the Hurricane Ridge syncline. The angularity of the pebbles, which are composed of soft sedimentary rocks, demands a nearby source.

A southeastern source is indicated by a general decrease in grain size of the sands toward the west. The Princeton is a coarse sand and conglomerate in the southeastern exposures but it is composed of fine-grained sand in the most westerly exposures. The Blackwood sandstone member is characterized by thick deposits of clean sands in the eastern part of the basin and by sands containing interlaminated clays toward the west.

The Stony Gap sandstone member at the base of the Hinton formation, except in the structurally lowest part of the Hurricane Ridge syncline, is composed of clean medium-grained quartz sand in a single unit about 60 feet thick on both flanks and across the trough in the shallow up-plunge part of the structure in West Virginia. In outcrops nearest the structurally lowest part of the syncline, the Stony Gap sandstone loses its identity as a persistent zone of orthoquartzite. Several thin sandstones occur through about 400 feet of section composed mainly of gray clay shales; this interval apparently represents the Stony Gap. The individual sandstones are less than 30 feet thick and four or more different sandstones are present. These are fine-grained sandstones containing flakes of mica and detrital grains of fine-grained quartz-mica rock. During deposition of the Stony

Gap washing by waves and marine currents carried the fine materials from the shallower parts into the deeper, axial portion of the developing structure.

The Princeton formation throughout most of the area is less than 50 feet thick and is composed of clean medium- to coarse-grained quartz sand containing rounded quartz pebbles. In the trough of the Hurricane Ridge syncline the Princeton is in excess of three or four times its average thickness on the flanks of the structure and in the up-plunge part of the syncline. The formation is composed of fine-grained sands and contains small amounts of limonite cement in some of the sections. Interbeds of dark-gray clay shale are common in the thick sections, and the thickness of the shale is proportionate to the total thickness of the formation. Washing of the fine materials from the shallower parts of the syncline into the deep part of the structure served to concentrate the fine materials in the structurally lowest part of the trough.

On U. S. Highway 460 south of Princeton, West Virginia, the Princeton formation in the trough of the Hurricane Ridge syncline is made up of a thick orthoquartzite bed; however, a series of sandstone lenses overlap the thick bed which comprises the Princeton elsewhere. These lenses pinch out up dip toward the northwest and thicken down dip by truncation of underlying beds of mudstone; however, they grade laterally to mudstones down dip toward the trough of the syncline. Sand was washed by currents moving down the northwest flank of the syncline, and as the currents lost velocity near the trough of the syncline basins were scoured into the soft muds and the sand was dumped into these basins. Eddying action of the current as the currents lost velocity mixed the sand and eroded mud producing the lateral gradation from sandstone to mudstone now recorded in the outcrop.

The Blackwood sandstone member of the Pennington formation is a relatively clean well sorted sandstone in the eastern exposures; however, on the west side of the outcrop on Pine Mountain the member contains interbeds of clay shale, and clay is interlaminated with some of the sand. The relatively well sorted sands and the widespread nature of most of these units indicate deposition by broad marine currents. Channels cut into fine-grained sand and clay are filled by medium-grained sand in the Blackwood sandstone member on Pine Mountain. The channels were probably scoured by currents transporting a heavy load of sand from the eastern side of the depositional area where the entire Blackwood is composed of medium- to coarse-grained sand.

The sandstone beds in the Adria member of the Hinton formation are characterized by remarkably smooth contacts, but groove casts are common on the under surfaces of most of the beds. The sweeping action of broad marine currents is indicated by the contacts of the sandstone beds and by the presence of the scour features.

The limestone members of the Upper Mississippian require a markedly different environment of deposition from that which characterized most of the Upper Mississippian. A slight increase in water depth may have been produced by a minor transgression of the sea or by decreased rate of sedimentation which failed to keep pace with downwarp. The minor importance of the source area along the eastern margin of the basin is reflected in the mudstones and claystones which represent the limestone member along the eastern margin of outcrop. There is a general westward decrease in clay in the limestone; and in the most westerly sections the limestone is essentially free of clay. Other local limestone units were probably deposited in areas which from time to time experienced a slackened rate of sedimentation.

The shore line along the southeastern side of the Hurricane Ridge syncline shifted alternately toward the trough and away from it, and locally organic clays were deposited in coastal swamps. Clayey coals are common throughout the succession; however, they are limited to sections high on the southeast flank of the Hurricane

Ridge syncline. Coaly beds are present only on the southeastern margin of Upper Mississippian exposures in Tazewell County, Virginia, and Mercer County, West Virginia. The coal swamps spread westward in latest Mississippian and the coaly beds in the uppermost Bluestone and Pennington formations extend for some distance to the west.

Coal swamps had spread over much of the area by the initiation of Pennsylvanian deposition. Variations in thickness of the Pennington formation in the Middlesboro syncline are most abrupt in the upper part which suggests that in the area of southwestern Virginia and eastern Kentucky at least some erosion of the Mississippian occurred before deposition of the Pennsylvanian. In the structurally lowest part of the Hurricane Ridge syncline there is an apparent gradation between the Bluestone and overlying Pennsylvanian rocks.

Locally on the southeast flank of the Hurricane Ridge syncline north of Bluefield, West Virginia, the Bluestone and the Pennsylvanian are separated by an angular unconformity which indicates that considerable folding of the syncline occurred before the Pennsylvanian was deposited. Pebbles of Mississippian limestone in the basal Pennsylvanian conglomerate indicate that erosion of Mississippian limestone on the southeast flank of the Hurricane Ridge syncline continued to be active during the earliest

Pennsylvanian.

Post-Lithification Adjustments

The rate of sedimentation was probably sufficient to keep the Hurricane Ridge syncline essentially filled at all times. However, because of continued downwarp of the axial portion of the structure and early lithification which led to relatively greater compaction in the thicker sections in the axial portion of the structure, the slope of the sediment-water interface was from time to time probably as much as four or five degrees. Dips in excess of two degrees are sufficient to generate soft-sediment slumping (Pettijohn, 1957). Presumably such dips would also cause early post-lithification settling, perhaps similar to the high angle faults in the Tertiary of the Gulf Coast geosyncline.

A number of small folds and a small fault occur along the northwest flank of the Hurricane Ridge syncline a short distance from the trough. The folds are oriented parallel to regional strike and have steepened dips toward the trough. The fault has its down thrown side on the southeast toward the deeper part of the basin. These structures indicate early settling and shifting toward the trough of the syncline initiated by downwarp of the structure and greater compaction of the thicker sections in the trough.

The mudstone-pebble conglomerates in the vicinity of Princeton, Mercer County, West Virginia, and Glenlyn, Giles County, Virginia, probably resulted from slumping. The typical maroon mudstones of the upper Hinton weather into characteristic small angular blocks, and it is likely that the blocky character of the mudstones was attained during lithification. With the partly lithified muds resting on a relatively steeply dipping (as much as 4 degrees) bottom the mass of mudstone became unstable. A high-density mudflow may have been initiated by a current or by simple gravity instability on the bottom. A mudflow composed of small blocks of partially lithified mud perhaps moved only a very short distance down the slope of the bottom toward the trough of the Hurricane Ridge syncline. Rounding of the pebbles could have been accomplished by the movement of the mudflow carrying only partly lithified muds; however, the lack of deformation of the pebbles indicates that they were at least partly lithified.

SUMMARY AND CONCLUSIONS

The Upper Mississippian clastic sequence in the Hurricane Ridge syncline area is distinct from that in the Middlesboro syncline. The Bluefield, Hinton, Princeton, and Bluestone formations are recognized in the former area; and the Bluefield and Pennington formations comprise the sequence in the latter. The Bluefield formation is essentially the same throughout the region; however, it may not have the same age range everywhere. The Stony Gap sandstone member at the base of the Hinton formation is approximately equivalent to the Blackwood member at the base of the Pennington formation. The Avis member of the Hinton is correlated with the Pound Gap member of the Pennington. The sandstones of the Abbs Valley Ridge member of the Hinton, the Princeton, and the lower part of the Bluestone are similar to those of the upper Pennington; and these two sequences are probably equivalent. However, the upper part of the Bluestone is probably not represented in the Pennington formation. The contact between the Pennington and overlying Pennsylvanian strata is an erosional unconformity. The Bluestone is overlain by a coal bed of questionable Pennsylvanian age in the structurally lowest part of the Hurricane Ridge syncline, and there is apparently no appreciable break in the sequence. An angular unconformity separates the Bluestone formation from Pennsylvanian sandstones on the southeast flank of the Hurricane Ridge syncline in the vicinity of Bluefield, West Virginia; however, in the adjacent trough of the structure the beds are conformable, which indicates that the local unconformity has little time significance.

The top of the Mississippian limestone division in the western Appalachians is correlated with the top of the New Design group of the standard section. The fauna of the Bluefield formation brackets its age as Homberg group. Fossiliferous beds in the Pennington and Hinton formations indicate correlation with the Elvira group. The uppermost Pennington and the Bluestone formation are younger than the top of the standard section of the Mississippian. It is difficult to correlate the complete and much thicker Appalachian sequences with the standard section of the Mississippian; however, the positions of the thinner units in the type area could better be determined in the Appalachian sequences. The thick complete sequence in the Appalachians would have perhaps been the best choice for the standard section of the Mississippian; and, subsequent to detailed paleontological study, this succession would be the most valuable Mississippian reference section in the eastern United States.

The Hurricane Ridge syncline was undergoing active downwarp at the time of deposition of the Upper Mississippian. Sections in the structurally lowest part of the syncline are markedly thicker than those of the adjacent flanks of the structure. The general eastward thickening from the Cincinnati Arch continues regularly across the Middlesboro syncline and Abbs Valley anticline but increases abruptly into the Hurricane Ridge syncline. The source of the maroon mudstones, which comprise most of the section in the Hurricane Ridge syncline, was apparently in Pennsylvania in the vicinity of the thick development of the Mauch Chunk red beds. These red sediments were washed into the sinking Hurricane Ridge syncline, and greater amounts of sediment accumulated there because more space was provided as a consequence of continuing downwarp. The sandstones and conglomerates of the Upper Mississippian were probably derived from beds ranging from Mississippian down to Silurian age along the southeast side of the Hurricane Ridge syncline. These materials must have been relatively elevated on an anticline southeast of the present St. Clair fault. Orthoquartzite marker beds, which are persistent on the flanks of the syncline, lose their identity down dip in the structurally lowest part. The orthoquartzites grade to a much thicker clay shale and fine-grained sandstone sequence in the deeper trough portion of the structure. These relationships indicate washing of fine materials from the shallower parts of the syncline into the structurally lowest part. A number of adjustment structures formed soon after partial lithification as a result of down-sinking of the trough and relatively greater compaction in the thicker sections in the axial portion of the syncline. These small structures, which have dips steepened toward the axis of the regional structure, indicate settling and shifting of partially lithified sediments toward the trough of the structure.

MEASURED SECTIONS

Geologic Section 13.—Pennington and Bluefield formations on northwest side of Pine Mountain at Hurricane Gap, State Highway 160, Letcher County, Kentucky.

	Thickness (Feet)
Lee formation (Pennsylvanian)	
22. Orthoquartzite, yellowish-brown, medium grained, rounded pebbles of quartz as much as 0.5 inch in diameter; thick bedded	
Pennington formation (775 feet)	
Upper Pennington (249 feet)	
21. Covered	14
20. Claystone, gray, thin bedded	15
19. Claystone, yellowish-brown, thin bedded . .	60
18. Mudstone, olive-drab and maroon-drab, blocky to fissile; few thin interbeds of maroon-drab, very fine-grained sandstone in lower 10 feet	70
17. Sandstone, yellowish-brown, very fine grained, semi-friable; in even beds as much as 2 feet thick, thin shaly partings	8
16. Mudstone, maroon-drab mottled with olive-drab, blocky; thin interbeds	

of brown, very fine-grained sandstone . . . 36

15. Mudstone, olive-drab, blocky; interbeds of gray, very fine-grained sandstone as much as 2 feet thick; unit is about equally divided between mudstone and sandstone 24

14. Orthoquartzite, light-gray, fine grained; in even beds as much as 2 feet thick; current ripple marks 22

Pound Gap member (31 feet)

13. Mudstone, dark blue-gray, calcareous, blocky to fissile; lenses of blue-gray medium-grained limestone as much as 1 inch thick and 1 foot wide 31

Middle Pennington (291 feet)

12. Clay shale, light-gray to dark-gray, soft, fissile 105

11. Sandstone, greenish-gray, fine grained; single bed 6

10. Covered 180

Blackwood sandstone member (204 feet)

9. Orthoquartzite, light-gray, fine grained; in slightly uneven beds 1 inch to 1 foot thick 68

8. Sandstone, light-gray, very fine

grained; very finely laminated with dark-gray clay; thin shaly beds; small lenses of sandstone as much as 0.25 inch with interlaminated clay; interbeds of light-gray fine-grained sandstone as much as 3 feet thick 22

7. Orthoquartzite, light-gray, medium grained; in even beds as much as 3 feet thick 18

6. Sandstone, grayish-brown, very fine grained; very finely laminated with dark-gray clay; thin shaly beds; lenses of sandstone as much as 0.25 inch thick with interlaminated clay . . . 12

5. Orthoquartzite, yellow-brown, medium grained; in even beds 6 inches to 4 feet thick; rounded pebbles of dark-gray claystone in upper 1 foot 20

4. Mudstone, dark-gray, blocky to fissile 20

3. Sandstone, gray, very fine grained; very finely laminated with dark-gray clay; thin shaly beds; small lenses of sandstone as much as 0.25 inch thick with interlaminated clay;

interbeds of grayish-brown fine-grained sandstone as much as 10 feet thick; sandstone makes up about 75 per cent of the unit 44

Bluefield formation (183 feet)

2. Mudstone, yellowish-brown, blocky to fissile 3

1. Covered 180

Gasper limestone

Geologic Section 14.—Pennington and Bluefield formations on northwest side of Pine Mountain along U. S. Highway 119, 5 miles south of Whitesburg, Letcher County, Kentucky.

	Thickness (Feet)
Lee formation (Pennsylvanian)	
30. Orthoquartzite, light-gray to yellowish-brown, medium to coarse grained, rounded pebbles of quartz as much as 1.5 inches in diameter; thick bedded	
Pennington formation (687 feet)	
Upper Pennington (353 feet)	
29. Claystone, light-gray mottled with olive-drab; thin bedded	29
28. Sandstone, light-brown, very fine grained; in uneven beds less than 1 inch thick	3
27. Mudstone, maroon-drab mottled with olive-drab, blocky to fissile	29
26. Orthoquartzite, grayish-brown, medium grained, micaceous; massive, essentially unbedded	43
25. Orthoquartzite, white mottled with yellow and red, medium grained,	

friable; thick bedded	23
24. Clay shale, dark-gray to black, fissile	5
23. Covered; chips of gray clay shale in soil	31
22. Sandstone, grayish-brown, very fine grained; very finely interlaminated with gray clay; thin shaly beds	7
21. Claystone, light-gray to medium-gray, laminated; in even beds as much as 2 inches thick	172
20. Sandstone, grayish-brown, fine grained; single bed	5
19. Sandstone, dark-brown, fine grained, limonite coating on individual quartz grains; single bed; lower 3 feet weathers pitted, probably because of leaching of limestone pebbles; impressions of fenestrate bryozoans, crinoid columnals, and fragments of brachiopod shells in lower 3 feet; boulder of brown mudstone 1 foot by 3 inches in lower part	6

Pound Gap member (not present)

Middle Pennington (139 feet)

18. Mudstone, maroon-drab mottled with olive-drab, blocky to fissile; thin interbeds of maroon, very fine-grained sandstone in lower 10 feet	38
17. Sandstone, grayish-brown, fine grained; two even beds	2
16. Mudstone, maroon-drab mottled with olive-drab, few thin layers of dark-gray mudstone, blocky to fissile; few thin interbeds of maroon, very fine-grained sandstone in upper 10 feet	99
Blackwood sandstone member (195 feet)	
15. Orthoquartzite, light-gray to white, fine grained; in even beds 1 foot to 6 feet thick	74
14. Mudstone, gray, blocky	4
13. Sandstone, light-gray, very fine grained; thin bedded	4
12. Mudstone, maroon-drab with layers of dark-gray, blocky; shaly coal layer at top, 3 inches thick	7
11. Sandstone, light-gray, fine grained; 2 uneven beds, each 2 feet thick; parting of maroon-drab mudstone 2 feet thick	6

10. Mudstone, maroon-drab with layers of dark-gray, blocky	10
9. Sandstone, white, very fine grained; very thin wavy laminae of dark-gray clay and carbonaceous material; single bed	1
8. Clay shale, dark-gray, carbonaceous, fissile; lenses of light-gray, very fine-grained sandstone as much as 0.25 inch thick	35
7. Orthoquartzite, white, fine grained; thick bedded	34
6. Sandstone, white, fine grained; very finely laminated with dark-gray clay; interbeds of dark-gray clay shale; sandstone makes up about 50 per cent of unit	5
5. Orthoquartzite, light-gray, fine grained; thick bedded	15
Bluefield formation (195 feet)	
4. Claystone, blue-gray, thin bedded	40
3. Covered	102
2. Claystone, light-gray to olive-drab, thin bedded	21
1. Covered	32
Gasper limestone	

Geologic Section 15.—Pennington and Bluefield formations on northwest side of Pine Mountain at Pound Gap, U. S. Highway 23, Letcher County, Kentucky.

	Thickness (Feet)
Pennington formation (Geologic Section 11)	
Bluefield formation (276 feet)	
4. Mudstone, dark-gray, blocky	3
3. Clay shale, gray-brown with few layers of maroon-drab, fissile	91
2. Clay shale, gray to dark-gray, finely fissile	20
1. Covered; few scattered beds of blue-gray fine-grained limestone in lower 20 feet; fossils weathered out in soil, <u>Cleiothyridina sublamellosa</u>, <u>Spirifer increbescens</u>, <u>Composita subquadrata</u>, <u>Amplexizaphrentis spinulosum</u>	162
Gasper limestone	

Geologic Section 16.—Pennington and Bluefield formations along Louisville and Nashville Railroad at Pennington Gap in Stone Mountain, Lee County, Virginia.

	Thickness (Feet)
Lee formation (Pennsylvanian)	
21. Orthoquartzite, light-gray to brown, medium grained; thick bedded	
Pennington formation (893 feet)	
Upper Pennington (418 feet)	
20. Clay shale, gray, fissile; interbeds of gray fine-grained sandstone as much as 1 foot thick; unit is about 60 per cent clay shale	26
19. Sandstone, olive-drab, fine grained; in beds as much as 6 feet thick, thin units of thin-bedded sandstone	39
18. Covered	232
17. Orthoquartzite, light yellowish-gray, medium grained; in even beds 1 foot to 4 feet thick	97
16. Covered	15
15. Mudstone, olive-drab, blocky	9
Pound Gap member (13 feet)	

14. Limestone, blue-gray, fine grained, argillaceous; thin shaly beds	13
Middle Pennington (163 feet)	
13. Covered	25
12. Sandstone, light-gray, fine grained; in uneven beds less than 4 inches thick	83
11. Mudstone, yellowish-brown, blocky to fissile	55
Blackwood sandstone member (299 feet)	
10. Orthoquartzite, yellowish-gray, fine grained; thick bedded	10
9. Sandstone, light-gray, very fine grained; very finely laminated with dark-gray clay; uneven beds of sandstone as much as 0.25 inch thick; interbeds of yellowish-gray fine-grained sandstone as much as 3 inches thick	26
8. Orthoquartzite, light yellowish-gray, fine grained; in even beds as much as 3 feet thick	23
7. Sandstone, light-gray, very fine grained; very finely laminated with dark-gray clay; uneven beds of	

sandstone as much as 0.25 inch thick; interbeds of yellowish-gray fine-grained sandstone as much as 3 inches thick	26
6. Orthoquartzite, light yellowish-brown, fine grained; in even beds 2 inches to 2 feet thick	22
5. Clay shale, light-gray to dark-gray, fissile; interbeds of light-gray, very fine-grained sandstone as much as 0.5 inch thick in upper 5 feet	46
4. Sandstone, light yellowish-gray, medium grained; upper 20 feet in beds less than 3 inches thick with thin partings of clay shale; lower part in even beds as much as 3 feet thick	86
3. Clay shale, light-gray to dark-gray, fissile	17
2. Sandstone, light grayish-brown, fine grained; in uneven beds less than 6 inches thick	43
Bluefield formation (106+ feet)	
1. Clay shale, light-gray to dark-gray, fissile	106

End of exposure.

Geologic Section 17.—Pennington and Bluefield formations in Big Stone Gap where Powell River cuts through Stone Mountain, along Southern Railroad, Wise County, Virginia.

	Thickness (Feet)
Lee formation (Pennsylvanian)	
20. Orthoquartzite, yellowish-brown, medium to coarse grained, rounded pebbles of quartz as much as 0.5 inch in diameter; thick bedded	
Pennington formation (1054 feet)	
Upper Pennington (651 feet)	
19. Mudstone, gray to greenish-gray, blocky; interbeds of greenish-gray fine-grained sandstone; mudstone in zones as much as 6 feet thick and interbeds of sandstone as much as 2 feet thick; unit is about 75 per cent mudstone	32
18. Mudstone, maroon-drab, blocky; single thin interbed of maroon siltstone at base	12
17. Sandstone, brownish-gray, fine grained, with chips of greenish-gray	

claystone; single bed 2

16. Mudstone, maroon-drab mottled with olive-drab, blocky 10

15. Sandstone, light greenish-gray, fine grained; thick bedded 18

14. Covered 524

13. Orthoquartzite, brownish-gray, medium grained, scattered pebbles of quartz as much as 0.75 inch in diameter; lenses of quartz-pebble conglomerate as much as 6 inches thick; in beds as much as 4 feet thick, lenses and discontinuous uneven beds 44

12. Covered 19

Pound Gap member (44 feet)

11. Mudstone, blue-gray, calcareous, blocky to fissile; few thin interbeds of blue-gray fine-grained argillaceous limestone 10

10. Limestone, blue-gray, fine grained, argillaceous; shaly; <u>Amplexizaphrentis spinulosum</u>, <u>Composita subquadrata</u>, <u>Stenocisma explanata</u> 23

9. Limestone, blue-gray, fine grained, argillaceous; in uneven beds as much

as 3 inches thick; interbeds of blue-gray calcareous mudstone as much as 6 inches thick; unit is about 60 per cent mudstone; Diaphragmus elegans, Dictyoclostus inflatus, Orthotetes kaskaskiensis, Amplexizaphrentis spinulosum 11

Middle Pennington (155 feet)

8. Sandstone, light gray-brown, fine grained; in even beds 2 inches to 2 feet thick 10

7. Conglomerate, gray to blue-gray; rounded pebbles of blue-gray medium-grained limestone and gray-brown fine-grained limestone; matrix of clastic limestone; single bed, contacts slightly uneven 2

6. Mudstone, maroon-drab with layers of greenish-gray, blocky to fissile 16

5. Sandstone, gray-brown, fine grained; in even beds 3 inches to 4 feet thick 31

4. Covered 96

Blackwood sandstone member (204 feet)

3. Orthoquartzite, brownish-gray, medium

grained; in uneven beds as much as 6 feet thick 30

2. Covered 36

1. Orthoquartzite, light-gray to white, medium grained; in uneven beds as much as 2 feet thick 138

Bluefield formation (Geologic Section 2)

Gasper limestone

Geologic Section 18.—Pennington and Bluefield formations at Little Stone Gap in Little Stone Mountain along State Road 610, Wise County, Virginia.

	Thickness (Feet)
Lee formation (Pennsylvanian)	
Pennington formation (Geologic Section 10)	
Bluefield formation (569 feet)	
15. Claystone, yellowish-brown; thin bedded	68
14. Covered	50
13. Claystone, light-gray to dark-gray; thin bedded, laminated	88
12. Claystone, yellowish-brown, sandy; thin bedded	6
11. Claystone, gray, soft; thin bedded, laminated	24
10. Sandstone, light-brown, fine grained; single bed	6
9. Claystone, gray and yellowish-brown, soft; thin bedded, laminated	23
8. Covered	94
7. Claystone, light-gray and yellowish-brown, soft; thin bedded, laminated	15
6. Claystone, olive-drab to light-gray;	

thin bedded; abundant fossils in upper 10 feet, Dictyoclostus inflatus, Linoproductus ovatus, Spirifer increbescens, Punctospirifer sp., Allorisma sp., Straparolus sp., Polypora sp., Fenestrellina sp., Griffithides sp.	31
5. Claystone, gray to yellowish-brown, soft; thin bedded	26
4. Clay shale, gray, fissile	31
3. Covered	78
2. Claystone, olive-drab to yellowish-brown; thin bedded	23
1. Limestone, gray-brown, fine grained, argillaceous; shaly	6

Gasper limestone

Geologic Section 19.—Princeton, Hinton, and Bluefield formations on northwest side of Stony Ridge along State Highway 16, Tazewell County, Virginia.

	Thickness (Feet)
Princeton formation (Geologic Section 7)	
Hinton formation (Geologic Section 3)	
Bluefield formation (774 feet)	
23. Clay shale, dark-gray, fissile	40
22. Mudstone, blue-gray, highly calcareous; fissile to thin bedded; thin interbeds of blue-gray fine-grained limestone; unit is about 80 per cent shale	33
21. Mudstone, maroon-drab, fissile to blocky	12
20. Clay shale, yellowish-brown, fissile . . .	3
19. Covered	62
18. Limestone, blue-gray, fine grained, argillaceous; interbeds of blue-gray calcareous mudstone; in uneven beds less than 3 inches thick; unit is about 60 per cent limestone	23
17. Limestone, gray-brown, fine grained; single bed	3

16. Clay shale, dark-gray to gray-brown, fissile; interbeds of gray fine-grained sandstone, 2 inches to 2 feet thick; unit is about 95 per cent clay shale	108
15. Covered	16
14. Claystone, light-gray, fissile to thin bedded	81
13. Sandstone, light-gray, fine grained, friable; single bed	3
12. Claystone, gray; thin bedded; carbonaceous claystone, 6 inches thick, 10 feet above base	24
11. Covered	14
10. Limestone, blue-gray, fine grained, argillaceous; thin shaly beds; Diaphragmus elegans, Spirifer leidyi, Orthotetes kaskaskiensis, Chonetes chesterensis, Pterotocrinus spatulatus	23
9. Covered	14
8. Limestone, blue-gray, fine grained with scattered medium crystals of calcite; single bed	6
7. Mudstone, gray-brown, calcareous;	

thin shaly beds	21
6. Limestone, dark blue-gray, medium grained, crinoidal; in even beds 1 foot to 2 feet thick	25
5. Mudstone, dark-gray to blue-gray, calcareous; thin shaly beds; few small lenses of blue-gray medium-grained limestone in lower 10 feet	73
4. Clay shale, gray, fissile	30
3. Limestone, gray-brown, fine grained, argillaceous; upper half in thin shaly beds, lower part in beds as much as 2 feet thick	80
2. Limestone, blue-gray, medium to coarse grained; single bed; <u>Dictyoclostus</u> <u>inflatus</u>, <u>Diaphragmus</u> <u>elegans</u>, <u>Spirifer</u> <u>increbescens</u>, <u>Brachythyris</u> <u>chesterensis</u>, <u>Amplexizaphrentis</u> <u>spinulosum</u>, <u>Griffithides</u> sp.	4
1. Mudstone, blue-gray, calcareous; thin shaly beds; <u>Archimedes</u> sp. (whole specimens with frond attached)	76

Greenbrier limestone

Geologic Section 20.—Princeton, Hinton, and Bluefield formations on Abbs Valley Ridge along State Road 655 between Mud Fork and Abbs Valley, Tazewell County, Virginia.

	Thickness (Feet)
Princeton formation	
91. Orthoquartzite, white to light-brown, medium grained; thick bedded	
Hinton formation (1627 feet)	
Abbs Valley Ridge member (354 feet)	
90. Covered	78
89. Clay shale, black, fissile	16
88. Covered	4
87. Claystone, rust-brown; thin bedded; limonitic staining	29
86. Sandstone, brown, fine grained; in uneven beds less than 2 inches thick . . .	13
85. Clay shale, black at top grades downward to maroon at base, fissile . . .	7
84. Sandstone, gray-brown, fine grained; single bed	1
83. Mudstone, maroon-drab, blocky	5
82. Sandstone, gray-brown, fine grained; in uneven beds less than 2 inches	

thick	3
81. Mudstone, dark-gray to black, blocky	4
80. Mudstone, maroon-drab mottled with greenish-gray in upper 4 feet, blocky	13
79. Covered	22
78. Orthoquartzite, light-brown, medium grained; in even beds 2 inches to 1 foot thick; uniform foreset bedding inclined to southeast, faint rill marks on top surfaces of foreset beds	43
77. Covered	26
76. Mudstone, maroon-drab, blocky	3
75. Sandstone, brownish-gray, fine grained; in even beds less than 6 inches thick	3
74. Covered	84
Avis member (18 feet)	
73. Limestone, blue-gray, fine grained, argillaceous; shaly; Composita subquadrata	18
Adria member (807 feet)	
72. Covered	74

71. Mudstone, maroon-drab and greenish-gray, blocky to fissile	19
70. Mudstone, maroon-drab, blocky to fissile	69
69. Sandstone, maroon, very fine grained; in even beds less than 2 inches thick, thin partings of maroon mudstone; unit is about 75 per cent sandstone	11
68. Mudstone, maroon-drab, blocky to fissile; interbeds of maroon very fine-grained sandstone; unit is about 90 per cent mudstone	18
67. Mudstone, maroon-drab, blocky; calcareous nodules and lenses as much as 2 inches thick in upper 2 feet; greenish-gray mudstone in thin layers associated with calcareous nodules	9
66. Sandstone, maroon, very fine grained; thin shaly beds	23
65. Mudstone, gray, highly calcareous, blocky	4
64. Mudstone, maroon-drab mottled with greenish-gray, blocky	15

63. Covered	43
62. Sandstone, maroon, very fine grained; thin uneven beds; partings of maroon mudstone; unit is about 60 per cent sandstone	16
61. Mudstone, maroon-drab, blocky	64
60. Claystone, light yellowish-gray; thin bedded, laminated	19
59. Sandstone, gray, fine grained; in uneven beds as much as 2 feet thick . . .	11
58. Clay shale, dark-gray, fissile	61
57. Sandstone, dark-brown, medium grained, friable, chips of gray claystone as much as 0.25 inch across; in uneven beds up to 4 feet thick	26
56. Claystone, gray-brown, thin bedded to fissile	5
55. Covered	19
54. Clay shale, dark-gray, fissile	27
53. Covered	79
52. Claystone, light-gray, laminated	29
51. Mudstone, maroon-drab, silty, blocky	3
50. Mudstone, maroon-drab, blocky; thin	

interbeds of gray fine-grained limestone in lower 4 feet	9
49. Mudstone, maroon-drab, blocky; interbeds of brown fine-grained sandstone in lower half	5
48. Covered	38
47. Claystone, gray-brown, sandy; thin bedded; thin interbeds of brown fine-grained sandstone; unit is about 75 per cent claystone	23
46. Sandstone, gray-brown, fine grained; thin shaly beds	5
45. Mudstone, maroon-drab, blocky to fissile	6
44. Sandstone, brown to maroon, very fine grained; in even beds less than 2 inches thick	7
43. Claystone, light-gray; black carbonaceous claystone, 6 inches thick, 9 feet above base	44
42. Sandstone, light-brown, very fine grained; thin shaly beds	6
41. Covered	20
Stony Gap sandstone member (448 feet)	
40. Sandstone, brown, fine grained; in	

even beds as much as 2 feet thick	9
39. Mudstone, dark-gray at top grades downward to maroon-drab at base, blocky	10
38. Sandstone, gray-brown, fine grained; in uneven beds less than 4 inches thick; interbedded brown sandy clay shale; unit is about equally divided between sandstone and clay shale	24
37. Mudstone, maroon-drab, blocky to fissile	6
36. Siltstone, yellowish-brown; thin shaly beds	8
35. Covered	3
34. Mudstone, dark-gray, blocky	16
33. Covered	30
32. Orthoquartzite, gray-brown, medium grained; in even beds as much as 4 inches thick	18
31. Claystone, light-gray, sandy; thin bedded	17
30. Orthoquartzite, white, medium grained; single bed	4
29. Sandstone, gray-brown, medium grained; in uneven beds less than	

3 inches thick	13
28. Clay shale, black, fissile; lenses of yellow-brown medium-grained sandstone as much as 2 inches thick; unit is about 75 per cent clay shale . . .	9
27. Covered	73
26. Mudstone, maroon-drab mottled with greenish-gray, blocky	7
25. Orthoquartzite, yellowish-brown, medium grained; single bed	3
24. Mudstone, light greenish-gray, blocky to fissile	4
23. Clay shale, yellow-brown, sandy, fissile	66
22. Limestone, dark blue-gray, fine grained, argillaceous; shaly	27
21. Claystone, yellowish-brown	5
20. Covered	34
19. Claystone, white	5
18. Orthoquartzite, white, medium grained; in even beds as much as 2 feet thick . . .	7
17. Orthoquartzite, gray-brown, medium grained; in even beds as much as 6 inches thick, single bed 2 feet thick in middle; thin partings of gray clay . . .	25

16. Orthoquartzite, gray-brown, fine to medium grained; in uneven beds 4 inches to 1.5 feet thick 8

15. Orthoquartzite, gray-brown, medium grained; in uneven beds less than 2 inches thick; interbeds of gray clay shale; unit is about 75 per cent orthoquartzite 6

14. Clay shale, black, fissile; interbeds of brown medium-grained sandstone, in uneven beds and discontinuous lenses as much as 2 inches thick; unit is about 60 per cent clay shale 11

Bluefield formation (873 feet)

13. Clay shale, dark-gray at top grades to light-gray at base, fissile 178

12. Limestone, blue-gray, fine grained, argillaceous; shaly 17

11. Mudstone, buff, blocky to fissile 32

10. Limestone, dark blue-gray, fine grained, argillaceous; in uneven beds as much as 6 inches thick 2

9. Covered 5

8. Mudstone, maroon-drab, blocky to fissile 12

7. Limestone, dark-gray, fine grained; two beds	3
6. Mudstone, maroon-drab at top grades downward to greenish-gray in lower 4 feet, blocky to fissile	21
5. Limestone, blue-gray, fine grained, argillaceous; shaly; lenses of blue-gray fine-grained limestone as much as 2 inches thick; unit is about 85 per cent argillaceous limestone	23
4. Clay shale, yellow-brown to olive-drab, fissile	190
3. Limestone, blue-gray, fine grained, argillaceous; thin shaly beds	44
2. Claystone, yellow-brown; thin bedded	46
1. Covered	300

Greenbrier limestone

Geologic Section 21.—Hinton and Bluefield formations between Boissevain and Abbs Valley along State Road 644, Tazewell County, Virginia.

	Thickness (Feet)
Hinton formation (639+ feet)	
Adria member (609+ feet)	
54. Siltstone, yellow-brown; thin shaly beds	13
53. Claystone, light-gray; thin bedded	51
52. Mudstone, maroon-drab, blocky	23
51. Clay shale, greenish-gray, fissile	73
50. Sandstone, greenish-gray, medium grained; in even beds as much as 1 foot thick	11
49. Covered	75
48. Sandstone, light-brown, medium grained; in even beds as much as 3 feet thick	17
47. Mudstone, maroon-drab mottled with greenish-gray; blocky	26
46. Sandstone, maroon, very fine grained; thin shaly beds	6
45. Covered	11
44. Sandstone, white, fine grained; in	

even beds as much as 3 feet thick; simple foreset bedding inclined toward northwest	18
43. Covered	21
42. Sandstone, salmon to white, fine grained; in uneven beds less than 6 inches thick	14
41. Mudstone, maroon-drab with thin beds of greenish-gray, blocky	35
40. Siltstone, maroon; thin shaly beds	9
39. Claystone, light-gray; thin bedded	21
38. Sandstone, maroon, very fine grained, micaceous; upper half in thin shaly beds, lower half in even beds as much as 2 feet thick	21
37. Mudstone, maroon-drab mottled with greenish-gray in lower 10 feet, blocky to fissile	53
36. Clay shale, bright-olive, fissile; interbeds of brown fine-grained sandstone as much as 4 inches thick, in upper 2 feet	23
35. Mudstone, maroon-drab mottled with greenish-gray, blocky	18
34. Sandstone, yellow-brown, fine grained,	

micaceous; thin shaly beds 4

33. Clay shale, dark-gray, fissile; interbeds of gray fine-grained sandstone in beds as much as 3 inches thick, in upper 10 feet and lower 10 feet 66

Stony Gap sandstone member (30 feet)

32. Orthoquartzite, white, medium grained; in uneven beds less than 4 inches thick at top grade downward to even beds as much as 2 feet thick at base 19

31. Sandstone, white to light-brown, medium grained; thin shaly beds; interbeds of gray clay shale; unit is about 75 per cent sandstone 11

Bluefield formation (819 feet)

30. Clay shale, light-gray to dark-gray, finely fissile 53

29. Mudstone, maroon-drab, blocky 1

28. Clay shale, light-gray to dark-gray, finely fissile 4

27. Sandstone, maroon, fine grained, micaceous; thin shaly beds 2

26. Clay shale, dark-gray, fissile 26

25.	Claystone, yellow-brown; thin bedded . . .	4
24.	Limestone, gray-brown, fine grained, argillaceous; shaly	1
23.	Clay shale, dark-gray, fissile	22
22.	Claystone, yellow-brown, soft	19
21.	Claystone, gray, carbonaceous, small fragments of plant fossils	8
20.	Coal, black, soft, clayey	1
19.	Claystone, dark-gray, small fragments of plant fossils in upper 2 feet	13
18.	Covered	12
17.	Sandstone, light-gray to white, fine grained; in slightly uneven beds as much as 3 feet thick, thin shaly beds in middle part	14
16.	Claystone, medium-gray, thin bedded; few thin interbeds of light-gray fine-grained sandstone; unit is about 90 per cent claystone	21
15.	Covered	48
14.	Clay shale, dark-gray, fissile	9
13.	Claystone, yellowish-gray, soft	6
12.	Clay shale, olive-drab, fissile	81
11.	Clay shale, dark-gray, fissile; interbeds of light-brown fine-grained	

sandstone less than 2 inches thick, in upper half; unit is about 90 per cent clay shale	80
10. Covered	18
9. Limestone, dark-gray, fine grained, argillaceous; thin shaly beds	2
8. Covered	52
7. Limestone, dark-gray, fine grained, argillaceous; thin shaly beds	25
6. Covered	110
5. Limestone, dark-gray to blue-gray, medium to coarse grained, crinoidal; in even beds as much as 2 feet thick; few nodules of black chert as much as 3 inches in length and 1 inch thick; Diaphragmus elegans, Brachythyris chesterensis, Cleiothyridina sublamellosa, Schizophoria sp., Pentremites brevis, Archimedes meekanus	45
4. Covered	45
3. Limestone, blue-gray, fine grained, argillaceous; thin shaly beds	15
2. Covered	71
1. Limestone, blue-gray, fine grained,	

argillaceous; thin shaly beds 11

Greenbrier limestone

Geologic Section 22.—Composite section of Princeton, Hinton, and Bluefield formations at Stony Gap along State Highway 25 and U. S. Highway 19-21-460, 2 miles northeast of Bluefield, Mercer County, West Virginia.

	Thickness (Feet)
Princeton formation (37 feet)	
61. Orthoquartzite, yellowish-brown, medium to coarse grained; rounded pebbles of dark-gray mudstone as much as 0.5 inch in diameter in lower half; thick bedded	37
Hinton formation (1418 feet)	
Abbs Valley Ridge member (440 feet)	
60. Covered	88
59. Sandstone, yellowish-brown, fine grained, soft; thin shaly beds with few even beds as much as 3 feet thick . . .	67
58. Mudstone, yellowish-brown, blocky	12
57. Mudstone, maroon-drab, blocky	36
56. Sandstone, maroon, very fine grained; single bed	9
55. Mudstone, maroon-drab, blocky	6
54. Sandstone, light-gray, fine grained;	

in uneven beds less than 4 inches thick; interbeds of maroon-drab mudstone; unit is about 60 per cent sandstone 6

53. Mudstone, maroon-drab with thin layers of greenish-gray, blocky 18

52. Sandstone, light-brown, fine grained; in uneven beds less than 4 inches thick; interbeds of gray clay shale; unit is about 60 per cent sandstone . . . 6

51. Claystone, dark blue-gray 6

50. Sandstone, light-brown, fine grained; in uneven beds less than 4 inches thick; interbeds of gray clay shale; unit is about 60 per cent sandstone . . . 6

49. Claystone, dark blue-gray; thin bedded 11

48. Sandstone, light-gray, fine grained; in uneven beds less than 4 inches thick; interbeds of gray clay shale; unit is about 60 per cent sandstone . . . 4

47. Claystone, dark blue-gray; thin bedded 8

46. Mudstone, gray to olive-drab, blocky to fissile 53

45. Sandstone, pinkish-gray, very fine grained; single bed 6

44. Claystone, dark blue-gray; thin bedded 17

43. Claystone, orange to yellowish-brown; thin bedded 11

42. Claystone, light-gray, soft 6

41. Mudstone, maroon-drab mottled with olive-drab, blocky 15

40. Sandstone, maroon, very fine grained, soft; thin shaly beds; interbeds of maroon-drab mudstone; unit is about 50 per cent sandstone 3

39. Mudstone, maroon-drab mottled with olive-drab, blocky to fissile 22

38. Sandstone, maroon, very fine grained, soft; thin shaly beds; interbeds of maroon-drab mudstone; unit is about 50 per cent sandstone 8

37. Claystone, light-gray; thin bedded 16

Avis member (24 feet)

36. Mudstone, yellowish-brown, blocky; Dictyoclostus inflatus, Orthotetes kaskaskiensis, Sulcatopinna missouriensis, Allorisma sp.,

<u>Schizodus</u> sp.	24
Adria member (834 feet)	
35. Claystone, yellowish-brown	18
34. Covered	7
33. Mudstone, maroon-drab, blocky to fissile	79
32. Mudstone, brown mottled with olive-drab, blocky to fissile	18
31. Sandstone, yellowish-brown, fine grained; thick bedded	11
30. Covered	201
29. Mudstone, maroon-drab, blocky to fissile	48
28. Sandstone, light-gray, medium grained; single bed	4
27. Covered	185
26. Sandstone, yellowish-brown, fine grained; thin shaly beds	6
25. Clay shale, dark-gray, fissile	16
24. Mudstone, maroon-drab mottled with olive-drab, blocky	31
23. Sandstone, brown, fine grained; in even beds as much as 2 feet thick	21
22. Mudstone, maroon-drab, blocky	9
21. Mudstone, gray to dark-gray, some	

	layers calcareous, blocky	30
20.	Mudstone, maroon-drab, blocky	3
19.	Clay shale, olive-drab, fissile	4
18.	Claystone, light-gray, sandy; thin bedded	8
17.	Mudstone, dark-gray to olive-drab, blocky	18
16.	Claystone, brownish-gray, small fragments of plant fossils; thin layers of black carbonaceous claystone	11
15.	Mudstone, yellowish-brown, blocky	7
14.	Claystone, gray, carbonaceous, small fragments of plant fossils; thin layer of coaly clay in middle	4
13.	Sandstone, yellowish-gray, fine grained; in uneven beds as much as 6 inches thick, average 1 inch thick; interbeds of gray clay shale; unit is about 60 per cent sandstone	8
12.	Claystone, dark-gray; thinly laminated	13
11.	Clay shale, light-gray to dark-gray, fissile	10
10.	Sandstone, yellowish-gray, fine	

grained; single bed 3

9. Claystone, dark-gray, sandy; thin bedded 9

8. Mudstone, olive-drab, blocky 9

7. Coal, black, clayey 1

6. Claystone, gray, soft 5

5. Mudstone, blue-gray, calcareous, blocky to fissile 3

4. Limestone, blue-gray, fine grained, argillaceous; shaly 18

3. Mudstone, maroon-drab, blocky 7

2. Clay shale, gray, finely fissile 10

Stony Gap sandstone member (120 feet)

1. Orthoquartzite, white to light-brown, fine to medium grained; in slightly uneven to even beds as much as 4 feet thick; uniform foreset bedding inclined to southeast 120

Bluefield formation (Geologic Section 1)

Greenbrier limestone

Geologic Section 23.—Bluestone and Princeton formations along State Road 10-7 and Norfolk and Western Railway at Rock, Mercer County, West Virginia.

	Thickness (Feet)
Pocahontas group (Pennsylvanian)	
38. Orthoquartzite, brownish-gray, medium grained; in even beds 3 inches to 2 feet thick; uniform foreset bedding . . .	
Bluestone formation (722 feet)	
37. Covered	101
36. Mudstone, maroon-drab, blocky	4
35. Covered	123
34. Mudstone, maroon-drab, blocky to fissile	10
33. Sandstone, light-gray, very fine grained; single bed	2
32. Mudstone, maroon-drab, blocky to fissile	5
31. Sandstone, light-gray, very fine grained; single bed	3
30. Mudstone, maroon-drab with thin layers of greenish-gray, blocky to fissile	72
29. Sandstone, brown, fine grained;	

rounded pebbles of dark-gray mudstone as much as 0.25 inch in diameter in lower 3 inches; single bed	3
28. Mudstone, maroon-drab with few thin layers of greenish-gray, blocky	21
27. Sandstone, brownish-yellow, fine grained; thin shaly beds	2
26. Mudstone, maroon-drab mottled with greenish-gray, blocky	10
25. Sandstone, brownish-yellow, fine grained; single bed	4
24. Mudstone, maroon-drab, blocky	5
23. Sandstone, brownish-yellow, fine grained; single bed	5
22. Mudstone, maroon-drab with few thin layers of greenish-gray, blocky	9
21. Sandstone, brownish-gray, fine grained; single bed	2
20. Mudstone, olive-drab, blocky to fissile	6
19. Claystone, light-gray, soft	1
18. Claystone, dark-brown to black, small fragments of plant fossils; thin coaly layer at base	1
17. Claystone, dark-gray, carbonaceous	1

16. Claystone, light-gray, small fragments of plant fossils; thin bedded	11
15. Mudstone, yellowish-brown, blocky	6
14. Sandstone, brownish-gray, fine grained; single bed	3
13. Claystone, bright-yellow mottled with orange and bright-red, soft	17
12. Covered	17
11. Sandstone, brownish-gray, fine grained; in even beds 1 foot to 6 feet thick; thin partings of yellowish-brown mudstone	14
10. Mudstone, olive-drab, blocky to fissile; thin interbeds of brown fine-grained sandstone; coaly bed 2 feet below top; unit is about 75 per cent mudstone	10
9. Sandstone, brownish-gray, fine grained; in two even beds 3 feet thick	6
8. Mudstone, yellowish-brown, blocky to fissile	6
7. Mudstone, dark-gray, calcareous, blocky to fissile	11
6. Mudstone, greenish-gray, sandy,	

blocky to fissile	11
5. Mudstone, dark-gray, blocky, in beds as much as 2 feet thick; interbeds of gray, very fine-grained sandstone as much as 2 feet thick; unit is about 60 per cent mudstone	37
4. Covered	34
3. Mudstone, yellowish-brown, sandy, blocky to fissile	18
2. Siltstone, dark-gray to black; thin bedded to fissile; weathers into pencil-like slivers	125
Princeton formation (50 feet)	
1. Orthoquartzite, light-gray, medium to very coarse grained, few rounded pebbles of quartz as much as 0.5 inch in diameter; in slightly uneven beds 6 inches to 6 feet thick	50
Hinton formation (covered)	

Geologic Section 24.—Lower Hinton formation along west side of New River in northwest part of Glenlyn, Giles County, Virginia.

	Thickness (Feet)
Hinton formation (689 feet)	
Trough of Hurricane Ridge syncline; higher part of Hinton formation not exposed.	
Adria member (666 feet)	
62. Mudstone, maroon-drab, blocky	15
61. Sandstone, maroon, very fine grained; in uneven beds as much as 1 foot thick; interbeds of maroon-drab mudstone; unit is about 50 per cent sandstone	20
60. Mudstone, maroon-drab, blocky	12
59. Mudstone, blue-gray, calcareous, blocky	5
58. Limestone, gray mottled with maroon, fine grained; in even beds 2 to 8 inches thick	4
57. Mudstone, maroon-drab, blocky	6
56. Sandstone, maroon, very fine grained; in even beds as much as 2 feet thick; thin partings of maroon mudstone	12

55. Mudstone, maroon-drab, blocky	5
54. Mudstone, gray, calcareous, blocky	5
53. Limestone, gray mottled with maroon, fine grained; single bed	4
52. Siltstone, maroon-drab; single bed; channel filling with 2 feet of relief at base	4
51. Limestone, yellowish-gray, fine grained, argillaceous; single bed	1
50. Mudstone, maroon-drab, blocky	2
49. Siltstone, maroon; single bed	5
48. Mudstone, gray, blocky to fissile	4
47. Limestone, blue-gray, fine grained, argillaceous; shaly	7
46. Mudstone, blue-gray, blocky to fissile	11
45. Coal, black, clayey	1
44. Claystone, dark-gray, carbonaceous	1
43. Claystone, blue-gray, calcareous; thin bedded	14
42. Clay shale, dark-gray, fissile; thin coaly layers 1, 3, and 4 feet below top	8
41. Siltstone, light-gray; thin shaly beds	35

40. Sandstone, gray, fine to medium grained; in uneven beds 2 inches to 2 feet thick; interbeds of blue-gray mudstone; interbeds of dark-gray claystone containing small fragments of plant fossils, coaly layers; unit is about 50 per cent sandstone	16
39. Mudstone, blue-gray, calcareous, blocky	54
38. Mudstone, blue-gray, calcareous, blocky to fissile	20
37. Limestone, dark blue-gray, fine grained; single bed	1
36. Mudstone, maroon-drab with thin layers of blue-gray, blocky to fissile	19
35. Limestone, dark-gray, fine grained; single bed	1
34. Mudstone, blue-gray with few layers of maroon-drab, calcareous, blocky to fissile	48
33. Sandstone, brownish-gray, very fine grained; single bed	2
32. Mudstone, blue-gray, calcareous; blocky to fissile	13

31. Claystone, dark-gray; thin bedded	10
30. Sandstone, grayish-brown, fine grained; in even beds 2 inches to 2 feet thick	6
29. Claystone, dark-gray; thin bedded; thin coaly layer at top	3
28. Siltstone, dark-gray, carbonaceous, small fragments of plant fossils; shaly	15
27. Mudstone, blue-gray, calcareous, blocky	7
26. Clay shale, olive to grayish-brown, fissile	11
25. Mudstone, dark-gray, calcareous, blocky	26
24. Mudstone, maroon-drab with layers of olive-drab, blocky	10
23. Sandstone, grayish-green, fine grained; in even beds 2 inches to 2 feet thick; thin partings of gray clay shale	15
22. Mudstone, maroon-drab, blocky	12
21. Sandstone, grayish-brown, fine grained; in slightly uneven beds less than 3 inches thick; thin	

partings of gray clay shale	7
20. Mudstone, maroon-drab with thin layers of olive-drab, blocky	11
19. Sandstone, maroon, very fine grained; single bed	3
18. Mudstone, maroon-drab with olive-drab; blocky to fissile	28
17. Clay shale, dark-gray, fissile	3
16. Limestone, yellowish-gray, fine grained; single bed	4
15. Mudstone, dark-olive, blocky; thin coaly layer at base	5
14. Mudstone, dark-gray, calcareous, blocky	3
13. Sandstone, brownish-gray, fine grained; in uneven beds 2 to 8 inches thick; thin partings of gray clay shale	16
12. Mudstone, maroon-drab, blocky	22
11. Sandstone, maroon, very fine grained; in uneven beds 2 to 4 inches thick	2
10. Mudstone, maroon-drab and olive-drab, blocky to fissile	47
9. Sandstone, maroon, very fine	

grained; single bed	2
8. Mudstone, maroon-drab, blocky	16
7. Limestone, yellowish-gray, fine grained, argillaceous; single bed	1
6. Mudstone, maroon-drab, blocky	10
5. Sandstone, maroon, very fine grained; single bed	4
4. Mudstone, maroon-drab, blocky to fissile	8
3. Siltstone, yellowish-brown; thin shaly beds; interbeds of dark-gray blocky mudstone; unit is about 50 per cent siltstone	11
Stony Gap sandstone member (23 feet)	
2. Sandstone, brown, fine grained; in even beds up to 2 feet thick in lower part, in thin beds in upper part	5
1. Sandstone, grayish-brown, fine grained; in even beds as much as 3 feet thick	18

Bluefield formation (covered)

Geologic Section 25.—Upper Hinton formation on State Highway 18 in north environs of Athens, Mercer County, West Virginia.

	Thickness (Feet)
Hinton formation (244+ feet)	
Abbs Valley Ridge member (188+ feet)	
13. Covered, top of Abbs Valley Ridge member not exposed	
12. Orthoquartzite, light-brown, fine grained; thick bedded	38
11. Claystone, olive-drab, blocky	4
10. Orthoquartzite, light-brown, fine grained; thick bedded	24
9. Mudstone, maroon-drab, blocky	11
8. Siltstone, maroon; thin shaly beds	4
7. Mudstone, maroon-drab mottled with greenish-gray, blocky	12
6. Clay shale, dark-gray, fissile; buff calcareous siltstone bed 6 inches thick, 4 feet below top	26
5. Siltstone, gray; in beds 2 feet thick, weathers blocky; current ripple marks; gently warped beds dip as much as 18° to the northwest,	

structure is limited to about 10 feet stratigraphically and about 100 feet laterally 21

4. Covered 8

3. Sandstone, brown, fine-grained; thick bedded; foreset bedding dips northwest 21

2. Clay shale, olive-drab, fissile 19

Avis member (56 feet)

1. Limestone, blue-gray, fine to medium grained; in beds as much as 2 feet thick; interbeds of blue-gray fine-grained argillaceous limestone; shaly interbeds of dark-gray fine-grained argillaceous limestone; Composita subquadrata, Dictyoclostus inflatus 56

End of exposure, stream valley.

Geologic Section 26.—Princeton and upper Hinton formations north of Laurel Creek on State Highway 20, 1 mile north of Athens, Mercer County, West Virginia.

	Thickness (Feet)
Princeton formation (25 feet)	
19. Orthoquartzite, light-brown, coarse grained, rounded pebbles of quartz as much as 0.75 inch in diameter; thick bedded; compound cross-bedding . . .	25
Hinton formation (280+ feet)	
Abbs Valley Ridge member (280+ feet)	
18. Claystone, olive	6
17. Mudstone, maroon-drab, blocky	4
16. Mudstone, greenish-gray with few layers of maroon-drab; thin shaly beds; thin interbeds of gray, very fine-grained sandstone	19
15. Mudstone, maroon-drab, blocky	16
14. Sandstone, yellow-brown, fine grained; in even beds as much as 1 foot thick	10
13. Mudstone, maroon-drab, blocky	6

12. Covered	22
11. Orthoquartzite, light-gray, fine grained; thick bedded	15
10. Stratigraphic interval of beds involved in angular unconformity (Pls. 16, 17)	35
9. Sandstone, greenish-gray, fine grained; in uneven beds as much as 4 inches thick, thin clay partings	14
8. Clay shale, gray, fissile	17
7. Mudstone, maroon-drab, blocky; few thin silty layers	28
6. Sandstone, greenish-gray, fine grained, chips of gray clay shale as much as 0.5 inch across; in uneven beds as much as 2 feet thick, thin clay shale partings	16
5. Mudstone, maroon-drab with thin layer of greenish-gray at top, blocky; thin silty layers	15
4. Siltstone, maroon; thin shaly beds	18
3. Clay shale, olive-drab, fissile	10
2. Sandstone, brownish-gray, very	

fine grained; thick bedded 7

1. Mudstone, maroon-drab, blocky 12

End of exposure, stream valley.

Geologic Section 27.—Bluestone and Princeton formations on south end of Bent Mountain, 1.5 miles north of Athens, Mercer County, West Virginia.

	Thickness (Feet)
Bluestone formation (528+ feet)	
15. Covered, top of Bent Mountain; loose blocks of yellow mudstone, brown fine-grained sandstone, and purple clay	85
14. Orthoquartzite, gray, fine grained; in even beds as much as 1 foot thick	69
13. Clay shale, maroon, fissile	8
12. Sandstone, yellowish-brown, very fine grained, soft, crumbly; thin shaly beds	7
11. Sandstone, yellowish-brown, fine grained; single bed	5
10. Clay shale, olive-drab, fissile	12
9. Sandstone, gray, fine grained; in even beds as much as 2 feet thick; thin partings of olive-drab clay shale	17
8. Claystone, dark greenish-gray to	

olive-drab; thin bedded to fissile; thin interbeds of gray fine-grained sandstone in upper part	45
7. Sandstone, greenish-gray, fine grained, micaceous; thin shaly beds	30
6. Covered; few scattered small outcrops of olive-drab mudstone	102
5. Sandstone, gray-brown, fine grained; bedding obscured by poor exposure	29
4. Mudstone, brown, silty	39
3. Covered	10
2. Clay shale, brown to brownish-gray, fissile	70
Princeton formation (25 feet)	
1. Orthoquartzite, light-brown, coarse grained, rounded pebbles of quartz as much as 0.75 inch in diameter; thick bedded	25

Geologic Section 28.—Princeton and Hinton formations on northeast end of Tallery Mountain along State Highway 18, 5 miles south of Hinton, Summers County, West Virginia.

	Thickness (Feet)
Princeton formation (23 feet)	
59. Orthoquartzite, brown, medium to coarse grained, lower part contains rounded pebbles of quartz as much as 1 inch in diameter; thick bedded . . .	23
Hinton formation (1045+ feet)	
Abbs Valley Ridge member (396 feet)	
58. Claystone, light brownish-gray; thin shaly beds	28
57. Claystone, gray-brown; limonitic casts of fossils; <u>Dictyoclostus inflatus</u>	1
56. Mudstone, olive-drab, blocky	40
55. Limestone, dark blue-gray, fine grained, argillaceous; shaly; <u>Composita subquadrata</u>, <u>Dictyoclostus inflatus</u>, <u>Sulcatopinna missouriensis</u>, <u>Amplexizaphrentis spinulosum</u>	2
54. Mudstone, olive, blocky	32

53. Sandstone, yellowish-brown, very fine grained, soft; thin shaly beds . . .	10
52. Claystone, olive-drab with layers of yellow at top; soft	17
51. Mudstone, maroon-drab, blocky; few thin lenses of olive-drab, very fine-grained sandstone	51
50. Sandstone, brown, fine grained, contains chips of gray clay shale as much as 0.5 inch across; thick bedded	11
49. Mudstone, maroon-drab, blocky	23
48. Sandstone, maroon, very fine grained; thin shaly beds	4
47. Mudstone, maroon-drab, blocky	19
46. Limestone, dark-gray, fine grained, argillaceous; single bed	1
45. Clay shale, greenish-gray, fissile	3
44. Sandstone, greenish-gray, fine grained, micaceous; in even beds 2 inches to 1 foot thick, thin clay partings	7
43. Claystone, greenish-gray, blocky	20
42. Sandstone, greenish-gray, fine grained, micaceous; in even beds	

about 8 inches thick; fragments of plant fossils	5
41. Clay shale, brown, fissile; thin shaly interbeds of brown, very fine-grained sandstone; unit is about 80 per cent clay shale	43
40. Claystone, greenish-gray, blocky	17
39. Mudstone, blue-gray to greenish-gray, calcareous; shaly	62
Avis member (46 feet)	
38. Limestone, blue-gray, fine grained, argillaceous; shaly; few beds of blue-gray fine-grained limestone; <u>Composita subquadrata</u>, <u>Dictyoclostus inflatus</u>, <u>Allorisma</u> sp.	46
Adria member (603+ feet)	
37. Mudstone, maroon-drab, blocky	30
36. Sandstone, maroon, fine grained; single bed	5
35. Mudstone, maroon-drab, blocky	10
34. Sandstone, maroon, fine grained; single bed	12
33. Mudstone, maroon-drab with layers of greenish-gray, blocky	59
32. Sandstone, maroon, very fine grained,	

micaceous; thin shaly beds	6
31. Mudstone, maroon-drab, blocky	11
30. Sandstone, maroon, fine grained, micaceous; shaly	3
29. Covered	24
28. Mudstone, maroon-drab, blocky	14
27. Sandstone, maroon, fine grained, micaceous; in even beds as much as 4 inches thick	3
26. Mudstone, maroon-drab, blocky	7
25. Siltstone, dark-gray, calcareous; thick bedded	12
24. Mudstone, maroon-drab, blocky	4
23. Sandstone, maroon, very fine grained, micaceous; single bed	4
22. Mudstone, maroon-drab, blocky	11
21. Limestone, yellowish-gray, fine grained, argillaceous; single bed, weathers blocky	3
20. Mudstone, maroon-drab, blocky	13
19. Sandstone, light-gray, very fine grained, calcareous; single bed	2
18. Mudstone, maroon-drab with layers of greenish-gray, blocky; thin interbeds of maroon, very fine-	

	grained sandstone	14
17.	Limestone, gray, fine grained; shaly; small fragments of brachiopod shells	3
16.	Sandstone, maroon, fine grained; thin shaly beds; interbeds of maroon mudstone as much as 2 feet thick; unit is about 75 per cent sandstone . . .	37
15.	Clay shale, dark-gray, fissile	3
14.	Mudstone, maroon-drab with thin layers of greenish-gray, blocky	20
13.	Sandstone, maroon, very fine grained; single bed	2
12.	Clay shale, gray, fissile	3
11.	Sandstone, gray, fine grained; single bed	1
10.	Mudstone, maroon-drab with thin layers of greenish-gray, blocky	16
9.	Sandstone, maroon, very fine grained; in even beds as much as 1 foot thick	23
8.	Mudstone, maroon-drab with layers of greenish-gray, blocky; few thin silty layers	52
7.	Limestone, yellowish-gray, fine	

grained, argillaceous; single bed	1
6. Mudstone, maroon-drab with a persistent greenish-gray layer 6 inches thick, 10 feet above base, blocky	38
5. Sandstone, maroon, very fine grained; thin shaly beds; thin partings of maroon mudstone	48
4. Sandstone, gray, very fine grained; in uneven beds as much as 2 feet thick	86
3. Mudstone, dark-gray, blocky	12
2. Limestone, blue-gray, fine grained; single bed	3
1. Mudstone, gray, blocky	8

End of outcrop; approximately 5 feet covered to water surface of Bluestone Reservoir.

Geologic Section 29.—Princeton and Hinton formations on north end of Wolf Creek Mountain 0.5 mile southeast of Hinton, Summers County, West Virginia.

	Thickness (Feet)
Princeton formation (35 feet)	
63. Orthoquartzite, white to light-brown, medium to coarse grained, rounded pebbles of quartz as much as 1 inch in diameter; weathers friable; thick bedded	35
Hinton formation (1160+ feet)	
Abbs Valley Ridge member (390 feet)	
62. Covered	23
61. Clay shale, dark-gray to black, fissile	10
60. Covered	57
59. Claystone, olive-drab; thin bedded	17
58. Siltstone, olive; thin shaly beds	7
57. Mudstone, dark-gray, blocky	7
56. Sandstone, light-gray, very fine grained; thin shaly beds, with a prominent 1-foot bed at base	8
55. Clay shale, dark-gray to black, fissile	18

54. Mudstone, maroon-drab with thin layers of olive-drab, blocky	16
53. Orthoquartzite, brownish-gray, medium grained; in slightly uneven beds as much as 3 feet thick; uniform foreset bedding dips to northwest	31
52. Mudstone, olive-drab, blocky	6
51. Mudstone, maroon-drab, blocky	2
50. Mudstone, olive-drab, blocky	23
49. Coal, black, clayey, fragments of plant fossils	1
48. Clay, dark-gray	2
47. Clay shale, light blue-gray, fissile	5
46. Clay shale, olive, fissile	9
45. Limestone, dark-gray, fine grained, argillaceous; single bed	1
44. Mudstone, olive-drab, blocky to fissile	3
43. Siltstone, greenish-gray; thin shaly beds	17
42. Clay shale, light-gray, fissile	4
41. Limestone, dark blue-gray, fine grained, argillaceous; in two even	

beds 1 foot thick	2
40. Mudstone, olive-drab, blocky	25
39. Limestone, yellowish-gray, fine grained, argillaceous; single bed	5
38. Limestone, blue-gray mottled with yellow, fine grained, argillaceous; in uneven beds as much as 1 foot thick; interbeds of gray blocky calcareous mudstone as much as 3 feet thick; unit is about 50 per cent limestone	17
37. Mudstone, maroon-drab, blocky	6
36. Mudstone, dark-gray, calcareous, blocky	15
35. Sandstone, gray, fine grained, calcareous; in even beds as much as 3 feet thick; thin partings of gray clay shale; few thin interbeds of shaly sandstone; unit is about 85 per cent sandstone	19
34. Mudstone, greenish-gray, calcareous, blocky	2
33. Mudstone, olive-drab, blocky to fissile	32

Avis member (60 feet)

32. Limestone, blue-gray, fine grained, argillaceous; in even beds as much as 6 feet thick, few interbeds of shaly limestone near base; Composita subquadrata, Dictyoclostus inflatus 40

31. Mudstone, dark blue-gray, calcareous, blocky; thin interbeds of blue-gray fine-grained limestone; unit is about 90 per cent mudstone; Orthotetes kaskaskiensis, Reticulariina spinosa 20

Adria member (689 feet)

30. Mudstone, maroon-drab with thin layers of greenish-gray, blocky 4

29. Mudstone, maroon-drab, calcareous, blocky 2

28. Mudstone, maroon-drab, blocky 3

27. Sandstone, maroon, very fine grained; thick bedded 6

26. Mudstone, maroon-drab, blocky; few thin layers of maroon siltstone 15

25. Mudstone, maroon-drab, blocky 65

24. Sandstone, maroon, very fine

grained; thin shaly beds	4
23. Mudstone, maroon-drab, blocky	15
22. Sandstone, maroon, very fine grained; in even beds as much as 8 inches thick	10
21. Mudstone, maroon-drab, blocky	25
20. Sandstone, gray, fine grained; in even beds 1 foot to 5 feet thick	26
19. Mudstone, maroon-drab, blocky	73
18. Mudstone, maroon-drab with layers of olive-drab, calcareous, blocky	12
17. Covered	55
16. Mudstone, maroon-drab, calcareous, blocky	2
15. Mudstone, maroon-drab, blocky	34
14. Sandstone, brownish-gray, very fine grained; thin bedded; thin partings of gray mudstone	22
13. Mudstone, maroon-drab with layer of olive-drab at top, blocky	23
12. Covered	78
11. Sandstone, maroon, very fine grained; single bed	3
10. Mudstone, maroon-drab with layers	

of olive-drab, blocky	8
9. Covered	40
8. Mudstone, yellowish-brown, blocky	10
7. Sandstone, grayish-brown, fine grained; in even beds as much as 4 feet thick	27
6. Mudstone, maroon-drab with layer of olive-drab at top, blocky	25
5. Covered	24
4. Mudstone, maroon-drab with layers of greenish-gray, blocky to fissile . . .	32
3. Sandstone, brown, very fine grained; in even beds as much as 1 foot thick in upper half, thin bedded in lower part	22
2. Mudstone, olive-drab, blocky to fissile	24
Stony Gap sandstone member (21+ feet)	
1. Orthoquartzite, grayish-brown, fine grained; in even beds 2 inches to 2 feet thick	21

End of exposure.

Geologic Section 30.—Lower Bluestone, Princeton, and Hinton formations along dirt road on west end of Big Sewell Mountain, 1 mile east of Sandstone, Summers County, West Virginia; Stony Gap sandstone member of Hinton formation at New Richmond, Summers County, West Virginia.

	Thickness (Feet)
Bluestone formation (109+ feet)	
68. Clay, light-gray	5
67. Mudstone, buff, blocky	11
66. Siltstone, olive; thin shaly beds	12
65. Mudstone, maroon-drab with layers of greenish-gray, blocky	23
64. Sandstone, brownish-gray, very fine grained; thin shaly beds, weathers blocky	22
63. Mudstone, olive-drab and maroon-drab; shaly, weathers blocky	16
62. Sandstone, brownish-gray, fine grained; in beds as much as 1 foot thick	10
61. Clay shale, dark-gray, fissile	10
Princeton formation (14 feet)	
60. Sandstone, gray, fine grained;	

in beds as much as 2 feet thick,
thin partings of shaly sandstone 14

Hinton formation (974 feet)

Abbs Valley Ridge member (377 feet)

59. Clay shale, gray, fissile	10
58. Sandstone, brown, very fine grained; thin shaly beds	23
57. Clay, gray	40
56. Covered	34
55. Clay shale, olive, fissile	30
54. Clay, gray	6
53. Mudstone, maroon-drab with layers of greenish-gray, blocky	34
52. Sandstone, yellowish-brown, fine grained; single bed	2
51. Mudstone, maroon-drab, blocky	6
50. Sandstone, maroon, very fine grained; single bed	2
49. Mudstone, maroon-drab, blocky	9
48. Sandstone, olive, very fine grained; thin shaly beds	8
47. Mudstone, maroon-drab with layers of greenish-gray, blocky	7
46. Sandstone, maroon, very fine grained, micaceous; thin shaly beds	3

45. Mudstone, maroon-drab mottled with greenish-gray, blocky	49
44. Sandstone, gray, fine grained; in 2 even beds 1 foot thick	2
43. Clay, gray	10
42. Mudstone, maroon-drab with layers of greenish-gray, blocky; few thin interbeds of maroon, very fine-grained sandstone	44
41. Limestone, blue-gray, fine grained; single bed	1
40. Mudstone, maroon-drab with layers of greenish-gray, blocky	17
39. Sandstone, brown, fine grained; in even beds as much as 1 foot thick; thin partings of gray clay	6
38. Mudstone, maroon-drab, blocky	5
37. Mudstone, gray, calcareous, blocky	10
36. Mudstone, maroon-drab with layers of greenish-gray, blocky	19
Avis member (46 feet)	
35. Limestone, blue-gray, fine grained with scattered medium crystals of calcite; in even beds 6 inches to 2 feet thick; <u>Orthotetes</u>	

<u>kaskaskiensis</u>, <u>Composita subquadrata</u> 38

34. Covered 5

33. Claystone, yellow; <u>Sulcatopinna missouriensis</u>, <u>Dictyoclostus inflatus</u> 3

Adria member (476 feet)

32. Mudstone, maroon-drab with layers of greenish-gray, blocky 33

31. Sandstone, yellowish-brown, fine grained; single bed 1

30. Mudstone, maroon-drab with layers of greenish-gray, blocky 45

29. Sandstone, maroon to dark-brown, fine grained, micaceous; in uneven beds as much as 2 feet thick 47

28. Mudstone, maroon-drab with layers of greenish-gray, blocky 54

27. Siltstone, maroon-drab; single bed 1

26. Mudstone, maroon-drab mottled with greenish-gray, blocky 17

25. Mudstone, maroon-drab mottled with greenish-gray, calcareous; single bed 2

24. Mudstone, maroon-drab, blocky 4

23. Sandstone, maroon, very fine grained, micaceous, calcareous; thin shaly beds	18
22. Mudstone, maroon-drab, blocky	7
21. Sandstone, brown, fine grained; single bed; groove casts on under surface	4
20. Siltstone, maroon; thin shaly beds	7
19. Mudstone, maroon-drab with thin layers of greenish-gray in upper part, blocky	11
18. Sandstone, maroon, very fine grained; thin shaly beds	2
17. Mudstone, maroon-drab with layers of greenish-gray, blocky	23
16. Sandstone, maroon, very fine grained; thin shaly beds	15
15. Mudstone, maroon-drab with layers of greenish-gray, blocky	10
14. Limestone, blue-gray, fine grained, argillaceous; single bed	1
13. Sandstone, maroon, very fine grained; single bed	4
12. Mudstone, maroon-drab, blocky	9
11. Sandstone, maroon, very fine	

grained; single bed	1
10. Mudstone, maroon-drab, blocky	9
9. Limestone, yellowish-gray, fine grained, argillaceous; single bed	3
8. Mudstone, maroon-drab with thin layers of greenish-gray, blocky	12
7. Siltstone, maroon; thin shaly beds	11
6. Mudstone, maroon-drab with thin layers of greenish-gray, blocky; thin interbeds of maroon, very fine-grained sandstone	12
5. Sandstone, olive, very fine grained; thin shaly beds	5
4. Mudstone, maroon-drab, blocky	11
3. Sandstone, brown, very fine grained; thin shaly beds	6
2. Mudstone, maroon-drab with thin layers of greenish-gray, blocky	91
Stony Gap sandstone member (75 feet)	
1. Orthoquartzite, white to light-brown, medium grained; in slightly uneven beds 6 inches to 2 feet thick; uniform foreset bedding dips southwest	75

Bluefield formation (covered)

Geologic Section 31.—Lower Bluestone, Princeton, Hinton, and upper Bluefield formations along dirt road on south end of Cross Mountain, 12 miles northwest of Lewisburg, Greenbrier County, West Virginia.

	Thickness (Feet)
Bluestone formation (79+ feet)	
36. Covered grassy slope, no outcrop	
35. Sandstone, yellow-brown, fine grained; in uneven beds as much as 5 inches thick; interbeds of gray clay shale	23
34. Mudstone, yellow-brown	40
33. Mudstone, olive-drab, blocky	16
Princeton formation (11 feet)	
32. Orthoquartzite, light-gray to yellow-brown, medium to coarse grained, rounded quartz pebbles as much as 0.25 inch in diameter; thick bedded	11
Hinton formation (743 feet)	
Abbs Valley Ridge member (256 feet)	
31. Covered	26
30. Claystone, yellow-brown; thin bedded	5

29. Siltstone, dark-brown, micaceous; thin shaly beds	10
28. Mudstone, olive-drab, blocky	5
27. Claystone, dark-gray	5
26. Claystone, olive	17
25. Mudstone, olive, blocky	12
24. Mudstone, maroon-drab with thin layers of greenish-gray, blocky	40
23. Sandstone, maroon, very fine grained; thin shaly beds	2
22. Mudstone, maroon-drab, blocky	2
21. Limestone, maroon mottled with gray, fine grained, argillaceous; single bed	3
20. Mudstone, maroon-drab with thin layers of greenish-gray, blocky	32
19. Sandstone, maroon, fine grained, micaceous; in even beds as much as 1 foot thick	14
18. Mudstone, maroon-drab, blocky; few thin silty layers	51
17. Clay shale, olive, fissile	12
16. Clay shale, gray, calcareous, fissile	20

Avis member (3 feet)

15. Limestone, blue-gray, fine grained, argillaceous; single bed; small fragments of brachiopod shells	3
Adria member (436 feet)	
14. Clay shale, gray, calcareous, fissile	10
13. Mudstone, maroon-drab, blocky	11
12. Sandstone, maroon, very fine grained; in even beds as much as 3 feet thick	8
11. Mudstone, maroon-drab mottled with greenish-gray, blocky	60
10. Sandstone, maroon, fine grained; in even beds as much as 3 feet thick; rounded chips of maroon-drab mudstone as much as 1 inch in diameter in lower 3 feet	57
9. Mudstone, maroon-drab with layers of greenish-gray, blocky; few thin silty layers; partly covered	290
Stony Gap sandstone member (48 feet)	
8. Orthoquartzite, light-gray to gray-brown, fine grained; in slightly uneven beds as much as 2 feet thick	48

Bluefield formation (226+ feet)

7. Mudstone, maroon-drab with thin layers of greenish-gray, blocky	39
6. Sandstone, maroon, very fine grained; thin shaly beds	10
5. Mudstone, maroon-drab with thin layers of greenish-gray, blocky	102
4. Sandstone, maroon, very fine grained; thin shaly beds	12
3. Claystone, light-yellow	24
2. Claystone, dark-gray	1
1. Claystone, yellow-gray	38

End of exposure, stream valley.

Geologic Section 32.—Bluestone, Princeton, Hinton, and Bluefield formations on south end of Kennison Mountain along State Highway 39, Pocahontas County, West Virginia.

	Thickness (Feet)
Pocahontas group (Pennsylvanian)	
Orthoquartzite, gray-brown, coarse grained, rounded quartz pebbles as much as 0.25 inch in diameter; no outcrop, boulders in sandy soil	
Bluestone formation (124 feet)	
63. Mudstone, maroon-drab, blocky	12
62. Sandstone, yellowish-gray, very fine grained; in even beds as much as 8 inches thick	17
61. Covered	46
60. Mudstone, yellow-brown, blocky	23
59. Claystone, dark-gray to black, carbonaceous; coaly layer at base	4
58. Clay, gray to dark-gray; plant fossils in upper part	10
57. Mudstone, yellow-brown, blocky	12
Princeton formation (35 feet)	

56. Orthoquartzite, light-gray to gray-brown, fine to medium grained; in slightly uneven beds as much as 3 feet thick; 3-foot thick lens of limestone-pebble conglomerate at base, rounded pebbles of blue-gray fine-grained limestone as much as 0.5 inch in diameter 35

Hinton formation (645 feet)

Abbs Valley Ridge member (283 feet)

55. Mudstone, maroon-drab with layers of greenish-gray, blocky; thin silty interbeds 25

54. Covered 15

53. Mudstone, maroon-drab with layers of greenish-gray, blocky; thin silty interbeds 14

52. Sandstone, maroon, very fine grained; discontinuous beds, overlapping lenses; thin interbeds of maroon mudstone 7

51. Mudstone, maroon-drab mottled with greenish-gray, blocky 18

50. Mudstone, maroon-drab mottled with greenish-gray, calcareous, blocky;

thin lenses of maroon fine-grained argillaceous limestone; thin silty interbeds in lower part 34

49. Limestone, light-gray mottled with pale-maroon, fine grained, argillaceous; single bed 2

48. Sandstone, maroon, very fine grained; in even beds as much as 3 feet thick; interbeds of maroon-drab mudstone; unit is about 75 per cent sandstone 23

47. Sandstone, maroon, very fine grained; in even beds as much as 1 foot thick; interbeds of shaly maroon sandstone and maroon mudstone; unit is about 50 per cent sandstone; beds have gentle undulations with low dips (Fig. 6-A) 17

46. Sandstone, maroon and gray, fine grained; thick bedded; uniform foreset bedding dips to northwest 26

45. Conglomerate, gray, rounded pebbles of maroon mudstone and blue-gray limestone as much as

0.5 inch in diameter; single bed 3

44. Mudstone, maroon-drab with layers of greenish-gray, blocky; interbeds of maroon, very fine-grained sandstone; 2-inch bed of black fine-grained limestone 5 feet below top 17

43. Mudstone, maroon-drab with layers of greenish-gray, blocky; thin interbeds of maroon, very fine-grained sandstone 29

42. Sandstone, gray, very fine grained; single bed, grades laterally to beds 1 foot thick, partings of maroon mudstone 6

41. Mudstone, maroon-drab, blocky; single bed of maroon, very fine-grained sandstone in middle of unit, maximum thickness of sandstone 3.5 feet thins laterally northeastward to pinch-out within 200 feet (Pl. 6, fig. 1) 47

Avis member ? (1 foot)

40. Limestone, gray, fine grained, argillaceous; single bed; small

fragments of brachiopod shells	1
Adria member (341 feet)	
39. Mudstone, maroon-drab and greenish-gray, calcareous, blocky	6
38. Sandstone, maroon, very fine grained; in even beds as much as 2 feet thick	7
37. Mudstone, maroon-drab mottled with greenish-gray, blocky; few silty layers in lower part	52
36. Covered	34
35. Mudstone, maroon-drab, blocky	29
34. Sandstone, maroon, very fine grained; thin shaly beds; interbeds of maroon mudstone	11
33. Mudstone, maroon-drab, blocky	5
32. Covered	40
31. Sandstone, maroon, very fine grained; micaceous; thick bedded, fine cross-lamination	12
30. Mudstone, maroon-drab with layers of greenish-gray, blocky; interbeds of maroon siltstone	108
29. Covered	20
28. Sandstone, maroon, very fine	

grained, micaceous; in uneven beds as much as 1 foot thick; interbeds of maroon mudstone; base of unit fills channel approximately 8 feet deep, slightly warped beds in channel (Fig. 6-B) 17

Stony Gap sandstone member (20 feet)

27. Sandstone, maroon to gray-brown, fine grained; thick bedded; base slightly irregular 20

Bluefield formation (315 feet)

26. Mudstone, olive to greenish-gray; in beds as much as 2 feet thick, blocky; interbeds of gray fine-grained sandstone; base of unit fills broad shallow channel, beds slightly warped (Fig. 6-C) 17

25. Mudstone, maroon-drab, blocky; silty layers near top 51

24. Mudstone, olive, blocky 6

23. Mudstone, maroon-drab with layers of greenish-gray, blocky; nodules of gray argillaceous limestone 25

22. Clay shale, yellowish-gray to olive, calcareous, fissile 10

21. Claystone, blue-gray, blocky; lower part calcareous, grades to underlying limestone	6
20. Limestone, blue-gray, fine to medium grained; single bed; <u>Spirifer increbescens</u>, <u>Composita</u> sp.	2
19. Sandstone, olive, very fine grained; single bed	4
18. Claystone, olive-drab; thin bedded	30
17. Claystone, olive to gray; thin interbeds of blue-gray fine-grained argillaceous limestone; <u>Spirifer increbescens</u>, <u>Diaphragmus elegans</u>, <u>Punctospirifer</u> sp., <u>Fenestrellina</u> sp., <u>Polypora</u> sp.	4
16. Limestone, blue-gray, fine grained, argillaceous; single bed; <u>Spirifer increbescens</u>	4
15. Claystone, olive-drab; thin bedded; breaks with conchoidal fracture	11
14. Limestone, dark-gray, fine grained with scattered coarse crystals of calcite; thick bedded	8
13. Covered	17

12. Clay shale, gray, calcareous, fissile; interbeds of blue-gray fine-grained limestone; _Spirifer increbescens_, _Cleiothyridina sublamellosa_, _Orthotetes kaskaskiensis_	8
11. Limestone, blue-gray, fine grained, argillaceous; thin shaly beds; _Spirifer increbescens_, _Cleiothyridina sublamellosa_, _Diaphragmus elegans_	11
10. Limestone, blue-gray, medium grained; single bed; _Spirifer increbescens_, _Diaphragmus elegans_	3
9. Mudstone, maroon-drab and greenish-gray, blocky	28
8. Limestone, light-gray, fine grained, argillaceous; thin shaly beds	8
7. Limestone, dark-gray, fine grained; thick bedded	8
6. Sandstone, yellowish-gray to gray-brown, fine grained, semi-friable; in uneven beds as much as 6 inches thick	6
5. Mudstone, blue-gray, blocky	11
4. Mudstone, maroon-drab, blocky	20

3. Limestone, blue-gray, fine to medium grained; interbeds of oolitic limestone; limestone pebbles, whole fossils and fossil fragments scattered through oolitic limestone; in uneven beds as much as 6 inches thick, irregular lenses; festoon cross-bedding	8
2. Sandstone, brown, fine grained, calcareous, chips of maroon mudstone as much as 0.5 inch across; in uneven beds as much as 6 inches thick, irregular lenses, festoon cross-bedding	8
1. Clay shale, olive to gray, fissile	4

Greenbrier limestone

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APPENDIX

FOSSIL COLLECTING LOCALITIES

Top of Greenbrier-Gasper limestone

Locality 1.—Floor of Abbs Valley on State Road 655, Tazewell County, Virginia.

TC-13 *Talarocrinus* sp.

Locality 2.—Northwest side of Stony Ridge, 1.5 miles south of Bishop, on State Highway 16, Tazewell County, Virginia.

TC-6 *Pentremites godoni*

TC-15 *Pterotocrinus spatulatus*

Locality 3.—South side of Little Stone Mountain, 0.5 mile south of Little Stone Gap on State Road 610, Wise County, Virginia.

TC-7 *Pentremites pyriformis*

TC-11 *Agassizocrinus conicus*

TC-12 *Agassizocrinus laevis*

TC-16 *Archimedes swallovanus*

TC-33 *Eumetria vera*

TC-73 *Griffithides* sp.

Locality 4.—West side of Pine Mountain, 3.5 miles east of Jenkins on U. S. Highway 23, Letcher County, Kentucky.

TC-4 *Amplexizaphrentis spinulosum*

TC-31 *Diaphragmus elegans*

TC-58 *Composita subquadrata*

Bluefield formation

Locality 5.—Cuts along Virginian Railway at Oakvale, Mercer County, West Virginia.

TC-27	_Linoproductus ovatus_
TC-28	_Dictyoclostus inflatus_
TC-30	_Diaphragmus elegans_
TC-34	_Spirifer leidyi_
TC-37	_Brachythyris chesterensis_
TC-44	_Orthotetes kaskaskiensis_
TC-46	_Chonetes chesterensis_
TC-57	_Composita subquadrata_
TC-69	_Orthoceras_ sp.
TC-72	_Griffithides_ sp.
TC-74	_Glyptopora_ sp.

Locality 6.—Cuts along State Highway 12, 3.5 miles east of Bluefield water filtration plant, Mercer County, West Virginia.

TC-39 _Stenocisma explanata_

Locality 7.—Cuts along State Highway 25, 1.5 miles southwest of Stony Gap, Mercer County, West Virginia.

TC-5 _Michelinia_ sp.

TC-18 *Archimedes symmetricus*

Locality 8.—Floor of Abbs Valley at intersection of State Roads 644 and 701, 0.5 mile south of Boissevain, Tazewell County, Virginia.

TC-8 *Pentremites brevis*

TC-17 *Archimedes meekanus*

TC-40 *Cleiothyridina sublamellosa*

TC-75 *Schizophoria* sp.

Locality 9.—Northwest side of Stony Ridge, 1.5 miles south of Bishop, Tazewell County, Virginia.

TC-3 *Amplexizaphrentis spinulosum*

TC-14 *Pterotocrinus spatulatus*

TC-36 *Spirifer increbescens*

Locality 10.—South side of Little Stone Mountain, 0.5 mile south of Little Stone Gap on State Road 610, Wise County, Virginia.

TC-21 *Polypora* sp.

TC-23 *Fenestrellina* sp.

TC-48 *Punctospirifer* sp.

TC-62 *Allorisma* sp.

TC-68 *Straparolus* sp.

Adria member of Hinton formation

Locality 11.—Northwest side of Stony Ridge, 2 miles south of Bishop on State Highway 16, Tazewell County, Virginia.

TC-64 *Aviculopecten* sp.

TC-65 *Nuculana* sp.

Pound Gap member of Pennington formation

Locality 12.—North side of Little Stone Mountain, 0.3 mile north of Little Stone Gap on State Road 610, Wise County, Virginia.

TC-19 Archimedes sp.
TC-47 Punctospirifer sp.
TC-70 Paraconularia sp.
TC-71 Sargentina allani

Locality 13.—Cuts along Southern Railroad 2.5 miles north of Big Stone Gap, Wise County, Virginia.

TC-29 Diaphragmus elegans
TC-38 Stenocisma explanata
TC-56 Composita subquadrata

Locality 14.—West side of Pine Mountain, 4 miles east of Jenkins on U. S. Highway 23, Letcher County, Kentucky.

TC-2 Amplexizaphrentis spinulosum
TC-10 Agassizocrinus conicus
TC-20 Polypora sp.
TC-22 Fenestrellina sp.
TC-26 Dictyoclostus inflatus
TC-32 Linoproductus ovatus

TC-35 <u>Spirifer increbescens</u>

TC-43 <u>Orthotetes kaskaskiensis</u>

TC-51 <u>Reticulariina spinosa</u>

Avis member of Hinton formation

Locality 15.—South end of Keeney Mountain on unpaved road, 3 miles northwest of Clayton, Summers County, West Virginia.

TC-61 Allorisma sp.

Locality 16.—Northwest side of Stony Ridge, 0.5 mile northeast of Stony Gap on U. S. Highway 460-21-19, Mercer County, West Virginia.

TC-60 Sulcatopinna missouriensis

TC-66 Schizodus sp.

Locality 17.—Northwest side of Abbs Valley Ridge, 1.5 miles south of Boissevain, Tazewell County, Virginia.

TC-9 Agassizocrinus conicus

TC-45 Schizophoria sp.

TC-50 Reticulariina spinosa

TC-52 Eumetria costata

TC-55 Composita subquadrata

Locality 18.—Northwest side of Stony Ridge 100 yards west of crest on State Highway 16, 3.5 miles south of Bishop, Tazewell County, Virginia.

TC-1	<u>Amplexizaphrentis spinulosum</u>
TC-25	<u>Dictyoclostus inflatus</u>
TC-42	<u>Orthotetes kaskaskiensis</u>

Abbs Valley Ridge member of Hinton formation

Locality 19.—Road cut 1.0 mile north of Athens on State Highway 20, Mercer County, West Virginia.

TC-24 *Dictyoclostus inflatus*

TC-41 *Orthotetes kaskaskiensis*

TC-49 *Reticulariina spinosa*

TC-54 *Composita subquadrata*

TC-63 *Cypricardella* sp.

Locality 20.—Northeast end of Tallery Mountain, on State Highway 18, 1.5 miles northeast of True, Summers County, West Virginia.

TC-59 *Sulcatopinna missouriensis*

Locality 21.—Southeast side of Abbs Valley Ridge, 2 miles south of Boissevain, Tazewell County, Virginia.

TC-53 *Punctospirifer transversa*

Bluestone formation

Locality 22.—Un-numbered road approaching Mercer County Airport, 0.3 mile east of airport entrance, Mercer County, West Virginia.

TC-67 Straparolus sp.

TC-76 Lingula sp.

TABLE 3

STRATIGRAPHIC DISTRIBUTION OF UPPER MISSISSIPPIAN FOSSILS

	Bluestone fm.	Abbs Valley Ridge mbr.	Avis mbr.	Pound Gap mbr.	Adria mbr.	Bluefield fm.	Top of Gasper-Greenbrier
Conularids:							
Paraconularia sp.				x			
Corals:							
Amplexizaphrentis spinulosum			x	x		x	x
Michelinia sp.						x	
Blastoids:							
Pentremites brevis						x	
Pentremites godoni							x
Pentremites pyriformis							x
Crinoids:							
Agassizocrinus conicus			x	x			x
Agassizocrinus laevis							x
Pterotocrinus spatulatus						x	x
Talarocrinus sp.							x
Bryozoa:							
Archimedes meekanus						x	
Archimedes swallovanus							x
Archimedes symmetricus						x	
Archimedes sp.				x			
Fenestrellina sp.				x		x	
Glyptopora sp.						x	
Polypora sp.				x		x	

TABLE 3 (continued)

	Bluestone fm.	Abbs Valley Ridge mbr.	Avis mbr.	Pound Gap mbr.	Adria mbr.	Bluefield fm.	Top of Gasper-Greenbrier
Brachiopods:							
Brachythyris chesterensis						x	
Chonetes chesterensis						x	
Cleiothyridina sublamellosa						x	
Composita subquadrata		x	x	x		x	x
Diaphragmus elegans				x		x	x
Dictyoclostus inflatus		x	x	x		x	
Eumetria costata			x				
Eumetria vera							x
Lingula sp.	x						
Linoproductus ovatus				x		x	
Orthotetes kaskaskiensis		x	x	x		x	
Punctospirifer transversa		x					
Punctospirifer sp.				x		x	
Reticulariina spinosa		x	x	x			
Schizophoria sp.			x			x	
Spirifer increbescens				x		x	
Spirifer leidyi						x	
Stenocisma explanata				x		x	
Pelecypods:							
Allorisma sp.			x			x	
Aviculopectin sp.					x		
Cypricardella sp.		x					
Nuculana sp.					x		
Schizodus sp.			x				
Sulcatopinna missouriensis		x	x				
Gastropods:							
Straparolus sp.	x					x	
Cephalopods:							
Orthoceras sp.						x	
Trilobites:							
Griffithides sp.						x	x
Ostracods:							
Sargentina allani				x			

ABSTRACT

The Upper Mississippian strata in southwestern Virginia, southern West Virginia, and eastern Kentucky are almost entirely clastic sediments. The Upper Mississippian clastic sequence in the Hurricane Ridge syncline area of Virginia and West Virginia is lithologically distinct from that in the Middlesboro syncline in southwestern Virginia and eastern Kentucky. The sequence in the Hurricane Ridge syncline is predominantly maroon mudstones as contrasted to the sandy sequence in the Middlesboro syncline. The sequence in the Hurricane Ridge syncline contains the Bluefield, Hinton, Princeton and Bluestone formations; the sequence in the Middlesboro syncline is composed of the Bluefield and Pennington formations.

Correlations between the Appalachian sequences and the standard section of the Mississippian in the Mississippi Valley are difficult to establish. However, the positions of the units in the standard section may be established within the complete and much thicker Appalachian sequences. Faunal evidence indicates that the Upper Mississippian strata are Chesterian in age, but the youngest Mississippian in the Appalachians is younger

than the type Mississippian of the Mississippi Valley.

The Upper Mississippian clastic sediments in the structurally lowest part of the Hurricane Ridge syncline are markedly thicker than in other parts of the region. Maroon muds from the same source area as that of the Mauch Chunk red muds were washed into the downwarping Hurricane Ridge syncline in large volumes. However, the red muds did not spread to the southwest of that structure. Sandstones and conglomerates were derived from beds ranging from Mississippian down to Silurian age, which were exposed on partly emergent Appalachian anticlines close to the Hurricane Ridge syncline. Orthoquartzite units, which are persistent in the flanks of the Hurricane Ridge syncline, lose their identity in sequences of sandstone and clay shale in the structurally lowest part of the syncline. A local angular unconformity occurs between the Mississippian clastic sequences and overlying Pennsylvanian sandstones on the overturned southeast limb of the Hurricane Ridge syncline, but the beds are conformable in the adjacent trough of the structure. Small angular unconformities also occur within the Upper Mississippian clastic sequences which were probably induced to crumple and move down structure as a consequence of gradual downsinking of the Hurricane Ridge syncline.