COMMONWEALTH OF VIRGINIA

STATE COMMISSION ON CONSERVATION AND DEVELOPMENT

VIRGINIA GEOLOGICAL SURVEY

ARTHUR BEVAN, *State Geologist*

Bulletin 42

Geologic Map of the Appalachian Valley of Virginia with Explanatory Text

BY

CHARLES BUTTS

PREPARED IN COOPERATION WITH THE UNITED STATES GEOLOGICAL SURVEY

UNIVERSITY, VIRGINIA

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COMMONWEALTH OF VIRGINIA
DEPARTMENT OF MINES, MINERALS AND ENERGY
DIVISION OF MINERAL RESOURCES

GEOLOGIC MAP
OF THE
APPALACHIAN VALLEY IN VIRGINIA

BY CHARLES BUTTS

STATE COMMISSION ON CONSERVATION AND DEVELOPMENT
VIRGINIA GEOLOGICAL SURVEY
Arthur Bevan, State Geologist

IN COOPERATION WITH THE
UNITED STATES GEOLOGICAL SURVEY

Map edited by George W. Stose,
Geologic Map Editor, U. S. Geological Survey

Field work by Mr. Butts, 1926-1931, assisted by R. P. Meacham, Wade Safford, C. R. L. Oder, Benjamin Gildersleeve, and R. S. Edmundson.

Based also upon published folios of the U. S. Geological Survey by M. R. Campbell, N. H. Darton, and Arthur Keith; published reports of the Virginia Geological Survey on the west foot of the Blue Ridge by G. W. Stose, H. D. Miser, F. J. Katz, and D. F. Hewett; on the coal fields of southwestern Virginia by M. R. Campbell, J. B. Eby, A. W. Giles, T. K. Harnsberger, Henry Hinds, G. W. Stose, and C. K. Wentworth; on the Valley coal fields by M. R. Campbell and R. J. Holden; and on the Roanoke area by H. P. Woodward; Geology of Massanutten Mountain by A. C. Spencer; Geologic map of Virginia, 1928; and upon unpublished reports of the Virginia Geological Survey on the Natural Bridge and Eagle Rock quadrangles by H. P. Woodward, on the Abingdon quadrangle by G. W. Stose, and on the lead and zinc district of southwestern Virginia by L. W. Currier.

Engraved and printed by U. S. Geological Survey; C. H. Birdseye, Chief Engraver.

1933

Scale: 1 to 250,000
(Approximately 1 inch = 4 miles)

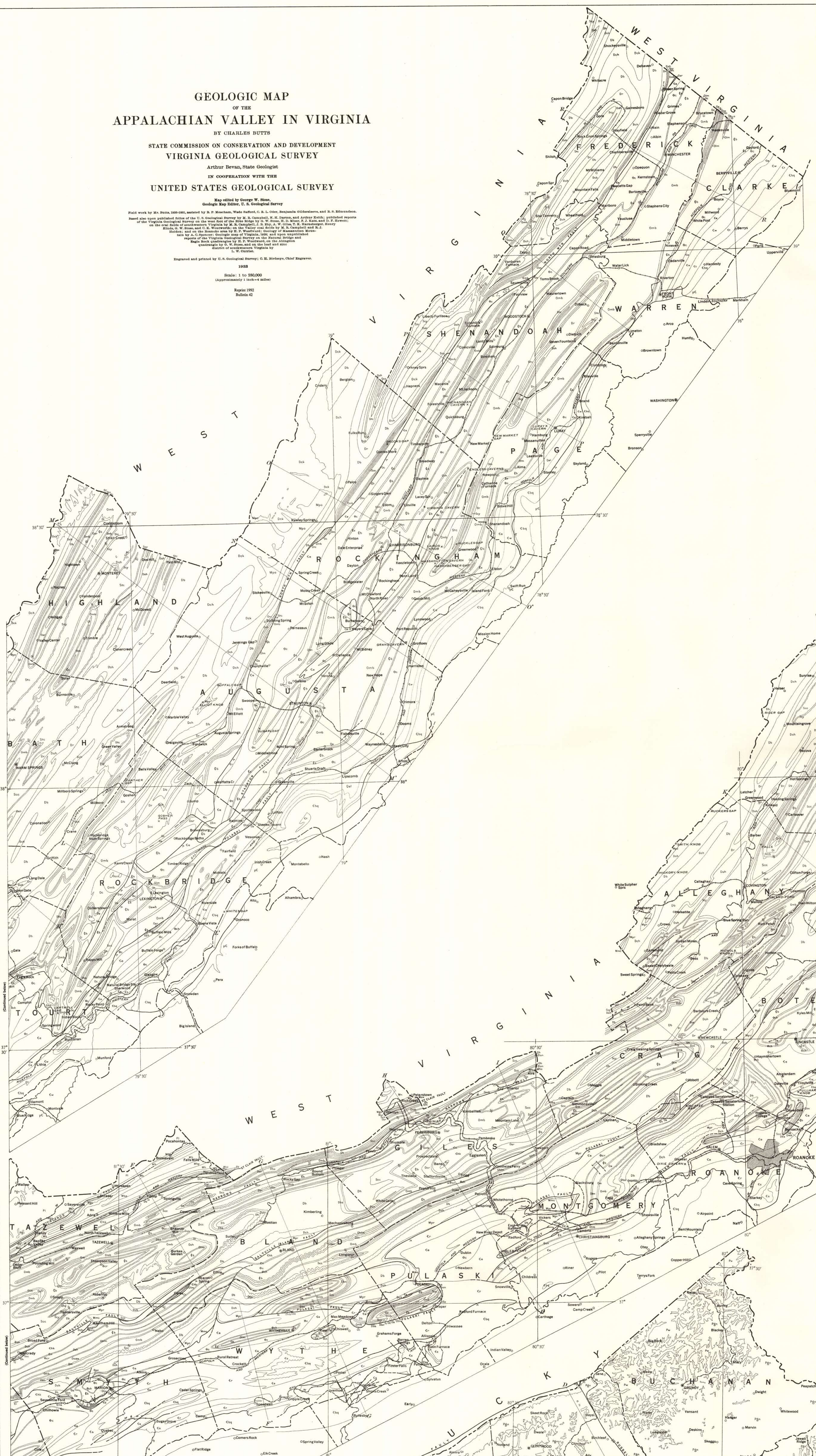
Reprint 1992
Bulletin 42

GENERALIZED COLUMNAR SECTION FOR THE APPALACHIAN VALLEY AND APPALACHIAN RIDGES IN VIRGINIA

Age classification does not conform entirely with that of U. S. Geological Survey, which is shown in the explanation on the right margin

SCALE: 1 INCH = 1000 FEET

System	Series	Group	Formation	Symbol	Thickness
PENNSYLVANIAN		Pottsville	Harlan sandstone	Ph	800±
			Wise formation	Pw	2800
			Gladeville sandstone		(100)
			Norton formation	Pgn	1400
			Lee formation	Pl	1550
MISSISSIPPIAN			Bluestone formation	Mbp	400
			Princeton sandstone		(50±)
			Pennington formation (in southwest) Hinton formation (in Bluefield region)	Mpe Mh	200-1300±
		Chester	Bluefield shale, Cove Creek limestone (Greendale syncline); Glen Dean limestone (Cumberland escarpment)	Mb Mcc	800-1000
			Fido sandstone	(Mdgsl)	(80±)
			Gasper limestone	(Mgsf) Mgs	200-1000±
			Ste. Genevieve limestone		200-1300±
		Meramec	St. Louis limestone		300±
			Limestone of Warsaw age	Msw	600±
			Fort Payne chert		(15±)
			Maccrady shale	Mmc	50-500
		Osage	Pocono sandstone (in northeast) Price formation (in southwest)	Mpo Mpr	850-1700
DEVONIAN	UPPER		Catskill formation	Dck	500-2000
			Chemung formation	Dch	2000±
			Brallier (upper Portage) shale	Db	2000-4000
	MIDDLE		Romney shale (in north) Black shale (in south)	Dr Dbs	500-1000
			Onondaga limestone	Don	50-100
	LOWER		Oriskany sandstone		50-150
			Helderberg limestone	Doh	200-500
SILURIAN	CAYUGAN		Tonoloway limestone	Scy	150-800
			Wills Creek sandstone		50±
			Bloomsburg formation		200
			McKenzie limestone		100±
	NIAGARAN		(Rochester age) Clinton formation	Scc Stc	100-500
	ALEXANDRIAN		Tuscarora quartzite (in north) Clinch sandstone (in south)		50-200
			Juniata formation (in north) Sequatchie formation (in southwest)	Sj Ss	300-700
ORDOVICIAN	UPPER (CINCINNATIAN)		Oswego sandstone	Oos	100-500
		Maysville	(Orthorhyncula zone) (Reedsville shale)	(Or)	(250-600±)
		Eden	Martinsburg shale	Omb	1500-3000±
	MIDDLE (MOHAWKIAN)	Trenton	(Trenton limestone)	(Ot)	(300-500±)
			Chambersburg limestone	Oc	200-400
		Black River	Lowville limestone (in northwest) Moccasin limestone (in southeast)	Ol Om	500-1000
			Ottosee limestone	Oo	200-400
	LOWER	Blount	Athens shale (sandstone and limestone in places)	Oa	600-5000±
			(Whitesburg limestone)	(Ow)	
			Holston limestone	Oh	200-300
		Stones River	Lenoir and Mosheim limestones (Murfreesboro limestone also present in northwestern belt)	Olm	250-1000
CANADIAN		Beekmantown dolomite	Limestone and dolomite equivalent to Bellefonte dolomite of Pennsylvania		200-1500
			Dolomite equivalent to Nittany dolomite of Pennsylvania	Єb	500-1200
			Stonehenge limestone member	Єs	100-500
			Chepultepec limestone	Єch	
OZARKIAN			Conococheague limestone (in southeast) Copper Ridge dolomite (in northwest)	Єc Єcr	1200-2000
CAMBRIAN	UPPER		Nolichucky shale	Єn	100-600
		Honaker dolomite / Elbrook dolomite	Maryville limestone		(Єe-1800)
	MIDDLE		Rogersville shale	Єmrr	800-1000
			Rutledge limestone		
			Waynesboro formation (in north) Rome formation (in south)	Єw Єr	1500-2000
	LOWER		(Ivanhoe limestone member)		
			Shady dolomite	Єs	1500-3000
			(Patterson limestone member)		
		Basal quartzite	Antietam quartzite (in north) Erwin quartzite (in south)		500-1200
			Harpers shale (in north) Hampton shale (in south)	Єbq	2000±
			Weverton quartzite Loudoun formation (in north); Unicoi formation (in south)		2000±
PRE-CAMB.			Crystalline rocks		



EXPLANATION

Qal Alluvium (sand, gravel, and boulders; fan deposit at the west foot of the Blue Ridge from the latitude of Greenville to Luray) — QUATERNARY

IGNEOUS ROCKS: Peridotite, granophyre, and related rocks (dikes and stocks, probably post-Pennsylvanian)

Ph Harlan sandstone (sandstone and shale with coal beds; small remnants cap hills along the northwest margin of the State)

Pw Wise formation (sandstone and shale with many coal beds)

Pgn Gladeville sandstone, Norton formation (sandstone and shale with coal beds; Gladeville sandstone persistent at top)

Pl Lee formation (conglomerate at base, sandstone and shale above; valuable coal beds (Pocahontas) in the Bluefield region) — PENNSYLVANIAN

Mbp Bluestone formation, Princeton sandstone (shale and sandstone; some red shale in upper part; Princeton sandstone at base)

Mp Mh Pennington formation, Hinton formation (shale, sandstone, and some impure fossiliferous limestone; characterized by much red shale; prominent ridge-making sandstone (Piney Ridge sandstone of Reger) at base; Pennington in southwest Virginia; Hinton in Bluefield region; red shale and basal sandstone absent in Greendale syncline)

Mb Bluefield shale (soft bluish calcareous fossiliferous shale; weathers yellowish; a few thin red layers in upper part)

CUMBERLAND ESCARPMENT — **Mcc** Cove Creek limestone (mainly argillaceous limestone weathering to dark shale; some purer beds weathering white)

CUMBERLAND ESCARPMENT — Newman limestone: **Mdgsl** Glen Dean limestone (thin-bedded, fossiliferous); Gasper limestone (thick-bedded, oolitic); Ste. Genevieve limestone (thick-bedded, oolitic); St. Louis limestone (thick-bedded, dark, cherty)

Greenbrier limestone: **Mgs** Gasper limestone, Ste. Genevieve limestone (thick-bedded, oolitic); **Msw** St. Louis limestone (thick-bedded, cherty); Limestone of Warsaw age (thin-bedded)

Newman limestone: **Mgsf** Fido sandstone, Gasper limestone, Ste. Genevieve limestone (mainly argillaceous limestone weathering to shale; some beds of pure limestone; red sandstone (Fido) at top); **Msw** St. Louis limestone (Dark, thick-bedded, cherty); Limestone of Warsaw age (argillaceous gray shaly limestone; some sandstone)

Mmc Maccrady shale (red shale or mudrock; some red and green sandstone)

Mpr Mpo Price formation, Pocono sandstone (Price, mainly marine fossiliferous shale and sandstone in southwest Virginia; shale and sandstone, mainly nonmarine, with coal beds, in Pulaski and Montgomery counties; Pocono, coarse, thick-bedded sandstone and conglomerate, nonmarine, with little coal, in and northeast of Highland County) — MISSISSIPPIAN; CARBONIFEROUS OF U. S. GEOLOGICAL SURVEY

Dck Catskill formation (red shale and sandstone, unfossiliferous; mostly nonmarine)

Dch Chemung formation (shale and sandstone, mostly gray and green, highly fossiliferous)

Db Brallier (upper Portage) shale (stiff greenish siliceous shale and thin evenly bedded fine-grained greenish sandstone; scant diminutive fauna of western Portage types; post-Naples, middle and late Portage age; corresponds to Hatch and Gardeau shale of New York)

BIG STONE GAP REGION — **MDbp** Big Stone Gap shale (dark to black shale, Devonian or Mississippian); Portage shale (green and gray shale with bands of black); Genesee (?) shale (black fissile shale containing Schizobolus)

Dbs Dr Romney shale in north (black fissile shale, early Portage (Naples) age, above; olive-green shale and sandstone of Hamilton age in middle; black shale (Marcellus) and green shale of Onondaga age at base); Black shale in south (black fissile shale, locally pink, of early Portage (Naples) age above and Marcellus age below)

Don Onondaga limestone (mostly medium-bedded gray to dove-colored limestone; argillaceous and thin-bedded at top and bottom; almost everywhere silicified to chert at outcrop)

Doh Oriskany sandstone (coarse calcareous sandstone leaching to friable sandstone; used as glass sand); Helderberg limestone (argillaceous nodular bluish coarse-grained thin-bedded limestone and intercalated beds of sandstone)

SOUTHWEST OF NEWCASTLE, BIG STONE GAP REGION — **Dh** Helderberg limestone (limestone and sandstone locally containing manganese ore; Oriskany sandstone absent) — DEVONIAN

Scy Formations of Cayuga age (thin-bedded limestone (Tonoloway) on northwest; gray fossiliferous sandstone and shale (Wills Creek); red shale and sandstone (Bloomsburg) in Great North Mountain and Massanutten Mountain; dark fossiliferous limestone (McKenzie) in Monterey region)

Scc Stc Clinton formation, Clinch sandstone, Tuscarora quartzite (thick-bedded gray quartzite (Clinch in southwest, Tuscarora in north) overlain by green shale and sandstone and locally red sandstone (Clinton))

Ss Sj Sequatchie formation, Juniata formation (Juniata, mainly red shale and red sandstone, a few gray beds at top; Sequatchie in extreme southwest, argillaceous bluish fossiliferous limestone and shale, mottled red) — SILURIAN

Oos Oswego sandstone (thick-bedded gray sandstone; Little North Mountain and Paddy Mountain and vicinity, north of latitude of Harrisonburg)

Omb Martinsburg shale (shale, partly calcareous; weathers yellowish and greenish; includes thin layers of fossiliferous limestone of Trenton age, more abundant in the lower third)

NORTHWESTERN BELTS — **Or** Reedsville shale (shale with thin limestone); **Ot** Trenton limestone (largely thin-bedded coarsely crystalline limestone; in Lee, Scott, and Wise counties)

Black River group: **Oc** Chambersburg limestone (mainly evenly thin-bedded bluish limestone, partly nodular, argillaceous and thick-bedded at top); **Ol Om** Lowville limestone, Moccasin limestone (northwest belt of Valley, dove-colored limestone, mainly thin bedded, partly pure (Lowville); in southeastern part of Valley, partly dove-colored limestone below and argillaceous limestone (Moccasin) above)

Blount group: **Oo Oa Osr Ooh Oawh** Oo, Ottosee limestone (highly fossiliferous); Oa, Athens shale (black graptolitic shale, limestone, and much sandstone southeast of Abingdon); Ow, Whitesburg limestone; Oh, Holston limestone (coarse bluish and pink) (The different combinations of letter symbols on the map indicate different combinations of these units overlapping)

Stones River group: **Olm Ohlm** Lenoir limestone, Mosheim limestone (medium coarse dark limestone (Lenoir) above; light dove-colored compact limestone (Mosheim) below; in Saltville belt, Holston limestone included, Ohlm)

NORTHWESTERN BELTS, NEW RIVER TO TENNESSEE — **Osr** Stones River limestone group (medium-bedded blue limestone, partly cherty; includes Lenoir, Mosheim, and Murfreesboro limestones) — ORDOVICIAN; ORDOVICIAN OF U. S. GEOLOGICAL SURVEY

Єb Beekmantown dolomite, Beekmantown limestone above Stonehenge member (thick-bedded dolomite, mostly middle Beekmantown (equivalent of Nittany) in southwest; largely limestone in Shenandoah and Frederick counties; mostly upper Beekmantown (equivalent of Bellefonte) in northeast from Staunton to West Virginia) — CANADIAN

Єs Єch Єs, Stonehenge limestone member of Beekmantown limestone; Єch, Chepultepec limestone (upper Ozarkian) undivided (mostly Chepultepec to southwest; Stonehenge to northeast)

Єcr Copper Ridge dolomite (thick-bedded dolomite; contains beds of sandstone, which are the characteristic feature)

SOUTHEASTERN BELTS — **Єc** Conococheague limestone (limestone with some dolomite; contains beds of sandstone, which are the characteristic feature) — OZARKIAN

Єn Nolichucky shale (green shale with thick beds of banded limestone at top and bottom)

IN EXTREME SOUTHWESTERN BELTS ST. PAUL TO CLINCHPORT — **Єmrr** Maryville limestone (banded blue); Rogersville shale (gray shale with thin sandstone); Rutledge limestone (blue-banded)

Єhk Honaker dolomite (thick-bedded dolomite, locally argillaceous, weathering to ocherous clay; in middle belts, Pearisburg to Bristol and Speers Ferry)

SOUTHEASTERN BELTS — **Єe** Elbrook dolomite (thick-bedded to shaly argillaceous dolomite; some pure limestone)

Єr Єw Rome formation, Waynesboro formation (shale and sandstone, largely red, dolomite, and limestone; Єw, north of Roanoke; Єr, southwest of Roanoke)

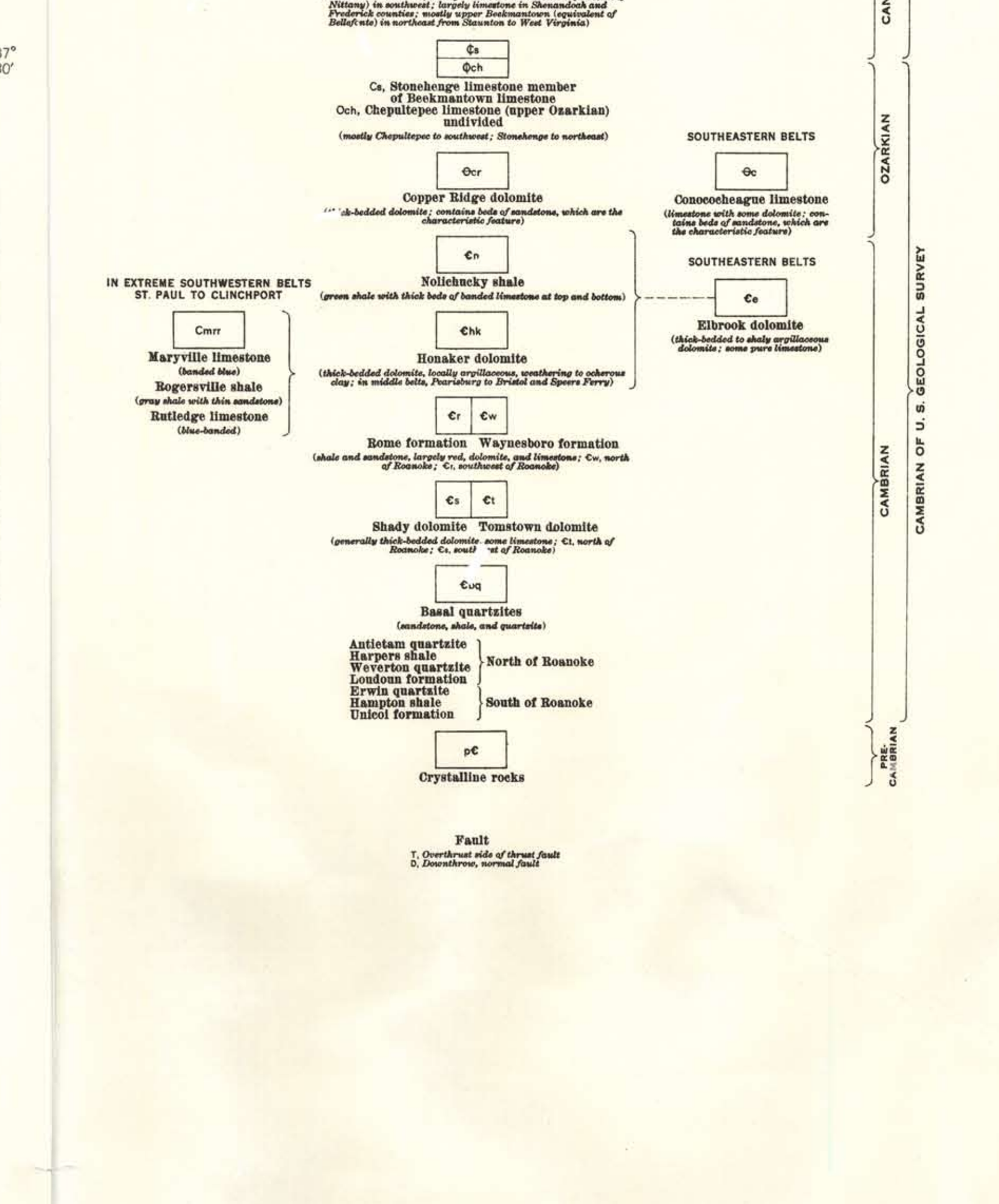
Єs Єt Shady dolomite, Tomstown dolomite (generally thick-bedded dolomite, some limestone; Єt, north of Roanoke; Єs, south of Roanoke)

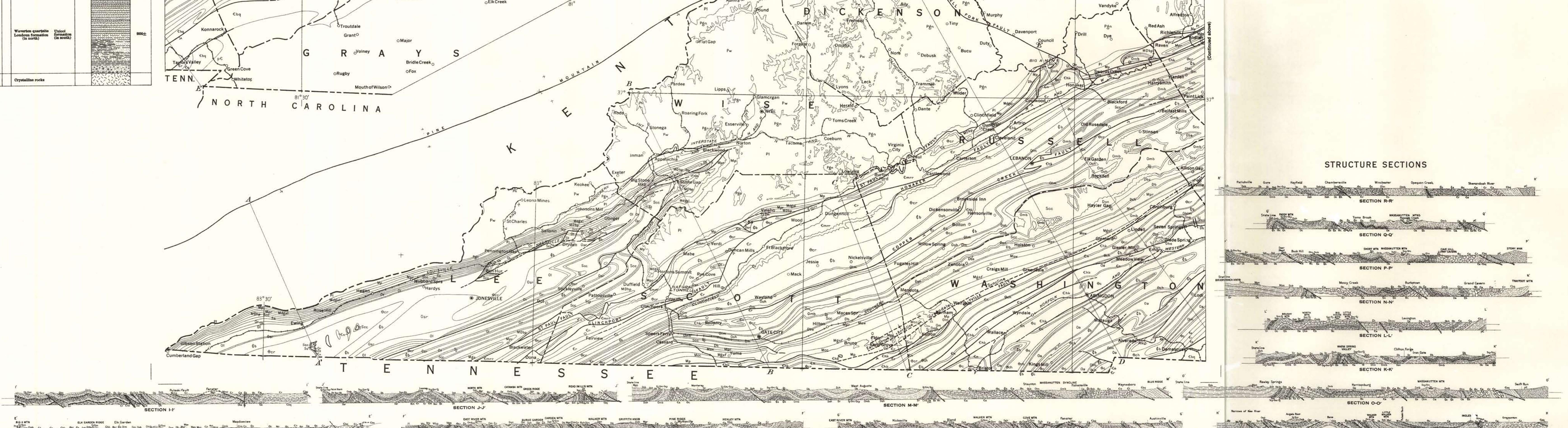
Єuq Basal quartzites (sandstone, shale, and quartzite): Antietam quartzite, Harpers shale, Weverton quartzite, Loudoun formation — North of Roanoke; Erwin quartzite, Hampton shale, Unicoi formation — South of Roanoke — CAMBRIAN; CAMBRIAN OF U. S. GEOLOGICAL SURVEY

pЄ Crystalline rocks — PRE-CAMBRIAN

Fault
T, Overthrust side of thrust fault
D, Downthrow, normal fault

STRUCTURE SECTIONS





STATE COMMISSION ON CONSERVATION AND DEVELOPMENT

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Executive Secretary and Treasurer, Richmond

LETTER OF TRANSMITTAL

COMMONWEALTH OF VIRGINIA
VIRGINIA GEOLOGICAL SURVEY
UNIVERSITY OF VIRGINIA

CHARLOTTESVILLE, VA., March 15, 1933.

To the State Commission on Conservation and Development:

GENTLEMEN:

I have the honor to transmit and to recommend for publication as Bulletin 42 of the Virginia Geological Survey series of reports the manuscript for the *Explanation of the Geologic Map of the Appalachian Valley of Virginia,* by Dr. Charles Butts, of the United States Geological Survey.

Doctor Butts was engaged during the field seasons of 1926-1932 in mapping all of the formations between the northwest foot of the Blue Ridge in Virginia and the State lines of West Virginia, Kentucky, and Tennessee. This was a cooperative project between the United States Geological Survey and the Virginia Geological Survey. He was assisted in the field by several graduate students from the School of Geology, University of Virginia, who were employed by the Virginia Geological Survey.

The geologic map prepared by Doctor Butts is a noteworthy contribution to the understanding of the complex geology of the Appalachian Valley and thus to the best development and utilization of its vast mineral wealth. The map and explanatory text will be of great value also for use in schools and colleges throughout the nation. They reflect the results of a lifetime study of the stratigraphy of the Appalachian Valley from New York to Alabama.

A complete illustrated report upon the formations in the Appalachian Valley in Virginia is being cooperatively prepared by Doctor Butts for the Virginia Geological Survey.

Respectfully submitted,

ARTHUR BEVAN,
State Geologist.

Approved for publication:

State Commission on Conservation and Development,
Richmond, Virginia, March 17, 1933.
RICHARD A. GILLIAM, *Executive Secretary and Treasurer.*

CONTENTS

TABLE

Explanation of the Geologic Map of the Appalachian Valley of Virginia

By Charles Butts

Prepared in Cooperation with the United States Geological Survey

INTRODUCTION

The geologic map of the Appalachian Valley of Virginia is based on field work by the author in the seasons of 1926-1932, assisted by R. P. Meacham, Wade Safford, C. R. L. Oder, Benjamin Gildersleeve, and R. S. Edmundson; upon several folios of the United States Geological Survey by M. R. Campbell, N. H. Darton, and Arthur Keith; upon reports of the Virginia Geological Survey on the Virginia coal fields by Henry Hinds, T. K. Harnsberger, J. B. Eby, A. W. Giles, C. K. Wentworth, M. R. Campbell, and R. J. Holden; report on the Big Stone Gap region by G. W. Stose; report on Massanutten Mountain by A. C. Spencer; reports of the Virginia Geological Survey on the Roanoke area by H. P. Woodward and on the manganese deposits by G. W. Stose, H. D. Miser, F. J. Katz, and D. F. Hewett; geological map of Virginia, edition of 1928; unpublished work on the zinc district in Smyth and Wythe counties by L. W. Currier; unpublished work on the Eagle Rock and Natural Bridge Special quadrangles by H. P. Woodward; unpublished work on the Abingdon quadrangle by G. W. Stose; and reports by the West Virginia Geological Survey on several counties bordering upon Virginia. Special acknowledgment is due E. O. Ulrich for invaluable contributions to the knowledge of Appalachian stratigraphy.

The colors and hachure patterns shown on the map are of different values. Some of these represent single formations, as the Nolichucky shale (Cn), or Conococheague limestone (Oc); others represent combinations of formations. For example, on the Cumberland escarpment, the Glen Dean limestone, Gasper limestone, Ste. Genevieve limestone, and St. Louis limestone are combined into one map unit, Mdgsl. The different formations in such combinations differ in their character and areal distribution to such an extent that adequate description is not possible in the ordinary map legend. The object of this bulletin, which is really an expanded legend, is to give the fuller information needed.

A summary of the stratigraphy is given in Table 1 (p. 49).

PRE-CAMBRIAN ROCKS (pC)

The pre-Cambrian rocks consist of igneous and metamorphic rocks, such as granite and granitoid rocks, greenstone, gneiss and schist. These are very ancient rocks, highly folded and eroded, and they constitute the basement or foundation upon which the Paleozoic rocks of the Valley lie. They crop out mainly east of the Valley of Virginia, chiefly in the Blue Ridge province and in the Piedmont province farther east.

CAMBRIAN SYSTEM

BASAL QUARTZITES (Cbq)

The basal Cambrian rocks include four formations, for which the name Chilhowee group has been used by Woodward.[1] The name is derived from that of Chilhowee Mountain, Tenn., in which these basal Cambrian formations are at least partly represented. In Virginia these rocks form the summit of the Blue Ridge for considerable distances, and for almost the entire distance across the State they form the northwest slope of that ridge. Northeast of Roanoke (Roanoke County) these formations bear one set of names and southwest of Roanoke they bear a different set of names, as follows:

Northeast of Roanoke	*Southwest of Roanoke*
Antietam quartzite	Erwin quartzite
Harpers shale	Hampton shale
Weverton quartzite	Unicoi formation
Loudoun formation	

The *Loudoun formation* is a rather heterogeneous mass of fine conglomerate, quartzite, and shale, some of which is red or purple. In places some of its beds are difficult to distinguish from the underlying pre-Cambrian rocks from which its basal beds are derived. It is 100 to 800 feet thick.

The *Weverton quartzite* is made up mainly of quartz sand but contains considerable feldspar. It is 200 to 1,000 feet thick and is apparently persistent from Loudoun County in northern Virginia to Roanoke.

The *Unicoi formation* is composed in the upper part of gray, thick-bedded sandstone; in the lower part of coarse arkosic sandstone, some of it reddish, a few thin beds of red shale, and a few beds of conglomerate. About the middle of the Unicoi is a persistent bed of amygdaloid, a dark-green igneous rock, about 200 feet thick.

[1] Woodward, H. P., Geology and mineral resources of the Roanoke area, Virginia: Virginia Geol. Survey Bull. 34, p. 28, 1932.

The Unicoi is about 2,600 feet thick, as shown in a vertical section on the road through the gap between Straight and Grave mountains, about 2 miles northeast of Konnarock, Washington County, Va. The upper 1,000 feet is fully exposed on the Bristol-Mountain City road on the northeast slope of Holston Mountain in Tennessee. The most accessible exposure of the amygdaloid bed is on the Damascus-Mountain City road just south of the State line.

The *Harpers* and *Hampton shales* consist of gray siliceous shale with thin layers of sandstone throughout most of the mass. To the north of Roanoke the formation is called Harpers shale, and to the south of Roanoke it is called Hampton shale. The sandstone seems to increase in the proportion and thickness of its layers in the upper part. The thickness is 1,200 to 2,000 feet. It is fully exposed on the Bristol-Mountain City road on the northwest slope of Holston Mountain in northern Tennessee.

The formation called *Antietam quartzite* north of Roanoke and *Erwin quartzite* south of Roanoke is mainly thick-bedded gray sandstone, but in places, or at some horizons, the beds are thinner and dark bluish gray with rusty blotches. The rusty layers have rare fragments of trilobites (*Olenellus*) and brachiopods (*Obolella*). Good exposures of the quartzite are the one at the Crimora mine, Augusta County, the one in the sandstone quarry east of Waynesboro, Augusta County, and one west of Whites Gap in Rockbridge County. The Erwin quartzite is abundantly displayed in Lick Mountain south of Wytheville, Wythe County.

The thickness has not been generally determined but may be estimated at about 1,000 feet.

TOMSTOWN DOLOMITE (Ct) AND SHADY DOLOMITE (Cs)

Shady and Tomstown are two names applied to the same unit, Shady being applied southwest of Roanoke and Tomstown northeast of Roanoke. The formation was also named "Sherwood limestone" by H. D. Campbell, from Sherwood, Rockbridge County, Va.

The *Tomstown* is prevailingly a dolomite, generally medium thick bedded and medium grained but has coarsely crystalline beds. The fine-grained rock is bluish-gray, but the coarse-grained rock is light gray to nearly white. There seems to be some thin-bedded limestone northeast of Riverton in Warren County. The *Shady* is also mostly dolomite, much like the Tomstown, but has rather more of the coarse light-gray rock (saccharoidal member) and in the basal part considerable limestone (*Patterson limestone member*) that varies much in thickness and distribution. At the top in the vicinity of Ivanhoe, Wythe County, is a thick limestone (*Ivanhoe limestone member*). The zinc deposits at Austinville, Wythe County, are in the saccharoidal rock.

This dolomite is reported to be about 1,000 feet thick in Pennsylvania and Tennessee, but it is certainly 1,800 feet thick at Austinville, Va., and seems equally thick northeast of Front Royal in Warren County.

The formation crops out entirely across Virginia, except where covered by overthrust rocks, but only in a single belt at the northwest foot of the Blue Ridge.

As far south as Front Royal it is well exposed at places on and near the Shenandoah River, as just below the mouth of Goose Creek 3½ miles northeast of Front Royal and at several other points along the river farther northeast into West Virginia. From Front Royal southwest to Greenville, Augusta County, the Tomstown has not certainly been found in outcrop, probably being concealed by overthrusting or by talus and wash at the foot of the Blue Ridge. From the vicinity of Buena Vista, Rockbridge County, the formation crops out and is more or less exposed southwestward to Fullhardt Knob, 5 miles north of Roanoke. It is well exposed in the vicinity of Sherwood and in a quarry by James River 1 mile east of Buchanan, Botetourt County.

Except for two small areas 1 to 3 miles south of Roanoke the Shady dolomite between Roanoke and Hiwassee, Pulaski County, is concealed by the Cambrian quartzites or by the pre-Cambrian rocks, which are thrust over it on to the overlying Rome formation. About 1 mile southwest of Hiwassee, the Shady reappears from beneath the fault and continues in outcrop in wide areas southwest to Tennessee, in the vicinity of Damascus and Taylors Valley in Washington County. It is especially well exposed in the vicinity of Austinville and Ivanhoe, Wythe County, where it carries zinc and lead ores.

At Austinville the Shady, usually very sparingly fossiliferous, has yielded a trilobite and brachiopod fauna, the zone of which can be fairly definitely correlated with the Lower Cambrian Kinzers formation, of Tomstown age, near York and Lancaster, Pa.

ROME FORMATION (Cr) AND WAYNESBORO FORMATION (Cw)

Like the formations already described this one bears two names, being called *Waynesboro formation* northeast of Roanoke and *Rome formation* southwest of Roanoke. This formation has been called Watauga shale in folios of the United States Geological Survey on northern Tennessee, and in the report on the manganese deposits at the west foot of the Blue Ridge,[2] and Russell formation in the Bristol[3] and Estillville[4] folios of southwestern Virginia.

[2] Stose, G. W., and others, Manganese deposits of the west foot of the Blue Ridge, Virginia: Virginia Geol. Survey Bull. 17, 1919.
[3] Campbell, M. R., U. S. Geol. Survey Geol. Atlas, Bristol folio (No. 59), 1899.
[4] Idem, Estillville folio (No. 12), 1894.

The Rome is a very heterogeneous formation. Its distinctive feature is its red color, which is mainly due to the red mudrock or shale. Its principal constituents are shale, sandstone, limy clayey beds, dolomite, and pure blue limestone. These rock types are in relatively thin alternating beds distributed without any regular order through the full thickness of the formation. About 75 per cent of the mass is either red mudrock or green sericite shale, each in definite layers from 1 to 50 feet thick. The sandstone is commonly in thin beds, generally fine grained, and red, brown, or green. The sandstone beds are more abundant in Tennessee, as north of Morristown, where the lower 1,000 feet of the Rome was mapped in the Morristown folio (No. 27) as Rome sandstone. The calcareous argillaceous beds weather to a yellowish, or less commonly, reddish ocher through leaching of the limy contents. The beds of dolomite and the rare beds of limestone may reach a thickness of 50 feet, but together they probably do not exceed 10 per cent of the formation.

The full thickness of the Rome crops out only in the first belt northwest of the Blue Ridge, where, owing to minor folding and faulting, accurate measurement of the thickness is difficult and perhaps impossible. From the width of outcrop and generally steep dip, the thickness here is estimated to be at least 2,000 feet. At a favorable exposure just south of Brookside Inn, Russell County, on the Abingdon-St. Paul road (Route 19), an accurate measurement of the upper 1,100 feet, extending down to an overthrust fault, was obtained. North of Morristown, Tenn., Keith[5] gives a maximum exposed thickness of 1,300 feet.

The Waynesboro is poorly exposed north of Buena Vista, Rockbridge County. There are scattered road-cut exposures of the characteristic red and green shale south of Gaylord and east of Berryville in Clarke County, a good exposure in a railroad cut in Waynesboro, Augusta County, and small exposures elsewhere in the town, a good exposure just east of Buchanan on the Chesapeake & Ohio Railway, and other partial exposures in the belt between Buchanan and Roanoke. The Rome is considerably exposed in the city of Roanoke and southeastward to and beyond Salem but is little shown southwest of Salem to localities south of Christiansburg, Montgomery County. One of the best exhibits is on the Norfolk & Western Railway for a mile northward from Delton, Pulaski County. Another is on the highway within 2 miles north of Speedwell, Wythe County. There are also excellent exposures in the northwestern belts at Brookside Inn and north to St. Paul and the vicinity of Dungannon, Scott County.

[5] Keith, Arthur, U. S. Geol. Survey Geol. Atlas, Morristown folio (No. 27), 1896.

The Rome is sparingly fossiliferous, the occurrence of *Olenellus* indicating that it is Lower Cambrian, but according to some geologists it is in part Middle Cambrian.

The Waynesboro or Rome formation is succeeded by limestone and dolomite formations as shown in the subjoined table.

Formations overlying the Rome formation in different parts of the Valley in Virginia

Lee and Scott counties, southwest of St. Paul, Russell County	Middle belts, New River to Tennessee between Bristol and St. Paul	Belts on southeast side of valley from Frederick County to Tennessee
Nolichucky shale (Cn)	Nolichucky shale (Cn)	
Maryville limestone Rogersville shale (Cmrr) Rutledge limestone	Honaker dolomite (Chk)	Elbrook dolomite (Ce)
Rome formation (Cr)	Rome formation (Cr)	Waynesboro (Cw) and Rome formations

ELBROOK DOLOMITE (Ce)

The *Elbrook* is predominantly dolomite, varying from thick bedded medium coarse rather pure dolomite, to thinly laminated, finely crystalline light bluish gray shaly dolomite. In the upper third, layers 1 to 5 feet thick of pure light-gray limestone are common. The thinner bedded dolomite is apparently generally argillaceous, as indicated by its pale yellowish gray shaly character when weathered and where much of the lime has been leached out. These characteristics seem to be persistent along its entire outcrop in Virginia.

According to reliable measurement at Wytheville, Wythe County, the thickness of the Elbrook is 1,800 feet. Stose[6] gives its thickness near its type locality, Elbrook, Franklin County, Pa., as 3,000 feet. It probably does not exceed 2,000 feet in Virginia.

There are good exposures of the formation in the Pedlar Hills between Salem, Roanoke County, and Christiansburg and at Wytheville.

The Elbrook corresponds to the Honaker dolomite and the Nolichucky shale, as shown by the occurrence of *Crepicephalus,* a typical Nolichucky trilobite, in its very top on Widner Branch 13 miles east of Abingdon, Washington County. Except for these and a few small trilobites 1 mile northwest of Holston Mill, Smyth County, a few linguloid brachiopods half a mile northwest of Holston Mill, and a few

[6] Stose, G. W., U. S. Geol. Survey Geol. Atlas, Mercersburg-Chambersburg folio (No. 170), 1909.

occurrences of cryptozoans, no fossils have been found in the Elbrook in Virginia. The *Crepicephalus* proves the uppermost part of the Elbrook to be early Upper Cambrian (Nolichucky). As will be shown farther on, the fossils of the Rutledge limestone, the equivalent of which is included in the lower part of the Elbrook, are of Middle Cambrian age.

HONAKER DOLOMITE (Ꞓhk)

The *Honaker dolomite* occurs in the middle part of the Valley in southwest Virginia, between Bristol and St. Paul, Wise County, and extends in several belts from New River to Tennessee. It differs from the Elbrook in not including any representative of the Nolichucky and from the Maryville-Rutledge sequence in the absence of the Rogersville shale.

It is prevailingly a dolomite, generally coarse, bluish or light gray, and in some areas highly argillaceous, in which it weathers to a brownish mealy clay or ocher, as shown at an exposure in the road 1½ miles northwest of Abingdon.

The thickness of the Honaker is generally about 1,200 feet, but it may be thicker in the Marion-Bristol belt, in which the width of outcrop is greater than it is in other belts.

The only known fossil of the Honaker is a cryptozoan, chertified heads of which are abundant along a narrow strip lying a mile or so north of Abingdon and extending a few miles along the strike. A thin cryptozoan zone in the lower part of the formation in that locality is indicated.

RUTLEDGE LIMESTONE, ROGERSVILLE SHALE, AND MARYVILLE LIMESTONE (Ꞓmrr)

The three formations here described are combined into one map unit, Ꞓmrr.

The *Rutledge limestone* is a blue banded limestone 250 feet thick, shown by its trilobites, *Dolichometopus, Zacanthoides,* etc., to be of Middle Cambrian age.

The *Rogersville shale* is a yellow or gray-green shale with very thin layers of sandstone which carry a few trilobites that are probably Middle Cambrian types. It is 100 to 125 feet thick and very persistent in character and thickness throughout its extent from Maryville, Tenn., to St. Paul, Va.

The *Maryville limestone* is a rather thick-bedded blue partly banded limestone about 500 feet thick. It is supposed to be Upper Cambrian. Upper Cambrian fossils have been assigned to the Maryville, but it is possible that many or even most of such forms really came from limestone in the Nolichucky shale.

The formations just described are developed mainly in Russell, Scott, and southern Lee counties, and occupy a relatively narrow belt extending southwest from St. Paul and Castlewood between Speers Ferry and the Powell Mountain syncline to Tennessee. The Rogersville disappears in the vicinity of St. Paul, and the Rutledge and Maryville limestones unite to form the Honaker dolomite. Excellent exposures of the full sequence occur along the slopes immediately southeast of the Clinch River northeast of Clinchport, Scott County, and along the extension of that belt from Clinchport to Purchase and farther southwest. The thick-bedded limestone so well exposed in the cuts along the Clinchfield Railroad between Clinchport and Hills station is Rutledge. These exposures are easily visible from the parallel highways.

NOLICHUCKY SHALE (Ɛn)

The *Nolichucky shale* is predominantly a soft greenish, yellow-weathering shale but generally changes upward into a blue banded fossiliferous limestone as much as 100 feet thick. In areas where the underlying formation is the Honaker dolomite an easily distinguishable fossiliferous limestone next above the dolomite is also included in the Nolichucky.

The thickness of the Nolichucky is about 500 to 600 feet in the southwestern part of Virginia, but it thins and disappears as a separate formation toward the Bristol-Marion-Wytheville belt and also to the northeast, where, in the vicinity of Bland and Narrows, Giles County, it is shale with thinly laminated argillaceous limestone not more than 50 feet thick. The Nolichucky crops out in several narrow strips on the northwestern side of the Valley between New River and Tennessee, and in the southern part of the State it is present as far southeast as Bristol. It is not known to extend northeast of New River but is present in the oval area of Cambrian in the vicinity of Bane, 4 miles south of Pearisburg, Giles County.

The Nolichucky is abundantly fossiliferous, and the occurrence of several species of *Crepicephalus* shows it to be early Upper Cambrian.

OZARKIAN SYSTEM[7]

CONOCOCHEAGUE LIMESTONE (Ɵc)

The *Conococheague* is a thick-bedded limestone with a small proportion of dolomite. It is especially distinguished by beds of quartz sandstone with well-rounded grains and by siliceous or argillaceous laminae in the limestone beds, which show as slightly projecting thin crinkly ribs on weathered surfaces.

[7] Uppermost Upper Cambrian of the United States Geological Survey.

The thickness of the Conococheague is about 1,500 to 2,000 feet.

The Conococheague occurs along the southeast side of the Valley from Pennsylvania through Virginia and at least halfway across Tennessee, where it has been called "Jonesboro limestone." There are two or three belts from West Virginia northeast of Frederick and Clarke counties to Roanoke in the area southeast of Little North Mountain, scattered belts and patches from Roanoke to Wytheville, Wythe County, and two or three belts between Wytheville and Tennessee.

The formation is extensively exposed. Among the best exposures are several on Route 50 between Winchester and Chambersville, Frederick County, where the beds of sandstone are especially well displayed in the road cuts. There is an excellent exposure on Buffalo Creek between Buffalo Mills and Buffalo Forge, Rockbridge County, and another complete section on Widner Branch 13 miles due east of Abingdon, Washington County.

A trilobite, *Tellerina,* occurring in close association with a sandstone bed 1 mile north of Natural Bridge, indicates an age corresponding to the lower Ozarkian of Ulrich.

COPPER RIDGE DOLOMITE (Ocr)

The *Copper Ridge* is a thick-bedded gray cherty dolomite of rather uniform character. Like the Conococheague, it is characterized by beds of quartz sandstone scattered through its full thickness, beginning in some sections close above the Nolichucky shale at the bottom and recurring at different horizons to the very top.

The thickness of the Copper Ridge is 1,200 to 1,400 feet.

The Copper Ridge crops out in six different belts northwest of Bristol. Each belt in succession from the northwest disappears northward, the first one northwest of Bristol extending farthest northeast to the vicinity of Sinking Creek in Craig County.

The best exposure of the Copper Ridge is along the new road on Buchanan Branch 3 miles southwest of Saltville, Washington County. Another good exposure is on the Clinchfield Railroad and on the highway along Troublesome Creek just north of Speers Ferry station, Scott County.

Because beds of sandstone 1 to 50 feet thick occur in both the Conococheague and Copper Ridge and in no other limestone or dolomite formation in the Valley, and because both formations are underlain by the Nolichucky and overlain by the Chepultepec (described below), they are believed to be two facies of the same formation. This conclusion is supported by the additional fact that the two facies are continuous with each other around the northeast end of Tinker Mountain north of Roanoke.

CHEPULTEPEC LIMESTONE (Och)

The *Chepultepec* is a rather pure medium thick-bedded limestone in the southeastern belts of the Valley rocks in Washington County and southward into Tennessee. It has, however, been recognized both through lithology and fossils as far north as Strasburg, Shenandoah County, where it is mapped with the overlying Stonehenge limestone (Cs). In the Rich Valley-Saltville belt in southwestern Virginia it is a limestone 20 to 30 feet thick lying between the Copper Ridge dolomite and Beekmantown dolomite and is known by its fossils from the vicinity of Greendale, Washington County, northeast to the vicinity of Saltville. Similar limestone occurs at its horizon as far northeast as Chatham Hill in Smyth County, and it is mapped to the northeast extremity of that belt near Sinking Creek, Craig County, although its persistence throughout has not been proved. Chert with Chepultepec fossils occurs 3½ miles southeast of Cumberland Gap, and the formation is represented there by dolomite of unknown but probably small thickness lying between known Copper Ridge close below and known Beekmantown (Nittany dolomite) close above. The thickness of the limestone in the southeastern belts appears to reach about 500 feet in the Abingdon region, and it seems to be of comparable thickness at Natural Bridge, Rockbridge County.

An excellent exposure of the full or nearly full thickness occurs at De Busk Mill, 6 miles northeast of Abingdon, where it is immediately overlain by thick-bedded rough surfaced, gray dolomite of the Beekmantown (Nittany). Another good exposure is on the Lee Highway (Route 11), beginning about one-fourth of a mile east of the road to Emory and Henry College, Washington County, and extending east for a mile. It is also well displayed at Natural Bridge, the bridge itself and the gorge which it spans being within the Chepultepec.

The Chepultepec age of this limestone is known from the common occurrence of cephalopods of the genera *Dakeoceras* and *Levisoceras,* and the local occurrence of the gastropod *Gasconadia.* The same age of the dolomite southeast of Cumberland Gap is known through the occurrence of the gastropod *Helicotoma uniangulata* and of the cephalopod genus *Clarkoceras.* All these genera and species are common and characteristic fossils of the Chepultepec dolomite of Alabama and of the Gasconade dolomite of Missouri.

CANADIAN SYSTEM[8]

The Canadian system in Virginia is coextensive with the Beekmantown group of the Nittany Valley of central Pennsylvania. In that region the Beekmantown includes in descending order the Bellefonte

[8] Lower or Beekmantown part of the Ordovician system of the United States Geological Survey.

dolomite, Axemann limestone, Nittany dolomite, and Stonehenge limestone and is therefore properly a group. In central Pennsylvania the Bellefonte and Nittany dolomites are separated by the fairly persistent and easily recognizable Axemann limestone, and the Stonehenge, which is a blue limestone, is thereby clearly separable from the Nittany dolomite.

In Virginia the Axemann limestone is not present as a means of separating the Nittany part of the Beekmantown from the Bellefonte part, and in the northeastern part of the Valley, as in Frederick County, where the Stonehenge appears to be thickest, the Nittany part of the Beekmantown as well as the Stonehenge part are limestone and not easily separable.

Owing to the conditions described above the stratigraphic elements of the Beekmantown in Virginia are designated and arranged as follows:

Dolomite or limestone, according to locality, equivalent to Bellefonte dolomite of central Pennsylvania (Ꞓb).

Axemann limestone absent.

Dolomite or limestone, according to locality, equivalent to Nittany dolomite of central Pennsylvania (Ꞓb).

Stonehenge limestone member (Ꞓs).

STONEHENGE LIMESTONE (Ꞓs)

The *Stonehenge* is a thick-bedded limestone. It is combined with the Chepultepec on the map. In the southern part of the Valley it constitutes a thin upper part of the combined unit that is denoted by the symbol Ꝋch, whereas in the northern part of the Valley, in Frederick and Shenandoah counties, it seems to constitute the greater part of the unit, which is therefore denoted by the symbol Ꞓs. It may range in thickness from 50 feet in the south to 100 feet or more in the north.

The Beekmantown age of this limestone in southern Virginia is indicated by the occurrence of a species of the gastropod genus *Eccyliopterus,* a genus which does not appear to be known below the Beekmantown. The Stonehenge age of this limestone in the northern part of Virginia is shown by such fossils as *Ophileta complanata* and possibly *O. hunterensis,* both of which occur in the Tribes Hill limestone of New York, with which the Stonehenge is correlated.

NITTANY DOLOMITE EQUIVALENT (Ꞓb)

The *Nittany dolomite* equivalent is a thick-bedded gray medium coarse dolomite in the southern part of the Valley but takes on more of a limestone facies in the northern part, as in Frederick County. It

yields abundant chert as far north as the latitudes of Luray, Page County, and Woodstock, but much less north of those lines.

The thickness of the Nittany in southern Virginia is about 1,000 feet northwest of Bristol but only 500 feet east of Bristol. It is probably 500 to 800 feet in the vicinity of Staunton, Augusta County, and Harrisonburg, Rockingham County. Farther north, where chert is scarce, the limits and thickness of the Nittany are not closely determined, but the thickness is probably more than 500 feet.

The Nittany is distinguished by the gastropod genera *Lecanospira* and *Roubidouxia,* which seem to be confined to it and persistently mark it from Canada throughout the Appalachian Valley, Texas, and Oklahoma.

BELLEFONTE DOLOMITE EQUIVALENT (Ꞓb)

The post-Nittany part of the Beekmantown, equivalent to the *Bellefonte dolomite* of central Pennsylvania, in the southwest part of the Valley, in the belts northwest of Bristol, is a cherty dolomite much like the Nittany; but in the belts southeast of Bristol it includes a considerable proportion of pure pearl-gray limestone. It includes much limestone in the vicinity of Staunton, and seems to become preponderantly limestone at the latitude of Harrisonburg and northward. In Lee, Scott, and Russell counties a bed of gray and red shale with layers of pinkish dolomite in and just above the dolomite probably belongs in this division.

Northwest of Bristol, where its limits are obscure, the post-Nittany Beekmantown may be as much as 200 feet thick, possibly more or less. Southeast of Bristol it seems to be less than 100 feet thick. On Middle River 2 miles north of Staunton it has increased to 1,500 feet and is not less than that north of Staunton to West Virginia. This post-Nittany part of the Beekmantown is characterized by the curious fossil *Ceratopea,* through which, as well as by other fossils and its stratigraphic position, it is correlated with the Bellefonte dolomite of central Pennsylvania and the Cotter and Powell dolomites of Missouri.

One of the best exposures of the Beekmantown, mainly Nittany equivalent, in its dolomitic facies is on the Clinchfield Railroad immediately north of Speers Ferry station west of Gate City, Scott County. It is also well exposed in quarries on New River. In its thinner development east of Bristol it is fully exposed at Vance Mill, 1½ miles southwest of Abingdon. The post-Nittany part is well exposed on Middle River 2 miles north of Staunton and at Cedar Grove Church 2 miles east of Harrisonburg. The limestone facies is also extensively exposed in the vicinity of Winchester, Frederick County, and Berryville, Clarke County.

ORDOVICIAN SYSTEM[9]

STONES RIVER GROUP (Osr)

General features.—In the southwestern counties of the State—Lee, Scott, Russell, and Tazewell—where, in ascending order, the Murfreesboro limestone, Mosheim limestone, and Lenoir limestone, are recognized, they are combined in the map unit Stones River group.

The *Murfreesboro limestone* is relatively thin bedded, with argillaceous and cherty beds in most of its extent, but in some areas, as on New River near Pearisburg, Giles County, it is a more uniform and apparently purer limestone. There it includes layers like the overlying Mosheim limestone.

The *Mosheim* in these areas is a pure light-gray thick-bedded compact limestone 20 to 40 feet thick.

The *Lenoir* is a thick-bedded, coarsely crystalline or fragmental, cherty, and dark-gray limestone 50 feet thick. It is considered to be about equivalent to the Ridley limestone of the typical Stones River group of central Tennessee.

In the Bluefield region (Tazewell County, Va., and Mercer County, W. Va.) these different components of the Stones River have not been discriminated, but as shown in the section just south of St. Clair railroad station 3 miles southwest of Bluefield (Graham), Va., there is a fairly uniform mass of blue, apparently rather pure limestone, about 1,000 feet thick that is referred to the Stones River. In Rye Cove, Scott County, and along the belt from Gate City to Tazewell a few feet of limestone, in rather thick layers full of angular chert fragments, immediately succeeds the dolomite or reddish shale at the top of the Beekmantown. These beds, together with overlying shaly and cherty limestone, in all perhaps 50 to 100 feet thick, are also referred to the Stones River. In the vicinity of Pearisburg similar dolomite with chert fragments occurs locally at the base of the Stones River group (in the Murfreesboro limestone). It is a basal conglomeratic bed made up of the débris from the underlying Beekmantown.

The Stones River limestone ranges from 50 to 1,000 feet in thickness. It is 380 feet on Yellow Branch 5 miles southeast of Rose Hill, Lee County, 400 to 500 feet at Pearisburg and Ripplemead, Giles County, perhaps 50 feet at Hansonville, Russell County, and along Route 19 from Wardell to Tazewell, and 1,000 feet at Bluefield, Va. Its areal range is in the broad belt between Clinch Mountain on the southeast and the Mississippian or Pennsylvanian areas on the northwest side of the Valley and from the northeast end of Sinking Creek Valley, 3 miles southwest of Newcastle, Craig County, to Tennessee. Among

[9] Post-Beekmantown part of Ordovician system of the United States Geological Survey.

the best exposures is one on Yellow Branch 5 miles east of Rose Hill, that already mentioned just south of St. Clair station west of Bluefield, Va., and one on New River at and just below Ripplemead.

The age of the Lenoir is believed to be about the same as that of the Ridley limestone of central Tennessee, through the occurrence of *Maclurea magna* in both. The Mosheim is below the Lenoir in Virginia, but there is no such bed below the Ridley of Tennessee. The beds below the Mosheim are therefore referred to the Murfreesboro, which underlies the Ridley in central Tennessee. This reference, and the reference of the entire sequence to the Stones River, is justified by the occurrence of such fossils as *Maclurea magna* and *Helicotoma tennesseensis* among others not yet fully identified.

Mosheim and Lenoir limestones (Olm).—Except in the areas of the Stones River just described, only the Mosheim and Lenoir limestones are present. In such areas the *Mosheim* is a pure, compact or glassy textured limestone (typical vaughanite), generally light gray, but in places it is a dark-gray rather thick-bedded limestone. In the median and southeastern belts of the Valley, where the Murfreesboro limestone is not present, the Mosheim is in contact with Beekmantown dolomite or limestone. It is generally persistent in the belts of outcrop mapped but is locally very thin or absent. It ranges from 5 to 100 feet in thickness; generally it is 20 to 50 feet. The Mosheim is notable for its large gastropods, many species having been identified by Ulrich.

Immediately succeeding the Mosheim is the *Lenoir limestone,* a dark to black, medium coarse-grained limestone, commonly full of nodules of black chert. It usually includes beds of very distinctive nodular gray argillaceous rock, which characterize it from Virginia to Alabama.

The Lenoir is generally less than 100 feet thick and prevailingly 25 to 50 feet.

The Lenoir also is persistent through the Valley from Virginia to Alabama, and has been recognized by the writer in Pennsylvania.

The Lenoir is fully exposed on Tumbling Run, one-fourth of a mile northwest of its intersection with the Lee Highway (Route 11) about 1½ miles southwest of Strasburg in Shenandoah County, in the quarry back of the railroad station at Marion in Smyth County, along the old highway 1½ miles southwest of Marion, and on the creek in Wassum Valley a few hundred feet above its junction with Walker Creek, 2¼ miles west of Marion. At the last two places occur many fine specimens of *Maclurea magna.* This distinctive fossil of the Lenoir serves to correlate it with the Crown Point limestone of the Lake Champlain region. The Crown Point is of middle Chazy age and is also characterized by *M. magna.*

Owing to their persistence, thinness, and distinctive character, the Mosheim and Lenoir limestones are mapped together throughout the Valley and designated by the symbol Olm. In Rich Valley, near Saltville in Smyth County, the Holston limestone, of the Blount group, is mapped with the Mosheim and Lenoir under the symbol Ohlm.

BLOUNT GROUP

The Blount group includes the following formations, named in ascending order: Holston limestone, Whitesburg limestone, Athens shale (and limestone), and Ottosee limestone. The recognition of this group is one of the important contributions of Ulrich to the stratigraphy of the Valley.

Holston limestone (Oh).—The Holston is a thick-bedded, coarsely crystalline light-gray to dark-gray limestone, including locally, as at Gate City, Scott County, layers blotched with reddish tints, suggesting the Holston marble of Tennessee.

In the main belts of the Holston southwest of Tazewell and northwest of Clinch Mountain, where it is mapped with the Ottosee limestone, it is 200 to 300 feet thick.

The Holston is well exposed in the Marcem quarry 2 miles west of Gate City, in the fields near Hansonville, Russell County, along and just southeast of Route 11 from Dickensonville to Lebanon, and from Wardell, Tazewell County, to the vicinity of Tazewell. In these belts the Holston is included with the Ottosee limestone under the symbol Ooh. There are extensive exposures a mile or so northwest of Lexington, Rockbridge County, along Route 60. In this locality it was named "Murat limestone" by H. D. Campbell before its identity with the Holston was established.

This limestone is known to be the Holston through its fossils, as determined by Ulrich, and by the fact that the Gate City belt is continuous with outcrops of Holston marble in the vicinity of Knoxville, Tenn.

Whitesburg limestone (Ow).—This is a coarse-grained bluish, rusty weathering, fossiliferous limestone, persistent in the belts southeast of Clinch Mountain in southwestern Virginia. It is generally 5 to 20 feet thick, but attains 75 feet at the base of Walker Mountain 6 miles southwest of Bland, Bland County. Wherever present it is mapped with the Athens shale under the symbol Oaw.

Among the best exposures of the Whitesburg is one at the northwest base of Walker Mountain, 6 miles southwest of Bland and another half a mile northwest of Lexington.

The Whitesburg is highly fossiliferous, about 175 species having been identified by Ulrich. It is notable as one of the few Ordovician

formations in which a species of the mainly Cambrian trilobite genus *Agnostus* occurs.

Athens shale and Athens limestone (Oaw), or (Oa) where the Whitesburg limestone is absent.—The Athens is a variable formation. Generally there is a black fissile graptolitic shale commonly a few hundred feet thick at the base. In the Rich Valley region southeast of Saltville, Smyth County, and southwestward as far as the southwest end of Walker Mountain it is mainly shale. At the meridian of Chatham Hill, Smyth County, and northeastward in this belt it is largely a thin-bedded black compact conchoidal limestone. In the vicinity of Harrisonburg, Rockingham County, this black limestone facies reaches its maximum development and 2 miles northeast of the town occupies a broad folded belt 6 miles wide. At the base here, however, is shale with thinly laminated shaly limestone. This rock quarried at Harrisonburg is being utilized as a black marble. At Lexington the Athens is a thinly laminated argillaceous limestone with beds of purer limestone. In Pine Ridge just southeast of Wytheville and in the several broad synclinal belts east and southeast of Abingdon, including the ridge known as the Great Knobs, there is no limestone but black shale at the base as usual, overlain by a great thickness of thick-bedded arkosic sandstone with thin partings of shale carrying the characteristic graptolites of the Athens.

In these deep synclines the Athens reaches its maximum thickness, but as no younger rocks occur and the top of the Athens is not preserved its total original thickness here is not known though it possibly reaches at least 5,000 feet in the broad belt next northwest of Holston Mountain in southern Virginia and northern Tennessee. At Lexington the thickness seems to be at least 2,000 feet. In Rich Valley, where the top and bottom are both present, its thickness is about 600 feet.

The Rich Valley belt of the Athens extends northeastward at least as far as Bland, but thins out between Bland and Poplar Hill, Giles County. The outcrop along the northwest side of the Massanutten syncline disappears south of Strasburg, Shenandoah County, but that on the southeast side of the syncline continues to the area north of Riverton, Warren County, and possibly is represented at the West Virginia line by a thin graptolitiferous shale.

The best exhibits of the shale and sandstone facies of the Athens are in the synclines southeast of Abingdon and particularly on the highway through the Great Knobs, Route 110. The best development of this facies, however, is in Tennessee just south of the State line, where it is well exposed on the Bristol-Mountain City road (Tennessee Route 34) for a distance of 4½ miles beginning half a mile northeast

of the bridge over Holston River and extending southeast to the great fault on the northwest slope of Holston Mountain, where the Unicoi formation is thrust over the Athens. The limestone facies of the Athens is best exposed at and northwest of Harrisonburg.

The Athens is known through its graptolites to correspond essentially to the Normanskill shale of New York and the Glen Kiln shale of Scotland. These horizons are characterized the world over by the *Nemagraptus* graptolite fauna represented in the Athens by *N. gracilis.*

Ottosee limestone (Oo).—The Ottosee is a prevailingly thin-bedded to nodular very fossiliferous limestone. Layers of pink marble occur in the top part in Rich Valley south of Chatham Hill, Smyth County. The Ottosee is 300 to 400 feet thick.

The formation occurs in Rich Valley with the Athens (Ooaw); also in the two belts, Ooh, northwest of Clinch Mountain, and in Rye Cove in the area denoted by the symbol Oo. In Rye Cove, Scott County, and at the southeast base of Big A Mountain 2 miles northwest of Honaker, in Russell County, the Ottosee reaches the farthest northwestward extension of any of the formations of the Blount group. The Rich Valley belt extends northeast to Bland but was not recognized in the Little Walker Creek section south of Poplar Hill. The Ottosee is mapped with the Holston limestone in the two belts northwest of Clinch Mountain under the map symbol Ooh.

The best exposures of the Ottosee are in Rye Cove. Another is on Little Indian Creek on Route 19, 2 miles southwest of Wardell, Tazewell County. Here nearly the full thickness of the formation and its contacts are shown. The contrast of its argillaceous nodular basal layers with the thick-bedded, coarse-grained Holston limestone is strikingly displayed.

Among the more notable fossils of the Ottosee are *Receptaculites, Echinosphaerites* and other cystids, all of which are fairly common.

The Ottosee corresponds to part of the Sevier shale of the type locality southeast of Knoxville, Tenn., possibly only to the basal part, and is the same as the Chickamauga limestone of the belt next northwest of Clinch Mountain as mapped in the Morristown folio.[10]

Owing to varying distribution, different combinations of the formations of the Blount group are mapped. In the two belts northwest of Clinch Mountain only the Holston and the Ottosee are present, as denoted by the symbol Ooh. In the Rich Valley belt, next southeast of Saltville, the Holston is mapped with the Lenoir and Mosheim, under the symbol Ohlm, as all three form a limestone sequence of economic value, being extensively quarried for use by the Mathieson Alkali Works at Saltville. In the Rich Valley belt also, the Whitesburg,

[10] Keith, Arthur, U. S. Geol. Survey Geol. Atlas, Morristown folio (No. 27), 1896.

Athens, and Ottosee are combined under the symbol Ooaw. In the extreme southeastern belts, where only the Athens is present, it is designated by the symbol Oa.

The Blount group may be compared to a great elliptical lens thinning out entirely in all directions from a central area marked by Knoxville, Tenn., and Bristol, Va.-Tenn. It is not present in central Pennsylvania nor in the vicinity of Birmingham, Ala. In both regions limestone of Lowville age, which overlies, so far as known in normal sequence, the Ottosee in parts of Virginia, rests upon the upper part of the Stones River group which underlies the Blount group in Virginia, with a consequent hiatus measured by the maximum thickness of 6,000 to 7,000 feet of the absent Blount group.

BLACK RIVER GROUP

Lowville limestone (Ol).—The Lowville, the basal formation of the Black River group, is a dove-colored or blue limestone, partly thin bedded or shaly, largely medium thick bedded, but some of the shaly layers are of gray lumpy, crumbly mudrock, similar, except in color, to the red mudrock of the Moccasin, next to be described. There are good exposures of the typical Lowville in the vicinity of Cumberland Gap, along the northwest slope of Wallen Ridge from a few miles south of Big Stone Gap, Wise County, to Tennessee, and in the vicinity of Crabbottom, in Hightown Valley, Highland County.

The Lowville is perhaps 1,000 feet thick at Cumberland Gap and about 350 feet in Hightown Valley. The Lowville occurs only along the northwestern side of the Valley in Lee County and north to Big Stone Gap and to Hightown Valley, which is in general strike with the Lee County area. In both regions it succeeds limestone of Stones River age, the Blount group being absent, as in central Pennsylvania and in the vicinity of Birmingham, Ala.

The Lowville is correlated with the typical Lowville of Jefferson County, N. Y., through its distinctive fossils, especially *Tetradium cellulosum* and *Beatricea gracilis,* which are present throughout Virginia.

Moccasin limestone (Om).—The Moccasin limestone is a facies of the Lowville limestone. It is characteristically a red argillaceous limestone or mudrock, but its lower 50 to 100 feet is made up of persistently blue limestone like the Lowville, with here and there layers of red rock. Also within the main mass of red rock are a few layers of pure blue limestone. This type of Moccasin prevails in the median belts from Rye Cove on the northwest to Walker Mountain on the southeast, and northeastward to Roanoke and to Sinking Creek in Craig County. About 1 mile northwest of Newport, in Sinking Creek Val-

ley, two or three beds of sandstone and fine conglomerate appear in the upper part of the Moccasin, which is there otherwise typical blue limestone below and shaly red mudrock in the upper part. This sandstone persists along the northwest base of Walker Mountain, southward to the area along the north base of the mountain west of the meridian of Clinchfield, Russell County, where the sandstone beds become more prominent, one bed near the middle of the Moccasin being a dense white quartzite apparently 10 to 20 feet thick. At the south end of Catawba (Paris) Mountain, in Montgomery County, and along the northwest base of Catawba Mountain and in the detached strips next north of Salem, the sandstone facies is especially strongly developed, the fine-grained greenish sandstone being 200 feet thick at the south end of Paris Mountain. It makes the striking knobby spurs on the northwest base of Catawba Mountain southwest of Catawba Sanatorium. This sandstone facies is also present in Crocketts Cove, 4 miles north of Wytheville, Wythe County, and in the strips of Moccasin next north and northwest of Marion.

Southeast of a line from Crocketts Cove, northwest of Wytheville, to Roanoke, the Lowville and Moccasin are absent and the still younger Ordovician Chambersburg limestone succeeds the Athens shale or the Lenoir limestone.

The thickness of the Moccasin is about 1,000 feet at Tazewell, 800 feet at the south end of Catawba (Paris) Mountain, and about 200 feet north of Salem. It thins out entirely northeastward in the Roanoke and Sinking Valley regions. The Moccasin facies is well displayed at Gate City, Scott County, Little Moccasin Gap, Washington County, and at North Tazewell, Tazewell County.

The Lowville age of the Moccasin is satisfactorily established by its stratigraphic relations and by the occurrence of diagnostic Lowville fossils, some of which, like *Tetradium cellulosum* and certain types of ostracodes, occur in the blue limestone beds intercalated in the red rock as well as in the pure blue limestone with intercalated red beds in the base of the Moccasin.

Chambersburg limestone (Oc).—The Chambersburg limestone is next in sequence above the Lowville, and in its type region, Chambersburg, Pa., is underlain by the Lowville. In Virginia, however, the Lowville is not present in the same areas as the Chambersburg, and there the Chambersburg rests upon the Athens shale or the Lenoir limestone.

The Chambersburg is a blue thin-bedded limestone, some layers of which are highly nodular. At the top in the vicinity of Strasburg, Shenandoah County, is 50 feet or so of very thick bedded argillaceous limestone. Thin beds of volcanic ash or bentonite occur in the vicinity of Strasburg. These general features seem to be constant throughout the known extent of the Chambersburg.

The thickness of the Chambersburg seems to be not more than 100 feet southeast of Massanutten Mountain; it is well determined to be 450 feet on Tumbling Run, 2 miles southwest of Strasburg, 400 to 500 feet along Little North Mountain southwest of Staunton, and more than 300 feet at its southern limit at the south base of Draper Mountain 3 miles southeast of Pulaski, Pulaski County.

The Chambersburg crops out in narrow bands along both sides of Massanutten Mountain nearly as far south as Harrisonburg, Rockingham County. Farther northwest but southeast of Little North Mountain there are detached belts nearly as far south as Buchanan, Botetourt County. The most southern known extension is in Draper Mountain southeast of Pulaski.

The best exposures are on Tumbling Run 2 miles southwest of Strasburg and in the large area surrounding Big House and Little House mountains northwest of Lexington, Rockbridge County.

A species of the peculiar fossil called *Nidulites,* scattered specimens of *Receptaculites,* and locally abundant *Echinosphaerites* characterize the Chambersburg. At the northeast end of Green Hill, 10 miles nearly west of Lexington, is a bed 5 feet thick almost entirely composed of *Echinosphaerites.* The thick bed of argillaceous limestone at the top carries the brachiopod *Christiania* and is known as the *Christiania* zone. All these fossils characterize the Chambersburg in its type locality.

TRENTON LIMESTONE (Ot)

In the Big Stone Gap-Cumberland Gap region the Lowville limestone is succeeded by limestone of Trenton age. This limestone is a medium thick-bedded rather coarsely crystalline or fragmental rock with shaly or clayey partings. It is 250 feet thick at Harrogate, Tenn., near Cumberland Gap, and 600 feet near Big Stone Gap, Wise County. This development extends southeast to the Powell Mountain ridge, in Scott County, and, with a less pronounced limestone development, to Clinch Mountain, in the Gate City region, where it is incorporated in the basal part of the Martinsburg shale.

Good exposures of the Trenton occur on the slope of the ridge just northwest of Harrogate, Tenn., near Cumberland Gap, in the road on the northwest slope of Wallen Ridge in Turkey Cove 4 miles southwest of Big Stone Gap, and on almost any road crossing Wallen Ridge or Powell Mountain ridge in Scott County. This limestone carries abundant fossils, such as the following, which occur in the limestones of Trenton age in Kentucky and Tennessee: *Dalmanella bassleri, Hebertella frankfortensis, Rhynchotrema increbescens,* and *Cyrtodonta grandis.*

REEDSVILLE SHALE (Or)

As will be shown farther on, the Martinsburg shale includes in its lower third the equivalent of the Trenton limestone just described. Where the limestone of Trenton age is removed from the Martinsburg and given the status of an independent unit, the shale remaining is called the Reedsville shale. It was erroneously called Sevier shale in the folios of the United States Geological Survey in Virginia, and in the Morristown and Maynardville folios of Tennessee.[11]

The *Reedsville* is a dark or yellow-weathering shale with thin layers of argillaceous limestone and of fine-grained sandy rock. Probably it is largely calcareous throughout in its natural unweathered condition.

The thickness at Cumberland Gap is 350 feet; near Pennington Gap in Lee County it is 450 feet; and on Wallen Ridge and Powell Mountain it is more than 600 feet.

The Reedsville is well exposed along the old road between Cumberland Gap and Harrogate, on the Louisville & Nashville Railroad half a mile northeast of Ben Hur, Lee County, and on Route 411 on the northwest slopes of Wallen and Powell mountains.

The Reedsville shale is Upper Ordovician and of about the same age as that of the Eden group and the lower half of the Maysville group of the Cincinnati region, Ohio.

MARTINSBURG SHALE (Omb)

The *Martinsburg* (called Sevier shale in some folios of the United States Geological Survey on this region) is predominantly shale with thin layers of impure fossiliferous limestone and sandstone. In the Massanutten area in the northern part of the Valley, it includes several hundred feet mainly of fine-grained, evenly bedded green sandstone. In the Massanutten syncline also it is at the base a dark-colored evenly laminated calcareous, slaty rock or shale. In the median belts of the Valley there is more limestone in thin layers in the lower part, increasing in proportions northwestward to the belts in which it becomes separable as the Trenton limestone. One or more beds of bentonite, a volcanic ash, are present in the Martinsburg, near the bottom, throughout the Valley region southwest of Lexington, Rockbridge County.

The thickness is greatest in the Massanutten syncline, though owing to structural conditions its thickness there has not been accurately determined but is estimated to be at least 3,000 feet. In the Walker Mountain and Clinch Mountain belts in southwestern Virginia its thickness is about 1,500 feet.

[11] U. S. Geol. Survey Geol. Atlas, Folios Nos. 12, 26, 27, 44, 56, and 75.

It is abundantly exposed everywhere. A very large part of it can be seen on the Lee Highway (Route 211) between New Market, Shenandoah County, and the southeast base of Massanutten Mountain, where the green sandstone mentioned above is laid open in a road cut. It is very largely exposed on Route 39 between Staunton and Fishersville, Augusta County, showing its sandy facies well on the western side of the syncline. It is nearly completely exposed on the road on the northwest slope of Catawba Mountain going down to Catawba Sanatorium, in Roanoke County, on the northwest slope of Walker Mountain between McCall Gap and Saltville, Smyth County, and on the northwest slope of Clinch Mountain between Hayter Gap and Elk Garden, Russell County. The lower beds, with much limestone and with *Cryptolithus* common, are well exposed on Buffalo Creek in the first mile or so northwest of Zollmans, about 4 miles southwest of Lexington, Rockbridge County.

The Trenton age of the lower part of the Martinsburg, with its limestone beds, is shown by the common occurrence of *Cryptolithus tessellatus, Prasopora simulatrix,* and *Diplograptus amplexicaulis.* The Eden age of the overlying shale is shown by the presence of *Dalmanella multisecta* and the less common *Cryptolithus bellulus,* and the Maysville age of the upper beds is proved by the profuse and universal occurrence at the very top of *Orthorhyncula linneyi, Byssonichia radiata,* and many other pelecypods of that horizon. This bed, with characteristic fossils and lithology, is invariably present throughout the Appalachian Valley from Pennsylvania to Tennessee.

OSWEGO SANDSTONE (Oos)

The *Oswego sandstone* in this region consists of thick-bedded greenish-gray, iron-speckled sandstone 200 feet or less to 500 feet thick. It occurs only in Little North Mountain, Great North Mountain, and Paddy Mountain, north of the latitude of 38° 30′. Two miles southeast of Rawley Springs, Rockingham County, is a high knob named the Giants Grave, which is made by a thick-bedded sandstone 500 feet thick that is probably the Oswego, and if so, is its most southwestern known occurrence. The best exposure of the Oswego is in Brocks Gap, in Little North Mountain; the first sandstone at the southeast entrance of the Gap.

The Oswego is the next formation in normal sequence, overlying the *Orthorhyncula* zone in the top of the Martinsburg, a position which it holds from central Pennsylvania to northern Virginia. There is no other formation known intervening between the two, and it is thought that the Oswego may be correlated with the McMillan formation, the uppermost formation of the Maysville group, next overlying the *Orthorhyncula* zone at Cincinnati, Ohio.

SILURIAN SYSTEM

JUNIATA FORMATION (Sj) AND SEQUATCHIE FORMATION (Ss)[12]

The names Juniata and Sequatchie are applied to two different facies of stratigraphically equivalent beds.

The *Juniata* is predominantly red shale or mudrock and proportionally less red sandstone. Some gray sandstone occurs near the top. It is a nonmarine formation through most of its extent, but in southwestern Virginia the marine Sequatchie facies is gradually introduced by a few thin layers of argillaceous limestone bearing a few fossils.

The *Sequatchie* is predominantly limestone with shale as a minor constituent. The limestone is thin bedded, partly argillaceous, and partly stained red; the shale is green or, where it forms partings in the limestone, red.

The Juniata is 700 feet thick on Lantz Mountain, west of Monterey, Highland County, but only 300 feet on Powell Mountain, Scott County, and those extremes about indicate its range in thickness. The Sequatchie is 400 feet thick at Cumberland Gap, where that facies is fully developed.

The Sequatchie facies is only developed in the Cumberland escarpment from Cumberland Gap to Big Stone Gap, Wise County, and in Wallen Ridge, Lee and Scott counties; all the other belts and areas of the formation in Virginia are of the Juniata facies.

The Juniata is well exposed at and just northwest of Clinch, Walker, Monterey, and most of the other ridges in the Valley on any of the highways. A particularly good display is on Route 835, on Lantz Mountain, 4 miles northwest of Monterey. The Sequatchie is nearly all exposed along the old road—Tennessee Route 32—half a mile southeast of Cumberland Gap.

The Juniata is considered to be the same formation as the Queenston shale in Niagara gorge. At the western end of Lake Ontario, fossils of Richmond age appear in the Queenston, including *Drepanella richardsoni.* At Cumberland Gap and at Big Stone Gap, Richmond fossils occur in the Sequatchie, including here also *D. richardsoni.* The Richmond age of the Juniata and Sequatchie seem therefore assured.

[12] Included in the Ordovician system by the United States Geological Survey.

CLINCH SANDSTONE AND TUSCARORA QUARTZITE
CLINTON FORMATION (Scc and Stc)

The formations coming under this head are combined on the map as follows:

Southwestern Virginia		*Northeastern Virginia*	
Clinton formation Clinch sandstone	(Scc)	Clinton formation Tuscarora quartzite	(Stc)

Clinch sandstone and *Tuscarora quartzite* are names applied to a well-defined sandstone or quartzite unit, the formation being called Clinch sandstone in southwestern Virginia and Tuscarora quartzite in northeastern Virginia, Maryland, and Pennsylvania. The Clinch is entirely sandstone, white or gray, and very hard and persistent. At Cumberland Gap it is a thin fossiliferous grit below; a fossiliferous limestone, perhaps corresponding to the Brassfield of Kentucky and Ohio, represents its upper part. Being generally highly inclined, it nearly everywhere makes a high ridge along its outcrop. Clinch Mountain in southwest Virginia, North Mountain in the northeast part of the Valley, and Tuscarora Mountain in Pennsylvania are a few examples.

The Clinch is 50 to 200 feet thick; 125-200 feet in Clinch Mountain and generally less than 100 feet in the ridges of Scott and Lee counties. The grit at Cumberland Gap is only about 20 feet thick.

The combined Tuscarora and Clinton interval in Massanutten Mountain in the northeastern part of the Valley, is 500 feet thick, but it is not known whether this is all Tuscarora or part of it is Clinton. In Little North Mountain to the west the thickness probably does not exceed 100 feet, and it is generally less. Probably the same is true for Great North Mountain.

From the preceding description it will be seen that the Clinch, or its equivalent, the Tuscaroa, crops out in all the ridges on the northwest side of the Valley. At Buchanan, Rockbridge County, this belt of ridges in Purgatory Mountain approaches within a mile or two of the Blue Ridge. At the south end of Walker Mountain the Clinch thins out entirely 2 miles north of Glade Springs, Washington County. At Seven Springs, the Onondaga rests upon the Juniata. The Clinch, nearly flat, caps a number of synclinal mountains of Martinsburg shale; for example, Paint Lick Mountain southwest of Tazewell, Elk Garden Mountain north of Elk Garden, Russell County, and Short Mountain of the Massanutten group east of Mount Jackson, Shenandoah County.

There are good exposures of the formation along the crests of all the main ridges. An excellent exhibit showing its ridge-making

effect is at the Narrows of New River, in Giles County, where it is exposed as the core of Peters Mountain, rising from the river to the summit of the mountain and dipping southeastward. The best exposure in Virginia is the great arch in the gorge of James River at the Iron Gate 1½ miles east of Clifton Forge, Alleghany County. The Tuscarora is exposed in the fine arches on Paddy Run and Duck Run in their gorges through Great North Mountain in southwestern Frederick County.

The Clinch and Tuscarora are wholly nonmarine in most of their extent, but fossils at Cumberland Gap and in the equivalent of the formation in Niagara Gorge prove that it is of about the same age as the Brassfield limestone of the Kentucky and southwestern Ohio region.

The *Clinton formation* is made up of shale, sandstone, and a very little limestone. The lower part, 300 feet or less, in a large area is green shale, some green sandstone, and beds of hard fine-grained, dense, deep-red sandstone which is distinctive ("Cacapon sandstone" of Darton). The higher part of the Clinton is green shale, thin green sandstone, and coarse-grained, thick-bedded gray sandstone locally, as in Rich Patch Mountain at Iron Gate, Alleghany County, where it is a nearly continuous mass 100 to 200 feet thick. This sandstone is the *Keefer sandstone* or includes a representative of the Keefer. Red shale occurs in the Clinton, as in Walker Mountain northwest of Marion and at Cumberland Gap, but is a minor constituent. Two miles southeast of Crabbottom, Highland County, the Rochester shale is represented by 20 feet of shale and thin beds of limestone. In other parts of the Valley the Clinton is more largely shale with thin beds of fine-grained, greenish or brownish sandstone. In Lee County the Clinton includes a bed or two of fossil red iron ore which has been mined on a small scale.[13]

The Clinton is present through the northwestern Valley ridges, including Little North Mountain. It thins out entirely at the southwest end of Walker Mountain within a few miles northeast of Lyons Gap which is about due west of Marion. The red sandstone beds of the lower part are mainly confined to the area between the West Virginia line and New River. The Keefer sandstone also reaches its maximum thickness in this area. The Clinton as a whole is 300 to 500 feet thick throughout most of its area. It is possible that the 500 feet of sandstone in Massanutten Mountain (Stc) includes a representative of the Clinton (Keefer).

The Clinton is fully or almost fully exposed along the Louisville & Nashville Railroad just southeast of Cumberland Gap, on the southeast slope of Powell Mountain west of Pattonsville, Scott County, on

[13] Butts, Charles, Fensters in the Cumberland overthrust block in southwestern Virginia: Virginia Geol. Survey Bull. 28, 1927.

Route 19, half a mile northwest of Holston River, Washington County, in Panther Gap west of Goshen, Rockbridge County, in the Iron Gate Gorge 1½ miles east of Clifton Forge, Alleghany County, and on the southeast slope of Jack Mountain, 3 miles east of Monterey. The Keefer sandstone is particularly well displayed at the top of the Iron Gate gorge.

The Clinton of the northern Appalachian Valley is characterized by a great abundance of Ostracoda, different genera and species of which occur only in definite zones in the formation. Noteworthy, too, is the fact that *Pentamerus oblongus,* which is abundant in parts of the Clinton of New York and Alabama, does not occur in the Valley north of Alabama and Georgia. In the shale of Rochester age southeast of Crabbottom, Highland County, *Dalmanites limulurus,* or a closely related species, occurs.

FORMATIONS OF CAYUGA AGE (Scy)

The formations of Cayuga age comprise the McKenzie formation, Bloomsburg shale, Wills Creek (?) formation, and Tonoloway limestone, in ascending order.

The *McKenzie formation* is best known in the section on Route 802, 2 miles southeast of Crabbottom, Highland County, but is probably present on the road between Doe Hill and Palo Alto, Highland County. Southeast of Crabbottom it is about 175 feet thick. It was also observed as a fissile yellow shale in the gap of Great North Mountain on Route 50, 1½ miles due east of Gore, Frederick County. The thin limestone layers of the formation and also some of the shale are crowded with small ostracodes, such as *Dizygopleura* and *Kloedenia,* which are common in the McKenzie.

The *Bloomsburg* consists of red shale and red and green, rather coarse, and medium thick-bedded sandstone. Its thickness is about 200 feet. It is best known in Great North Mountain as far south as Alum Springs, Shenandoah County, and probably extends to Fulks Run, at the south end of the mountain, though it was not observed there. It appears to be present also in Brocks Gap in Little North Mountain. It is persistent in all the ridges of the Massanutten Mountain complex. The best exposures noted are one in the gap through Great North Mountain on Route 50 and one on the southeast slope of Powell Mountain of the Massanutten group, beginning at the summit just north of the fire tower 3 miles east of Woodstock, where a thickness of 200 feet was measured. As elsewhere, the Bloomsburg is unfossiliferous and probably nonmarine.

The *Wills Creek sandstone* seems to be represented by a gray or greenish, rusty mottled, fossiliferous friable sandstone and shale. The friability of the sandstone in the weathered state indicates a calcareous

rock. The sandstone is 20 to 30 feet thick in the vicinity of Monterey and Crabbottom, Highland County; perhaps 50 feet or more thick at Craig Healing Springs, Craig County; 5 to 10 feet on the southeast slope of Clinch Mountain from the vicinity of Hayter Gap northeast to Asberrys, Tazewell County; 37 feet at Big Stone Gap, Wise County; and 25 feet on Route 411 a mile north of Pattonsville, Scott County.

The general distribution of the Wills Creek is indicated by the preceding paragraph. In addition the formation is present along the southeast slope of Powell Mountain ridge near Pattonsville and probably continues southwest along that belt to Sneedville, Tenn., where it is represented in the Sneedville limestone. The formation is well exposed on Route 802 about 2 miles southeast of Crabbottom, in a field north of the highway 1¼ miles due east of Monterey, in the gorge of Grannys Run just southeast of Craig Healing Springs, Craig County, just south of East Stone Gap, and on Route 411, a mile north of Pattonsville.

The Wills Creek at the exposures near Crabbottom and Monterey is underlain by the McKenzie and overlain by the Tonoloway. There are no red beds of Bloomsburg type in the section. At Craig Healing Springs limestone of Helderberg, probably New Scotland age, closely overlies it, but the Tonoloway may intervene. On Clinch Mountain between Tannersville, Tazewell County, and Hayter Gap it lies between the Clinton and Onondaga, and at Big Stone Gap it appears to lie between the Clinton and Tonoloway. The reference of this bed to the Wills Creek is based on the abundant occurrence of *Leperditia elongata willsensis* and the stratigraphic relations. Several species of *Pterinea* and other pelecypods are constant members of the fauna of this zone.

The *Tonoloway limestone* is a thin-bedded to laminated, dark-colored, sparingly fossiliferous limestone. It is 25 feet thick in Buffalo Gap through Little North Mountain, Augusta County; 300 feet 2½ miles southeast of Crabbottom; 200 feet at Clifton Forge in the Iron Gate gorge; 200 feet in Johns Creek gorge through Peters Hill 2 miles northwest of Newcastle, Craig County; and about 190 feet at East Stone Gap, Wise County.

As indicated above, the Tonoloway is mainly distributed along the northwest side of the Valley from Monterey to Big Stone Gap. Beds of Cayuga age that may be either Tonoloway or Wills Creek occur in Massanutten Mountain (Harshberger and Woodstock gaps) above the Bloomsburg.

Some of the best exposures of the Tonoloway are on Route 802, 2 miles southeast of Crabbottom, in the Iron Gate gorge, in Johns Creek gorge through Peters Hill, Craig County, and near the railroad trestle just south of East Stone Gap.

The Tonoloway is pretty generally marked by the ostracode *Leperditia alta.*

DEVONIAN SYSTEM

HELDERBERG LIMESTONE (Dh and Doh)

The Helderberg limestone and the overlying Oriskany sandstone are combined into one map unit, Doh; where the Oriskany is absent the Helderberg is mapped by itself under the symbol Dh. In the northern part of the area, where the Helderberg is recognized as a group, it is divided into the following units named in ascending order: Keyser limestone, Coeymans limestone, New Scotland limestone, and Becraft limestone, all being recognizable in Virginia.

The *Keyser* is all limestone at Keyser, W. Va., but shale comes into it south of Keyser and continues southward to the Monterey region, Highland County, Va. In the Hot Springs-Clifton Forge region to the south the shale is replaced by sandstone, which reaches a thickness of 100 feet (*Clifton Forge sandstone*).[13a] Both below and above the sandstone the Keyser is mainly limestone. The Keyser in Virginia decreases in thickness from a maximum of about 200 feet in the Monterey-Hot Springs region and thins out entirely apparently somewhere in Alleghany County south of James River.

The *Coeymans* is a thick-bedded limestone as much as 20 feet thick. It is not very easily recognizable in Virginia.

The *New Scotland* is mainly an impure argillaceous, nodular and cherty limestone. In the Hot Springs region a sandstone or very sandy limestone, 20 to 50 feet thick (*Healing Springs sandstone* member),[13a] 225 feet above the bottom of the Helderberg, is tentatively assigned to the base of the New Scotland. The New Scotland seems to be 250 feet thick on Jackson River 11 miles north-northeast of Covington, Alleghany County, but it is generally not more than 15 to 50 feet thick.

The *Becraft* varies much in facies. In the Hot Springs region and to the north it is predominantly a thick-bedded, coarse-grained limestone. South of James River it becomes sandy, and at and south of New River it seems to have changed almost completely to a coarse sandstone, which is probably calcareous in the fresh condition but becomes a friable sandstone on the weathered outcrop where the limy cement has been leached out. Locally, as south of Pearisburg, on Flat Top Mountain, Giles County, it carries minable amounts of manganese ore[14] in small irregular masses and stringers. South of New River it seems to be almost the exclusive representative of the Helderberg, although the New Scotland is present in the Big Stone Gap area

[13a] Swartz, F. M., The Helderberg group of parts of West Virginia and Virginia: U. S. Geol. Survey Prof. Paper 158, pp. 27-75, 1929.

[14] Stose, G. W., and Miser, H. D., Manganese deposits of western Virginia: Virginia Geol. Survey Bull. 23, pp. 134-142, 1922.

in Wise County and at Bluefield, W. Va. This sandstone has usually been identified as Oriskany, but the fossils point to its Becraft age. It is almost everywhere south of New River followed by the Onondaga limestone or chert, the Oriskany being generally absent. The thickness of the Becraft is usually as much as 50 feet, but is believed to exceed that amount in places.

The thickness of the Helderberg as a whole in Virginia ranges from 100 feet or less to as much as 400 feet, as on Jackson River between Kincaid and Greenwood north of Covington, Alleghany County.

The general distribution of the Helderberg has been sufficiently indicated in connection with the description of its members, but in addition it is present in local strips at least along the line of Little North Mountain from West Virginia to Goshen Gap, Rockbridge County, and along the same general belt to Eagle Rock and nearly to Buchanan, Botetourt County. In Brocks Gap, Buffalo Gap, and Bells Gap, the Keyser, with its sandstone bed, is present and the general succession is comparable with that of the Helderberg in the Hot Springs region, Bath County. Its intermittent occurrence north of Brocks Gap may be due to discontinuous sedimentation or to faulting. It is present though thin in Passage Creek Valley in Massanutten Mountain.

Some of the best exposures of the Helderberg are along Route 39, southeast of McDowell, Highland County; in the gorge of Jackson River between Kincaid and Greenwood, 11 miles north-northwest of Covington; along the Valley southeast of Bells Gap; and in the gorge of Jackson River at Iron Gate. The Becraft crops out in an extensive area, known as Flat Top Mountain, south of Pearisburg, Giles County, where it is well exposed in manganese mines. It is also exposed on Route 21 a mile north of Rocky Gap, Bland County, on Stone Mountain 5 miles southwest of Richlands, Tazewell County, and along the line of the old dummy railroad to the Virginia & Southwestern Railway station in the north environs of Big Stone Gap, Wise County.

The Keyser is marked by *Chonetes jerseyensis, Cladopora rectilineata,* and other characteristic Keyser fossils; the Coeymans carries the usual diagnostic *Gypidula coeymanensis;* the New Scotland is equally well distinguished by *Spirifer macropleurus* and *S. perlamellosus;* and the Becraft by *Aspidocrinus,* which is present throughout the area from Flat Top Mountain south of Pearisburg to Big Stone Gap, and by *Spirifer concinnus,* which is characteristic of the Becraft of Maryland.

ORISKANY SANDSTONE (Doh)

The Oriskany is a calcareous sandstone, generally weathering to a friable sandstone, thick bedded, rather coarse grained, in places and at some horizons abundantly fossiliferous, of uniform character through-

out except at the south end of Walker Mountain in Washington County, where it is a thin highly iron-stained coarse, friable grit.

The thickness of the Oriskany ranges from a few feet to 150 feet. It is 150 feet in Brocks Gap, Rockingham County, about 150 feet in the Monterey region, 35 feet in Panther Gap, west of Goshen, Rockbridge County, and 20 feet at Island Ford between Clifton Forge and Covington, and 20 feet near Arritts 10 miles southwest of Covington. Along the south end of Walker Mountain it occurs in discontinuous lenses not more than 5 feet thick.

The Oriskany is present throughout Little North Mountain, in areas on Great North Mountain and southward along the northwest valley ridges to James River, and still farther southwest in Alleghany County to the vicinity of Arritts. In the tangle of sandstones farther southwest to and southwest of Paint Bank, Craig County, the Oriskany has not been satisfactorily identified. The topmost sandstone in that region may be Becraft. The Oriskany is not known southwest of New River except in the south end of Walker Mountain.

Among the best displays of the Oriskany are that in the gap between Paddy and Threemile mountains west of Woodstock, Shenandoah County, that in Brocks Gap, that in the vicinity of Monterey, and those at Island Ford and Lowmoor between Covington and Clifton Forge. Along the southern part of Walker Mountain it is exposed in every road crossing the mountain from the old Bland road north of Wytheville to the abandoned road through Shannon Gap northwest of Marion.

The Oriskany carries in Virginia its typical fauna, including *Spirifer arenosus* and *Renssellaeria ovoides*. It corresponds faunally and lithologically exactly to the Ridgeley sandstone, the upper formation of the Oriskany group of Maryland and West Virginia.

ONONDAGA LIMESTONE (Don)

The *Onondaga* in southwestern Virginia, is mainly a dense, thick-bedded rugged chert on weathered outcrops. A few fresh exposures show it as a medium thick-bedded blue gray cherty limestone. At the base are a few feet of brown sandy material or gray shale with thin layers of argillaceous limestone. Some of the sandy beds weather to a yellow or brown friable and locally glauconitic sandstone.

The character described above obtains only in southwest Virginia; elsewhere the Onondaga is a shale and forms the basal member of the Romney formation, next described.

The Onondaga limestone is about 75 feet in maximum thickness according to the best measurements obtainable. These measurements were made on the southeast base of Clinch Mountain—one on Tumbling

Run 3½ miles west of Saltville, Smyth County, and another in a ravine 1 mile north of Holston and 8 miles northwest of Abingdon, Washington County. It is 50 feet thick 1 mile north of Rocky Gap, Bland County, and 5 to 10 feet thick on both Catawba Mountain and Smith Ridge in the Roanoke region.

This limestone-chert facies of the Onondaga, separately mapped, lies mainly west of the meridian of 80° 30′ and is thickest along the southeast slopes of Clinch and Walker mountains. It persists to the south end of Walker Mountain but dies out on Clinch Mountain between Little Moccasin Gap and Hilton, Scott County, where it is not present. It has been recognized in the vicinity of Mendota, Washington County. It is not exposed and probably is not present on Walker (Gap) Mountain where crossed by the road southeast of Newport, Giles County, but farther southeast it apparently extends as a thin bed northeast to the Roanoke region, where, at the reservoir dam of the Roanoke waterworks 1⅓ miles northwest of Hollins College, it lies at the base of the shale facies of the Onondaga included in the Romney and is 5 feet or more thick. There is about 1 foot of chert in Panther Gap, west of Goshen, Rockbridge County.

The fresh condition of the Onondaga limestone is exposed on Tumbling Run and in the ravine north of Holston, mentioned above. The cherty condition is abundantly displayed everywhere on the southeast slopes of Clinch and Walker mountains to the north of Abingdon and Wytheville.

The Onondaga is abundantly fossiliferous, such fossils as *Amphigenia curta, Anoplotheca acutiplicata,* and *Bollia* cf. *B. ungula* being common and *Chonetes acutiradiata, Eodevonaria arcuata,* and *Spirifer duodenaria,* being present but less abundantly than the first named.

ROMNEY SHALE (Dr)

The *Romney* is a thick mass composed predominantly of fissile black shale, lying between the Oriskany sandstone below and the greenish Brallier shale (of late Portage age) above. It includes, in ascending order, representatives of the Onondaga limestone, Marcellus shale, Hamilton formation, Genesee (?) shale, and early Portage (Naples) beds. These formational constituents have not been precisely delimited within the mass and their boundaries established. The Onondaga member at the base is a dark-colored to greenish shale weathering yellowish; locally it is black. It is present throughout the extent of the Romney. The Marcellus member is a black shale with less well-defined limits than the Onondaga but is believed to be persistent. The Hamilton member consists of dark-greenish fossiliferous shale and sandstone in the valley of Passage Creek in Massanutten Mountain (Shenandoah

County), and in the northwestern belts as far southwest as Liberty Furnace. The farthest southwestern point at which it has been recognized is 1¼ miles due southwest of Conicville, Shenandoah County, at the northeast base of the knob named Deer Head. The Genesee shale may be represented, but it has not been certainly identified. The beds of early Portage (Naples) age are dark-colored, stiff, or fissile black shale, or soft pink shale.

The thickness of the Romney is loosely estimated at about 1,000 feet. It probably exceeds that amount in the Massanutten Mountain area.

The Romney as composed above is regarded as extending southwest to the region in which the Onondaga is separated out as a limestone. In that region the black shale persists, however, but, so far as determined, includes only representatives of the Marcellus, Naples, and perhaps the Genesee. Owing to this difference in its formational composition, the name Romney ceases to be applicable, and the provisional designation, *Black shale of Devonian age* is adopted.

The Romney is abundantly exposed throughout its area, and there is no need to cite places where it can be seen.

The Onondaga member carries everywhere a number of the fossils already mentioned in the discussion of the limestone facies, such as *Anoplotheca acutiplicata* and *Bollia* cf. *B. ungula.* The Marcellus member carries *Leiorhynchus limitare* and *L. mysia;* the Hamilton member is marked by an abundance of *Tropidoleptus carinatus, Spirifer granulatus* and *Sp. mucronatus;* and the beds of Naples age by *Probeloceras lutheri, Paracardium doris,* and *Buchiola retrostriata.*

BLACK SHALE OF DEVONIAN AGE (Dbs)

In southwest Virginia the Onondaga limestone is succeeded by black shale continuous with part of the Romney. It is here provisionally designated black shale of Devonian age.

Lithologically this unit is composed predominantly of fissile black shale, but there are also beds of green and of gray shale. Its thickness has not been exactly determined but is hardly less than 500 feet generally and probably is as much as 750 feet in places.

The distribution of this unit is partly indicated by the distribution of the Onondaga, as shown on the map. Other areas are also included as, for example, the belt next north of Roanoke, in which the Hamilton is not known but in which the Onondaga is present, mainly as a shale. However, the areas in the vicinity of Monterey and Hot Springs have been called Romney, owing to previous usage, though the presence of the Hamilton has not been established.

The lower part of the black shale unit carries such fossils as *Leiorhynchus* cf. *L. limitare, L. mysia,* and *Buchiola halli* and is probably of Marcellus age. The upper part everywhere is marked by a Naples fauna, including *Probeloceras lutheri,* species of *Manticoceras, Paracardium doris, Buchiola retrostriata, Ontaria halli,* and species of *Lunulicardium* and *Pterochaenia.* The early Portage (Naples) age of the upper part of the black shale of this unit, as well as of the upper part of the Romney shale farther north, which is continuous with it, is firmly assured. Whether the Genesee is represented, or the Hamilton either, under a facies of fissile black unfossiliferous shale has not been proved.

BRALLIER (UPPER PORTAGE) SHALE (Db)

The *Brallier shale* of Portage age consists of shale and sandstone, with shale predominating. The shale is a mixture of siliceous, micaceous, stiff, thinly laminated slaty rock and of ordinary argillaceous laminated rather soft rock. The laminae of the siliceous shale are commonly crinkled or wavy on the surface. The clay shale weathers to a yellowish tint; the siliceous shale is generally stained a manganese-black on weathered surfaces. The sandstone is fine grained and greenish and occurs in very even-surfaced layers of uniform thickness throughout all exposures. These layers of sandstone are commonly from 1 inch to 1 foot thick, separated by shale, and are distributed in groups roughly estimated to extend through 50 to 100 feet of thickness. There are a few beds of sandstone 20 feet or more in thickness. The color of the fresh rock is greenish but weathered surfaces are yellowish, brownish, or rusty.

The Brallier is 3,000 to 4,000 feet thick in Bland and Pulaski counties, being 4,000 feet in the large area drained by Kimberling Creek north of Bland. Here it is the lower part of the Kimberling shale of the Pocahontas folio.[15] The thickness decreases southwestward and is about 1,500 feet at Hayter Gap 9 miles southwest of Saltville, Smyth County, 1,000 feet at Dump Creek, Russell County, and only a few hundred feet at Cassard, Scott County.

The distribution of the Brallier is apparent from the map. It is well exposed in many places. The best section is just southeast of Bastian, Bland County, where nearly the full thickness of about 4,000 feet is exposed. Other good sections are on the bluff of Cowpasture River northwest of Millboro, Bath County, and on Route 39 immediately northwest of Jennings Gap, Augusta County, and northwest of Shenandoah Mountain through Headwaters to Cowpasture River. There are generally good exposures on the roads crossing its belts of outcrop.

[15] Campbell, M. R., U. S. Geol. Survey Geol. Atlas, Pocahontas folio (No. 26), 1896.

The Brallier is very scantily fossiliferous. The few fossils are generally small pelecypods, *Buchiola* and *Pterochaenia*. It is a sparse Portage fauna. The lithology is that of the Hatch and Gardeau shale members of the Portage formation of the Genesee gorge between Portageville and Mount Morris, N. Y.

CHEMUNG FORMATION (Dch)

The *Chemung formation* is composed at the bottom of shale and sandstone similar to that of the Brallier, and there is no sharply marked lithologic change from the one to the other. However, the differences are perceptible at no great distance either above or below the boundary, which is determined by the appearance of Chemung fossils, such as *Spirifer disjunctus* and others that are unknown in the Brallier. Although it resembles the Brallier, the shale of the Chemung is more of a lumpy, poorly fissile greenish mudrock weathering yellowish; the sandstone is coarser than that of the Brallier, generally occurs in thicker layers, and is in greater proportion to the whole formation. In some areas, beds of red shale are present, as in the Elliott Knob-Crawford Mountain ridge northwest of Buffalo Gap, Augusta County, and on the west slope of Price Mountain in the east angle of Craig County. In other areas, as on Mason Creek north of Salem, Roanoke County, thick-bedded, medium-grained, compact, hard reddish or purplish sandstone is a conspicuous constituent.

In all its belts northeast of Bland County, the Chemung is estimated to be about 2,000 feet thick. It thins southwestward from Bland County and dies out in Brushy Mountain west of Marion and in Poor Valley, near Mendota, Washington County. Its fossils occur at Zenobia, 6 miles northeast of Mendota.

There are good exposures of the Chemung on the road crossing its outcrop in Frederick County west and northwest of Winchester; on the old Parkersburg pike 1½ miles northwest of Buffalo Gap where the red shale can be seen; along Mason Creek north of Salem; on Route 23 on the northwest slope of Brushy Mountain, Montgomery County; and north of Bland on Route 21, for a distance of about 1 mile northwestward, beginning on the southeast at a point 1 mile north of Bland, Bland County.

The Chemung is abundantly fossiliferous throughout its extent, such typical Chemung fossils as *Spirifer disjunctus, Leiorhynchus mesacostale, Productella lachrymosa, Leptodesma,* and *Modiola* being common, the last at the top of the formation. The Chemung corresponds to the upper part of the Jennings formation and to part of the Kimberling shale.

CATSKILL FORMATION (Dck)

The *Catskill formation* is composed almost entirely of unfossiliferous red shale and red sandstone. There are some beds of gray or brownish rock. It is not sharply separated from the Chemung because, as already said, in places there are red beds associated with the uppermost green and gray beds carrying Chemung fossils, as in western Frederick County; northwest of Buffalo Gap, Augusta County; and on the northwest slope of Price Mountain, Craig County. This transitional zone persists into central Pennsylvania.

The Catskill reaches a maximum thickness of 2,800 feet in Shenandoah Mountain, Pendleton County, W. Va.[16] It probably does not exceed 2,000 feet in Virginia and is much less than that at its southern limit, as in the vicinity of Elliott Knob, Augusta County.

In Virginia the Catskill extends southwest through western Frederick and Shenandoah counties to a southern terminus in the vicinity of Elliott Knob. The red beds referred to the upper part of the Chemung extend southwestward to North Mountain west of Catawba Sanatorium, Roanoke County, but do not occur southwest of that locality. The best exhibit of the Catskill is on the road along Dry River, Route 814, between Rawley Springs, Rockingham County, and the summit of Shenandoah Mountain.

GENESEE (?), PORTAGE, AND BIG STONE GAP SHALES (MDbp), IN PART MISSISSIPPIAN (?)

The map unit marked MDbp consists mostly of black fissile shale but in some areas includes beds of greenish-gray shale of the Brallier type. Its thickness at Cumberland Gap is about 500 feet, at Big Stone Gap 1,000 feet, and it is several hundred feet thick in the belt along the southeast base of Powell Mountain.

The shales crop out in a narrow belt from Cumberland Gap northeastward along the base of the Cumberland escarpment, through the Big Stone Gap cove, Wise County, and around the south end of Powell Mountain by way of Pattonsville, and in detached areas northeastward along the southeast base of Powell Mountain, through Hunter Valley to the vicinity of Richlands, Tazewell County. In the belt southeast of Powell Mountain there is more gray shale than elsewhere.

The beds included in this map unit are generally not well exposed. The upper and lower parts are exposed along Powell River northwest of Big Stone Gap, and there are extensive exposures in the vicinity of Duffield, Scott County, and in the vicinity of Richlands. At Big Stone Gap the lowest black shale, exposed within 100 feet above the sand-

[16] Tilton, J. L., and others, Pendleton County: West Virginia Geol. Survey County Reports, p. 176, 1927.

stone of Helderberg age, carries an abundance of *Schizobolus* and has been referred to the Genesee shale, but as the lowest Devonian black shale elsewhere, of probable Marcellus age, also carries *Schizobolus,* the reference to the Genesee is not without doubt. Above this basal black shale at Big Stone Gap is partly exposed black, dark-colored, and gray shale of Brallier type, with more black shale than the typical Brallier. The supposed Genesee and the Brallier type of shale make up the Genesee (?) and Portage parts of the unit. At the top of the unit is black and dark-colored shale with thin layers of sandstone, named by Stose the Big Stone Gap shale.[17] This shale is referred by Ulrich to the Mississippian on the evidence of conodonts and a linguloid brachiopod, *Barroisella subspatulata,* but possibly it is in part Upper Devonian.

MISSISSIPPIAN SYSTEM[18]

PRICE FORMATION (Mpr) AND POCONO SANDSTONE (Mpo)

Price and Pocono are two names for essentially the same unit—Price being used for mostly marine deposits southwest of James River and Pocono for nonmarine deposits northeast of James River.

The *Price formation* is all sandstone and shale. At Cumberland Gap it is a crumbling green sandy shale with a small thickness of red shale in the bottom part. In the Big Stone Gap and Powell Mountain regions in Wise County, there is considerable thick-bedded sandstone at the top, some of which is locally reddish, and in places it has a basal red shale a few feet thick. It is a mixture of gray or greenish sandstone and shale elsewhere as far northeast as New River. In Montgomery and Pulaski counties it carries minable beds of anthracitic coal.[19] In that general region there is at the base a fairly coarse conglomerate or conglomeratic sandstone, 20 to 50 feet thick, to which the name "Ingles conglomerate member of Price formation" has been applied in earlier reports. This name is unfortunate because the sandstone at the south end of Ingles Mountain, from which the name was taken, is Clinch sandstone. The Price outside of the coal-bearing areas is mostly marine or includes beds carrying marine fossils.

The *Pocono sandstone* is almost wholly a thick-bedded gray sandstone but has a little shale and coal. It is nonmarine.

At Cumberland Gap the Price is 300 feet thick; on Brush Mountain northwest of Blacksburg, Montgomery County, its thickness is given by Campbell and Holden as 1,700 feet; on Pine Mountain, 2 miles south of Speers Ferry, Scott County, it is 1,200 feet thick. The Pocono

[17] Stose, G. W., Big Stone Gap shale: *in* The geology and mineral resources of Wise County and the coal-bearing portion of Scott County, Virginia, Virginia Geol. Survey Bull. 24, pp. 46-53, 1923; The black shale of southwestern Virginia: Jour. Geology, vol. 32, pp. 311-315, 1924.

[18] Lower part of Carboniferous system of the United States Geological Survey.

[19] Campbell, M. R., and others, The Valley coal fields of Virginia: Virginia Geol. Survey Bull. 25, 1925.

occupies a synclinal area in a valley at and southwest of Rawley Springs, Rockingham County, but elsewhere only high ground, and its top is nowhere defined by overlying younger rocks. The maximum thickness remaining after erosion of the higher parts probably does not exceed 500 feet.

The Price crops out continuously on the Cumberland escarpment from Cumberland Gap by way of Big Stone Gap to the south end of Powell Mountain, thence northeastward in four separated narrow areas in strike through Bluefield to New River. Another belt extends along the northwest side of the Greendale syncline through Saltville, Smyth County, to the vicinity of Bland, Bland County. Still farther southeast is the irregular belt extending from Wytheville northeast to North Mountain west of Catawba Sanatorium, Roanoke County, the detached area of the Blacksburg fenster[20] (Price Mountain southeast of Blacksburg, the type locality), and the belt on the southeast slope of Fort Lewis Mountain. In some areas, as in parts of Pulaski and Montgomery counties, the formation extends beneath the surface an unknown distance southeast from this general area of outcrop and southeast of the final outcrop of the Pulaski thrust fault, having been buried in such areas by older rocks overthrust from the southeast.

The main area of the Pocono sandstone is the synclinal belt in Shenandoah and Rockingham counties, extending from North River through and a few miles north of Rawley Springs. There are also a few small hilltop areas in this region and along the State line northwest of Monterey, Highland County.

There are good exposures of the Price at Cumberland Gap, along the Clinchfield Railroad through Pine Mountain 5 miles southwest of Gate City, Scott County, in Broadford Gap 5 miles northwest of Saltville, Smyth County, and on the southeast slope of Brush Mountain on Route 23 northwest of Blacksburg.

The fossils of the Price show it to be of the age of the New Providence group of eastern Kentucky, of the Logan and Cuyahoga formations of Ohio, and through them is correlative with the Burlington limestone (of the Osage group) of the Mississippi Valley.

MACCRADY SHALE (Mmc)

In his original definition of the Maccrady, Stose[21] included in it the overlying limestone of Warsaw age, here separated as a distinct formation.

The *Maccrady* as here restricted is a red shale or mudrock with less red argillaceous sandstone. Stose believes that the salt and gypsum at Saltville are in the Maccrady.

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[20] Campbell, M. R., op. cit., p. 45 and Plate 1.

[21] Stose, G. W., Geology of the salt and gypsum deposits of southwestern Virginia: Virginia Geol. Survey Bull. 8, pp. 53-54, 1913.

The Maccrady is 50 to 60 feet thick in the Greendale syncline, where its top is defined by the overlying limestone of Warsaw age, and as much as 500 feet thick in the Pulaski-Blacksburg region, where even with this thickness, it is not known to be all present, owing to overthrust faulting.

Red rock at the top of the Price at Olinger, Lee County, and Little Stone Gap in the Big Stone Gap cove and at Horton Summit at the south end of Powell Mountain, may be Maccrady. The Maccrady is present in the north end of Newman Mountain, a quarter of a mile south of Blackwater, Lee County. There is 60 feet of red shale with sandstone at Maccrady, Smyth County, the type locality, and a thin bed extends southwestward along Holston River to Hayter Gap, and it is reported farther southwest. From Broadford northeast it thickens greatly and appears to be persistent, except where faulted out, northeastward to and beyond Blacksburg.

The Maccrady is especially well displayed at Pulaski and was originally named "Pulaski shale," a name that has been abandoned because it was preoccupied. The shale is also exposed to a thickness of several hundred feet in the road 2½ miles north of Blacksburg.

Fossils occurring in red rock at the Maccrady horizon near Horton Summit, at the south end of Powell Mountain, indicate its Osage (New Providence) age.

It is of interest that red rock of New Providence age occurs at the "Red Winds" on a road on the northwest slope of Pine Mountain a few miles southwest of Elkhorn City, Ky.

FORT PAYNE CHERT

Thin-bedded chert is present between the Price formation and the St. Louis limestone at Cumberland Gap but is elsewhere absent. It is of the character of the *Fort Payne chert,* of Osage age, present in Tennessee and Alabama, and is believed to be the feather edge of that formation. It is not mapped, and its relation to the Maccrady is unknown.

LIMESTONE OF WARSAW AGE AND ST. LOUIS LIMESTONE (Msw)

These two formations are combined into one map unit. The *limestone of Warsaw age* represents the upper and main part of the Maccrady of Stose. It is an argillaceous, shelly gray limestone that includes some calcareous sandstone.

The thickness of the Warsaw in the road section north of Greendale, Washington County, is 600 feet, and it apparently holds that thickness in the Greendale syncline. Beds referred provisionally to the Warsaw in the Msw belt at and northeast of Richlands, Tazewell County, are about 100 feet thick.

The main occurrence of the Warsaw is in the Greendale syncline, along the northwest limb of which it crops out in the Msw belt from the Tennessee line to Saltville. There is a detached area along the same belt 10 miles northeast of Saltville. It is also believed to occur in the Richlands belt but is not certainly known in the Bluefield belt or at the Narrows of New River, Giles County.

The best exposures of the Warsaw are on Route 19, 2 miles northwest of Greendale and along the road between Cedar Branch and Maccrady 1 mile northeast of Saltville.

The limestone here described is marked by such fossils as *Spirifer bifurcatus, Polypora varsoviensis,* and *Fenestralia sancti-ludovici,* all fairly distinctive Warsaw fossils. Its Warsaw age is also made reasonably sure by its position here, as in the Mississippi Valley, beneath the St. Louis limestone, next to be described.

The *St. Louis* is a thick-bedded, rather coarsely crystalline, cherty black limestone, preserving very persistently the characters distinguishing it in the Mississippi Valley and in the intermediate region.

The St. Louis differs greatly in thickness in different places. At Cumberland Gap and Big Stone Gap it consists of 5 to 10 feet of thick-bedded black limestone, included with the Gasper and Ste. Genevieve in the unit denoted by the map symbol Mdgsl. On Route 19, 1¾ miles north of Greendale it is 300 feet thick; in Baptist Valley northeast of Richlands it appears to exceed 100 feet and seems to hold that thickness to Bluefield and to New River at the Narrows.

The St. Louis is fairly persistent along the Cumberland escarpment northeastward to the Narrows of New River, but its main outcrop is along the Holston River Valley on the northwest limb of the Greendale syncline, where it succeeds the limestone of Warsaw age.

It is almost all exposed on the highway 1¾ miles north of Greendale, on Route 111 at and just south of the bridge over Holston River south of Hayter Gap, and at the Mathieson Alkali Works at Saltville. It is also fully exposed on the road on the north side of the low ridge between Cleveland and Dump Creek, in Russell County, and along the road from Baptist Valley to Bandy, Tazewell County.

The guide fossils of the St. Louis in the Mississippi Valley, *Lithostrotion canadense* and *L. proliferum,* occur throughout most of its area in Virginia. They are plentiful in the small area of St. Louis just north of Holston River, and a quarter of a mile east of the bridge on the road from Gate City to Kingston, and on the road from Cleveland to Dump Creek, on the north side of the low ridge 1 mile north of Cleveland where the St. Louis is included in the map unit Mdgsl. The beds carrying *Lithostrotion* here crop out just above the road at the sharp bend where the road turns abruptly northward in going to Dump Creek. They are rather common on the road from Baptist Val-

ley to Bandy, about 1 mile north of Baptist Valley. They occur but are scarce at Bluefield, W. Va. More prevalent is a species of *Syringopora,* probably *S. monroensis,* which is present in the thick layers of dark-colored limestone throughout the extent of the St. Louis in Virginia.

ST. LOUIS LIMESTONE, STE. GENEVIEVE LIMESTONE, GASPER LIMESTONE AND GLEN DEAN LIMESTONE (Mdgsl)

The formations composing this map unit crop out in a narrow band on the Cumberland escarpment from Cumberland Gap to Big Stone Gap, Wise County, thence around the head of Big Stone Gap cove, around the south end of Powell Mountain, and thence northeastward in detached areas to Big A Mountain northwest of Honaker, Russell County. The detached strips are caused by the faulting out of the formation along the intermediate strips.

This group of formations corresponds to the Newman limestone in the Big Stone Gap belt. The St. Louis, Ste. Genevieve, and Gasper correspond to the Greenbrier limestone of the Bluefield-Narrows belt.[22]

The St. Louis limestone has been described above.

The *Ste. Genevieve* is a thick-bedded gray partly oolitic limestone. At Cumberland Gap it is about 80 feet thick; at Bluefield, W. Va., it is more than 400 feet thick. So far as known it is persistent from Cumberland Gap to Bluefield and the Narrows on New River. It and the overlying Gasper are fully exposed at the pinnacle at Cumberland Gap, in a quarry at the southeast end of the gorge of Powell River at Big Stone Gap, and in Bluefield, W. Va., particularly at the angle of the main road (Route 21), 3 miles east-northeast of Bluefield and in a quarry just west of Nemours, W. Va., in the Abbs Valley belt. At those places, as also in the Greendale syncline, Washington County, the Ste. Genevieve and the Gasper alone compose the map unit Mgs.

The Ste. Genevieve is generally well enough marked by its guide fossil, *Platycrinus penicillus* (*huntsvillae*), throughout its extent in Virginia. It seems to correspond exactly to the Fredonia limestone of western Kentucky.

Lithologically the *Gasper limestone* is very similar to the Ste. Genevieve, and the two are separable only by their fossils. It has the same distribution as the Ste. Genevieve and is continuously exposed with the latter at the places described above. The Gasper is about 150 feet thick at Cumberland Gap, 250 feet at Big Stone Gap, and about 500 feet at Bluefield, W. Va.

[22] Campbell, M. R., U. S. Geol. Survey Geol. Atlas, Pocahontas folio (No. 21) and Tazewell folio (No. 44), 1895 and 1897.

The characteristic fossils of the Gasper are species of *Talarocrinus, Pterotocrinus serratus,* and *Pentremites godoni.* These fossils and *Platycrinus penicillus* of the Ste. Genevieve are infallible guides to the two formations from the Mississippi Valley to Virginia.

The *Glen Dean limestone* consists of shale and thin-bedded, blue limestone, alternating thick beds of limestone and shale as at Cumberland Gap or mainly bluish shale with thin layers of blue limestone scattered through it as in Big Stone Gap of Powell River.

At both Cumberland Gap and Big Stone Gap the Glen Dean limestone is 300 to 350 feet thick. It extends in outcrop from Cumberland Gap to Big Stone Gap but has not been elsewhere recognized as such. It is probably represented in the Bluefield shale of the Bluefield region, West Virginia, and in the Cove Creek limestone of the Greendale syncline, to be described. It is fairly well exposed in shallow ravines above the main limestone cliff of Ste. Genevieve and Gasper at Cumberland Gap and is almost continuously exposed on the Interstate Railroad in Big Stone Gap on Powell River.

Some of the guide fossils of the Glen Dean collected at Cumberland Gap are *Pentremites brevis, P. canalis, P. pyramidatus, Pterotocrinus spatulatus,* and *Prismopora serrulata.*

In the outcrops extending from the vicinity of Richlands, Tazewell County, through Bluefield, W. Va., to the Narrows of New River in Giles County, and also in the wedgelike area in Abbs Valley, southwest of Nemours, W. Va., the Ste. Genevieve and Gasper limestones are combined in the map unit Mgs, and for that general belt of outcrop have already been described.

In the Greendale syncline the two formations are also combined in a map unit, Mgsf, but are of a very different facies from that which they display along the northwestern belts already described. In the Greendale syncline they are composed of limestone, shale, and sandstone. Shale predominates on the weathered outcrops but appears to be largely or mostly the weathered and leached product from an argillaceous limestone. Intercalated in the shale are beds of pure limestone, largely of fragmental (crinoidal) origin. These limestone beds are most abundant in the lower or Ste. Genevieve part of the mass but occur, at least locally, at the very top in the Gasper. A very few beds of fine-grained sandstone occur. A persistent bed of red argillaceous, bryozoan limestone of importance as a horizon marker occurs 1,300 feet above the base.

The combined thickness of the two units in the Greendale syncline is about 2,300 feet, which is three to eight times their thickness in other regions, a feature in accordance with the semiclastic composition of the mass.

As this facies occurs only in the Greendale syncline, no further description of its distribution, which is obvious from the map, is needed.

Almost complete exposures are accessible on the highway south of the river south of Hilton, Scott County, along Route 19 between Greendale and the North Fork of Holston River, on the highway between Lindell and the North Fork, and along the abandoned railroad grade on Halfacre Creek 1 mile west of Plasterco, Washington County.

Platycrinus penicillus, the guide fossil of the Ste. Genevieve, extends upward to the band of red argillaceous limestone 1,300 feet above the bottom as described above, so at least 1,300 feet of the mass here described is of Ste. Genevieve age. This fossil occurs in a thick bed of crinoidal limestone immediately beneath the red bed on Route 111 a mile north of Lindell and in the same position on a private road in the first ravine southwest of Blackwells Branch at a point about 1 mile due west of Blackwell, Washington County. In limestone at the very top of the mass *Talorocrinus inflatus, T. sexlobatus,* and *Pentremites pyriformis* occur and assure the Gasper age of that part. The exact boundary between the Ste. Genevieve and Gasper in this area has not been determined.

FIDO SANDSTONE INCLUDED IN MGSF

The *Fido sandstone* is a red thick-bedded to massive, friable sandstone, probably calcareous in the fresh condition, about 50 feet thick. It occurs only in the Greendale syncline, and is a persistent bed of uniform character from Tennessee to a point about 1 mile northeast of Lindell, Washington County, where its outcrop is cut out by the Saltville fault. The position of its outcrop is marked by the boundary between the Gasper and Ste. Genevieve limestones below and the Cove Creek limestone above. Really the very distinctive and easily recognizable Fido serves as a boundary between the Gasper below and the Cove Creek above.

The Fido has yielded a few fragmentary specimens of a large *Pentremites* that can only be referred to *P. macalliei.* This fossil seems to be related to *P. obesus* of the Golconda limestone of southern Illinois and western Kentucky. The Golconda is immediately underlain by the Cypress sandstone and that by the Gasper limestone. As the Fido is also underlain by the Gasper and also carries the pentremite named above as possibly related to the Golconda *P. obesus,* it is reasonable to conclude that the Fido occurs at a horizon comparable to that of the Cypress or the Golconda.

BLUEFIELD SHALE (Mb)

The *Bluefield* is a shale with a few thin layers of limestone. It is probably highly calcareous in the fresh condition but weathers to shale,

most of which is bluish or yellow-green on extreme weathering. At Bluefield, the type locality, there are several bands of red shale in the upper 450 feet.

As originally defined by Campbell[23], at Bluefield it extends from the top of the Greenbrier limestone (Gasper limestone of present map) to the sandstone making Stony Ridge (Stony Gap sandstone of Reger). Within these limits the formation is 1,000 feet thick at Bluefield and about 750 feet on its northwestern outcrop near Pocahontas, Va.

The Bluefield shale in Virginia crops out only in the vicinity of Bluefield, W. Va., and around the northeastward-pitching synclinal area extending southwest from the Bluefield region to the vicinity of the Baptist Valley-Bandy highway in Tazewell County.

The best exposure of the shale is on Route 21, 3 miles east-northeast of Bluefield, where it is nearly all visible together with its contacts with both the underlying limestone and the overlying sandstone (Stony Gap of Reger). It is also fully exposed in the road from Pocahontas to Abbs Valley about 1 mile southwest of Pocahontas.

The Bluefield is fairly fossiliferous, fenestellid bryozoa being especially plentiful. The fossils have not been sufficiently studied to determine whether any stratigraphically distinctive forms are present. From its position above the Gasper limestone, however, it is believed to include in its lower part an equivalent of the Glen Dean limestone, which succeeds the Gasper at Big Stone Gap and Cumberland Gap, and on the same grounds it is correlated with the Cove Creek limestone of the Greendale syncline.

COVE CREEK LIMESTONE (Mcc)

Succeeding the Fido sandstone in the Greendale syncline is the *Cove Creek limestone,* so named[24] from its excellent exposures along Cove Creek 5 miles due southwest of Mendota, Washington County.

The Cove Creek is mainly a laminated argillaceous limestone, but there are some beds of fragmental, crinoidal limestone and partings of shale. The laminated limestone weathers to a stiff gray shale. Some of the purer layers of limestone weather white and make a rather conspicuous display in places.

The Cove Creek is about 1,000 feet thick. It is persistent throughout the Greendale syncline but does not occur elsewhere. It is well exposed along Route 19, beginning 3,000 feet northwest of Greendale and extending to a point 1 mile northwest of Greendale, where the Fido sandstone crops out. It is also well displayed along Cove Creek, as already said.

[23] Campbell, M. R., U. S. Geol. Survey Geol. Atlas, Pocahontas folio (No. 26), 1896.
[24] Butts, Charles, Oil and gas possibilities at Early Grove, Scott County, Virginia: Virginia Geol. Survey Bull. 27, p. 16, 1927.

Fossils are scarce in the Cove Creek limestone. A fossiliferous horizon within 200 feet of the top carries species of *Pterotocrinus* and *Archimedes communis*. *A. communis* is almost invariably present in collections of Glen Dean fossils in the Mississippi Valley and rare or doubtfully present in collections from other formations. It is not recorded by either Ulrich or Weller from post-Glen Dean formations. So its occurrence in the Cove Creek supports to some extent the correlation of that formation with the Glen Dean.

PENNINGTON FORMATION (Mp) AND HINTON FORMATION (Mh)

The Pennington and Hinton are probably the same formation under different names for different areas of outcrop. Both are almost entirely clastic and noncalcareous.

The *Pennington formation* in Virginia is composed of bluish shale, sandstone, red shale, conglomerate, and a few thin beds of fossiliferous limestone, the proportions of each constituent decreasing in the order named. At the base in the Big Stone Gap, Wise County, is 100 feet of gray sandstone, which is probably the *Stony Gap sandstone* of Reger, the basal member of the Hinton at Bluefield. A sandstone which is also probably the Stony Gap is present along the northwest slope of Pine Mountain near the crest in Kentucky. Although red shale is usually the distinctive feature of the Pennington, it makes but a small proportion of the formation in Lee and Wise counties, and none is present in the Greendale syncline. There seems to be more red shale along the Pine Mountain outcrop, and there is surely much more northeastward toward Bluefield, W. Va.

The thickness of the Pennington at Cumberland Gap is about 200 feet, at the type section north of the town of Pennington Gap, Lee County, it is about 1,200 feet, and at Big Stone Gap it is also about 1,200 feet. In the Greendale syncline it is 1,000 feet or more thick, its original thickness in that area being unknown, the upper part having been faulted out.

The Pennington crops out continuously from Cumberland Gap around Big Stone Gap Cove and the south end of Powell Mountain to the vicinity of St. Paul, Wise County, where its outcrop is interrupted for 10 miles by the Hunter Valley fault. Beyond this break is another outcrop extending to the southwest base of Big A Mountain on the Buchanan—Russell County line.

The best exposure of the Pennington observed by the writer is the type section 1½ miles north of the town of Pennington Gap. Fairly good exposures occur at Pound Gap and at Osborne Gap on Pine Mountain, along the northwest boundaries of Wise and Dickenson counties. The basal sandstone member (correlated with the Stony Gap

sandstone of Reger) is fully exposed at the tunnel on the Interstate Railroad in the Big Stone Gap of Powell River and is fully or partly exposed on the highway descending from Pound Gap to Jenkins, Ky., at the Raven Rock a short distance northeast of the road, and just north of Osborne Gap 7½ miles northeast of Pound Gap.

The Pennington is sparingly fossiliferous, but it is not fully known what its fauna may reveal as to the correlation of the formation. The occurrence of *Sulcatopinna missouriensis* in several localities indicates latest Chester age (Menard to Clore) of the Mississippi Valley, an assignment that is supported and apparently justified by its stratigraphic position above beds not older than the Glen Dean limestone. The relation of the Pennington of the Greendale syncline to the Pennington of the northwestern belts can not be considered as definitely known.

The *Hinton formation* is composed mainly of shale, sandstone, a few thin beds of argillaceous limestone, and a few very thin beds of impure coal. Red shale is in much larger proportion and much more conspicuous in the Hinton areas than in the Pennington areas, and a few beds of sandstone are reddish. The basal bed of the Hinton at Bluefield, as of the Pennington farther southwest, is the conspicuous Stony Gap sandstone member, which makes a rather high linear ridge in the northwestern environs of Bluefield, W. Va.

On the road northwest of Bluefield to Nemours, W. Va., the width of the Hinton outcrop is 1 mile perpendicular to the strike, and the average of nine measurements of the dip is 25° NW., which gives a thickness of 2,200 feet. There is no reason to suspect any duplication by undetected faults. No other determinations were made, so it is not known how far such thickness persists. The Stony Gap sandstone member at the base is 35 to 85 feet thick.

The Hinton occurs only in the syncline between Bluefield, W. Va., and Pocahontas, Va., which extends southwestward along Mud Fork to the vicinity of Richlands. There is a strip also along the northwest side of this syncline next to the Pennsylvanian rocks. Pocahontas is partly located on this strip. The best exposure of the Hinton is the one already mentioned on the road a quarter of a mile to 1¼ miles north of Bluefield (Graham), Va.

The Hinton and Pennington of the northwestern belts both carry a considerable Mississippian fauna, some of the more common fossils identified by Girty[25] being *Archimedes,* two or three species, *Composita subquadrata, Diaphragmus elegans, Orthotetes kaskaskiensis, Productus inflatus, Spirifer increbescens, Spiriferina spinosa, Spiriferina transversa,* and *Myalina,* five or six species. *Composita subquadrata,* like *Sulcatopinna* of the Pennington, is a late Mississippian fossil in the

[25] Girty, G. H., *in* Mercer, Monroe, and Summers counties: West Virginia Geol. Survey County Repts., pp. 847-851, 1926.

Mississippi and Ohio valleys and is thus an item of evidence for the late Mississippian age of the Hinton.

It is the writer's opinion that the Hinton and Pennington are the same formation, but others think the Pennington may include the equivalent of the overlying Princeton sandstone and Bluestone formation, so the name Hinton formation is used in this area.

PRINCETON SANDSTONE AND BLUESTONE FORMATION (Mbp)

The *Princeton* is a thick-bedded gray conglomeratic sandstone with quartz pebbles. It is about 30 to 50 feet thick—30 feet at Pocahontas on the northwest and 50 feet at the highway crossing 1¼ miles northwest of Bluefield, Va. It crops out in a narrow band around the syncline between Bluefield, Va., and Pocahontas, Va., and also underlies the Bluestone formation, which occupies the axial part of that belt. There is also a short strip on the northwest margin of this syncline making a narrow ridge between Pocahontas and Boissevain. The formation is well exposed in Princeton, W. Va., and vicinity. In Virginia there is a full exposure at the highway and railroad crossing of Bluestone River 1¼ miles northwest of Bluefield (Graham), Va., and it is also exposed, though rather poorly, at the village of Falls Mills to the northwest of the railroad crossing.

The *Bluestone formation* is composed below of dark-colored shale and sandstone in thin beds. The upper half is similar but includes several beds of red shale, giving it the aspect of the Hinton or Pennington. A very few thin layers of impure limestone or calcareous shale occur.

The maximum thickness of the Bluestone is estimated at 800 feet by Campbell[26] and by Reger[27] in Mercer County, W. Va. The writer measured a fairly direct section half a mile south of Lashmeet Branch, Mercer County, W. Va., and found a thickness of about 500 feet.

The Bluestone in Virginia occurs as the surface formation along the axis of the syncline between Bluefield (Graham), Va., and Pocahontas. With the underlying Princeton sandstone it extends about 20 miles southwest of the State line. Another narrow belt lies along the boundary of the Pennsylvanian rocks between Pocahontas and Boissevain. No satisfactory exposure of the Bluestone in Virginia has been observed.

A few fossils are recorded from the Bluestone as follows:[28] *Edmondia equilateralis, Allorisma andrewsi?, Parallelodon* aff. *P. micronema,* and *Caneyella richardsoni.* These are probably sufficient to prove its Mississippian age.

[26] Campbell, M. R., U. S. Geol. Survey Geol. Atlas, Pocahontas folio (No. 26), 1896.
[27] Reger, D. B., Mercer, Monroe, and Summers counties: West Virginia Geol. Survey, County Reports, p. 314, 1926.
[28] Girty, G. H., op. cit., p. 847.

PENNSYLVANIAN SYSTEM[29]

The Pennsylvanian system is represented in Virginia only by its lowest division, the Pottsville group, which is subdivided into five formations, described below in ascending order.

LEE FORMATION (Pl)

The *Lee,* the basal formation, is composed of conglomerate, sandstone, and shale, through which are distributed several beds of workable coal. In Lee and Wise counties at least there are three conglomerates or conglomeratic sandstone members 75 to 200 feet thick, at the bottom, in the middle, and at the top. These are separated by shale and thinner sandstone beds in which occur the coal beds.

In the Big Stone Gap region, Wise County, the total thickness is 1,500 to 1,800 feet, in Tazewell County 1,700 feet, and along Pine Mountain on the State line only about 800 feet.

The Lee occupies a rather wide belt of country extending from eastern Tazewell County to the Pennington Gap region of Lee County, southwest of which it continues as a narrow strip in Virginia along the summit of the Cumberland escarpment to Cumberland Gap. It occupies nearly the entire surface of Powell Mountain in Scott and Wise counties. It also makes the crest of Pine Mountain through Dickenson County and northern Wise County.

The best exhibits of the Lee are in Big Stone Gap, Little Stone Gap, and in the Breaks in the northeast corner of Dickenson County, where Russell Fork of Big Sandy River crosses the Pine Mountain belt through a deep gorge.

The Lee carries the well-known Pocahontas coals in eastern Tazewell County, as well as a few other less well known beds. There are also thinner but still minable coal beds elsewhere nearly throughout its extent.

NORTON FORMATION (Pgn)

The *Norton formation* consists of shale and less sandstone, some beds of which are conglomeratic. There are eight to ten minable coal beds.

The thickness of the Norton is 1,300 to 1,500 feet on the southeast from Big A Mountain to Big Stone Gap and 800 feet on the northwest along the southeast slope of Pine Mountain.

The Norton forms most of the surface of Buchanan and Dickenson counties and underlies all of Wise County north of St. Paul,

[29] Upper part of Carboniferous system of the United States Geological Survey. The Pennsylvanian rocks are described in detail in Virginia Geological Survey Bulletins 9, 12, 18, 19, 21, 22, 24, and 26.

Norton, and Appalachia. There are a few hilltop outliers on Powell Mountain.

Some of the best exposures are in the road north of Council in southern Buchanan County, on Fryingpan Creek three-fourths of a mile south of Bucu in Dickenson County, and in the face of the bluff above the railroad 1¾ miles east of Tacoma, Wise County.

GLADEVILLE SANDSTONE (Pgn)

The *Gladeville* is mapped with the Norton in the map unit Pgn. It is generally a medium coarse-grained gray thick- or thin-bedded arkosic sandstone, which is rather more widely distributed and more generally recognizable than other similar sandstone members of the Norton and Wise formations. Near Wise (formerly Gladeville) it is thicker bedded and more siliceous than elsewhere. It is 50 to 100 feet thick.

WISE FORMATION (Pw)

The *Wise formation* consists of shale and sandstone with coal beds, lithologically the same as the Norton formation, but the proportion of shale is higher. Locally the basal 200 feet includes several rather thick beds of siliceous sandstone. Some of the sandstone beds higher in the formation are highly arkosic. There are 17 beds of workable coal.

The thickness of the Wise is 2,000 to 2,300 feet.

The Wise is the surface formation of nearly all of Wise County north of Tacoma and Appalachia to Pound River or to Kentucky farther west. It also is the surface formation of most of the coal-bearing area of Lee County.

Very good exposures of most of the formation occur along the South Fork of Pound River and up to the summit of Black Mountain.

HARLAN SANDSTONE (Ph)

The highest formation of the Pottsville, and the youngest Paleozoic formation in Virginia, is the *Harlan sandstone.* It is mostly conglomeratic sandstone at top and bottom and shale with two coal beds between the main sandstones.

The greatest thickness of the Harlan is about 850 feet on the summits of Black Mountain on the northwestern boundary of Wise County. It is present in Virginia only on the higher summits south of the State line in the northwestern part of Wise County.

ALLUVIUM (Qal)

The alluvium shown on the map is a thick mass of rock waste, boulders, gravel, sand, and clay derived from the Blue Ridge and spread over the level ground at its foot. It is thickest and most extensive north of the latitude of Greenville, Augusta County, and in this area completely conceals the Valley rocks, except in rare and scattered small patches.

IGNEOUS ROCKS

The igneous rocks are classed as basalt and melaphyre. They occur in the form of dikes and plugs penetrating the stratified rocks as high in the series at least as the Romney shale. They may be of post-Paleozoic age and possibly contemporaneous with similar rocks occurring in the Triassic formations of the Piedmont province. Conspicuous examples are the high symmetrical knob half a mile south of Monterey, Highland County, and Mole Hill a few miles west of Harrisonburg, Rockingham County. Such intrusive rocks are widely distributed in the Valley but are most abundant in the vicinity of Monterey.

Table 1.—*Stratigraphy of the Appalachian Valley in Virginia*

Paleozoic rocks	Approximate thickness (feet)
Pennsylvanian system	
Pottsville group	
Harlan sandstone	850
Wise formation	2,000-2,300
Gladeville sandstone	50-100
Norton formation	1,300-1,500
Lee formation	800-1,800
Mississippian system	
Bluestone formation	400-800
Princeton sandstone	30-50
Pennington formation-Hinton formation	200-2,200
Stony Gap sandstone member	35-85
Bluefield shale-Cove Creek limestone-Glen Dean limestone	[a]300-1,000
Fido sandstone	50
Gasper limestone	[b]150-1,000±
Ste. Genevieve limestone	[c]80-1,300±
St. Louis limestone	10-300

[a] The Bluefield shale is about 750 feet thick, the Cove Creek limestone 1,000 feet, and the Glen Dean limestone 300-350 feet.

[b] The Gasper is 150 feet thick at Cumberland Gap, 500 feet at Bluefield, W. Va., and 1,000 feet± in the Greendale syncline.

[c] The Ste. Genevieve is 80 feet thick at Cumberland Gap, 400 feet at Bluefield, W. Va., and 1,300 feet± in the Greendale syncline.

	Approximate thickness (feet)
Mississippian system—Continued	
Limestone of Warsaw age	100-600
Fort Payne chert	15
Maccrady shale	50-500
Price formation-Pocono sandstone	300-1,700
Devonian system	
Catskill formation	1,000-2,800
Chemung formation	0-2,000
Brallier (upper Portage) shale	200-4,000
Black shale / Onondaga limestone } Romney shale	[d]1,000
Oriskany sandstone	0-150
Helderberg limestone	100-400
Becraft formation	0-50
New Scotland limestone	15-250
Healing Springs sandstone	20-50
Coeymans limestone	20-40
Keyser formation	0-200
Clifton Forge sandstone	0-100
Silurian system	
Cayuga formations	
Tonoloway limestone	25-300
Wills Creek sandstone	5-50
Bloomsburg formation	200
McKenzie formation	175
Clinton formation	100-500
Keefer sandstone	(50-200)
"Cacapon sandstone"	(50-300)
Clinch sandstone-Tuscarora quartzite	50-200
Juniata formation-Sequatchie formation	[e]300-700
Ordovician system	
Oswego sandstone	200-500
Reedsville shale / Trenton limestone } Martinsburg shale	[f]1,500-3,000
Black River group	
Chambersburg limestone	100-500
Lowville limestone-Moccasin limestone	300-1,000
Blount group	
Ottosee limestone	300-400
Athens shale	600-5,000+
Whitesburg limestone	0-75
Holston limestone	0-300

d The Black shale is 500-750 feet thick and the Onondaga is 10-75 feet.
e The Sequatchie is about 400 feet thick.
f The Reedsville is 350-600 feet thick and the Trenton is 250-600 feet.

	Approximate thickness (feet)
Ordovician system—Continued	
Stones River group	
Lenoir limestone	25-100
Mosheim limestone	5-100
Murfreesboro limestone	0-250
Canadian system	
Beekmantown dolomite: Bellefonte dolomite equivalent	100-1,500
Beekmantown dolomite: Nittany dolomite equivalent	500-1,000
Beekmantown dolomite: Stonehenge limestone	50-100
Ozarkian system	
Chepultepec limestone	25-500
Conococheague limestone-Copper Ridge dolomite	[g]1,200-2,000
Cambrian system	
Nolichucky shale	100-500
Maryville limestone, Rogersville shale, Rutledge limestone (Honaker dolomite: Elbrook dolomite)	[h]1,200-2,000
Rome formation-Waynesboro formation	2,000±
Shady dolomite-Tomstown dolomite	1,000-1,800
Basal quartzites	[i]4,800-5,600
Antietam quartzite, Harpers shale, Weverton quartzite, Loudoun formation (Erwin quartzite, Hampton shale, Unicoi formation)	
Pre-Cambrian rocks	

[g] The Conococheague is 1,500-2,000 feet thick and the Copper Ridge is 1,200-1,400 feet.

[h] The Maryville limestone is about 500 feet thick, the Rogersville shale about 100 feet, and the Rutledge limestone 250 feet thick; the Honaker dolomite is about 1,000 feet thick and the Elbrook is 1,800 feet thick.

[i] The Erwin quartzite and Antietam quartzite are 500 to 1,000 feet thick, the Harpers and the Hampton shale are about 2,000 feet thick, the Weverton quartzite is 200 to 1,000 feet thick, the Loudoun formation is 100 to 800 feet thick and the Unicoi formation is at least 2,000 feet thick.

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