O.F.

VIRGINIA DIVISION OF MINERAL RESOURCES LIBRARY

Memorandum on Three Manuscripts
by Herbert P. Woodward
December 19, 1960

1. Geology and mineral resources of the Natural Bridge region (Eagle Rock and Natural Bridge topographic quadrangles), Virginia. Manuscript prepared for and filed with the Virginia Geological Survey in 1936. 350 mss. pp., maps and figures.

2. (with A. S. Furcron) Geology and mineral resources of the Stony Man quadrangle, Virginia. Manuscript prepared for and filed with the Virginia Geological Survey in 1936, revised in 1940. 230 mss. pp., maps and figures.

PUT IN VDMR LIBRARY Feb. 15, 1977

3. Geology and mineral resources of Scott County, Virginia. Manuscript prepared for and filed with the Virginia Geological Survey in 1937. 135 mss. pp., maps and figures.

The above manuscripts were prepared by me (in the instance of No. 2, with the collaboration of Dr. A. S. Furcron) during a sort of interim period in Appalachian geology, before the newer stratigraphic work of Dr. Butts had been completed which was the turning point of the modern school of interpretation. Thus as an outcome of Butts' work, together with my own studies and the subsequent excellent work of Prouty, the Coopers, Craig, Neuman and others, the ideas of Appalachian Paleozoic stratigraphy became modernized and revalued.

The history of these manuscripts is something as follows: While I was completing my published report on the Roanoke area in 1927, Dr. Harry S. Ladd started work on the Eagle Rock quadrangle, but was diverted from this project to assume other duties. It was then suggested that I pick up his work and continue the geologic study of the Eagle Rock quadrangle which I did during the 1928-1930 field seasons. Following this it was suggested that I next undertake the geology of the Natural Bridge Special quadrangle, field work for which was completed with the summer of 1934.

Individual reports were prepared and filed with the Virginia Geological Survey for both of these quadrangles, but in 1935 Dr. Bevan requested that they be combined into a single manuscript. This was done and the above-noted report was filed with the Survey in 1936.

A small section of the Natural Bridge Special quadrangle included Pre-Cambrian crystalline rocks, and Dr. A. S. Furcron was brought in as a contributing colleague for this portion of the report. During the summers of 1935 and 1936, Drs. Furcron and Woodward were assigned to work out the geology of the Stony Man quadrangle and a manuscript was submitted by the two authors in 1938 and later revised by Woodward in 1940.

Dr. Bevan suggested next a series of informal county reports designed for public school use. The first of these, on Russell County, was published in 1938; and the above-noted manuscript for an accompanying report on Scott County was submitted for publication. A third report on Craig County was prepared to be submitted after publication of the other manuscripts.

Viewed in the light of modern stratigraphy all of the above manuscripts are outdated and obsolete, yet they were considered to be useful and adequate at the time they were prepared. As above indicated, the fundamentals of Appalachian stratigraphy and structure were changing rapidly during this period and these manuscripts seem now quite old-fashioned. I believe the mapping is reasonably accurate in terms of the units used, but the texts are obsolete and it would involve too much effort to update them now. I do not recommend their publication.

I suggest instead that they be made available in the Survey's open files to anyone who wishes to use them and that a covering statement such as this be included as a foreword.

VIRGINIA DIVISION OF MINERAL RESOURCES
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See Open File
Field Map #219

COPY 1

GEOLOGY AND MINERAL RESOURCES

OF THE STONY MAN QUADRANGLE, VIRGINIA

by

A. S. Furcron

and

H. P. Woodward

INSERT

Editor:

This manuscript of a report on the Stony Man quadrangle supersedes all other copies, having been largely rewritten and thoroughly edited as of January 1, 1940. Although the present manuscript has been prepared without reference to any previous Survey editing of an earlier manuscript, it is specifically requested that perusal and final preparation for publication be made solely upon this copy, which is a complete, new unit.

Except, possibly, for minor slips, which are difficult for one reader completely to eliminate in a paper of this length, this copy is in excellent form, and fully meets the editorial requirements of the Virginia Geological Survey. All parts of the report have been carefully redrafted, and large sections have been entirely rewritten. In its present form, this manuscript is extensively the work of one author. Of its 7 major sections, 4 are exclusively the work of Dr. Woodward. In 2 other sections, only a few paragraphs on history, relief, and copper deposits of the Blue Ridge have been redrafted from material furnished by Dr. Furcron; discussion of igneous and metamorphic rocks is his main contribution. The remainder of the manuscript, and its complete editorial revision, including all sections previously prepared by Dr. Furcron, should be credited to this writer.

Note 3 consistent changes in the spelling of topographic terms: The possessive s has been dropped from Mary's Rock, Fisher's Gap, and Beahm's Gap.

Revision of Paleozoic descriptions necessitates some alterations in the symbols used on, and the legend for, the geologic map and structural sections which the Survey already has. Revision of these should be made in accordance with the text of this manuscript. Line drawings should likewise be checked for agreement with a revised text. For the large number of photographs previously submitted, the accompanying check-list will serve as identification. For any photographs that are selected for final publication and are returned to me, I will prepare more elaborate titles.

Check might be made to include any other pertinent data relating to the final creation of Shenandoah National Park, which was in embryonic form at the time of the field survey. If more recent data are available for local mineral deposits they may be added.

Note (a) addition to the local geologic column of the Clinton-McKenzie-Wills Creek formations; (b) new use and definition of the phrase Bloomsburg redbed facies; (c) retention of the phrase Romney black-shale facies; (d) identification of Chepultepec rather than Stonehenge limestone; and (e) differentiation of the basal Cambrian quartzite into Loudoun (eastern) and Weverton (western) members of correlative age. If these terms or interpretations are not approved by the Survey, footnotes to that effect may be added. Dr. Furcron should be consulted for whatever revision he wishes to make in descriptions of pre-Cambrian rocks.

I should like to see this manuscript published with a minimum of alteration.

Herbert W. Woodward

January 15, 1940

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Legend

To Accompany Geologic Map of the

Stony Man Quadrangle

SEDIMENTARY ROCKS

Devonian System

Romney-Onondaga shales (Dro)
Dark-gray to black shales of middle-late Devonian age (Romney black-shale facies) overlying yellow-green Onondaga shales of middle Devonian age.

Helderberg limestone (DShc)
Impure cherty limestones of early Devonian age; mapped with Cayugan (upper Silurian) limestone below.

Silurian System

Tonoloway-Wills Creek limestone (DShc)
Thin-bedded slabby limestone above (Tonoloway) and sandy shale and limestone below (Wills Creek); of Cayugan age; mapped with Helderberg limestone above.

Bloomsburg, McKenzie (?), Clinton formations (Sbcl)
Redbed facies of red shale and sandstone, above gray and brown Clinton sandstone; of middle Silurian age.

Tuscarora sandstone (Stc)
Gray quartzitic sandstone; of Medina (early Silurian) age.

Ordovician System

Martinsburg shale (Omb)
Calcareous and sandy shales and thin sandstones; of Trenton, Eden and Maysville age (middle and late Ordovician).

Chambersburg limestone (Oc)
Thin-bedded knobby dark limestone; of Black River (middle Ordovician) age.

Athens shale (Oa)
Black shales and dark slabby limestone; of Blount (lower Ordovician) age.

Lenoir-Mosheim limestones (Olm)
Dark-colored knobby Lenoir limestone above pure dove-colored Mosheim limestone; of Stones River (lower Ordovician) age.

Canadian Rocks

Bellefonte (?) dolomite (Ꞓb)
Massive dolomite and magnesian limestone; of late Canadian (Beekmantown) age.

Nittany (?) dolomite (Ꞓn)
Massive and irregularly bedded dolomites; of middle Canadian (Beekmantown) age.

Ozarkian Rocks

Chepultepec limestone (Ozch)
Heavy-bedded limestone and magnesian limestone; of late Ozarkian age.

Conococheague limestone (Ozc)
Limestone, dolomite, and calcareous shale; rare arenaceous zones; of middle Ozarkian (late Cambrian?) age.

Cambrian System

Elbrook limestone (Ꞓel)
Thin-bedded gray limestone and dolomite with interbedded calcareous shales; of late Cambrian age.

Waynesboro shale (Ꞓw)
Variegated shale and thin limestone; chiefly red; of early and middle Cambrian age.

Tomstown dolomite (Ꞓt)
Massive-bedded dolomite; of early Cambrian age.

Antietam sandstone (Ꞓa)
Irregularly bedded quartzitic sandstone; of early Cambrian age.

Harpers shale (Ꞓh)
Finely laminated sandstone and gray phyllitic shale; of early Cambrian age.

Basal Cambrian quartzite (Ꞓbq)
Sandstone, quartzite, arkose, shale, and phyllite (Weverton formation) west of the Blue Ridge crest; phyllites and quartz schist (Lemdown formation) east of the Blue Ridge crest; of earliest Cambrian age.

IGNEOUS AND METAMORPHIC ROCKS

Triassic

Diabase and basalt dikes (Trd)
Narrow dikes of basic igneous rocks; chiefly east of the Blue Ridge crest; of Triassic age.

Cambrian

Lower Cambrian amygdaloid (Ꞓam)
Red-brown to brown lava flows; commonly amygdaloidal; between basal Cambrian sediments and either greenstone or granodiorite; of earliest Cambrian age.

Pre-Cambrian

Catoctin greenstone (cg)
Basaltic flows, chiefly altered to epidote, quartz, etc.

Hypersthene granodiorite (hgd)
Massive granodiorite, rich in hypersthene, intrusive into Catoctin greenstone; garnet-bearing facies shown with red dots; with unseparated Old Rag granite shown in purple (hgi); unakite phase shown in red (hgdu).

Old Rag granite (org)
Pink epidote-bearing granite shown in red; garnet-biotite facies indicated with red dots; intrusive into Catoctin greenstone.

Lovingstone gneiss (lgn)
Gneiss derived from granite and quartz monzonite; intruded by hypersthene granodiorite and Old Rag granite; intrudes Catoctin greenstone.

GEOLOGY AND MINERAL RESOURCES

OF THE STONY MAN QUADRANGLE, VIRGINIA

By A. S. Furcron and H. P. Woodward

ABSTRACT

The Stony Man quadrangle is an area of about 240 square miles in central-northern Virginia. This report describes its topography, areal geology, geologic structure, geologic history, and mineral resources.

Topography.- The region holds both lowland and mountain country, extending from Massanutten Mountain and Page Valley at the northwest to the Blue Ridge at the east and south. Elevations range from 650 to 4,049 feet above sealevel, and the area drains into Potomac and Rappahannock rivers. An upland surface (Schooley peneplane) above the 3,000-foot level, is conspicuous on the Blue Ridge summit; the Valley-floor (Harrisburg) peneplane, at about the 900-foot level, occupies Page Valley. Both have been considerably dissected. The climate is pleasant, and soils of the valley lowland are fertile. Interesting scenic features--Skyline Drive in Shenandoah National Park, and Luray Caverns--attract many visitors to this area.

Areal geology.- The rocks of the quadrangle comprise pre-Cambrian crystalline rocks, a lower Cambrian lava flow, Paleozoic sedimentary rocks, intrusive ~~Triassic~~ Cambrian? basalt, and Quaternary surficial deposits.

The crystalline rocks include the Catoctin greenstone and several varieties of intrusive granitoid rocks--hypersthene granodiorite, Old Rag granite, etc.; the highly metamorphosed Lovingston gneiss occupies part of the eastern Blue Ridge Province. Notable also is the occurrence of unakite. The sedimentary rocks have at their base an early Cambrian lava flow, which is overlaid by a lower Cambrian arenaceous series--Weverton, Harpers, and Antietam clastic rocks--and a late Cambrian calcareous group--Tomstown, Waynesboro, and Elbrook formations. Early Cambrian sediments (Loudoun formation) also occur east of the main Blue Ridge crest. Above the Cambrian system (restricted) is a carbonate sequence consisting of the Conococheague formation, Chepultepec limestone, Nittany (?) dolomite, and Bellefonte (?) dolomite of Ozarkian and Canadian age. The Ordovician section (restricted) includes the Mosheim, Lenoir, Athens, Chambersburg, and Martinsburg formations in ascending order. Silurian rocks are represented by the Tuscarora, Clinton-McKenzie, Bloomsburg, Wills Creek, and Tonoloway formations. The incomplete Devonian section includes Helderberg limestone (with Keyser and Coeymans members), Onondaga shale, and the Romney black-shale facies of middle and late Devonian age. For many of the Silurian and Devonian rocks, Massanutten Mountain is the easternmost exposure. Quaternary materials, which blanket much of the bedrock, are conspicuous in numerous broad alluvial fans west of the Blue Ridge, and in widespread alluvial and residual soils.

<u>Geologic structure</u>.- The Paleozoic and older pre-Cambrian rocks are closely folded and faulted. ~~The latter~~ PreCambrian rocks form the Blue Ridge massif,

on the west flank of which are Cambrian quartzites that dip west and northwest under the Paleozoic carbonate rocks of Page Valley. The Blue Ridge overthrust fault passes through the foothill belt west of the Blue Ridge, where several smaller displacements also occur. Most of the rocks of Page Valley show dips toward the southeast and reveal an extremely close folding in which all structures possess axial planes that are inclined southeastward. Part of the Massanutten Mountain syncline crosses the northwest corner of the quadrangle.

Mineral resources.- The chief mineral resources are stone, limonite, and manganese ore; copper and ocher were formerly mined; underground water ~~is plentiful~~ problems are discussed -

INTRODUCTION

LOCATION AND AREA

This report describes a quadrangular area in central northern Virginia. (See Pl. .) The western part is mostly in Page County; parts of its eastern third are in Rappahannock and Madison counties; the northwestern corner extends slightly into Shenandoah County. The area is that of the Stony Man topographic quadrangle of the United States Geological Survey topographic atlas. (See Pl. .) It is bounded on the east and west by meridians of 78° 15' and 78° 30' West Longitude respectively, and north and south by parallels of 38° 45' and 38° 30' North Latitude respectively. It is approximately 13.7 miles wide in an east-west direction and 17.4 miles long in a north-south direction. Throughout the text of this report the phrase

Stony Man quadrangle refers to the land area portrayed in the map--scale 1 : 62,500--of that name.

NATURE OF THE REPORT

In 1932 the Virginia Geological Survey assigned the present authors to a geologic survey of the Stony Man quadrangle. A field program, begun in the summer of 1932, brought both authors into the area during the latter part of that season; the main field work was completed in the summer of 1934.

The geologic map of the quadrangle and an accompanying manuscript report were prepared and filed with the Survey early in 1935. This manuscript report was thoroughly revised and largely rewritten in December, 1939.

This report is a guide to the natural resources and geologic features of the Stony Man region. In view of the recent creation of Shenandoah National Park, it is hoped that the report may aid Park visitors to a better understanding and appreciation of the many features of the area described. Present and future possibilities of the natural resources of this region are discussed; a geologic map (Plate 1) shows the outcrop of the various rock formations of the region. Structural sections (Pl.) show the relations of these formations below ground; and the report contains discussions of surface features, rocks, and other ~~points~~ matters of geologic interest.

~~Descriptions of sedimentary rocks are made by Dr. Woodward; and those of igneous and metamorphic rocks are made by Dr. Furcron; other portions of the original manuscript were jointly prepared. Revision of the latter in December, 1939--save for the chapter on pre-Cambrian rocks--is the work of Dr. Woodward.~~

ACKNOWLEDGMENTS

~~Both~~ The authors are indebted to many sources for material presented herein. No small aid came from local residents who courteously coöperated in allowing free access to their property and furnished much information that would have been difficult otherwise to obtain. The authors have likewise drawn freely upon geologic literature dealing with this region. For cordial support and valuable geologic advice, they are indebted to Dr. Anna Jonas Stose and Dr. Charles Butts of the United States Geological Survey, and to Dr. Arthur Bevan, State Geologist of Virginia.

Mr. Robert A. Laurence, now geologist for the Tennessee Valley Authority, assisted Dr. Woodward in the field season of 1932; Dr. Robert L. Bates, now geologist for The Texas Company, acted in a similar capacity in 1934.

Mr. William M. Austin, resident engineer, U. S. Bureau of Public Roads, in charge of engineering and road work within Shenandoah National Park at the time of the field survey, gave cordial support during construction of Skyline Drive. Mr. L. Ferdinand Zirkel of Luray contributed data regarding springs, and other information. Messrs. T. C. Northcott and C. C. Logan, respectively president and superintendent of Luray Caverns Corporation, kindly allowed free access to Luray Caverns, and supplied data and photographs elsewhere acknowledged in the report.

SELECTED REFERENCES

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LAND FEATURES

DESCRIPTIVE GEOGRAPHY

TOPOGRAPHY

The Stony Man quadrangle is located in central-northern Virginia (Pl.), where its eastern and southern portions occupy a rugged section of the Blue Ridge. Its northwest third falls in Page Valley (Pl.)--an isolated alcove of the Valley of Virginia, which is separated from the latter by the long Massanutten range. A short part of this range crosses the northwest corner of the quadrangle. Page Valley is a fertile lowland bounded on the south and east by the

Blue Ridge and its foothills; on the northwest it adjoins Massanutten Mountain. Although a true part of the Appalachian Valley, its virtual isolation from the main lowland gives Page Valley its own geographic setting. Its widest portion, near Luray, is 7 miles across; elsewhere it narrows to less than 2 miles. It is drained by South Fork of the Shenandoah whose meandering course dissects the western side of the lowland.

The southeastern two-thirds is astride the Blue Ridge, the crest of which separates Stony Man quadrangle into two almost equal divisions. The west Blue Ridge slope descends abruptly to Page Valley with a low range of foothills--Hershberger (Pl.), Varner, Piney, and Hoak hills--at its foot. The drop to Page Valley, a matter of nearly 3,000 feet, is an escarpment as precipitous as occurs anywhere along the length of the entire Blue Ridge. (See Pls. .) East of the summit, slopes a mountainous piedmont of irregular relief, for the Blue Ridge descends less abruptly in this direction than on its western front. (Pl. .)

Several gaps through the Ridge have variously served as thorofares between Page Valley and eastern Virginia. Thornton Gap, elevation 2,304 feet, the lowest, now holds U. S. Highway 211, the Lee Highway; Fisher Gap, elevation 3,061 feet; and State Highway 231 to cross the ridge; Beahms (2,499 feet) and Milam (3,257 feet) gaps are not in present use.

The Stony Man area is sparsely settled. Luray, seat of Page County, is its largest town with a population of about 1,500 inhabitants. Other villages are Stanley (population about 260), Marksville, Blaineville, Kimball, and Vaughn, all of which lie

west of the Blue Ridge front. Only the small settlement of Nethers, and a few other scattered hamlets are east of the Blue Ridge crest. Deep mountain "hollows" are still dotted with cabins, but those settlers who can have moved to more fertile valley lowlands.

The Shenandoah Division of the Norfolk and Western Railway passes through Stanley, Luray, Kimball, and Vaughn. U. S. Highway 211, widely known as Lee Highway, carries a constant stream of traffic across the quadrangle. The newly constructed Skyline Drive, following the top of the Blue Ridge, amply repays with magnificent scenery, the thousands of motorists who visit Shenandoah National Park. State Highway 340 connects Luray with Elkton at the south and Front Royal to the north, while State Highway 266 crosses Massanutten Mountain from Luray to Edinburg. Several other roads are improved or macadamized, and many connecting roads have all-weather surfaces. Most of the back mountain roads, however, are still unimproved and are practically impassable after heavy rains.

HUMAN HISTORY

Blue Ridge Area

In the earliest days of Virginian settlement, English colonists located in tidewater and eastern Virginia, for the crest of the Blue Ridge was a barrier to westward migration. Later, when the Valley of Virginia was settled, the ridge served to separate the German pioneers in the Valley lowland from the English colonies of the Piedmont and Coastal Plain.

Some early pioneers who ascended the valleys of east-flowing streams, took over the east Blue Ridge slope as early as the close of the 17th century. More adventuresome hunters and Indian fighters

crossed the ridge, but while some lingered in the Valley, most passed west to what is now Ohio, Kentucky and Tennessee. Early in the 18th century, German Protestants came up the Valley from Pennsylvania, and settled Page Valley and the Luray region shortly after 1730.

Most of the early English settlers came to this part of the Blue Ridge, up the Rapidan and Rappahannock; some of the earliest came from Culpeper. It is believed that the first important settlement was at Avon Hall in the "Manor of Avondale," site of the present town of Washington, There is good reason to believe that the latter was surveyed by George Washington [1] in 1749,

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[1] Baggarly, F. C., History of the town of Washington, Virginia: published by the corporation, Washington, Virginia, n.d.

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although it was not until December, 1796, that the town was established by act of Assembly; whereupon 25 acres of land belonging to John Calvert, James Jett jr., and James Wheeler was laid off in lots.[1] The population of Washington in 1930 was 250 inhabitants.

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[1] Eckenrode, H. J., personal communication to A. S. Furcron, 1934.

Territory around Thornton Gap was granted to Francis Thornton at an early date, and small English and Scotch-Irish settlements occupied the Blue Ridge hollows between 1750 and 1800. Here grew large families, but the more adventuresome or energetic descendants always moved away to better lands. Thus, at the heads of the more remote hollows, social development has long remained at a standstill. It is practically impossible to wrest a living from these sections by agriculture alone; and a ruthless destruction

of timber during the last 50 years has left the hill people practically destitute. Small trees have been stripped for tan bark; forest fires have devastated the larger timber,, and blight has (now) destroyed the chestnut trees. Game disappeared with the oak and chestnut, first the elk, panther, bear; later the wild turkey and grouse. (Far up the dark winding hollows, generations of intermarriage and isolation have fostered social retrogression among the people) Many residents of the mountain hollows are now squatters without legal title to their patches of corn and potatoes. They live in small log-huts, pay no taxes, have no schools, attend no churches, and neither court nor relish contact with the outside world. Though they sing no ballads of 17th Century England--traditions of their hardy forebears are largely forgotten--their speech still reveals stilted phrases of the language of their ancestors.

At a fairly early date, the English and German settlements were connected by roads through Thornton and Milam gaps. The Warrenton and New Market Turnpike Company was chartered February 21, 1817; and the New Market Turnpike Company (was chartered) in 1819, to build a road between Thornton and Massanutten (New Market) gaps.

Page Valley

The Great Valley was a hunting ground and highway for Indian tribes long before the advent of white men; indeed, the Valley Pike, U. S. 11, follows the general course of an old Indian road. Another Indian trail connected Shenandoah and Page valleys across New Market Gap, and may have extended to the Piedmont by way of Thornton Gap. Its route today is that of the Lee Highway.

At the time of first white settlement, the Valley was only periodically occupied by Indian hunters. Early Quakers who wished to buy land in Page Valley could find no Indian tribe that admitted prior claim to the soil. As fires, even before colonial settlement, had all but destroyed its timber, much of the Valley was a pasture for buffalo, elk, deer, and small game. One pioneer reported grass so high in Page Valley that he could tie it before him as he rode along on a horse.

Indian mounds or burial grounds were once common. Kercheval[1]

[1] Kercheval, Samuel, History of the Valley of Virginia: p. 57, Samuel H. Davis, Winchester, 1833.

has described some mounds near Hawksbill Creek, a few miles above Luray, that covered a quarter of an acre of ground. One of these near the mouth of the creek, although reduced in dimensions by plowing, was 12 to 14 feet high and 60 yards in circumference when examined by Kercheval[1] who reported:

[1] Idem.

> "It is found to be literally filled with human skeletons, and at every fresh plowing a new layer of bones is brought to the surface. The bones are found to be in a calcareous state, with the exception of the teeth, which are generally sound. Several unusually large skeletons have been discovered in this grave."

John Lederer, a German explorer, is said to have reached the vicinity of Front Royal in 1670, and Louis Michelle and others, entering the Valley near Harper's Ferry, reached this district in 1707. Michelle's map of the then-explored region was republished 1921.[1]

[1] Kemper, Charles E., Documents relating to early projected Swiss colonies in the Valley of Virginia (1706-1709): Virginia Mag., vol. 29, January, 1921.

Colonization of the lower valley took place in 1731 when ~~Josh~~ Jost Heydt (or Hite) and Robert McCoy purchased 100,000 acres of land. The first waves of colonists were German emigrants that outnumbered the few early Scotch-Irish pioneers. A German settlement sprang up near Massanutten, a short distance west of this quadrangle, opposite the east entrance to New Market Gap. (Pl. .) It is said that the Germans lived amicably with the Indians until the outbreak of the French and Indian War, when the friendly Indians suddenly left the Valley to make an alliance with more hostile western tribes. Braddock's defeat in 1755 was followed by a period of Indian raids and massacres. Fortified log and stone houses near Luray, built during this period, have been described by Wayland.

Wayland, John W., History of Shenandoah County, Virginia: p. 56, 74, Shenandoah Publishing House, Strasburg, Virginia, 1917.

Some still standing were erected above cellars vaulted with stone to form "cellar forts."

The Redwell iron furnace, built in 1781 on Hawksbill Creek near the site of Luray, was operated until about 1799, and a traveler in 1808 reported several other furnaces between Thornton Gap and New Market. Settled (Located) near the site of an ancient Indian village, Luray was laid out as a town in 1812, and settlement prospered rapidly as ~~the~~ Page Valley became a rich farming district.

Page Valley was variously occupied by soldiers of both the Confederate and Union armies during the War between the States. General Stonewall Jackson, entering several times during his campaigns, crossed from New Market to Luray on May 21, 1862; he attacked Kenly at Front Royal on the 23rd, and two days later drove Banks out of Winchester. He returned in November, 1863,

with a corps of 25,000 men, and marched from New Market to Stanley and thence across the Blue Ridge at Fishers Gap along the old Gordonsville Pike.

Not far south of the town limits of Luray is a small cave on the east bank of Hawksbill Creek that furnished saltpeter to the armies of Lee and Jackson. Three miles south of Luray is a locally historic spot where one of Sheridan's raids was temporarily repulsed; twelve miles from Luray is the Millford battlefield, where entrenchments of both Federal and Confederate armies are still visible.

what direction

Directly south of the quadrangle at the head of Rapidan River is the President's Camp, established in 1929 and occupied for a time by President Hoover. It ~~stands~~ is situated in a beautiful and unmolested portion of the Blue Ridge between two small streams that form the headwaters of the Rapidan River. Community schoolhouse (Pl.), donated by the Hoovers to the mountain people, is near this camp. St. George and St. Luke missions are located at the head of Hawksbill Creek in the southwestern corner of the quadrangle, where they ~~are~~ maintained by the Protestant Episcopal Church of Virginia.

Transpose to page 15 This not in Valley

On Michelle's map of about 1709, Massanutten Mountain is called "Cenuntua," which may be the first English spelling of "Senantoah" or Shenandoah. Wayland finds 27 spellings of Shenandoah, which is generally supposed to mean "daughter of the stars." Heckwelder says it is derived from "Schindhandowi," which was

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Heckwelder, John, On Indian names: Amer. Phil. Soc. Trans., new ser., vol. 4, p. 327, 1834.

the Indian name for the river. He was so informed by White, a Nanticoke chief born in Maryland. According to White, the word is of Delaware origin, and means "sprucy stream," or "stream passing by spruce pines."

Massanutten Mountain is said first to have been called "Buffalo, or Peaked Mountain," while the term Massanutten was then applied to New Market Gap. The word Massanutten means "oblong basket," derived, perhaps, from the shape of Powell's Fort Valley in the Massanutten range.

The origin of the name Luray is not known. One authority states that it is an Indian name of forgotten meaning; another that it is a corruption of "Lorraine." A third explanation, based partly upon folk-lore, derives the name from Lew Ramey, a blacksmith and influential man who lived at Luray in 1812.

SHENANDOAH NATIONAL PARK

For some time prior to 1924 a great national park was desired within easy reach of the larger metropolitan areas of the East. To aid this end, the Southern Appalachian National Park Commission, created in 1924, was charged with finding a suitable park-site in the Appalachian Mountains. After study of the entire eastern cordillera, a site was chosen in the northern Blue Ridge of Virginia, and the name "Shenandoah National Park" was selected. A bill to create this Park was presented to Congress in 1926. Approved by both houses and signed by President Coolidge, this measure provided that the Federal Government survey the area and made necessary appropriations for that purpose.

Before the Park could be established, however, a serious obstacle had to be overcome. Land destined for the Park was mainly in private possession; and, as the Government has a precedent against buying land for National Parks, it was necessary for the State of Virginia to acquire the property. More than $2,000,000 was pledged by the citizens and Legislature of Virginia, and land purchases begun through the assistance of a group of interested citizens were continued until all property to be included within the Park was entirely procured.

Shenandoah National Park embraces an area of 327,000 acres in a roughly rectangular block of mountain country extending along the crest of the Blue Ridge from Front Royal at the northeast to Rockfish Gap at the south. Nearly sixty-five miles long, ~~it~~ and varies from 6 to 17 miles wide. It is within a three-hour ride ~~from Washington~~, and may be reached overnight by forty million people. It is readily accessible by rail and improved motor highways from all parts of eastern United States, and its own network of roads and trails connects with State and Federal highways in Virginia.

The most spectacular feature of this network is Skyline Drive, a modern macadamized road along the crest of the Blue Ridge. This route intersects four main highways: State Highway 3, near Front Royal; Lee Highway, U. S. 211, at Thornton Gap; the Spotswood Trail, State Highway 4, at Swift Run Gap near Elkton; and Jefferson Highway, State Route 5, at Waynesboro. Skyline Drive is one of the unique highways of the United States. It follows the Blue Ridge summit (Pls.) at an average elevation of nearly 3,000 feet, ~~and ascends~~ higher at many points;

its construction is an engineering accomplishment of high merit. Notable is the tunnel through a spur of Mary's Rock near Thornton Gap, which was necessary to maintain an even grade and to avoid precipitous cliffs. The drive justly deserves the high praise which thousands of Park visitors give it; it is an established scenic highway of steadily growing fame. Work is already under way to extend this highway south of the Park area on the southern Blue Ridge summit.

Reaching Skyline Drive at Thornton Gap from either Luray or Sperryville, one attains the mountain summit near the Pinnacle (elevation 3,720 feet) ~~where is~~ from which may be obtained an excellent view of Old Rag Mountain. Remarkably varied are the many glimpses of Page Valley, ~~that~~ showing plats of land in different stages of cultivation as in the pattern of an old-fashioned quilt, that may be seen from the Skyline Drive. (See Pl. .) Through deep gaps, one may look eastward to the irregular Piedmont upland. Stony Man Mountain and Hughes River Valley are best seen from Hughes River Gap; Page Valley spreads out below Crescent Rock and Franklin Cliffs. From Big Meadows, a new road leads eastward to Criglersville past Hoover Community School. (Pl. .)

To the naturalist, the Park affords opportunity to study many kinds of wild life. Large game is now scarce in the Blue Ridge, for the elk and panther are extinct in this section. However, the opossum, raccoon, and fox are not gone, and quail and hares abound in lowlands where grain and grass are plentiful. Once, bear~~s~~, turkeys, and squirrels were common, but a wasteful destruction of mast-bearing trees has done more to drive them away than the hunter's gun. Bear wallowed at the head of Jeremy

[illegible] late as 1920, and are occasionally found in the more rugged areas today. Wildcats, copperheads, and rattlesnakes were encountered during the field work on which this report is based. present geologic survey. Snakes are common on the Blue Ridge and Massanutten Mountain, but are rarer in the valley lowland. However, since the opening of the Park, venemous snakes have already begun to disappear and will ultimately be largely exterminated.

Shenandoah National Park includes a section of the Blue Ridge not excelled in eastern North America for beauty and ruggedness. Most of its area is clothed with sturdy timber, and its peaks and cliffs challenge the hardiest mountain climber. Deep canyons and rocky gorges invite the visitor to explore alluring mountain wildernesses, while the accessibility and general beauty of its famous Skyline Drive attract visitors from all the World areas.

Stony Man Mountain, which gives its name to this quadrangle, is a triangular peak 4,010 feet above sea-level; Hawksbill Mountain, elevation 4,049 feet, is the highest summit in the Park. (See Pls. .) White Oak Canyon, southeast of Stony Man Mountain, more than 2,000 feet deep, is one of the most picturesque gorges in eastern North America. These and many other spectacular features make Shenandoah National Park [1] an attractive and valuable addition to the park system of the United States.

[1] Several elaborate booklets describing the Park have been issued by various organizations.

CLIMATE

The Stones Man

This region is favored with a pleasant climate excellently suited for agriculture. The Its average annual rainfall, about 35 inches,[1] is well distributed throughout the year, while its mean

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[1] 34.17 inches at Woodstock, Shenandoah County, during a period of 42 years.

Source of information?

See also p 28 - weather contrast

annual temperature is about 54° F. Summers are warm but not excessively hot. The winters are like the "open" winters of the north, and severe weather is experienced only in the mountainous regions during January and February. (See Pl. ?.) The average temperature ranges between 30 and 35 degrees in January and is about 75 degrees in July. The mean minimum temperature for January is about 25 degrees; for July, the mean maximum is between 85 and 90 degrees. The Blue Ridge, which has the coolest average temperature in Virginia, protects Page Valley from the damp winter winds and fogs of the coast, but Massanutten Mountain and other more western ridges check cool summer winds from the west or northwest. Page Valley, therefore, is warmer in summer than might be expected from its latitude and elevation, although at ~~its~~ night the temperature~~s~~, even in an extreme summer, is ~~are~~ rarely uncomfortable.

Use of ?

Since ~~As~~ the last killing spring frost is about April 15, and ~~while~~ killing fall frosts do not come until about October 20, there is a long growing season in the lowlands of Page Valley. A marked difference in climatic conditions exists between this lowland and the Blue Ridge, for spring comes much later to the high crest of the mountain than it does to Page Valley.

SOILS AND AGRICULTURE

Because of the fertility of its soils, Page Valley is the most prosperous section of the quadrangle. (See Pls. .) The (Its) houses and farm buildings in the valley are large and well-kept; the ~~its~~ roads are more numerous and in better repair than those of other parts of the area. Farming, stock raising, and orcharding are the main agricultural activities, and the principal farm crops are wheat, corn, and hay. ~~As~~ much of the land has been under cultivation for more than 100 years, and many of the larger farms were operated by slaves before the War between the States.

Little agriculture is possible in the Blue Ridge where there are few level fields or fertile soils. Some mountain hollows are tenanted by settlers who cultivate small plots for pasture, corn, and home crops, but the hostility of a rugged terrain has deprived them of prosperity.

Several soil types are recognized in (the quadrangle this area). ~~These of~~ In the Blue Ridge area the soils are residual from igneous and metamorphic rocks. They are gray or yellow sandy loams peppered with fragmental rock debris. Although poorly located for cultivation, the typical Blue Ridge soil produces good pasturage where drained and cleared of stone. This soil type normally supports the typical Appalachian forest (Pl.); but, if too fully cleared, it becomes subject to drought and gullying ~~and~~ thus is quickly washed away.

Soils on the mountain summits are thin, (except save) on such local flat areas ~~such~~ as Big Meadows, Chestnut Flats, and Chestnut Levels, most of which are underlaid by greenstone. (See Pl. .) Weathered products of the latter, admixed with long-accumulated plant mold, have produced a dark loam whose thickness, richness,

and freedom from stone is in direct proportion to the width of the divide. Although too elevated for corn and wheat, this soil ~~gives~~ yields excellent pasture ~~land~~ that runs naturally into support blue grass. There are sudden changes to thin stony soil near hills and steep declines. This soil-type extends westward down Tanner Ridge, and into the valley of Jeremy Run. Its best development is on the flats between Skyland and Big Meadows, at Panorama, and near Rattlesnake Point. Where the divide is moderately but not excessively wide, as near Beahm, a red clay develops from the greenstone.

Near Hazel Mountain, between Old Rag Mountain and the Lee Highway, are thicker soils. ~~fill~~ in the hollows. Granite and granodiorite here produce a gray or yellow sandy loam that becomes gravelly and low in fine constituents upon steep slopes, such as those of Old Rag Mountain, which are too precipitous for soil accumulation. West of the Blue Ridge between the Lee Highway and Tanner Ridge, granodiorite weathers to a red clay-soil that is deficient in humus.

At the east foot of the Blue Ridge, a deep clay-soil floors F T Valley. This soil also occurs near Etlan east of Old Rag Mountain, and extends up Hughes River valley, and to Piedmont School; it corresponds closely to the area in which Lovingston gneiss is intruded by Old Rag granite.

The Hagerstorm clay-loam of central Page Valley is a heavy red-brown unctuous soil underlaid by several feet of soft red sticky clay. Residual from the weathering of limestone, it is extremely fertile and favorably located for agriculture. (Pl. .)

Its normal crop is blue-grass, but it is equally good for wheat, clover, and cereals. Large parts of its outcrop have never been cultivated and have always stood in grass. In a few areas, especially near Luray, this soil is intermixed with cherty debris from the underlying Beekmantown dolomite. The chert impedes cultivation of the soil, and these areas are uncleared and still sparsely forested.

The Hagerstown clay-loam (passes eastward on Page Valley below) alluvial debris from the high mountains in a belt about 2 miles wide at the west foot of the Blue Ridge. This debris is a loose gravelly assortment of alluvium of many kinds. It is difficult to till and comparatively unfertile. A thin stand of timber with much underbrush crowds the stream valleys, and only the more level interstream areas afford opportunity for cultivation. (See also pages .)

Northwest of Shenandoah River is the thin sandy soil of Massanutten Mountain, much of which is derived from its underlying shales and is dotted with alluvial boulders. Lack of level locations has prevented this soil from furnishing agricultural products.

Save as a forest reserve and a beautiful national park, the land of the Blue Ridge has little present value. Fifty years ago it nourished a valuable forest of white oak, chestnut-oak, chestnut, pine, and other trees. Fires, ruthless extraction of oak and chestnut for staves, ties, and tan-bark, and the recent chestnut blight, have left little valuable timber on the mountain (Pl.), where bare gray skeletons of dead chestnut trees stand

thickly over its sides and summit. Near the top, thicker forests of chestnut, oak, poplar, hickory, and walnut, flourish in the more fertile soil of various coves. Many slopes have a thick undergrowth of laurel, grape, and berry, and parts of the forested regions are difficult to traverse. The summit of the Neighbor is a dense tangle of underbrush, through which it is possible to progress only with extreme difficulty.

Many varieties of interesting plants enjoy the cool climate of the Blue Ridge summit. Ginseng is still gathered in some coves; laurel thickets cover the top and western slopes (Pl.); while balsam thickets grow on high summits. Blackberries, that ripen in the lowlands in June, come to maturity in August on the mountain top. Huckleberries grow in profusion upon the lower Cambrian rocks of the west Blue Ridge slope near Stanley, on Pine Mountain, and on the Neighbor. The gathering of ~~this crop~~ huckleberries is an important industry among mountain people in July and August.

Most of the Blue Ridge land is uncleared except for flats at the top that are used for pasture. Clearings in the hollows and on mountain slopes near streams, afford garden land for several seasons. Here, the trees are "deaded" by cutting a ring of bark from the trunk. Other trees are felled, and the logs and brush are pulled to the edge of the clearing to make a barricade (Pl.), while corn and potatoes are planted between the stumps. In such remote sections as Corbin Hollow, all work must be done with the axe and hoe.

Where the timber has been removed from the broad rolling mountain top, the dark Catoctin soil runs into blue grass, and long stretches of the Blue Ridge summit have been used as ranges

for cattle. Apple trees grow well in protected hollows on the east side of the mountain, but it is said that above 2,000 feet, sleet, snow storms, and heavy winds damage fruit trees. The famous Milam apple came from a seedling in Milams Gap.

PHYSIOGRAPHY

The physiography of the Stony Man area includes an interpretation of its surface features. In a broad sense, it is a study of the scenery, for the latter embraces a complex array of land features that have been produced during long periods of geologic time. Each stage in its development has left some imprint on the land surface, and when these have all been properly interpreted and arranged in chronologic order, a connected physiographic history can be prepared. At the end of this chapter is a summary history of the surface development of the Stony Man region. Other sections describe relief and drainage, physiographic provinces, erosion levels, and miscellaneous physiographic features of this quadrangle.

RELIEF AND DRAINAGE

This area has considerable relief; its eastern two-thirds holds rugged mountains; its northwestern corner is another ridge; only Page Valley is truly a lowland. The highest point is Hawksbill Mountain (Pl.), elevation 4,049 feet above sealevel, which commands a splendid view of the entire area. On a clear day this view is expanded for nearly 100 miles in any direction. Other conspicuous summits are Stony Man Mountain (Pl.), elevation

4,010 feet, Blackrock, elevation 3,721 feet, the Pinnacle, elevation 3,720 feet, Mary's Rock (Pl.), elevation 3,514 feet, Old Rag Mountain, elevation 3,291 feet, and Kennedy Peak (Pl.), elevation 2,552 feet. ~~Save~~ Except for Kennedy Peak, all ~~lie~~ are in the Blue Ridge. The lowest elevation is along the South Fork of Shenandoah River, which is 650 feet above sealevel, ~~as it~~ where the river leaves the Stony Man quadrangle. The maximum relief of this area is 3,400 feet. Page Valley stands 850 to 900 feet above sealevel with a floor that forms a conspicuous lowland between Massanutten Mountain ~~at~~ on the northwest and the Blue Ridge to the southeast. The crest of the Blue Ridge ~~ranges~~ is 2,500 feet above sealevel at the north and 3,500 feet at the south.

The western half of the area drains into the South Fork of Shenandoah River, which meets the North Fork at Riverton, 15 miles northeastward downstream, whence Shenandoah River proper flows northward ~~into~~ to join the Potomac near Harpers Ferry. Hawksbill Creek, which rises in the southwest part of this area, flows due north through Luray to join the South Fork 4 miles north of town. It has several tributaries, including East Hawksbill Creek, Dry Run, and Pass Run. Jeremy Run (Pl.), east of Vaughn, also flows north into the Shenandoah. That part of the quadrangle The section northwest of Kennedy Peak drains into Passage Creek, which joins the North Fork of Shenandoah River at Waterlick. The eastern half of the area is drained by many tributaries of Thornton and Hazel rivers into the Rappahannock River. Rapidan River taps the Blue Ridge near Community School.

Although most of the streams are permanent, some smaller branches flow only in the rainy season. Dry Run, largest of the intermittent streams, disappears completely into the gravels of ~~its~~ the valley

floor. Between Luray and Shenandoah River are many evidences of underground drainage--sinks, sink-holes, and caves. The soluble limestones of Page Valley are riddled with solution cavities (Pls.), and a considerable fraction of the rainfall sinks below the soil to emerge as springs, or to reach the water-table without reappearing at the surface of the ground. Some of its larger channels form Luray Caverns.

PHYSIOGRAPHIC PROVINCES

The Stony Man ~~area~~ ~~falls within~~ two distinct physiographic provinces. Its eastern two-thirds lies in the Blue Ridge province; the remainder is part of the Valley and Ridge province of the folded Appalachian Mountains. The dividing line is somewhat irregular, for the Blue Ridge is flanked by rows of foothills. Each province is a distinct geographic unit characterized throughout by similar features that have been produced as a result of analogous, or closely related, stages of geologic history. Each extends far beyond the limits of this quadrangle not only to the distant State boundaries, but also to those of the Appalachian region as well.

Blue Ridge Province

Strictly speaking, the term Blue Ridge includes the entire irregular mountain belt that lies directly southeast of the Great Valley, and has a topography developed upon resistant rock of complicated structure. ~~Loosely speaking~~, however, the term is commonly restricted to the crest of this mountainous region, or to its skyline viewed from either side. The Blue Ridge physiographic

province is underlaid throughout by igneous and metamorphic rocks of pre-Cambrian age, ~~save~~ except for small patches of ~~early Cambrian (?) quartzite~~ metasediments (pages). ~~Its~~ The ~~complicated~~ structure is essentially that of a great ~~overturned anticline~~ mass of igneous rock wherein Cambrian sediments at the west side of the ~~Blue Ridge~~ main ridge of the mountainous area ~~stand vertically~~ are nearly vertical or are overturned. ~~Locally they still cover parts of the crest of the anticline, but mostly they have been stripped from their pre-Cambrian basement.~~

The steep west face of the Blue Ridge, known as the Blue Ridge Front, is the most conspicuous scenic feature of the Stony Man region. (See Pls. .) This escarpment rises abruptly from the valley floor of Page Valley (elevation about 1,000 feet) to a crest that averages 3,300 feet and locally exceeds 4,000 feet in elevation. Stony Man and Hawksbill mountains (Pls.) rise prominently above the ridge crest, and the actual relief from their summits to the valleys directly below can not be exceeded in the eastern United States. Such deep ravines as Timber Hollow (Pl.), Kettle Canyon, and Shaver Hollow ~~are~~ were eroded by streams whose headwaters reach well toward the crest of the ridge.

The "front" has been produced chiefly by the difference in hardness of the mountain forming underlying rocks, for the Blue Ridge is an area of hard tough sandstone, quartzite, and igneous rock--all far superior in hardness to the shale and limestone of Page Valley. Some of the sharpness of this topographic unconformity has been lessened by such foothills as Hershberger and Piney hills (Pl.), while the alluvial apron skirting the front also shields the abruptness of the escarpment. The prominence of the latter, however, is by no means concealed, and its steep face, softened in the blue haze

of the Virginia atmosphere is appropriately named, for it rises from any vantage point as a picturesque "Blue Ridge."

The ridge was first called Blue Mountain--later Blue Ridge--from its appearance when viewed from the east.

The top of the Blue Ridge has a rolling surface between 2,450 and 3,600 feet above sealevel, which narrows near the gaps which cross it. The highest summits are monadnocks that rise above the general upland level (Pls.); the various windgaps are now convenient thorofares at lesser elevations. The flat or rolling summit ends abruptly on the western side (Pl.), and is deeply dissected on the eastern side, where long spurs extend out between deep hollows.

Big Meadows, the most extensive upland level, is directly southwest of Fisher Gap. (See Pls. .) Much of it is so level that it is poorly drained and holds an extensive marsh at the head of Dark Hollow Creek east of Blackrock. Its surface is 3,500 to 3,580 feet above sealevel, but a few low rounded hills--Blackrock and Stony Mountain --rise 60 to 140 feet higher. An intermittent lake, an acre or more in size, at the head of the west fork of Dark Hollow Creek, occupies a basin that may have been produced by wind action.

Big Meadows is separated from Hawksbill Mountain, which has another level surface at its base, by the narrow ridge that contains Fisher Gap. The latter is 460 feet lower than Big Meadows, at an elevation of 3,061 feet above sealevel. Another extensive flat, elevation 3,300 feet, is visible south of Skyland and Stony Man. Its eastern side is dissected by White Oak Canyon, Nigger Run, and tributaries of Hughes River. At Indian Run its surface

drops to the Thorofare Mountain flat, which extends around the south side of Stony Man, and coincides with the summit level at the head of Hawksbill Creek.

North of Skyland, the narrow ridge summit sinks to 3,070 feet at Hughes River Gap, and widens near Sexton Shelter to form Price Lands at the 3,270-foot level. Thence northward to Thornton Gap, the summit becomes narrow, and at the Pinnacle (elevation 3,720 feet) is a sharp-topped ridge. Mary Rock (Pl.), elevation 3,514 feet, rises 1,210 feet above Thornton Gap directly beneath it.

Thornton Gap (Pl. .), elevation 2,304 feet, is the most prominent windgap on the quadrangle. A long slope northeast of the gap carries the summit to the 2,800-level at the base of Pass Mountain. Here, the ridge separates the headwaters of Thornton River and Jeremy Run by a narrow crest that extends to Elkwallow Gap, at elevations between 2,400 and 2,800 feet. A general level at 3,000 feet surrounds Rattlesnake Point, from which in a northeasterly direction the ridge top gradually grows lower. Mt. Marshall, just north of this quadrangle, has an elevation of only 3,368 feet--less than Big Meadows.

The east side of the Blue Ridge is dissected by many streams (Pl.) cutting headward into the ridge. The summit level of about 3,200 feet drops to 2,200-2,500 feet near Hazel School, with a descent of nearly 700 feet in half a mile. Corbin, Hot, Oventop, and Fork mountains, and other unnamed summits reach this lower level.

Hard and soft belts in the southeastern bedrock of the quadrangle have permitted alignment of streams in northeast-southwest

direction. From Richardsville to Sperryville, through ~~Oldrag~~ Old Rag Post Office, Pine Hill Gap, and Thorofare Gap, there is a distinct depression bounded on the east by arkose and occupied by branches of Robertson, Hughes, and Hazel rivers. Most of this depression, beyond the limits of the quadrangle, is the wide F T Valley floored with gneiss. Between these valleys is a ridge of hard rock separated from the main Blue Ridge. Rose, Robertson, Hughes, and Hazel rivers cross this ridge, dividing it into numerous irregular isolated mountains, of which Old Rag, elevation 3,291 feet, is most conspicuous. The topography is more complex than this brief statement indicates, for between Old Rag Mountain and F T Valley are still lower mountains separated from one another by Popham Run and the valley followed by State Highway 16. Mountains east of Old Rag are low rounded summits that stand between 1,000 and 1,500 feet above sealevel.

Throughout the Blue Ridge province are maturely dissected mountains with disturbed rock structures and a coarse-textured topography. The dendritic drainage flows eastward into Rappahannock River. Although no stream crosses this part of the Blue Ridge, certain high gaps in the crest of the ridge suggest ancient drainage lines across the province. (See also pages .) Streams along the west side of the Blue Ridge are shorter and more active than those east of the crest.

Valley and Ridge Province

The Valley and Ridge province, occupying the northwestern third of this quadrangle, contains Page Valley and Massanutten Mountain. (See Pls. .) Adequately to describe this

province, it is necessary briefly to review the general arrangement of the Valley of Virginia at this latitude.

Great Valley in northern Virginia is a wide lowland bounded by the Blue Ridge and western Appalachian Mountains. At its broadest point--more than 30 miles across--it is bisected longitudinally into two lowlands by the long Massanutten range, which rises from the central valley floor. The western section between Massanutten and North mountains, which is drained by North Fork of Shenandoah River, is called Shenandoah Valley. The lowland between Massanutten Mountain and the Blue Ridge is Page Valley, drained by South Fork of Shenandoah River. The Massanutten range is an oval collection of ridges, mainly of synclinal structure, with a central canoe-shaped lowland northeast of New Market Gap, ridged on all sides. Known as Fort Valley, it drains northeastward with Passage Creek.

Page Valley (Pl.) is a dissected lowland rising gradually from an elevation of 850 feet above sealevel at the north to 920 feet above sealevel at the southwest edge of this quadrangle. It stands 200 to 250 feet above Shenandoah River and slopes gently upward to the edge of the Blue Ridge (Pl.). As it has been etched by many streams that flow into Shenandoah River, its surface is uneven and only locally level. The valley floor truncates a folded series of Cambrian and Ordovician rocks, upon which erosion and weathering have produced a residual soil that covers most of the bedrock. Near the Blue Ridge, an additional veneer of alluvial gravels completely blankets the valley floor and its residual soil. South Fork of Shenandoah River meanders along the

northwest edge of Page Valley, where it is entrenched against the flanks of Massanutten Mountain. Small local floodplains are found along the river, and evidences of older floodplains--in the form of high-level gravels--occur on the tops of meander spurs. (See Pls. .) Most streams tributary to Shenandoah River, such as Hawksbill Creek and Jeremy Run, are also entrenched well below the floor of Page Valley.

Resistant Silurian sandstones form the crest of Massanutten Mountain which stands more than 1,500 feet above Page Valley and strikes northeast with the grain of the folded Appalachian Mountains. Drainage within the range is trellis rather than dendritic. Inasmuch as the soil of Fort Valley is far less fertile and productive than that of Page Valley to the east or Shenandoah Valley to the west, the Massanutten range is still largely forested. Page Valley, however, which has been thoroughly and effectively cultivated, is one of the most fertile inner lowlands of the north-central Appalachians.

EROSIONAL FEATURES

At two separate elevations in the Stony Man region are more or less level surfaces that represent distinct stages in its physiographic history, having resulted from extensive denudation prior to the present time. Regarded as <u>peneplanes</u>, or planes of long-continued erosion, levels of this type are identified throughout the entire Appalachian tract, where, from their contrasting elevations, they are known as (1) the Upland (Schooley) peneplane and (2) the Valley-floor (Harrisburg) peneplane. Trenches or incised valleys below the latter represent a third cycle of erosional history.

The number of erosion levels recognizable in this area depends somewhat upon the observer and his criteria of identification. That the relatively even surface of Page and Shenandoah valleys is an erosion level of some type is recognized by nearly all geologists; and little or no doubt is cast upon the validity of a valley-floor epoch of peneplanation, producing a lowland surface correlative with the Harrisburg peneplane farther north. However, the number of erosion levels above the Valley-floor surface is subject to discussion. Stose [1] and others have suggested three levels above the Valley surface--an Intermediate peneplane at about 2,250 feet, an Upland peneplane at about the 3,000-foot level, and a Summit peneplane, at 3,500 feet. The present writers do not believe that it is possible definitely to identify more than one extensive peneplane in the Blue Ridge of this quadrangle. This level standing from 3,000 to 3,500 feet above sealevel is assigned to the Upland (Schooley) peneplane; save for the Valley-floor peneplane, it is the only major erosional surface recognized in the Stony Man quadrangle.

[1] Stose, G. W., and others, Manganese deposits of the west foot of the Blue Ridge, Virginia: Virginia Geol. Survey Bull. 17, p. 34-38, 1919.

Upland Peneplane

The highest erosion level of this area is the Upland (Schooley) peneplane, whose remnants now stand between 3,000 and 3,500 feet above sealevel in northern Virginia and rise to more than 4,000 feet in southern Virginia. Now greatly dissected, this ancient surface is visible only where later erosion has been unable entirely to obliterate its former broad extension. That a peneplane

of this type once passed across the entire Appalachian country is difficult to appreciate. Only when one stands upon a conspicuous remnant and imagines the whole landscape to be a level with his feet, can he visualize the possible extent of the Upland surface, or appreciate the erosion that has subsequently occurred.

Surfaces representing this peneplane form broad flats upon the crest of the Blue Ridge. Most conspicuous is Big Meadows, a level area of nearly three square miles between Fisher and Milam gaps (Pls.) near the 3,500-foot level. It is sparsely timbered, poorly drained, and descends precipitously on on nearly all sides. A similar but less extensive remnant is directly south of Hawksbill Mountain; there are other outliers near Skyland and at Price Lands, near the Pinnacle. No Upland remnant is identifiable in the northwest portion of this quadrangle, where the crest of Massanutten Mountain, which may formerly have reached the Upland level, is now reduced below the projected extension of the old peneplane.

For the production of broad level surfaces upon resistant rock of many types, it is necessary to invoke a long period of land stability during which the entire country was brought to nearly complete planation by erosion and weathering. This planation could scarcely take place if the area was high above sealevel, for peneplanation is a function of erosion upon a land surface near baselevel. Hence, it is reasoned that the Upland peneplane was ~~eroded~~ formed when this part of the continent was relatively near sealevel, and when interstream divides could be cut down largely to the common level, while hard as well as soft rocks were beveled

by erosion. It is assumed, also, that the whole region later became subject to uplift, and that streams became swifter and began to cut into the old plane. As a result of this second cycle of erosion, the former peneplane was mostly destroyed save where its remnants were fortunately located so as to escape attack by rejuvenated streams which elsewhere cut deeply into the older surface.

Inasmuch as Stony Man and Hawksbill mountains now stand 500 feet above Upland peneplane remnants, it is evident that they were never reduced to the Upland surface, and these mountains may have towered above that peneplane as monadnocks 700 to 800 feet high. It is believed that the master streams which formed the Upland surface flowed eastward to the Atlantic. Among them were Susquehanna, Potomac, and James rivers. Inasmuch as the Potomac and James are remarkably unaffected by the Blue Ridge--through which they now flow in deep watergaps at Harpers Ferry and Balcony Falls respectively--it is reasoned that the Blue Ridge was not a topographic feature at the time these streams were formed, but, rather, has been subsequently produced by differential erosion. Woodward believes that these east-flowing master streams may have been in existence as far back as Permian time, and that possibly they are direct descendants of rivers which flowed east into the Atlantic down the slopes of Appalachia--a borderland that supplied most of the sedimentary materials of this region.

Certain levels 700 to 800 feet below the Upland surface have been taken by some geologists to indicate a second high-level peneplane. Among these is the broad flat at the 2,600-foot level

near Hazel School; others occur between the headwaters of Piney River and Keyser Run, and near Old Rag Mountain. Those who insist upon recognition of two high-level surfaces assign these lower levels to the Upland peneplane, and invoke the presence of a still higher Summit peneplane [1] to account for the levels

[1] Stose, G. W., and others, idem.

herein treated as Upland remnants. With this interpretation the present writers do not concur.

As commonly interpreted, the Upland surface of the Appalachian Mountains is the Schooley peneplane of Pennsylvania and New Jersey.

Valley-floor Peneplane

The Valley-floor (Harrisburg) peneplane,[1] lowest widespread

[1] Stose, G. W., and others, op. cit., p. 39.

level of the Appalachian region, is visible on the floor of the Valley of Virginia, here represented by Page Valley. (See Pl. .) It may be traced from New Jersey to Alabama as a lowland surface that rises gently to the ridges which bound it on either side. No single stream produced this great lowland, which is the result of long-continued erosion upon a continuous belt of soft and soluble rock. In this quadrangle, the peneplane has but one main level; elsewhere in Virginia there are two or more benches at different elevations. Conspicuous in the area directly north of Luray, the Valley-floor surface (Pl.) stands 850 feet above sealevel near Oak Hill and is at the 920-foot level west of Long Store. It is now 200-250 feet above Shenandoah River, and has

been greatly dissected by tributaries of that stream. Only in interstream areas is it still an unbroken surface.

Production of the Valley-floor peneplane took no longer than to remove such portions of the Upland surface as were underlaid by weak rock; indeed, only limestone and shale areas were beveled during Valley-floor peneplanation, in contrast to the far greater surface reduction during the earlier Upland cycle. The Page Valley part of this lower peneplane is separated from other portions of the erosion surface by the Massanutten range, a conspicuous insular monadnock above the Valley-floor peneplane. (Pl. .) No definite remnants of the latter occur east of the Blue Ridge, and the peneplanation may have been restricted to the Paleozoic area west of the Blue Ridge front. Although an erosion surface, the so-called Piedmont peneplane, exists east of the Blue Ridge, its identification with the Valley-floor peneplane is not established definitely.

The time of Valley-floor erosion is uncertain, save that it must have been after the Upland cycle. If the latter was a result of Cretaceous erosion, the Valley-floor peneplane may be assigned to the Tertiary. Indeed, it is sometimes called the "Tertiary" peneplane; a local name, "Shenandoah" peneplane,[1] has also been suggested.

[1] Spencer, A. C., Geology of Massanutten mountain in Virginia: p. 4, Washington, D. C., 1897.

There is no local evidence more definitely to fix the age of this interesting land surface. It is the continuation and chronologic correlate of the Harrisburg peneplane of Pennsylvania and New Jersey.

For those mountain summits that exceed the valley level but fail to reach the Upland surface, an "Intermediate"[1] peneplane

[1] Stose, G. W., and others, op. cit., p. 39.

has been proposed. Some of these elevations are Pine Mountain, elevation 1,800 feet; Piney Hill, elevation, 1,600 feet; and Bailey Mountain, elevation 1,800 feet. There is no good evidence for assigning any definite time value to this hypothetical erosion surface, or to the one previously mentioned (pages) at the 2,600-foot level.

Trenches Below the Valley-Floor Peneplane

The floor of Page Valley has been dissected by modern streams that are well intrenched into the Valley-floor peneplane. Formation of the latter was permanently halted by local uplift that caused all streams to renew downcutting. This entrenchment is well exemplified by South Fork of Shenandoah, which follows an incised meandering course nearly 250 feet below the valley level. Hawksbill Creek is similarly intrenched in a distinct gorge, nearly 200 feet below Page Valley.

The Shenandoah and its larger tributaries have produced various terraces by the lateral side-cutting of their meander curves. Some are in old floodplain deposits; others are in the bedrock. Most are now covered with gravels and other alluvial material.

Minor Physiographic Features

Floodplains

Small floodplains line the inner meander curves of South Fork of Shenandoah River, where they are flat fertile grassy fields extending from the river edge to its abrupt meander scarps. They are separated from one another by reaches wherein steep cliffs descend to the water. As no main road or railroad follows this river, most of these floodplains, although intensively cultivated, are relatively inaccessible. In fact, some are so isolated that they were the only parts of the Valley not reached by raiders during the War between the States. Former floodplains, about 150 feet above the river, are revealed by abundant gravels and other alluvial debris.

Hawksbill Creek, East Hawksbill Creek, Dry Run, and Jeremy Run all have local floodplains (Pls.) in their middle and upper reaches, where they are not far below the Valley-floor level. Their surfaces are covered with alluvial debris that is coarser and less fertile than the materials of Shenandoah floodplains. (See Pl. .) No stream east of the Blue Ridge has any important floodplain in this quadrangle.

Windgaps

Several conspicuous windgaps in the local Blue Ridge attract physiographic attention. Chief of these are Thornton, Hughes River, and Fisher gaps. As the first two are located at contacts of hypersthene granodiorite and greenstone (see Pl. 1), they may owe their positions to this structural control; Fisher Gap[1] is

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[1] There is disagreement about the name of this gap. On the Stony Man topographic map it is called Fishers Gap, whereas mountain people call it Milam Gap or refer to it casually as "Red Gate."

wholly on the greenstone.

The origin of these windgaps is still a matter of conjecture, despite various elaborate theories that have been proposed to account for them. Some geologists attribute them to definite drainage lines of streams that once crossed the Upland surface; others believe that they were formed merely by headward erosion of active streams at places where some structural weakness facilitated the erosional attack. Certainly the lastword sloping gravel deposit in Swift Run gap [illegible] and Elkton

Possibly Thornton Gap, now occupied by U. S. 221, has the most convincing position for old stream occupancy. It is possible to stand near this gap (floor elevation 2,304 feet) and look westward to New Market Gap in Massanutten Mountain (elevation of gap 1,800 to 1,900 feet), which is more or less opposite a third (Brock) gap (elevation about 1,100 feet) in Little North Mountain, west of Shenandoah Valley. It is an attractive hypothesis to picture the ancient east-flowing stream which Watson and Cline

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Watson, T. L., and Cline, J. H., Drainage changes in the Shenandoah Valley region of Virginia: Phil. Soc. Univ. Virginia Bull., Sci. ser., vol. 1, p. 349-363, 1918.

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projected through these three gaps. This stream, they believe, was part of the drainage on the Upland surface, and, unlike the Potomac and James--much larger rivers--was finally obliterated during uplift of the land which followed the Upland cycle.

Unfortunately for this ingenious theory, present elevations of the gaps do not favor such a stream, and, indeed, suggest that a west-flowing stream--if any at all--flowed through the three gaps.

Since the above was written, discussion of these gaps by H. D. Thompson independently suggests a former west-flowing stream. (Geol. Soc. Amer. Bull., vol. 50, p. 1348, 1939.)

Gravels--such as one would expect in a windgap formerly occupied by a river--are rare in windgaps in this part of the Blue Ridge, and although their absence does not prohibit former stream occupancy, it does not support it. It is ~~this writer's (Woodwards)~~ the writers belief (1) that the gaps are later than the Upland surface, (2) that they are as likely products of normal headward erosion by streams on opposite sides of the ridge as remnants of old stream channels, and (3) that probably any interpretation accounts for only one stage of their history. Indeed, it is possible that the three gaps aligned above may have been occupied at different times by east- and west-flowing streams.

Alluvial Fans

Remarkable coalescing alluvial fans spread outward from the Blue Ridge front upon eastern Page Valley. Pass Run, North and South forks of Dry Run, the headwaters of both Hawksbill creeks, and innumerable smaller branches, have furnished material to these fans. The latter begin on the front at elevations of 1,200 and 1,400 feet, whence they extend westward for nearly two miles, thinning out at about the 900-foot level. They are best developed between Kimball and Stony Man.

These fans contain coarse and fine debris from the Blue Ridge. Their boulders average several inches in diameter, and are so intermixed with gravel and sand as to form a blanket that completely smothers any exposure of bedrock, except where active streams have lately worn through the thick cover. Probably the fans are 200 or more feet thick near the mountain front. (See Pl. .)

They cover one third to one half of Page Valley, with a uniformly coarse soil that is difficult to cultivate and has low fertility. Their surfaces support a scraggly growth of pines and hardwoods, and their alluvial debris merges imperceptibly with the floodplain deposits of Hawksbill and other creeks. In the interstream areas the fan debris grades into residual limestone soil.

Although alluvial accumulations of this type are uncommon in eastern United States, the steep front of the Blue Ridge furnishes an ideal source of material, and duplicates in many respects conditions under which alluvial fans develop in the more arid West. Headwaters of streams on both sides of the Blue Ridge are choked with stream boulders of all sizes, evincing that mechanical weathering and erosion are actively at work. Much of the coarser material is quartzite and greenstone; fragments of granite and other igneous rocks, as well as sandstone residuals, are in smaller quantity.

The areal distribution of these fans is shown on the accompanying geologic map (Plate 1) as an outcrop of Quaternary alluvium (Qa).

Luray Caverns

Cave Hill (Pl.), a low prominence one mile west of Luray, contains the famous Luray caverns. It is directly north of Lee Highway, U. S. 211, and the cave property is on its eastern side. The stone entrance building is about 100 yards from the highway, and a carillon tower has recently been erected nearby. Luray Caverns are 14 miles east of New Market and about 90 miles from Washington, D. C. They are easily reached from Shenandoah Division

of Norfolk and Western Railway at Luray, and are within a few miles of the central gateway of Shenandoah National Park. Among the largest developed caverns in Virginia, they are considered by many to be unusually attractive. Extensively described,[1] they

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[1] Selected publications relating to Luray Caverns include:

1. Ammen, S. Z., History and description of the Luray cave, Virginia: 3rd ed., 48 pp., Baltimore, 1882.
2. Hovey, H. C., Celebrated American caverns: 228 pp., Cincinnati, 1882.
3. Lusk, Graham, Luray Caverns: Columbia Sch. Mines Quart., vol. 7, p. 148-152, 1886.
4. Dolley, C. S., On the helictites of Luray caves, Virginia: Acad. Nat. Sci. Phila. Proc. for 1886, p. 351-2, 1887.
5. McGill, W. M., Caverns of Virginia: in Scenic and historic old Virginia, Asheville, 1930.
6. Bevan, Arthur, Caverns and associated features of the Valley of Virginia: Ill. Acad. Sci. Trans., vol. 23, p. 371-4, 1931.
7. McGill, W. M., Caverns of Virginia: Virginia Geol. Survey Bull. 35, p. 67-78, 1933. (This volume contains a complete bibliography to which the reader is referred.)

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are probably more widely known than any other Virginia caverns.

A small opening locally known as Ruffner Cave led to an exploration of the surface of Cave Hill in 1878, when another entrance into the ground was discovered in a sink-hole. Shortly thereafter the main caverns were entered for the first time, and within a few weeks were opened to the public; they have never since been closed. Electric lighting was installed in 1882, and many additional chambers and passages have been made available. Nearly twenty-seven acres of subterranean openings have been illuminated and exhibited, and other passages have been explored but are not yet developed for general inspection. Luray Caverns afford an excellent opportunity to examine the geological work of underground water, and have fascinated thousands of interested visitors.

The present cave entrance is 972 feet above sealevel and 272 feet above South Fork of Shenandoah River at Ruffner Ferry, two miles away. The entrance is 100 feet above Hawksbill Creek, 1.5 miles to the east. The foot of the stairway which leads to the caverns is 933 feet above sealevel, and the deepest point in the cave is about 900 feet--200 feet above Shenandoah River. The roof of the highest chamber--locally called "Dante's Inferno"--is 1,025 feet above sealevel and 50 feet below the top of Cave Hill. The various chambers range through 125 feet of bedrock at 4 distinct tiers, or levels. The path followed by visitors is 1.75 miles long, and retraces no portion of itself. The largest chamber--"Elfin Ramble"--is 150 by 300 feet and averages 10 feet high; its roof has but little central support. The highest chamber--"Giant's Hall"--located near the deepest section, has an interior height of about 65 feet.

Air within these passages maintains a uniform temperature of about 55° F. throughout the year. Observations over many years show a seasonal fluctuation of only 2°. The relative humidity remains approximately 87 percent. Tests of the purity of cavern air show that it is practically free from bacteria. Because of its purity, uniform temperature, and constant relative humidity, a unique experiment was made in 1901 by T. C. Northcott, whose home is built directly above Luray Caverns. An artificial opening was sunk into the cave, and a ventilation system was installed by which cave air was brought into the house in an early attempt at air conditioning.[1]

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[1] Stevens, W. W., Conditions home with cave air: Domestic Engineering, vol. 129, p. 43-6, 158-160, Dec. 28, 1929.

Luray Caverns contain an intricate system of branching and intersecting passages and chambers which are so arranged that a map of the cave resembles the web of a spider with lateral passages radiating in many directions from a central chamber. (See Pl. .) There is an unusually wide variety of stalactites, stalagmites, and other calcareous deposits of various shapes and forms. (See Pls. .) Branching stalactites, known as helictites, are common, as are nodular masses that resemble bunches of large grapes. Some stalactites are dome-like (Pl.), and hang above rounded potato-like structures not common to other caves. Floor growths of calcium carbonate form complicated terraced or turreted structures in "Giants Hall." (See Pls. .) Many walls are delicately tinted gray, white, brown, or orange (see Pls.), while graceful icicle-like pendants adorn the roofs of most chambers. (Pls. .) At least one small stream flows for a short distance in the caverns but soon leaves the explored area (Pl.). Interesting lime concretions on the floor of some rooms (Pl.) resemble marbles and show an internal radial structure. Most of the passages are fluted and scoured by rapidly flowing water which evidently aided, or caused, the development of the caverns.

Luray Caverns are in cherty Beekmantown limestone and dolomite (Nittany member) which dip about 10° SE., and are apparently overturned. At the cave entrance is a thick bed of dove-colored limestone which breaks with a conchoidal fracture. Most of the strata visible in the chambers are beds of limestone and vaughanite. Chert containing Nittany fossils (Lecanospira compacta) occurs on the summit of Cave Hill.

SUMMARY OF PHYSIOGRAPHIC HISTORY

The known geologic history of this area begins with the production of very ancient crystalline rocks that were already deeply eroded during a long and complicated epoch before the initial sedimentary rocks were deposited upon them. Indeed, the crystalline basement, upon which the first Cambrian sediments came to rest, now reveals a geologic history as complicated as the events which followed initial Paleozoic sedimentation. (See also pages .)

With the Paleozoic began a great era of rock deposition. Formations laid down during at least 4 geologic periods now lie within the limits of this quadrangle, and representatives of other systems may once have been present, although now removed by erosion. All were deposited in a long relatively narrow trough, or seaway, which then extended northeast-southwest along the line of the present Appalachian system. There was no Blue Ridge nor any nearby mountains, save at the east whence came the sediment-laden streams to deposit their burdens in the waters of the Appalachian geosyncline. This era of sedimentation was terminated by the Appalachian mountain revolution in which nearly all of eastern North America was involved in uplift, folding, and faulting. Existing rock strata were then contorted into the confused tangle in which they now occur. (See also pages .)

The most generally accepted explanation of Appalachian physiography calls for the production of a broad low-level erosional surface in the period immediately following the Appalachian revolution, when the entire Appalachian region is supposed to have attained a condition of low relief. It next assumes, along a zone

somewhat corresponding with the present Great Valley, that the earth's surface rose unequally to produce a broad dome upon whose surface such master streams as the Susquehanna, Potomac, and James rivers meandered in courses closely coincident with those they now possess. These meandering courses were taken at a time when beds of hard and soft rocks were alike buried beneath alluvium of floodplains; for the great anticlines and huge overthrust blocks previously produced during the revolution (see pages) are supposed to have been reduced mostly to a common level. Vertical uplift, or series of uplifts, during late Mesozoic and early Cenozoic times are invoked to give the streams a swifter flow; whereupon the rivers, in resuming their down-cutting, are thought to have discovered the alternating belts of hard and weak rocks hitherto concealed. As their courses lay athwart these beds, the rivers corraded the resistant rocks as rapidly as possible to produce the watergaps by which they now cross the folded basement; while lateral tributaries, sapping belts of weaker rock, etched into relief the linear outcrops of granite, sandstone, and quartzite through which the mainstreams were sawing.

This interpretation would thus explain the Upland (Schooley) peneplane as the product of the long erosional interval, and as the surface upon which the meandering streams came to maturity. From this surface, it is supposed that its streams were superimposed upon belts of weak and hard rock, and maintained their courses across the latter because they could cut downward faster than the land became elevated. By such a hypothesis, the gap of the Potomac in the Blue Ridge at Harpers Ferry is commonly explained. Shenandoah River, one of the lateral subsequent tributaries, was at work on the weaker rocks of Page Valley while the

Potomac was sawing through the crystalline rocks of the Blue Ridge belt. Tributaries of the Shenandoah, and streams east of the Blue Ridge, although still active, have not yet been able to make much headway against the tough greenstone and granite of the Blue Ridge belt, which, save where it was locally cut by streams let down from above (i.e. from the Upland surface) still remains a topographic prominence of high relief.

With parts of the above hypothesis, this author[1] disagrees,

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[1] Woodward, H. P., Interpretation of Appalachian geomorphic history (abstract): Geol. Soc. Amer. Bull., vol. 49, p. 1965, 1938.

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believing that the theory fails adequately to take into account many details of the known deformational history of the region. Prior to the Appalachian revolution, streams which brought Paleozoic sediments to the Appalachian geosyncline stemmed from the east; and their sediments--forming the coarse clastic Silurian, Devonian, and late Paleozoic (in western Virginia) rocks--came from highlands that must have been located east of the present site of the Blue Ridge. This oldland, from which the debris was derived, and which fed the west-flowing streams, was a long mountainous borderland called Appalachia. It separated the Appalachian geosyncline from the open Atlantic still farther east.

Into the geographic picture thus portrayed, the effects of the great Appalachian revolution must be brought. There was a borderland (Appalachia) with streams flowing east into the Atlantic and west into the geosyncline. In the latter was a tremendous volume of recently deposited Paleozoic rock; and deformation began.

This deformation acted northwestward upon the rocks of Appalachia, crumpling them into a contorted, but coherent, block which then transmitted pressure to the region lying to the northwest, i. e. to the sediments of the geosyncline. These materials were elevated into a series of anticlines and synclines, and at various points, were cut through b y great shear faults where pressure greater than the strength of the rocks was applied. It is believed that a zone of greatest disturbance began at the east and gradually moved wastward across the Appalachian tract. Above this zone of maximum deformation, it is believed the land surface was elevated into a divide between east- and west-flowing streams; and it is Woodward's hypothesis that this divide likewise moved westward approximately apace with the migrating axis of deformation. Migration of this divide would obliterate all former west-flowing drainage, but at the same time, would elongate east-flowing streams by recession of the highland at their sources. This hypothesis assumes that the east-coast streams of Appalachia were gradually lengthened by retreat of the divide at their headwaters. While the streams were being lengthened, it is thought that their interstream areas were partially planed, and that a land surface of more or less low relief gradually crept westward in the wake of the deformation. This surface, it is thought, was the Upland peneplane.

As both migrating zones of maximum deformation and drainage division are supposed to have passed westward beyond the site of the present Blue Ridge, it is held that the master streams were thus led across rocks of the present Blue Ridge province, which,

when deformation was ended, and dissection of the Upland surface was begun, became etched into its present relief. This hypothesis calls for the development of an ancient erosion surface, but assumes for the master streams a very different origin from that commonly explained.

After the Appalachian revolution came a broad elevation of the entire eastern continent, rejuvenating streams and making possible the more or less complete destruction of the older land surfaces. Almost all of the previous scenery was destroyed, and a long and complicated epoch of erosional history was begun. New tributaries and old master streams sought adjustment upon the corrugated rocks of the uplifted Appalachian highlands. Little by little, drainage was cut deeper into the bedrock, and as weak and soft rock were alike embedded in folds, the pattern of this drainage changed from time to time. Probably there were changes of considerable magnitude as the broad Page and Shenandoah lowlands were cut from the Upland surface. If the windgaps of this region were ever occupied by streams, it was in this preparatory stage of the present scenery, where favorable elevation and a softer bedrock led one stream to grow faster or cut deeper than a less fortunately located rival.

Ultimately, the elevation or uplift of the land halted long enough for streams on the soft rock belts to widen, rather than deepen, their valleys. In this epoch when Valley-floor peneplanation took place, the wide lowlands were given their broad smooth surfaces. While Valley-floor broadening was in progress, underground water was at work in the soluble limestones of the valleys, and extensive channels of subsurface drainage riddled parts of

the bedrock of Page Valley. Enlargement of these channels into caves took only time, and this epoch of peneplanation gave ample opportunity for work of this type.

Not far back in the past, Valley-floor peneplanation came to an end, and streams became again rejuvenated--apparently by new uplift. This renewed activity incised the stream pattern into the valley bottoms recently produced, and trenches were developed in the Valley-floor peneplanes.

Thus it is believed that each of the prominent scenic features of this area can be fitted into some part of this physiographic story. Stony Man and Hawksbill mountains were monadnocks above the old Upland surface, not then, nor since, lowered to the Upland level; of the latter, broad flats (Big Meadows) on the Blue Ridge summit are undestroyed remnants. The depth of Page Valley and the "hollows" along the Blue Ridge resulted during the uplift and deep erosion following production of the Upland surface. The width of Page Valley and its level floor represent the epoch of land stability when valley-widening, rather than incision, was dominant. Luray Caverns are the work of underground drainage during the same general epoch, or later. The valleys of Shenandoah River and its tributaries, now etched in the Valley-floor peneplane, are fairly recent products of renewed elevation. Indeed, these streams are today increasing the depths of their valleys.

For a somewhat more detailed statement of land sculpture, the reader is referred to the chapter on Geologic History. (See pages .)

ROCKS

GENERAL STRATIGRAPHIC STATEMENT

This ~~chapter~~ describes all rocks exposed at the surface of the Stony Man quadrangle. Intended as a guide to the identification of local rock types, it contains descriptions of the character, distribution, and correlation of each named formation.

Stony Man bedrocks are conveniently arranged in 5 groups as follows: (1) pre-Cambrian crystalline rocks; (2) lower Cambrian volcanic rocks; (3) Paleozoic sediments; (4) ~~Triassic~~ Lower Cambrian or later dikes of igneous rock; and (5) Quaternary surficial and unconsolidated deposits.

Although the pre-Cambrian outcrop occupies only the eastern two-thirds of the quadrangle, there is no doubt that these rocks would be reached in any well penetrating the overlying sediments in the western third of this area which contains the Paleozoic outcrop. Quaternary deposits are scattered in an irregular pattern over many parts of other outcrops. The accompanying geologic map (Plate 1) shows the distribution of all major rock systems as well as the more limited extent of many smaller units into which the larger groups are separable.

For purposes of description, local rocks are grouped into two major divisions that are separately discussed. Although both authors have collaborated in various rock descriptions, discussion of pre-Cambrian rocks is the work of Dr. Furcron; sedimentary materials have been described by Dr. Woodward; both authors have collaborated in a description of the early Cambrian lava flow.[1]

[1] Furcron, A. S., and Woodward, H. P., Basal Cambrian lava flow in northern Virginia: Jour. Geology, vol. 44, p. 45-51, 1936.

IGNEOUS AND METAMORPHIC ROCKS

INTRODUCTION

Igneous rocks of intrusive and extrusive origin crop out over the greater part of the Blue Ridge region of this quadrangle. The main mountain mass consists of granodiorite and granite which occur on the flanks of the ridge and extend at many points to its top. The Blue Ridge crest north of Thornton Gap and south of Hughes River Gap is composed of extensive flows of basalt that have been intruded by granodiorite and granite and are now generally altered to epidote greenstone. All these are of pre-Cambrian age. (See Pl. .) In addition, amygdaloidal lava flows occur at the base of the Cambrian system along the west side of the Blue Ridge, and dikes of [redacted] diabase intrude the crystalline rocks of the region. Rock descriptions in the following section are made by Dr. Furcron.

INSERT

Editor:

In preparing this copy of the Stony Man manuscript, I have extensively rephrased the section on igneous and metamorphic rocks which follows, so as to bring it to the editorial style of the remainder of the manuscript. For any further revision of the content or opinions expressed in this section, you should refer to Dr. Furcron who prepared the original draft of this part of the manuscript.

H. P. Woodward, January 1, 1940

Thank you A.S.F.

PRE-CAMBRIAN EXTRUSIVE ROCKS

Catoctin Flows

Introduction

Ancient basaltic flows extensively altered to epidote-chlorite greenstone occupy two important outcrops in Virginia. The eastern, Catoctin Mountain, belt enters Loudoun County at Taylorstown and extends southward through Bull Run Mountain, Warrenton, and Charlottesville to south-central Virginia. The western, Blue Ridge, belt enters Loudoun County at Harpers Ferry and follows the Blue Ridge crest southwestward to Balcony Falls (James River). Keith,[1] who first studied this rock in northern Virginia,

[1] Keith, Arthur, Geology of the Catoctin belt: U. S. Geol. Survey 14th Ann. Rept., pt. 2, p. 287-396, 1894. Also U. S. Geol. Survey Geol. Atlas, Harpers Ferry folio (No. 19), 1894.

called it the Catoctin schist. Although the rock is schistose in its eastern belt, it is usually massive in the Blue Ridge, where it is intruded by granodiorite and granite,[1] where and the term

[1] Furcron, A. S., Igneous rocks of the Shenandoah National Park area: Jour. Geology, vol. 42, p. 400-410, 1934.

"schist" is inappropriate.

Distribution

In this quadrangle, Catoctin flows now ~~underlie~~ overlie intrusive rocks at the top of the Blue Ridge, ~~and~~ where they commonly retain remnants of the Upland peneplane upon their exposed surfaces. (See pages .) The main belt is 2 from to 5 miles wide, and is discontinuous between Hughes River and Thornton gaps; it is widest just

~~just~~ north of Elk Wallow Gap. Lee Highway crosses Thornton Gap on greenstone, but granodiorite crops out in the gap immediately south of the road. Greenstone outcrops are confined to the mountain top south of Hughes River Gap except in Tanners Ridge, where the Catoctin descends nearly to Marksville in Page Valley. North of Thornton Gap, greenstone underlies early Cambrian arkose (Weverton formation[1]). The latter has been cut by Jeremys Run to expose a tongue

[1] A distinction is recognized, see pages , between the basal Cambrian sediments (Weverton formation) west of the Blue Ridge front, and inliers of possibly contemporaneous material (Loudoun formation) east of the ridge.

of greenstone which extends down this valley to the west base of the mountain. Knob Mountain (elevation 2,810 feet) north of Jeremys Run is nearly surrounded by greenstone, and a small isolated outcrop of greenstone--3.5 miles long and 0.5 miles wide--underlies Hoak Hill west of the Blue Ridge between Chub Run and Piney Hill.

Thickness

That Catoctin greenstone is preserved in this area ~~is~~ due to the fact that the baselevel of streams forming the Upland peneplane was slightly above the bottom of the flows. Estimates of Catoctin thicknesses are possible for exposures west of the Blue Ridge summit, but estimates there made may not apply to exposures farther east. The greenstone is about 500 feet thick at Crescent Rock; at Fishers Gap its thickness is about 600 feet. From Thornton Gap to Mount Marshall, northeast of this quadrangle, a continuous greenstone section suggests a thickness of 1,800 feet.

These are all present thicknesses of the rock; the original depth of the flows may have been much greater.

Megascopic Character

Catoctin basalt is generally altered to epidote greenstone in which secondary minerals are visible even to the unaided eye. Most of the rock is vesicular or locally scoriaceous, with vesicles that are generally filled with pink or milky quartz and epidote. These minerals also occur singly or together in many rock fractures. In some localities, red jasper is a common accessory, and small masses of greenish chalcedony are present, while fibrous quartz ~~and~~ which replaces asbestos ~~are~~ is also common. At other localities, epidote extensively replaces the basalt to form epidosite. As much of the basal portion of the greenstone is massive and non-amygdaloidal, it is locally possible rudely to divide the flows into an upper and lower member. Not everywhere, however, is the amygdaloidal member at the top, for it also occurs at the base.

Columnar jointing is prominent in a massive non-amygdaloidal facies of the basal Catoctin. This phase, several hundred feet thick, is erratic in distribution, and resembles a sill rather than a flow. It shows columnar jointing between Skyland and Fishers Gap, and at Crescent Rock. The profiles of Hawksbill and Stony Man mountains as well as the palisades of Franklin Cliffs are produced by a strong vertical jointing in greenstone of the steep west slope of the Blue Ridge. Large columns of greenstone several feet in diameter ~~make~~ occur at Little Devil Stairs in the northeastern part of the quadrangle. (See Pl. .)

Extrusive pre-Cambrian igneous rocks other than greenstone are rare in the Blue Ridge province as are any types of pyroclastic material. Near Rattlesnake Knob, and west of Little Devils Stairs, however, occurs an agglomerate of greenstone bombs in a fine ashy matrix. At the lower end of Little Devils Stairs is a small outcrop of reddish-brown flow-breccia largely composed of angular fragments of volcanic rock.

Microscopic Character

Thin sections show the greenstone to be a much-altered amygdaloidal basalt. (See Pl. .) Secondary minerals are mainly quartz and epidote derived from original pyroxene and plagioclase. Chlorite occurs where the rock is schistose; ~~while~~ small amounts of magnetite are usually present. Rods of plagioclase in various stages of alteration are seen in most thin sections. Olivine and pyroxene, although reported,[1] were not observed by this author (Furcron).

[1] Phalen, W. C., A new occurrence of unakite--a preliminary paper: Smithsonian Misc. Coll. vol. 45, p. 315, 1903.

A thin section of the red fragmental rock at the lower end of Little Devils Stairs reveals volcanic fragments in a reddish glassy matrix containing small laths of plagioclase. Some grains and patches of calcite and epidote are present.

Age

Early Cambrian (Weverton) sediments extend to the top of the Blue Ridge from Page Valley, and unconformably overlie the Catoctin greenstone. Isolated areas of Loudoun arkose occur on the top and east side of the range, where they are directly underlaid by greenstone

or its intrusives, and are composed of fragments of greenstone, diorite, and granite. These data indicate the Catoctin to be older than earliest Cambrian, and Furcron believes it to be one of the oldest elements of the local pre-Cambrian group.

Indeed, no vestige of a still older supporting or basement rock upon which the flows were poured out, has been found within this quadrangle. In F T Valley and other lowlands of the southeastern part of the quadrangle, there are outcrops of an ancient biotite gneiss and schist which resembles the Lynchburg gneiss. The latter is associated with Catoctin volcanics in central Virginia and is a pre-Cambrian rock of great age. That it is older than the volcanics, is not definitely established.

PRE-CAMBRIAN INTRUSIVE ROCKS

General Features

Granite and granodiorite of two major periods of intrusion are recognized in the Blue Ridge of this ~~district~~ area. The first period is represented by the Lovingston gneiss, which crops out near the east base of the range, where a batholith of granodiorite with granite differentiates representing the second period, invades the gneiss and forms the principal part of the range.[1]

[1] Furcron, A. S., ~~idem.~~ Igneous rocks of the [illegible] National Park area: Jour. Geol., Vol. 42, pp. 400-410, 1934.

That the gneiss is genetically related to the younger intrusives is shown by similarities in dominant minerals--quartz and feldspar. Both rocks are characterized by a large content of plagioclase, which frequently equals in volume the potash feldspars. The large

amount of plagioclase in the granites and gneisses of the Southern Appalachians is discussed by Watson.[1]

[1] Watson, T. L., Granites of the southeastern Atlantic states: U. S. Geol. Survey Bull. 426, 1910.

Lovingston Gneiss Complex

A belt of ancient granite-gneiss, quartz-monzonite gneiss, and other intrusive and metamorphic rocks, extends along the eastern side of the Blue Ridge throughout central Virginia. Previously called "biotite-quartz-monzonite gneiss,"[1] its outcrop

[1] Watson, T. L., and Taber, Stephen, Geology of the titanium and apatite deposits of Virginia: Virginia Geol. Survey Bull. 3-A, p. 59-66, 1913.

on the State geologic map (1928) was mapped as Lovingston granite-gneiss. Its belt in this area is wider than indicated upon the map.

Biotite Gneiss

One of the most ancient rocks of this district is a biotite gneiss which resembles Lynchburg gneiss.[1] It occurs commonly in

[1] Jonas, ~~Anna~~ I., Geologic reconnaissance in the Piedmont of Virginia, Geol. Soc. Amer. Bull., vol. 38, p. 845, 1927.
Furcron, A. S., James River iron and marble belt, Virginia: Virginia Geol. Survey Bull. 39, p. 20-22, 1935.

thin bands that are too narrow or discontinuous to show on the geologic map (Pl. 1). Their average strike is about N. 40° E. This rock has been intruded by Lovingston gneiss, and is thoroughly injected by Old Rag granite, which, in this section usually contains biotite, perhaps derived from the older gneiss.

Megascopic Character

The biotite gneiss of the east side of the Blue Ridge is generally a fine to medium coarse-grained pepper-and-salt rock containing a variable amount of fine biotite which is its diagnostic mineral. It ranges from a gray gneiss with some biotite to a heavy black biotite schist. For the most part it is of sedimentary origin, although there are many granite-like layers, as well as bands of hornblende gneiss.

Microscopic Character

Under the microscope the rock is a biotite schist or gneiss, composed principally of quartz and untwinned feldspar. It is generally fine to medium-fine and even-granular. Brown biotite metacrysts have ragged borders and include other minerals of the gneiss. Shreds of muscovite are interwoven with quartz and feldspar. The accessory minerals are magnetite, apatite, garnet, and epidote.

Granite-like layers with granitic texture are mashed and granulated. Their minerals, usually plagioclase, microcline, orthoclase, and quartz, show wavy extinction. There are shreds of greenish biotite and of secondary muscovite. Epidote is locally common as are leucoxene borders around titaniferous magnetite.

Age

Except that it is invaded by Lovingston gneiss which is cut by all other intrusives, the age of the biotite gneiss can not be determined. Patently more ancient than any rock which invades it, this rock can not be given any relative age in terms of the Catoctin greenstone. Possibly it is older than the greenstone, in which case it would be the most ancient pre-Cambrian rock of the Stony Man quadrangle.

Lovingston Gneiss

Distribution

This rock occupies low ground in the southeastern part of the quadrangle, where the best exposures are (1) near Etlan, (2) near Dulaney mountain, and (3) at Peola Mills in F T Valley. Its gneissic or schistose structure makes it subject to relatively rapid erosion; where it extends into the Blue Ridge, its outcrops form deep hollows on the east side of the mountain. Its strike is prevailingly northeast-southwest ~~and~~ which is reflected in the topography of the belt.

Megascopic Character

The Lovingston is a biotite gneiss or schist essentially composed of biotite, untwinned feldspar, and quartz, in different proportions at different localities. Its minerals are easily recognized in hand specimens. Where biotite is abundant, the rock is schistose. Light to dark-gray feldspars usually comprise an important part of the rock. In many places the latter was originally porphyritic, but its feldspars are now granulated and mashed into bands that include much quartz as well. Not uncommon is an augen gneiss in which crushed feldspars are enwrapped by a ground-mass of biotite and quartz. This rock usually breaks, or cleaves, around the feldspars so that new surfaces are covered with mica and have a silky luster. Small grains of blue or amethystine quartz are abundant, but decrease in abundance as biotite increases. Large partially crushed quartz grains are also present.

The gneiss forms rounded ledges which dip steeply to the southeast. Secondary cleavage cuts the schistosity at oblique angles giving a characteristic platy appearance to partly weathered outcrops. The rock forms a red soil that contains many fragments of milky vein-quartz. Much of the Lovingston outcrop is cleared into excellent farm land that comprises the finest agricultural section of Rappahannock County. Except in very fresh hand specimens, the feldspars are brown stained with iron oxide resulting from weathering of biotite. At Sharp Rock, on Hughes River, 1.7 miles below Nethers, excellent exposures of biotite gneiss occur near the ford.

Microscopic Character

Feldspar, quartz and biotite compose most of the rock. (See Pls. .) In some thin sections are potash feldspars, in others occurs plagioclase. Soda-lime feldspar is secondary to potash feldspar in the average section, while quartz and potash feldspar decrease in volume with any increase of biotite. Microcline is abundant, and most of the plagioclase is albite or oligoclase. There are micropegmatitic intergrowths of quartz and plagioclase lamellae that are frequently twisted or bent.

Biotite is usually greenish brown and very pleochroic, occurring commonly in long shreds that are woven around knots of feldspar and quartz to produce an augen gneiss. Small roundish garnets are present, and magnetite is common to all thin sections, where it is mostly surrounded by a rim of leucoxene.

Some biotite shows alteration to a pale-green chlorite; the plagioclase is more or less altered to muscovite, epidote, or other secondary products, although epidote grains are generally

Biotite-bearing facies of the granodiorite which have been sheared and metamorphosed on the east side of the Blue Ridge may be difficult or impossible to separate from Lovingston gneiss. Some metamorphosed granodiorite of this type may have been in cluded with the Lovingston gneiss near their contact in the southeastern corner of the quadrangle. Field evidence will not justify the assumption that Lovingston gneiss is merely a more metamorphosed facies of rocks such as granodiorite and granite here described in the Blue Ridge area. Its widespread distribution and petrographic character and intrusive associations indicate that it represents one of the older, highly metamorphosed batholitic intrusives of the Piedmont region; and that the less altered intrusives that here compose the Blue Ridge are of later origin.

scarce. Titaniferous magnetite is partly altered to brown titanite or to leucoxene.

Age

As this rock is intruded by granodiorite and Old Rag granite, it is assigned to the pre-Cambrian. Aplitic dikes of Old Rag granite cut the schistosity of the rock, and also separate it geographically from the Catoctin greenstone, so that its relation to the latter has not been determined. Its prevailing gneissic and schistose character suggest that it is very ancient, certainly older than other intrusives of this region. Granites intruded into Lovingston gneiss are prevailingly massive, a fact which indicates that the latter was already a gneiss in middle pre-Cambrian time. It invades the biotite gneiss previously described, and, hence, is a younger rock. Whether it is of younger, older, or contemporaneous age in comparison with the Catoctin greenstone, is not yet clear.

Hypersthene Granodiorite

Distribution

Bodies of granodiorite that contain relatively less intrusive granite are separated on the accompanying geologic map (Plate 1) from granodiorite extensively intruded by Old Rag granite, but any boundaries can only be approximated in terms of this criterion. The granodiorite of the west side of the mountain southwest of Thornton Gap contains less Old Rag granite than elsewhere. Mostly it is terminated at the mountain top by Catoctin greenstone, and at the base of the slope by the Blue Ridge overthrust.

At Thornton Gap this belt merges with extensive outcrops on the east side of the Blue Ridge that extend from Old Rag Mountain to the northeast corner of the quadrangle. Only locally in the eastern area can granite and granodiorite be separated, and even in this area, boundaries are not sharply marked. Two small areas of granodiorite crop out on Graves Mountain and in Rosson Hollow in the southeastern region of the quadrangle, where they are closely related to Old Rag granite. In this section the intrusive rock is generally too acid to class as granodiorite.

In E Central part of quad

also area S of Thornton Gap along Hazel River and Sams Run

Megascopic Character

Granodiorite is a coarse-grained dark-gray massive igneous rock with considerable variation in mineral composition and grain size. The average rock is coarse grained and has granitic texture; very coarse or very fine facies are rare.

Weathered surfaces of the granodiorite show alternating narrow lights and dark bands, the former being etched out in low relief. The dark bands contain more femic minerals, less quartz, and a darker feldspar than the lighter bands. This banding is generally indistinct upon freshly broken surfaces. It is interpreted as a primary structure produced during consolidation of the rock.

The feldspar is dark gray, greenish gray, or light gray. Some is untwinned, but polysynthetic laminae are common. The light-gray feldspar is usually accompanied by an increase in quartz, producing a rock intermediate between granodiorite and granite. Old Rag

Pyroxene, hornblende and biotite--the usual dark minerals--may be recognized in hand specimens where they are scattered locally in small amounts, although they may be abundant elsewhere. Some narrow light-colored zone-like pegmatitic bands carry considerable coarse hornblende or hypersthene. These are found between Marys Rock and The Pinnacle, and near the head of Hawksbill Creek. Biotite is also present at contacts of granodiorite and Old Rag granite, and as a primary mineral in the granodiorite at localities where no intrusive granite is visible. Biotite, not apparently associated with granite, is abundant in flakes up to one-fourth inch in diameter in slightly mashed granodiorite on the south side of Hawksbill Creek, 0.6 miles above St. George Mission. Blue or smoky quartz occurs in small or moderate amounts in the granodiorite, and small red garnets have been found in this rock.

Granodiorite is a massive rock, and has not been widely disturbed by regional metamorphism. It weathers rapidly by mechanical erosion and exhibits surfaces that are quite unaltered along steep slopes. Lowland outcrops weather to a red clay-soil, above or near ledges whose exposed surfaces are pitted by loss of minerals during weathering. Magnetite sands are common in roads and gullies on the outcrop of this rock.

Microscopic Character

Thin sections vary in proportions of feldspar and quartz. In basic varieties the dominant feldspar is generally andesine that lacks polysynthetic twinning. Orthoclase and microcline are commonly intergrown with albite to form microperthite. Coarse micropegmatitic intergrowths of quartz and feldspar are common. (See Pls. .)

Although the dominant pyroxene is hypersthene, augite is also common. Brown strongly pleochroic biotite occurs in some thin sections, and there are irregular-shaped patches of brown hornblende that show micrographic intergrowth with quartz. Apatite and magnetite are usual accessory minerals. (See Pls. .)

With (a) loss of femic minerals and plagioclase, and (b) increase in orthoclase, microcline, microperthite, and quartz, this rock approaches the composition of the Old Rag granite, a change observable in Hughes River Valley east of Thorofare Mountain.

Granodiorite has been described in various parts of the Blue Ridge. Watson and Cline preferred to classify it as a hypersthene syenite,[1] remarking that as "the chief feldspar

[1] Watson, T. L., and Cline, J. H., Hypersthene syenite and related rocks of the Blue Ridge region, Virginia: Geol. Soc. Amer. Bull., vol. 27, p. 193-234, 1916.

is andesine, with considerable but less alkali feldspar (orthoclase), the normal facies of the rock should be designated a pyroxene-granodiorite." It was classified as hypersthene granodiorite on the geologic map of Virginia, 1928.

5/ Following is an analysis of the rock from Milam Gap (Fishers Gap),[1] classified by Phalen as hypersthene akerite:

[1] See footnote page .

7 correct sometime

Analysis of hypersthene granodiorite from Milam (Fishers) Gap, Page County, Virginia.
W. C. Phalen, analyst.

SiO_2	60.52	Percent
Al_2O_3 (including TiO_2)	16.99	
Fe_2O_3	.60	
FeO	6.53	
MgO	1.59	
CaO	4.58	
Na_2O	2.83	
K_2O	3.91	
H_2O	.88	
P_2O_5	.74	
MnO	.25	
Cr_2O_3	Trace	
ZrO_2	Trace	
	99.42	

Phalen, W. C., A new occurrence of unakite: Smithsonian Misc. Coll., vol. 45, p. 306-316, 1903.

Near Fishers Gap the rock seems generally to have a higher pyroxene content than usual for the granodiorite. Watson, using the analysis by Phalen, designates this rock as hartzose. Analyses of hypersthene syenite from other parts of the Blue Ridge southwest of this district are given by Watson and Cline.

Watson, T. L., and Cline, J. H., op. cit., p. 202-3.

Relation to Catoctin Flows

The relation of any intrusives to the Catoctin flows of this region is difficult to determine in the general absence of known sharp contacts. Even the available exposures of contact zones reveal little that can definitely be interpreted as intrusive effects. Normal granodiorite, not intruded by granite, rarely is in direct contact with greenstone in the Stony Man area. Evidence, subsequently discussed--see pages --that Old Rag granite

intrudes the flows, and the close relationship of this granite to the granodiorite, suggest that the latter is also younger than the Catoctin.

Areas of granodiorite southwest of this quadrangle occur within masses of greenstone in an apparent intrusive relationship. On Skyline Drive, 1.1 miles east of Swift Run Gap near Elkton, granodiorite is in contact with greenstone. Here bodies of the former, 6 to 12 inches wide, cut the greenstone in a complicated network of veins. The granodiorite is partly altered to unakite, and its original feldspar appears to be andesine or basic oligoclase.

Relation to Lovingston Gneiss

It is inferred that the granodiorite invades the Lovingston gneiss, as the latter has been also intruded by Old Rag granite. The granodiorite intrusions of this area are invariably large bodies; no dikes of this rock are found in the gneiss. The massiveness of the granodiorite in contrast with the gneissoid character of the Lovingston suggests a more recent age. Evidence for intrusion occurs in the southeast part of the quadrangle where the granodiorite of Graves Mountain is nearly surrounded by the more highly metamorphosed gneiss.

Old Rag Granite

Definition

Except for granodiorite, this rock, named from Old Rag Mountain, is the most widespread intrusive of the Park area, where it occurs mainly on the east side of the range. It is a coarse blue-quartz granite resembling a facies of the Marshall granite

described by Jonas[1] as "pink to green granite and quartz

[1] Jonas, ~~Anna~~ I., Legend, geologic map of Virginia: Virginia Geological Survey, 1928.

monzonite; injected by a pegmatite with blue quartz." Marshall granite, as defined, occurs in a belt east of the Blue Ridge between granodiorite and Lovingston gneiss, where it intrudes both Lovingston gneiss and Catoctin greenstone.

The blue-quartz granite injected into the older facies of this rock can not be separated from the latter in the Warrenton region east of this quadrangle.[1] Several thin sections

[1] Furcron, A. S., Geology and mineral resources of the Warrenton quadrangle, Virginia: ~~unpublished manuscript in files of the~~ Virginia Geol~~ogical~~ Survey ~~since 1935.~~ Bull. 54, pp. , 1939.

Complete pp

were examined by Furcron from Marshall, the type locality. The greenish mashed variety contains orthoclase, orthoclase-microperthite, microcline, some pagioclase, and much quartz. Considerable greenish biotite occurs, much of which is secondary. The rock is more or less granulated, but is not an augen gneiss as is the Lovingston. Its feldspars have been considerably altered to muscovite since granulation and fracturing.

The blue-quartz facies, which here appears to be a pegmatite of the older granite, resembles Old Rag granite in hand specimens and thin sections. In the region of Old Rag Mountain, this rock becomes coarser and more widespread at the surface, where it may be mapped as a distinct type. In texture it resembles granodiorite which locally it grades into or invades.

Distribution

Distribution of Old Rag granite so closely follows that of granodiorite that it is difficult to distinguish their separate outcrops. Most typical occurrences of this granite are near Old Rag Mountain, Tom Mountain, and Browns Mountain in the southeastern part of the quadrangle, where the massive granite and granodiorite outcrops rise well above those of the more easily weathered Lovingston gneiss. Smaller areas occur in Thorofare Mountain, in the upper part of Corbin Hollow, and south of Thorofare Gap. A typical exposure occupying about two square miles occurs along Hazel Road, east of Beech Spring Hollow near the Lee Highway. Granodiorite east of the mountain top contains so many dikes and stringers of granite as to become almost a granite itself. These stringers are less common in the granodiorite outcrops west of the ridge in the belt southwest of Thornton Gap. (See Pl. .)

Megascopic Character

Light-gray untwinned feldspar and blue or smoky quartz are the chief minerals of this rock. Its larger bodies, as in Old Rag Mountain, are even coarser than the granodiorite. The feldspar is light gray or nearly white in very quartzose varieties. Quartz may be sparingly distributed through the rock or may be abundant in well-scattered grains; it may be concentrated in discontinuous planes to simulate a crude lamination.

Old Rag granite is uniform in its mineral composition and general appearance. It is usually a coarse rock, but in dikes and small intrusive bodies its minerals are about the size of

granulated sugar. Small bodies in the Lovingston gneiss are equigranular and moderately fine grained. Hand specimens, however, show sharp variations in texture. The granite is moderately fine grained near the Catoctin greenstone, and thin layers of granite injected into granodiorite may be as coarse as granodiorite.

Feldspars are generally equidimensional; coarser varieties are one-half to one inch in diameter. Idiomorphic crystals are rare, and the rock may resemble cleavable feldspar with smaller quartz grains. The feldspar is usually light gray--rarely white--or flesh-colored.

Quartz is generally light to dark blue, purple, colorless, or smoky. With feldspar it is chiefly responsible for the color of the rock. In some specimens large amounts of dark smoky quartz give the granite a peculiar dark pseudo-basic appearance.

Biotite and garnet, although not uncommon, are generally confined to restricted areas. Some large plates of mica have been reported from Hazel Mountain, but no that mica of commercial value has been discovered. There is a blue-gray granite on the road leading south toward Piedmont School from Lee Highway near Estes Store. Feldspar (orthoclase-albite perthite), which like the quartz has a blue color, causes this rock to be almost uniformly blue-gray.

Microscopic Character

Old Rag granite contains much quartz. Its feldspars are orthoclase and microcline, or orthoclase and microcline-microperthite (Pl.) with rods of albite. A few thin sections consist almost entirely of microperthite and quartz. Some plagioclase rods are very abundant and may constitute nearly 50 percent

of the microperthite. Potash feldspar and microperthite are generally accompanied by more or less albite or oligoclase. With more plagioclase and less quartz, the rock grades into granodiorite. Absence of ferro-magnesian minerals is conspicuous, and ~~while~~ although biotite and garnet occur locally, they are not typical of the rock. (See pages .) Most of the minerals are fresh, unaltered, and show few effects of mashing or metamorphism.

Green-gray biotite or garnitiferous granite occurs near the tunnel on Skyline Drive at Mary's Rock. A thin section shows this rock not to be true granite; its feldspars are albite-oligoclase, orthoclase, and orthoclase microperthite.

Relation to Lovingston Gneiss

Old Rag granite in large and small masses occurs in the Lovingston gneiss of this area. In Brown Mountain, the granite is practically surrounded by gneiss. East of the more massive Old Rag granite areas, are many granite dikes and stringers that usually follow, but occasionally cut across, the cleavage of the gneiss. Some small granite dikes show sharp contacts with the Lovingston; elsewhere, the granite has soaked deeply into gneiss. The granite is usually fresh, unaltered and unmetamorphosed, whereas the gneiss is profoundly altered by dynamometamorphism. Some of these small Old Rag intrusives are well exposed along the F T Valley road, southwest of Sperryville. There is a good example 2.2 miles west of the road to Culpeper.

Relation to Catoctin Flows

Greenstone is rarely bordered by Old Rag granite in this quadrangle, and any contact relations of these rocks must be determined from other sections. Rather fine-grained granite

underlies greenstone at Hughes River Gap, but does not appear to be intrusive. However, as the Old Rag granite intrudes the granodiorite, the former must be younger than Catoctin lava flows.

Clear-cut examples of intrusion of greenstone by granite are difficult to find. The best locality is near Mission Home in the southern part of the Elkton quadrangle. On the highway east of the Memorial to Bishop Whittle, a coarse-grained garnetiferous granite cuts Catoctin greenstone. Biotite and garnet tend to occur at contacts of this type, where a mixed rock with narrow bands of greenstone, biotite schist, and garnetiferous granite, is commonly produced. In the fields east of the Mission, layers of unaltered greenstone lie in the granite.

Relation to Hypersthene Granodiorite

Blue-quartz granite is persistently found with granodiorite throughout the Park area in an association which suggests that it is a pegmatite of the granodiorite, as it is injected both in large masses and as dikes and stringers. At some localities, narrow sheets of granite alternate with granodiorite, producing a rock which has a layered or banded character made prominent by weathering. Many granitic layers resemble granodiorite in mineral composition, but contain a larger amount of quartz.

It has been difficult in the field to determine whether some bodies should be mapped as granodiorite or as granite. In the upper part of Nicholson Hollow, there is a quartzose rock which seems to be intermediate between the Old Rag granite and the hypersthene granodiorite. Indeed, all variations from true granodiorite to true granite occur, with the intermediate

facies most difficult to separate from true granodiorite.

Large masses of Old Rag granite occur in granodiorite near the head of Corbin Hollow, and along Hazel Road, while narrow bands of granite inject granodiorite along Lee Highway east of Thornton Gap. The section along Skyline Drive west of the tunnel offers many examples of granite dikes and stringers that intrude the granodiorite. The granite in these dikes is moderately fine-grained, while coarse granite of the same type cuts all other intrusives.

Development of biotite and garnet seems to follow intrusion of granodiorite by granite. This is prominent north of Sperryville, and between the Lee Highway and Old Rag Mountain. Although most of the biotite occurs in small flakes, sheets of biotite one-half inch in diameter occur in granite and granodiorite near the head of Jenkins Hollow; and a plate of biotite several inches across was found on Hazel Road.

Dark-red garnet occurs sparingly in large irregular-shaped patches and grains that are commonly oxidized in hand specimens. Its distribution is irregular, and it is absent at many localities. Unusually garnetiferous granite occurs (1) along the road following North Fork of Thornton River, (2) along Hazel Road, (3) in fields west of Thorofare Gap, and (4) along the Lee Highway east of Thornton Gap.

An unusual variety of granite occurs in Buck Hollow, 0.7 miles south of the Lee Highway. It is white, very fine grained, and contains milky or transparent quartz and numerous small patches and grains of red garnet.

Age

Intrusion of this granite probably closely followed that of granodiorite. It invades all earlier pre-Cambrian rocks of the Blue Ridge, and is unconformably overlaid by early Cambrian sediments which are in part composed of its fragments.

Unakite and Epidote-bearing Granite

Definition

Pink epidote-bearing rocks of dioritic or granitic character are common in this region. They may be considered to be contact facies of granodiorite or Old Rag granite where they are near or were near Catoctin greenstone. Elsewhere they occupy dike-like bodies in the coarse intrusives where dykes of Old Rag granite have been altered to unakite. ~~that suggest a pegmatitic origin.~~ The term unakite, discussed subsequently (see pages), is used herein for the unakite facies of granodiorite ~~character in contrast to facies that resemble~~ and Old Rag granite. ~~It is not [illegible]~~

Distribution

The larger bodies of unakite and pink granite generally occur at or near the contact of granodiorite or granite with Catoctin greenstone. Small stringers and dike-like bodies also occur within the granodiorite; most of these are too small to show on the geologic map. Nearly all have a northeast strike. Many of these areas occur in the granodiorite on the west Blue Ridge front southwest of Thornton Gap, and there is a small area west of the ridge near Morning Star. A dike-like zone of granodiorite and granite altered to unakite crosses the old Gordonsville pike a short distance northwest of Fishers Gap.

s/

Tutwiler Hollow or Shaver Hollow vs. Sexton Shelter ?

A large belt of pink granite, unakite, and both granodiorite and Old Rag granite, occurs west of the Blue Ridge summit between Tanners Ridge and Sexton Shelter. It is interrupted west of Blackrock, where the pink granite is mainly absent. This belt adjoins Catoctin greenstone, on the west, and extends beneath it, at the exposure in Dark Hollow, east of Fishers Gap, where erosion has removed the volcanic rock. In the northeastern corner of the quadrangle, it occurs beneath greenstone in Little Devils Stairs. There is a small ~~patch~~ area of pink granite ~~at an~~ along the east margin of greenstone west of Corbin Hollow.

Exposure (?)-

W of Robertson Mts

Granite in Old Rag and Browns mountains shows relatively little ~~rock of~~ alteration to this facies.

Megascopic Character

Granitic varieties are coarse to medium fine, and pink or red. Chief constituents are (1) pink or red potash feldspar, (2) blue, milky, or smoky quartz, and (3) green grains, stringers, or veins of epidote. The rock occurs near the edge of the greenstone as dike-like veins in granodiorite and granite. It shows a wide range in composition, ranging from a pink orthoclase-microcline granite with blue quartz, to a pink granite with epidote; increase in epidote and loss of feldspar produces a quartz-epidote rock. All variations may occur between (a) normal granodiorite showing slight alteration of feldspar to epidote, and (b) quartzose rocks completely altered to epidote and pink feldspar. Colors range from brick or purple red through various shades of red and pink; varieties in the granites are light pink or flesh colored.

The general appearance of the rock varies markedly from place to place. [redacted] Good exposures occur along an abandoned road leading down the west side of the mountain from Hughes River Gap; here are exposures of pink granite, cut by veins and stringers of epidote.

Microscopic Character

Thin sections of the granitic facies show mostly potash feldspar, plagioclase, quartz, and epidote. (See Pl. .) Secondary epidote occurs in irregular-shaped patches and veinlets, where it may be associated with green chlorite, hematite or magnetite. Epidote, although a most abundant and important constituent of most types, may be nearly absent in other varieties. (See Pl. .)

Of the original minerals, orthoclase and microcline are most abundant feldspars, and are normally associated with plagioclase; indeed, orthoclase and plagioclase may occur as microperthite. Plagioclase grains are generally albite. Many of the feldspars show a wavy extinction or are granulated. Garnet and green hornblende may be present, the former partly altered to chlorite.

Relation to Catoctin Flows

The distribution of pink granite in this section of the Blue Ridge commonly follows the greenstone-granodiorite contact; there are other occurrences apparently unrelated to greenstone. The belt of granite west of the Blue Ridge extends northward into granodiorite beyond the greenstone outcrop.

The age relation of the pink granite & granodiorite ~~and~~ to greenstone is difficult to determine, as the greenstone is very little changed at its contact with granodiorite and granite. Farther south, near Buchanan, Botetourt County, a red granite intrudes greenstone. There are few available contacts in the Stony Man quadrangle. Granite bodies which crop out within greenstone areas suggest an intrusive relationship, as in the southwest corner of the quadrangle. A thin band of greenstone is found in granite just west of Hughes River Gap. In Little Devils Stairs, red and pink granite occurs under greenstone that is intruded by stringers of the granite which contains small amounts of chalcopyrite. Granite juices appear to have soaked into the flow but effects that may be attributed to contact action are confined to the basal inches of the greenstone. Here, as elsewhere, the granite, which is fine grained, commonly assumes a brick-red or jasper-red color. A fine-grained granular rock of epidote and quartz is not uncommon at the contact. The quartz may be red, milky, or colorless; the greenstone may contain red quartz grains.

Relation to Granodiorite ~~and~~ & Granite

Replacement of granodiorite & granite by pink feldspar and epidote has produced a rock called unakite. These minerals replace the feldspars and ferromagnesian minerals. ~~of the granodiorite.~~ There are extensive replacements in which green-gray feldspars of the granodiorite are (a) partly altered to epidote, or (b) are completely replaced by epidote and pink feldspar. Such effects are generally so local, that within a few feet, the intruded rock is unaffected.

In true unakite, pink feldspar comprises 50 - 75 percent of the mass; the remaining minerals are epidote and generally blue, smoky, or milky quartz. The term unakite was first applied by Bradley[1] from occurrences in the Unaka Mountains of North Carolina.

[1] Bradley, F. H., Amer. Jour. Sci., 3rd ser., vol. 7, p. 519-520, 1874.

There are several occurrences of unakite in this quadrangle. Small patches are found in the granodiorite southwest of Thornton Gap, and exposures on the old Gordonsville pike near Fishers Gap have been described by Phalen.[1] The largest unakite area

[1] Phalen, W. C., op. cit., p. 306-316.

is near the head of Dark Hollow, east of Fishers Gap. The rock has a variable composition, because part of the granodiorite is but little affected. Generally the feldspars are pink and are more or less replaced by, or altered to, epidote; some of the original feldspars are partly altered to a greenish mass of epidote and quartz. Small red quartz grains are scattered through the unakite or are included in its feldspars. Excellent hand specimens may be obtained at this locality, but the alteration to unakite is too irregular to render the rock of commercial value. Some of the original coarse dioritic texture has been preserved, in spite of complete replacement of original feldspar by pink feldspar and epidote.

A dike-like zone of unakite in granodiorite is crossed by the highway one mile due northwest of Fishers Gap, where several varieties occur. Specimens show (1) granodiorite with the addition of red feldspar, (2) true unakite consisting of red feldspar,

blue quartz and epidote, (3) masses of pink feldspar with some blue quartz, (4) epidote and blue quartz, (5) veins of epidote containing large pink feldspar and some blue quartz, and (6) masses of nearly pure epidote with pyrite cubes.

A narrow band of unakite, which may be an extension of the above, is crossed by the old road to Skyland on the west side of the mountain. Specimens contain light-pink feldspar, blue or smoky quartz, and patches and stringers of epidote that carry small red quartz grains. Unakite is also found in Little Devils Stairs. A poor grade showing slight replacement of granodiorite is found on Brushy Top at Skyland, and at Blackrock near Fishers Gap. Good specimens of several varieties of unakite may be collected on Skyline Drive northwest of Franklin Cliffs.

Bushy Top (one word)

Origin

Occurrences of unakite and pink granite in this quadrangle do not suggest or support any single hypothesis for their origin, but field studies elsewhere in Shenandoah National Park, indicate a tendency for this rock to favor contacts of granodiorite or granite with Catoctin greenstone and where unakite occurs [illegible] There are many contacts where it is absent, but more where there is some alteration of the intrusive rock to epidote and red iron oxide. The degree of alteration at any contact can not be anticipated. There may be a wide zone of altered granite or granodiorite, or the alteration may be local, or even absent.

The granite or granodiorite a greenstone roof now removed by erosion may have [illegible] immediately over it.

It is generally agreed that the epidote is secondary, probably produced by hydrothermal alteration of the calcium-bearing silicates. ~~[illegible]~~ Red iron oxide seems to produce the

jasper-red color common to the granite near the Catoctin contact. Thin seams and stringers of this oxide replace the granites and granodiorite, and the red color of the feldspars may be due to inclusions of this mineral. This is supported by exposures of granodiorite at Hughes River Gap, in which the minerals retain their original texture and composition, although in thin sections they have been replaced by iron oxide along cracks and cleavage planes. Iron oxide seems to be responsible for dark-red and purplish-red colors of the granite. That epidote and red iron oxide have been produced by hydrothermal action of downward circulating meteoric waters, however, does not adequately explain why these secondary changes should be [redacted] associated with the greenstone contact.

Alteration to unakite is extremely irregular, commonly extending downward in zones into the intrusive that may be some distance from the greenstone border. In such cases it is probable that a vigorous interchange of solutions took place at considerable depths. Elsewhere this type of unakite resembles a cross-cutting intrusive of Red Ray granite before it was replaced by epidote.

That the epidote-rich facies of granodiorite and granite occurs so generally near greenstone contacts, strongly suggests the latter as a source of iron and calcium. Possibly these elements were brought upward by hydrothermal solutions and deposited below the greenstone. Epidote contains more calcium than does anorthite, yet the most basic feldspar of the granodiorite is andesine; and it is difficult to find a process that could transport

and concentrate large amounts of calcium and ferric oxide under the Catoctin greenstone from rocks which are markedly deficient in these elements in contrast with the ~~epidotic facies~~ greenstone.

The relation of unakite and epidote-bearing granites to the borders of Catoctin flows ~~does not~~ imply an intrusive contact, and ~~but~~ suggests that hydrothermal solutions have reacted with minerals of the basalt to produce the border zone of epidotic rocks. ~~Indeed, the flows might even be younger than the granites; although~~ Evidence that the granites and granodiorite intrude the flows can be obtained also from other sources.

In describing the unakite as a type of hypersthene syenite, Watson [1] recognized its vein character in Madison County, North

[1] Watson, T. L., and Cline, J. H., Hypersthene syenite and related rocks of the Blue Ridge region, Virginia: Geol. Soc. Amer. Bull., vol. 27, p. 193-234, 1916.

Carolina, and believed that some of it arose as "magmatic segregations or secretions similar to schlieren or possibly pegmatite, some of whose original constituents may have altered to epidote chiefly by hydrometamorphism."

Jonas [1] regards pink granite in the Blue Ridge of southwest

[1] Jonas, ~~Anna~~ I., Granodiorite, its intrusion and replacement by the Air point granite in Virginia: Geol. Soc. Amer., Preliminary list of titles and abstracts, p. 29-30, 1933.

Virginia as "a coarse pegmatite, and the pink feldspars, orthoclase and microcline replace the more basic feldspars of the granodiorite in part or entirely, and with the accompanying epidote form a pink feldspar-epidote-quartz rock called unakite."

> insert

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Another paper by Jonas [1] suggests that hydrothermal changes

[1] Jonas, Anna I., Hypersthene granodiorite in Virginia: Bull. Geol. Soc. Amer., vol. 46, pp. 47-60, 1935.

in the granodiorite were "produced by residual magma extracts, which acted upon the consolidated portions of the granodiorite. In other words, the changes were deuteric, or epi-magmatic." It also discusses an alteration of granodiorite to unakite which was accompanied by albitization in the presence of sodic solutions.

In summary, evidence indicates that the red epidote-bearing facies of granite and granodiorite was produced by hydrothermal action, probably of upward-circulating solutions. It was formed after the intrusion of granites and granodiorite into the Catoctin series. The facies usually occurs directly under the volcanic rocks, or is found at the surface as a border zone of altered rock that separates the volcanics from the unaltered intrusives. It is believed that Catoctin volcanic rocks have been the chief source of calcium and ferric oxide, which in the form of epidote and free oxide, abundantly replace feldspars of the intrusives.

Age

According to the above theory of origin, pink granite and unakite were produced after intrusion of granodiorite and Old Rag granite or during its closing stages.

Early Cambrian arkose (Loudoun) contains red and pink feldspar fragments of unakite west of Bushy Top, where a wagon road to Oldrag P. O. crosses the headwaters of Whiteoak Canyon.

LOWER CAMBRIAN IGNEOUS ROCKS

Basal Cambrian Flows.

A purplish-red slaty amygdaloidal lava flow occurs in this part of the Blue Ridge at the base of the early Cambrian arkosic sediments. So far as is known, the flow is restricted to the west side of the range, i. e., below the Weverton formation. At the north, the belt containing the flow begins east of Rileyville; it extends across this quadrangle with good exposures on the east side of Knob Mountain, along Jeremys Run valley, and in Basin and Cubbage hollows. This flow in the Stony Man quadrangle was discovered in 1932, and has been jointly described by both authors.[1]

[1] Furcron, A. S., and Woodward, H. P., Basal Cambrian lava flow in northern Virginia: Jour. Geology, vol. 44, p. 45-52, 1936.

INSERT

Editor:

The following description of this rock is taken with only minor changes from the writers' previous paper on the flow.

H. P. Woodward, January 1, 1940

Distribution

The flow is exposed at many places along the west slope of the Blue Ridge between Rileyville and Stanley in Page County, where the elevations of its outcrops range from that of Page Valley, 1,100 feet above sealevel, nearly to the crest of the Blue Ridge, some 3,000 feet higher. (Pl. .) From its proximity and superficial resemblance to Catoctin greenstone, as well as from an obscure topographic position, this Paleozoic extrusive has escaped previous recognition.

Exposed ledges of amygdaloid are inconspicuous at the point where the flow was first observed along the western slope of Hoak Hill, 7 miles southeast of Luray. Additional and more diagnostic exposures, however, have been examined as far north as Rileyville, and an analogous extrusive rock is known to occur at a similar stratigraphic position in the Blue Ridge south of Stanley. Although the rock is not universally present along the western slope of the Blue Ridge, nevertheless it may be observed at many localities where the pre-Cambrian-Paleozoic contact is accessible. (See Pl. .)

This amygdaloidal flow at the base of the Weverton is generally reddish brown or dark brown. A few exposures show a chocolate-colored rock; at other points, the material superficially resembles reddish shales of the Waynesboro formation of early Cambrian age. The flow is variable in thickness and is locally absent--a fact which indicates that considerable erosion followed its extrusion and preceded the initial Cambrian sedimentation.

Several localities exhibit the flow to good advantage. A wide outcrop surrounds Knob Mountain, 8 miles northeast of Luray; and exposures are visible along both valley walls of Jeremy's Run, 1 mile east of Vaughn. It is exposed at the base of the Cambrian section along Lee Highway, 6 miles east of Luray and 1 mile east of Pumpkin Hill, as well as in slopes behind ~~Hill~~ Hall School. Another exposure, near Blaineville, is crossed on the western flank of Hoak Hill by the road which leads southeastward from Stony Man village. Deep narrow isolated recesses, including Basin and Cubbage hollows, have been eroded into the west foot of the Blue Ridge south of Stanley, and exhibit the lava flow at the base of the

Paleozoic group. A good exposure occurs in Lucas Gap on Tanners Ridge, between Basin Hollow and the valley of Hawksbill Creek.

The amygdaloid has been traced in a discontinuous belt from a point east of Rileyville nearly to Brown Gap at the junction of Albemarle and Rockingham counties. Mashed slaty facies of this rock are well exposed along the road west of Simmons Gap in Rockingham County. No exposures of the flow, however, have been observed on the eastern slope of the Blue Ridge, nor is it known definitely to underlie the outliers of Loudoun in the Blue Ridge proper.

Megascopic Character

The rock is non-porphyritic but commonly contains amygdaloidal vesicles that are usually filled with white or pink quartz. Fillings of epidote, which are characteristic of the Catoctin amygdaloids, are rare or absent in the Cambrian flows, where the amygdules are smaller than those of the Catoctin amygdaloids. Hand specimens of fresh rock are either dense or slaty. Upon weathering, the flow disintegrates readily to a soft clay-soil in which few fragments of solid rock occur. In deeply weathered cuts fresh specimens of the amygdaloid are rare. Wherever the rock has been strongly crumpled, a slight cleavage is present and the amygdules are crushed flat. In general, however, the Cambrian flow beds are less metamorphosed than those of the Catoctin greenstone.

Along the western side of the Blue Ridge, southwest of Luray, a green schistose rock locally occurs at this horizon. This material, which is distinctly porphyritic, is also found east of Elkton.

At the top of the Blue Ridge, on the western side of Big Flat Mountain, near the junction of Greene, Albemarle, and Rockingham counties, the porphyritic facies is extensively developed. In hand specimen the rock lacks epidote, is gray green in color, and is finely schistose. It exhibits the moderate metamorphism which is characteristic of the lower Paleozoic sediments of the region, and contains large, rectangular, feldspar phenocrysts that reach 1 inch in length and 1/2 inch in diameter. Some feldspars are crushed into flat light-gray masses. Where less strongly mashed, they are gray or greenish gray in color, and do not exhibit polysynthetic twinning. Where they have largely escaped crushing, the feldspars are little altered from their original condition, although there is some alteration to calcite. Several of these phenocrysts which were examined showed indices of refraction between 1.558 and 1.565.

In Cubbage Hollow, southwest of Stanley, the flow varies ~~between~~ 0 ~~and~~ 200 feet in thickness. It is not present on the western side of the hollow where the basal members of the Weverton rest directly upon the granodiorite. On the eastern side of the hollow, a short distance away, the amygdaloid has a thickness of at least 150 feet and immediately overlies granodiorite and unakite.

Near Lucas Gap in Basin Hollow, the flow has been partially reworked into sediment; and it apparently grades directly upward into the lowest members of the Weverton formation. The Catoctin greenstone beneath the flow is massive at this exposure, and contains several zones of a purplish amygdaloid which is rich in epidote. In the initial examination of the exposure, all of the

amygdaloidal material was tentatively assigned to the greenstone. It was not until the amygdaloid was found directly over granodiorite and under lower Cambrian sediments that the true age of the flow could be demonstrated.

In the vicinity of Baileys Store, 2 miles south of Stanley, the basal Cambrian sediments are largely composed of re-worked volcanic materials which superficially resemble red slaty varieties of the flow rock. This type of sediment may be well studied in an outlier 1 mile northeast of Baileys Store, where hand specimens of the rock contain grains of quartz and feldspar that were introduced from the old intrusives during the re-working of the material. In places this sediment is interlayered with beds of normal sandstone and shale.

An interesting but somewhat inaccessible exposure of the basal Paleozoic contact occurs below Franklin Cliffs at the head of Little Hawksbill Creek, 5 miles southeast of Stanley, at an elevation of about 2,500 feet above sealevel. The creek falls from ledges of greenstone across a narrow outlier of Weverton sediment in which the Cambrian arkoses lie at the contact of greenstone and granodiorite. The lowest Paleozoic unit is a coarse conglomerate which contains fragments of both types of pre-Cambrian igneous materials, as well as unrounded fragments of the amygdaloid.

Microscopic Character

Microscopically, the flows usually show a fine felt-like ground-mass of sericite with other secondary minerals. There is much red iron oxide, which is responsible for the prevailing color

of the rock. No feldspar phenocrysts appear in thin sections that were examined from exposures near Luray, although there are numerous elongated rectangular minerals that have been altered to sericite. Little epidote is present, and the flow appears to be less basic than the Catoctin greenstone.

In the absence of chemical analyses, it is not safe to attempt an exact classification of this rock. Its usual physical appearance is suggestive of a vesicular rhyolite, but it is probably more femic than a true rhyolite and more salic than the Catoctin metabasalts. The absence of epidote is notable. Through the introduction of secondary minerals and subsequent metamorphism, the flow has become altered to a slaty rock in which flow structures, such as banding, are rarely encountered. The rock does not remain uniform in character when traced along the line of strike. Southwest of Elkton, where it is locally sericitic, its color is similar to certain facies of the Loudoun formation.

As it is less resistant than the igneous rocks beneath and the sediments above, the flow produces no distinctive topography or soil; and its presence can be determined solely upon the identification of amygdaloidal material.

Age and Origin

This volcanic rock is assigned to the lower Cambrian. It occurs most commonly between the earliest sediments of the Paleozoic and the Catoctin greenstone. It has been found, however, above granodiorite in the absence of any greenstone--a fact which strongly suggests that the extrusive is later or younger than either the greenstone or granodiorite. Indeed, no other interpretation is

possible except to identify the amygdaloid with the greenstone in apparent contradiction of the lithologic and stratigraphic evidence. Small, narrow, linear inclusions of red, slaty volcanic rock likewise occur within the area of the Catoctin greenstone in the same manner as do similar outliers of lower Cambrian sediments. This mode of occurrence suggests that the surfaces of both greenstone and granodiorite were irregularly eroded before the Cambrian sediments were deposited or the amygdaloid extruded. Probably the erosion which preceded the extrusion of the flow was sufficient to penetrate the Catoctin greenstone, and to expose, at one locality at least, the invading granodiorite.

Some of the small, isolated patches of basal Cambrian are largely composed of fragments of slaty amygdaloid. This condition appears to be present both in the sediments along the foothill belt west of the Blue Ridge and in some of the sedimentary outliers within the Blue Ridge Province. It is probable that considerable amounts of the amygdaloid were eroded from this region before the initial Cambrian sediments were deposited, and the total absence of the flow in some localities points to an erosion interval following the early Cambrian volcanism.

Evidence presented above seems to indicate an early Cambrian age for the volcanic rock in question. In other areas along the Blue Ridge, amygdaloidal material is also known to occur either within, or at the base of, the Weverton, or its equivalent, the Unicoi formation. An amygdaloidal bed has been reported near the base of the Weverton east of Front Royal, and also on the Rock Fish Gap road southeast of Waynesboro.[1] Similar beds are now

[1] Stose, G. W., and others, Manganese deposits of the west foot of the Blue Ridge, Virginia: Virginia Geol. Survey Bull. 17, p. 13, 1919.

known to occur within the Unicoi in other parts of the State, as well as in the type locality of the Unicoi in northeastern Tennessee, where volcanic material occurs with the early Cambrian sandstones.

The presence of extrusive volcanic rocks at the base of the Cambrian system indicates a renewal of volcanism at the beginning of the Paleozoic Era, although the volume of Paleozoic volcanic material is far less than that to be found within the pre-Cambrian rocks. It is probable that further search for this flow will uncover additional exposures in areas where it has thus far escaped observation.

Dike Rocks

[redacted] rewrite

General Features

Dikes and sills of Triassic diabase occur widely in crystalline rocks west of the Atlantic Coastal plain from Massachusetts to South Carolina, where their intrusion is related to the deposition of shales and sandstones in downfaulted inland basins. The largest of these basins is continuous from southern New York to north-central Virginia. Triassic rocks in Virginia have been discussed by Roberts,[1] and the Triassic of an area east of the Stony Man quadrangle has also been described by Furcron.[2]

[1] Roberts, Joseph K., Geology of the Virginia Triassic: Virginia Geol. Survey Bull. 29, 1928, pp.

[2] Furcron, A. S., Geology and mineral resources of the Warrenton quadrangle: unpublished manuscript in files of the Virginia Geological Survey since 1935. Bull 54, pp. , 1939.

In this quadrangle [redacted] dikes are most common in the area north of Old Rag Mountain where they cut granodiorite and granite. (See Pl. .) None is known to intrude Catoctin

Greenstone Dikes

General Features

Narrow diabase dikes cut the granodiorite and Old Rag granite of the Park area and such dikes are common in the Stony Man area. They are usually dense, fined grained rock which is greenish in hand specimens. The term "greenstone" is not entirely applicable for they contain much pyroxene, whereas the Catoctin greenstone rarely, if ever, contains that mineral. These dikes represent original gabbros and gabbro diabases in which the pyroxenes are considerably altered. There is considerable differance in the degree of alteration, but they have not been altered by regional meta morphism. Some of the dikes contain much plagioclase and others very little. Similar dikes occur in the Piedmont east of the Park area.

Megascopic and Microscopic Character

The dikes are narrow ranging from a few feet to perhaps a 100 feet in width. They are difficult to trace in the field ~~and~~ there must be projected by means offew exposures. Their strike is mainly northwestward. One dike nearly 2 miles long is shown on the geologic map(Pl. 1) but most others are much shorter. Several narrow dikes intrude granodiorite and granite along the Lee Highway east of Thornton Gap.

The rock is dense, fine-grained, and green-black;its minerals cannot be recognized without magnification. Under the hand-lens, however, dark ferromagnesian minerals and gray, lath-shaped feldspars are readily visible.

Several thin sections that were examined showed an augite gabbro with the ophitic texture of diabase. Listed in order of importance are plagioclase, augite, and some quartz. The plagioclase has the broad twinning lamellae of labradorite, but is too much altered to assure certain identidication. Light colored augite, some in euhedral crystals is abundant but is considerably altered to chlorite;magnetite is also rather abundant. None of the minerals has been strained or mashed by regional metamorphism.

Geologic Age

The geologic age of these dikes is unknown but they are here tentatively ascribed to the Cambrian. Certainly they are later than all the pre-Cambrian rocks of the area, although they might be pre-Cambrian in age yet younger than the other pre-Cambrian rocks because the pre-Cambrian rocks of this area have not been much mashed or altered by regional metamorphism. They are not related to granodiorite and granite and do not have the prevailing northeast-southwest trend. Furcron in a later study of the igneous rocks of the Shenandoah National Park area has not been able to trace them into Catoctin greenstone rocks. They contain much unaltered pyroxene and the latter mineral is rare or absent in Catoctin greenstone.

Mineralogically they very much resemble the Triassic dikes of the Piedmont area, but are much more altered than the Triassic dikes. The relation of the Blue Ridge dikes to the Valley dikes of Triassic or Permian age is not known although geographically the relation is a close one. Mineralogically, however, there are many differences although it is obvious that some of the Valley dikes may owe their peculiar composition to assimilation of calcareous sediments.

Gen. Fea (Tr.) Geologic Age —

In this area

[redacted] greenstone dikes are found to be later in age than pre-Cambrian rocks. In trend and mineral composition they very much resemble the Triassic dikes of the Piedmont area, but show considerable alteration, a feature not present in Triassic intrusives from Georgia to Connecticut. They are therefore, here tentatively placed in the Lower Cambrian, thus may be connected in origin with the flows described above in the Lower Cambrian sediments.

greenstone or any of the Paleozoic sediments in this quadrangle, although dikes intrude early Cambrian deposits in the Warrenton area ~~district~~. ~~The local dikes are classified as Triassic mainly on the basis of their mineralogic resemblance to known Triassic intrusives elsewhere, and because they cut almost all other igneous rocks.~~

Megascopic Character

[redacted] dikes are generally narrow bodies that range from a few feet to perhaps 100 feet in width. They are difficult to trace in the field ~~and~~ thus must be projected by means of few exposures. Their strike is mainly northwestward, thus later than the "Appalachian" structural trend. One dike nearly 2 miles long is shown on the geologic map (Pl. 1), but most others are much shorter. Several narrow dikes crop out along the Lee Highway east of Thornton Gap, where they intrude granodiorite and granite. (See Pl. .)

Their rock is dense, fine-grained, and green-black; ~~its~~ the minerals cannot be recognized without magnification. Under the hand-lens, however, dark ferromagnesian minerals and gray lath-shaped feldspars are readily visible. The greenish color suggests some alteration of the ferromagnesians, but most of the rock is fresh, unmetamorphosed, and similar to that of Triassic dikes elsewhere in Virginia.

Microscopic Character

Several thin sections of these rocks were examined, each of which showed an augite gabbro with the ophitic texture of diabase. Listed in order of their importance are plagioclase, augite, and

some quartz. The plagioclase has the usual broad twining lamellae of labradorite, but is too much weathered to assure certain identification. Light-colored augite, some in euhedral crystals, is abundant but is considerably altered to chlorite; magnetite is also rather abundant. None of the minerals has been strained or mashed by regional metamorphism. The assemblage is that normal to Triassic diabase, but the rock is more weathered than fresh diabase from other parts of the Piedmont region.

SEDIMENTARY ROCKS

GENERAL FEATURES

The northwestern third of this quadrangle has a bedrock basement of Paleozoic sediments. Upon some of the latter as well as upon the crystalline outcrop are distributed certain unconsolidated deposits of Quaternary and Recent age. Scattered exposures of overlying sediments [redacted] occur in the Blue Ridge. (See Pl. .) All but the Valley are described in the following section, which is prepared by [redacted]. Woodward.

Inasmuch as Page Valley is almost entirely covered with deep residual soil and with an additional blanket of alluvial gravel, exposures of Paleozoic formations are unusually scarce, and the meager ledges do not fully reveal the various sedimentary rock units. For descriptions of many of the latter, it has been necessary to go beyond the strict limits of this quadrangle.

The following generalized columnar section indicates the local Paleozoic sequence in its proper chronologic order, the oldest formation being at the bottom. It shows the sedimentary

rocks of this region as they might be encountered in a well drilled through the entire section. (See also Pl. .)

Columnar Section of Paleozoic Rocks, Stony Man Area, Virginia

System	Formation	Thickness [1]
DEVONIAN 1,750± feet	Romney black-shale facies	1,600± Feet
	Onondaga shale	100±
	Helderberg limestone: Coeymans member	5 - 40
	Helderberg limestone: Keyser member	20 - 50
SILURIAN 1,380-1,655 feet	Tonoloway limestone	380 - 415
	Wills Creek formation	150 - 225
	Bloomsburg redbed facies	185 - 235
	McKenzie-Clinton formations	65 - 80
	Tuscarora sandstone	600 - 700
ORDOVICIAN 3,500± feet	Martinsburg shale	3,000±
	Chambersburg limestone	100±
	Athens shale	300±
	Lenoir limestone	75
	Mosheim limestone	30 - 50
CANADIAN 1,400-1,700 feet	Bellefonte (?) dolomite	800-1,000
	Nittany (?) dolomite	600 - 700
OZARKIAN 1,850± feet	Chepultepec limestone	100±
	Conochocheague limestone	1,750±
CAMBRIAN 5,350-6,800 feet	Elbrook limestone	1,300-1,800
	Waynesboro shale	800-1,200
	Tomstown dolomite	1,000±
	Antietam sandstone	550 - 600
	Harpers shale	500 - 600
	Weverton-Loudoun formation	1,200-1,600
	Approximate total	15,200-17,200
(pre-Cambrian crystalline rocks)		

[1] Many of these thicknesses are estimated from the width of outcrops or by analogy with nearby areas.

In many respects, the Paleozoic stratigraphy of this interesting region is of critical value. For all formations above the Martinsburg shale, the Massanutten synclinorium contains the easternmost outcrops in the north-central Appalachian region. Thus, the Tuscarora, Wills Creek, Tonoloway, and Helderberg exposures of

Fort Valley and Massanutten Mountain are wholly east of all other belts of these rocks. Unfortunately, however, their extension into this quadrangle is exceedingly limited, and most data regarding post-Tuscarora horizons have been obtained from exposures beyond the limits of this area.

The Massanutten fold also marks the site of an important Paleozoic environmental boundary, as is revealed by certain pre-Tuscarora formations of Page Valley that show differences from their counterparts in Shenandoah Valley. These differences are most marked in the Ordovician section. They decrease in magnitude toward the south, but become greater northward and are most important in northern Virginia and the eastern "panhandle" of West Virginia.

CAMBRIAN SYSTEM

Introductory Description

The Cambrian sequence of the Stony Man quadrangle contains the following six formations in descending order:

Cambrian Rocks

Calcareous group	Elbrook limestone.....	1,300 - 1,800 Feet
	Waynesboro formation.....	800 - 1,200
	Tomstown dolomite.....	1,000±
Arenaceous group	Antietam quartzite.....	550 - 600
	Harpers shale.....	500 - 600
	Weverton-[redacted]formation..	1,200 - 1,600
	Total.....	5,350 - 6,800

In addition to the formations listed above, two other units are sometimes included in the Cambrian of this region. These are the Conococheague limestone, which overlies the Elbrook limestone,

and the still younger Chepultepec limestone. Grouped together as Ozarkian, these two units are considered latest Cambrian by many authors. It has been suggested, however, by Ulrich,[1] Butts,[2]

[1] Ulrich, E. O., Revision of Paleozoic systems: Geol. Soc. Amer. Bull., vol. 22, p. 627-29, 649-50, 1911.

[2] Butts, Charles, Geologic map of the Appalachian Valley of Virginia: Virginia Geol. Survey Bull. 42, p. 8-10, 1933.

and others, that they may be sufficiently distinctive in lithologic character, geographic extension, and faunal content to warrant the erection of a distinct post-Cambrian system of independent rank. This proposal, although not widely accepted, has many staunch supporters whose defense of the new system can not be summarily dismissed. In view of a possible uncertainty as to the correct allocation of Ozarkian formations, descriptions of the Conococheague and Chepultepec limestones are here withdrawn from those of accepted Cambrian formations, and follow the latter under a separate heading, where they are jointly discussed with certain associated rocks of questionable Ordovician age.

Cambrian rocks, oldest non-crystalline materials of the Stony Man area, are limited in outcrop (1) to a narrow belt in the west-central portion of this quadrangle, and (2) to various isolated patches in the Blue Ridge of the Shenandoah Park area. The Cambrian system is readily divisible into an older arenaceous group and a younger calcareous unit. The resistant sandy beds of the older group form low foothills along the Blue Ridge, but the weaker limestones and shales of the younger division underlie the Valley lowland. Basal Cambrian beds rest unconformably upon the pre-Cambrian complex with ample evidence that a long period of disturbance and erosion preceded their deposition. The total Cambrian

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This formation as defined occurs [illegible] Precambrian Greenstone gneiss and granodiorite in the Blue Ridge [illegible]. Deposits, if present in the Stony Man area are small and unimportant. For a discussion of rocks formerly ascribed to this formation for this area see pages [illegible].

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thickness in this area is at least 5,300 feet and may reach 6,600 feet, not including the Conococheague and Chepultepec formations.

It has been suggested [1] that the Weverton, Loudoun, and

[1] Resser, C. E., Cambrian system (restricted) of the southern Appalachians: Geol. Soc. Amer., Sp. Paper 15, p. 2, 20, 1938.

Harpers formations should be excluded from the restricted Cambrian system and assigned to a pre-Cambrian Paleozoic system of independent rank. With this suggestion, the writer (Woodward) can find no point of agreement.

Weverton-Loudoun Formations

Definition

In describing the rocks of the Catoctin belt of northern Virginia, and eastern West Virginia and Maryland, Keith [1] named

[1] Keith, Arthur, Geology of the Catoctin belt: U. S. Geol. Survey 14th Ann. Report, p. 324-333, 1894.

and defined two units of the arenaceous basal Cambrian. One of these units, called Loudoun from its numerous exposures in Loudoun County east of the main Blue Ridge, is a heterogeneous formation of conglomerate, quartzite, slate, and phyllite; the other, called the Weverton formation from Weverton, Maryland--near Harpers Ferry--is a much thicker bedded arkosic quartzite. Keith recognized two phases of his Loudoun formation: (1) coarse sandstones occurring in synclines of crystalline rocks with no overlying Weverton present; and (2) slates associated with the Weverton. The former phase is restricted to outcrops in or east of the Blue Ridge massif; the latter occurs only on the west side of the Blue Ridge. It was his

interpretation that the Loudoun was an older and the Weverton a younger unit of a continuous columnar section of the basal Cambrian.

Throughout the area of this quadrangle, two distinct facies of basal Cambrian sediments are recognized: (1) an eastern phase occurring in synclines of crystalline rocks, and (2) a western facies occupying the foothill belt west of the Blue Ridge front. The eastern facies is obviously the Loudoun formation of Keith and others, and is so described. The western facies in this quadrangle is assigned wholly to the Weverton formation, and the two facies are here believed to be approximately contemporaneous rather than successive beds. There is no evidence within the Weverton formation of this quadrangle to warrant differentiation of a lower member to which the name Loudoun might be appropriate; and the latter is believed to be the eastern counterpart of the western Weverton.

Thus redefined, the Loudoun formation is the basal Cambrian rock of the Blue Ridge and Piedmont areas; the Weverton is the basal Cambrian formation of the Valley and Ridge belt, here cropping out only in the foothill belt west of the Blue Ridge. Both rocks are approximately synchronous with the Unicoi formation of the southern Appalachian.

(insert)

Weverton Formation

Distribution and Character

The Weverton formation of this quadrangle is restricted by definition to the foothill belt west of the Blue Ridge front, in an outcrop which is continuous from Compton to Stanley except for

⊗ Marksville

Recast ‖ ×

× outcrop continuous from Compton to {Pattleburg School / Piney Hill} Another belt from S end of Piney Shrunes to Marksville. Locally two small areas

Stanley vs. Marksville ?

two small areas directly south of Marksville and east of Piney Hill where faulting has eliminated the basal Cambrian. The belt is mostly about one-half mile wide, exceeding this width mainly where the Weverton rises toward the summit of the Blue Ridge on Knob Mountain (Pl.), the Neighbor (Pl.), and on the main crest between Beahms and Elkwallow gaps. Erosion of this Cambrian unit produces topography that is relatively smooth and possesses a fairly coarse texture. The resulting soils are usually fertile and support a sturdy growth of timber.

The Weverton formation is composed chiefly of sandstone, arkose, and sandy shale (Pl.); its general color is dark and its sandstones are commonly dark red-purple and medium grained. Cross-bedding is both common and conspicuous, showing clearly in the lighter-colored or streaked members of the formation. Many of the shales have been sufficiently metamorphosed to approach the lithologic character of phyllites or slates; they are commonly light colored, bluish, or silvery. As a unit, the Weverton is red stained after weathering, and yields small debris along its outcrop. The main rock is fairly massive, and does not stand long in strong ledges, weathering rapidly to a splintery soil. Mica is fairly prominent, much of it being secondary along cleavage planes. A considerable body of the Weverton is a heather-colored rock with many ledges of reddish pebble-conglomerate. The pebbles are generally somewhat flattened, and the rock has pseudo-cleavage which makes it difficult to trim. Its sandstones break readily, splintering into a loose sandy soil. Some of the pebbly beds are ferruginous, approaching, but not attaining, the iron content of Blue Ridge hematite commonly found in the Unicoi formation, the

more southerly equivalent of the Weverton. The upper portion of the Weverton contains more quartzitic material than the lower portion, and many of these upper quartzitic beds resemble those of the Antietam.

Although the lower Weverton is irregularly pebbly, there is no strong basal conglomerate. The formation generally overlies either Catoctin greenstone or hypersthene granodiorite. In a few localities, however, it succeeds a thin bed of amygdaloidal lava that is believed also to be of lower Cambrian age. [1] (See

[1] Furcron, A. S., and Woodward, H. P., Basal Cambrian lava flow in northern Virginia: Jour. Geology, vol. 44, p. 45-51, 1936.

pages .) At some places, as near Bailey Store, the lower beds are derived from the underlying lava; in other exposures, the flow is intercalated with the basal sediments. In the vicinity of Front Royal, the Weverton contains a higher basalt flow. The best Weverton exposures are (1) along upper Stony Run in Basin Hollow, (2) near Pumpkin Hill, and (3) near Compton.

Is Compton which Kimball

The Weverton contains no material of economic value. However, directly north of this quadrangle on Moody Creek, residual deposits of brown iron-ore occur near a contact of the Weverton and Catoctin greenstone. (See pages .)

A complete exposure of this formation is not available in this quadrangle. Estimated from the width of its outcrop and by comparison with early Cambrian sections in nearby areas, the Weverton thickness may be 1,200 to 1,600 feet. Its rock is everywhere inclined at angles of 50-70° in the foothill belt, and although not unusually deformed, has acquired a strong pseudo-cleavage

which has resulted from vigorous compression. Its conformable contact with the overlying Harpers shale is rarely visible.

Age and Correlation

No fossils have been found in the Weverton of this area. Its position, however, at the base of the Paleozoic sequence in the northern Appalachians, calls for an assignment to the lower Cambrian, where it is believed to be one of the oldest Paleozoic rocks of North America.

The Weverton formation of this report, as stated above, is re-defined to include all arenaceous Cambrian material below the Harpers shale and above the crystalline pre-Cambrian rocks. Therefore, it is equivalent to the Weverton and "Loudoun" formations west of the Blue Ridge in the Harpers Ferry section of Virginia, West Virginia, and Maryland. It is believed to be the close, if not exact, correlate of the Unicoi formation of the Blue Ridge south of James River in Virginia. ~~It's eastern counterpart, the Loudoun formation of this report, [illegible] be of contemporaneous [illegible].~~

Some geologists [1] would assign the Loudoun, Weverton, and

[1] Resser, C. E., op. cit., p. 2, 20.

Harpers formations to a distinct Beltian system, introduced into the standard geologic column as a system of independent rank at the beginning of the Paleozoic. Its sponsors believe this proposed system is earlier than the true Cambrian but later than the so-called pre-Cambrian. The present writer does not concur with such an interpretation, and believes the formations assigned to the "Beltian system" are of lowest, or earliest, Cambrian age.

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~~Loudoun Formation~~

Rocks along westerly.

~~Distribution and Character~~

By definition, ~~the Loudoun~~ these outcrops are confined to the eastern or central portion of the Blue Ridge ~~anticlinorium~~; no rocks of this type are ~~Loudoun to have~~ recognized in the early Cambrian sequence at the west foot of the Blue Ridge.

The chief [redacted]n outcrops of this quadrangle are isolated bodies of metamorphosed sediments intimately associated with pre-Cambrian crystalline rocks. (See Pl. .) In the southeastern corner of the quadrangle they extend from Thorofare Gap southwestward through Pine Hill Gap nearly to Hughes River, and from Robertson River to Fernham School and Dark Hollow. An interrupted belt, which occurs near the crest of the Blue Ridge, contains narrow inliers near Blackrock, Franklin Cliffs, Crescent Rock, and Skyland. Lee Highway (U. S. 211) crosses another outcrop near Beech Spring Church. These outcrops are all small, and, although they occur in connection with many varieties of igneous rocks, are most common along exposed borders of the Catoctin greenstone.

More highly metamorphosed than ~~its~~ analogues, t[redacted] of the foothill belt, these rocks ~~Loudoun~~ contains shales that have become contorted green phyllites, and includes arkosic beds that show a gneissoid structure which is difficult to distinguish from that of pre-Cambrian metamorphic rocks. These [redacted] phyllites contain mashed lumps, or bodies, of both quartz and feldspar in a green matrix of quartz, feldspar, chlorite, and sericite. Crumpled green phyllites are well exposed in Rose River Valley, south of Buzzard Rocks, and in Pine Hill Gap, where they disintegrate into a poor soil that generally supports a growth of scrub

pine. The feldspar and quartz of the massive arkosic beds have been rearranged into narrow bands, and in the area east of Community School, profound deformation has produced a fine-grained slaty white rock having a silky luster caused by secondary sericite. It is difficult to differentiate such rocks from deformed granites (mylonites).

A typical thin section[1] of green phyllite (Pl.) from Pine Hill Gap contained deformed, or partly crushed, lumps of quartz and feldspar. Bands of pleochroic green chlorite enwrap the crushed feldspar and quartz, while some of the latter minerals are drawn into bands of interlocking grains showing a wavy extinction. A thin section of arkose showed leaves of muscovite and biotite enclosing fine quartz grains. The latter were interwoven between crushed feldspar and quartz lenses, some of which were mashed into nearly straight bands. Most of the feldspars are perthite and plagioclase.

The most accessible [redacted] exposures are in Thorofare and Pine Hill gaps, and at Beech Spring Church. There is an interesting but somewhat inaccessible exposure below Franklin Cliffs at the head of Little Hawksbill Creek, where a coarse conglomerate forms the base of the section. (See pages .)

The structure of the [redacted] suggests its occurrence in extremely close-folded synclines whose compression has developed greater metamorphism than occurs west of the Blue Ridge front. ~~No determination of thickness is possible for the Loudoun of this quadrangle. Possibly as much as 800 to 1,000 feet of sediment may be involved in the sinuous Loudoun outcrop near Fernham School and the head of Robertson River.~~

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[1] Microscopic character described by Furcron.

Age and Correlation

As elsewhere discussed (see pages), the term Loudoun is herein restricted to basal Cambrian sediments involved within, or occurring east of, the Blue Ridge anticline, in distinction to the less-metamorphosed Weverton sediments which face the Blue Ridge front at the west. No Loudoun is recognized in the western Cambrian outcrop, and the hypothesis that the Loudoun is an older and the Weverton a younger Cambrian rock of the same sequence is here discarded.

It is believed that the Loudoun and Weverton formations of this area are largely contemporaneous, and that once they were parts of a continuous arenaceous Cambrian rock which covered the entire Blue Ridge. The greater metamorphism and alteration of the Loudoun, it is believed, has resulted from a more complex geologic history than that through which the western Weverton formation has passed. There are no fossils in the Loudoun, which is assigned to the basal Cambrian on the basis of its stratigraphic position.

Whereas the Weverton formation is overlaid by the Harpers shale, the Loudoun formation has no younger, overlying, Cambrian rocks in its area of outcrop.

Harpers Shale

Distribution and Character

The Harpers[1] shale ("phyllite") at Harpers Ferry, West Virginia,

[1] Keith, Arthur, op. cit., p. 333.

is a series of gray shales and thin sandstones that rests upon the Weverton formation. In this quadrangle, it occupies a belt which extends from a point east of Marksville northward to the northern edge of the area. (See Pl. .) The belt is interrupted (1) near Varner and Piney hills, and (2) in Green Hollow by an overthrust fault. Exposures are so meager that it is difficult to observe any bedrock that can be definitely ascribed to the Harpers. Ledges near the west end of Pumpkin Hill are probably the best local exposures of this formation. (See Pl. .) As it occupies a position between resistant sandstones, the easily eroded Harpers shale is responsible for a narrow lowland in the foothill ridges that is commonly covered with a thick veneer of gravel from adjacent sandstones. Valleys northeast of Piney Hill and northwest of Rattleburg School are floored with Harpers shale.

As here observed, the Harpers is essentially soft dark-colored sandy shale interbedded with thin layers of sandstone. Thinly and prominently laminated, it varies from a thin-bedded sandstone to a siliceous gray shale. Sandstone beds increase in thickness and abundance as the upper part of the formation is reached. The fresh rock, commonly blue to blue gray and fairly stiff, quickly weathers brown, and crumbles to soft fragments that leave no exposed ledges. Many of the shales are slightly phyllitic and possess abundant secondary sericite and mica. There are no materials of economic importance in the Harpers shale of this region.

Thickness

The Harpers shale ("phyllite") of northern Virginia is commonly reported to be from 1,200 to 2,000 feet thick, but it is doubtful if a thickness even approaching this estimate occurs in the Stony Man region, where the Harpers is believed to be from 500 to 600 feet thick. This thickness is compatible with that of the Hampton shale of the James River section of the Blue Ridge.

Age and Correlation

Although the Harpers is not known to contain fossils, there are obscure fucoidal markings on some of the beds at the west end of Pumpkin Hill. Possibly these represent some form of marine plants; on the other hand they may be wholly inorganic.

On the basis of its stratigraphic position, the Harpers is assigned to the lower Cambrian. It is an approximate equivalent of the Hampton shale of southwest Virginia and Tennessee, which occurs between the Erwin quartzite (above) and the Unicoi formation (below). In this region, as elsewhere in northern Virginia, the Harpers shale is directly underlaid by the Weverton formation, also of lower Cambrian age. At no point in this quadrangle is the Harpers shale found east of the Blue Ridge in the belts of Loudoun sandstone.

Antietam Sandstone

Distribution and Character

The Antietam is a medium-grained quartzitic sandstone, which extends along the west foot of the Blue Ridge of northern Virginia. Named from Antietam Creek, Washington County, Maryland,[1]

[1] Williams, G. H., and Clark, W. E., Maryland--its resources, industries, and institutions: p. 68, Baltimore, Maryland, 1893.

it passes southward into the Erwin quartzite of central and southern Virginia.

The Antietam sandstone extends in a narrow belt from a point near Stanley northeastward to the edge of the quadrangle in an outcrop that has been duplicated at several points by folding and faulting. Its best exposures occur (1) on Stony Run southwest of Stanley; (2) at the northeastern end of Pine Mountain; (3) on the Three Sisters; and (4) near Compton. The fresh rock is light colored to creamy white, and becomes slightly pink or reddish upon exposure. Typical Antietam sandstone is very dense, tough, and highly lithified, much of the material being truly quartzitic. There are at least two and probably three massive resistant members which produce bold ledges along the crests of ridges. (See Pl. .) The rock has been highly fractured and its brittle beds are commonly veined with secondary quartz. Even after considerable transportation, its fragmental debris remains wholly angular. (See Pl. .)

Locally there are large irregular masses of secondary quartzite-breccia near the contact of the Antietam and the Tomstown, or near the outcrop of a fault cutting the Antietam. This peculiar material consists of angular quartzite fragments in a talus breccia that has been recently cemented by circulating waters charged with silica. The most conspicuous exposure of breccia is on Jeremys Run, about 1 mile northeast of Vaughn. (See Pl. .) The rock is a heterogeneous assemblage of rock fragments of various sizes, and it occurs in sufficiently large bodies to simulate an exposure of primary bedrock.

Antietam sandy soils are so filled with boulders that they are sterile and ill adapted for cultivation. Under favorable conditions, the formation maintains foothills of considerable prominence, but the Antietam is irregular in its topographic expression. Its most rugged topography occurs where the rock is highly inclined.

Thickness and Relations

The thickness of the Antietam sandstone ranges from 500 to 600 feet. The most complete exposure is on Stony Run, southwest of Stanley, directly west of the edge of the quadrangle, where the following sequence is adapted from a measurement by Stose:

Stanley Section

Section [1] along Stony Run, near Stanley, Page County, Virginia.

Tomstown dolomite.....Not measured
Antietam quartzite.....500 Feet
1. White sandstone, crumbling readily to sand; upper layers somewhat harder; weathering red to rusty and porous. *Scolithus* common.....120
2. Hard thick-bedded vitreous white quartzite, with some *Scolithus*; upper cliff..... 40
3. Partly covered; probably crumbly white sandstone..... 90
4. Massive thick-bedded hard blue-white vitreous quartzite; middle cliff..... 80
5. Covered; probably crumbly white sandstone. 70
6. Hard white vitreous quartzite with some *Scolithus*; lower cliff.....100

Harpers shale.....Not measured

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[1] Stose, G. W., and others, Manganese deposits of the west foot of the Blue Ridge, Virginia: Virginia Geol. Survey Bull. 17, p. 16, 1919.

Elsewhere in the Stony Man area, the Antietam thickness must be estimated by the width of its sandstone outcrop.

Like other early Cambrian formations, the Antietam sandstone is inclined at moderate to steep angles. East of Marksville it is folded into a small anticline and a broken syncline; at Piney Hill it is nearly horizontal. Although its contact with the underlying beds is everywhere concealed, the Antietam is thought to lie conformably upon the Harpers shale, and to be disconformably overlaid by the Tomstown dolomite.

Mineral Resources

Several mines or prospects of brown iron and manganese ore have been worked along the Antietam outcrop, commonly near the Tomstown dolomite. At Compton, 3 miles north of this quadrangle, the workings are actually in the quartzite. These various deposits are described on pages .

Age and Correlation

The only fossil common throughout the Antietam sandstone is Scolithus linearis, which is believed to be a worm-burrow that has been filled with slightly different sand from that into which it was bored. The tubes are consistently at right angles to the bedding planes, and form a useful guide in determining structure. The Antietam is equivalent to the Erwin quartzite of the Blue Ridge south of James River.

Tomstown Dolomite

Definition and Distribution

The Tomstown dolomite, abruptly succeeding the Antietam quartzite, is the oldest calcareous rock in the Valley of Virginia. Named from Tomstown,[1] southern Pennsylvania, it is the

[1] Stose, G. W., Sedimentary rocks of South Mountain, Pennsylvania: Jour. Geology, vol. 14, p. 201-220, 1906.

stratigraphic equivalent of the Shady dolomite[1] which occupies

[1] Keith, Arthur, U. S. Geol. Survey Geol. Atlas, Cranberry folio (No. 90), p. 5, 1903.

this horizon from James River southwestward into Tennessee.

The Tomstown dolomite has two outcrops in the Stony Man area. One occurs in the southwestern portion of the quadrangle between Stanley and Hershberger Hill; the other stretches northward from Luray reservoir to Jeremy Run (Pl.), beyond which it is cut out by a fault. There are practically no local exposures of the Tomstown, the chief exception being a small dolomite ledge on the northeast side of Chub Run valley, three-quarter mile~~s~~ northeast of Marksville. The formation has not locally produced a distinctive soil, being so situated as to receive large quantities of alluvial material from the Blue Ridge. Normally, the Tomstown dolomite of other regions develops a red unctuous clay-soil.

Character and Thickness

The Tomstown is a coarsely crystalline white to gray dolomite in which limestone lenses are fairly common. The latter are blue, whereas the dolomite is generally light gray to white. Both rocks

weather readily and develop a brown color on exposed surfaces. Cleavage and minor jointing are common features in the fairly massive Tomstown dolomites. As revealed in exposures of nearby regions, much of the formation is a light blue-gray tough fine-grained splintery dolomite that is medium bedded and, although resistant to fracture and abrasion, is more soluble than other "Valley" limestones. Its outcrops usually form low ground sloping away from the foot of the Blue Ridge. Shaly zones are not uncommon near the base of the Tomstown, which is somewhat arenaceous and contains, or produces, both black and chalcedonic cherts.

The Tomstown can not be accurately measured in this region. To the north, it is nearly 1,000 feet thick, and its local thickness, as indicated by the width of its outcrop, is estimated to be 900 to 1,000 feet. Northeast of Marksville, it forms a shallow syncline bounded at the northwest by an outcrop of Antietam sandstone and at the southwest by a fault. Tomstown contacts are concealed in this area; elsewhere the basal contact is slightly disconformable although the upper contact is without apparent break.

Local deposits of brown iron and manganese ores have been worked at Stanley and at Compton near the eastern edge of Page Valley, where the ore is a residual surface concentrate near the Antietam contact. (See pages .)

Age and Correlation

Rare specimens of *Obolus* (*Lingulella*), *Salterella*, *Kutorgina*, and *Olenellus* have been reported from the Tomstown dolomite of

other areas and indicate the lower Cambrian age of the formation. Traced southward into central and southwest Virginia, the formation grades laterally into the Shady dolomite, from which a considerable early Cambrian fauna has been recently described.[1]

[1] Currier, L. W., Zinc and lead region of southwestern Virginia: Virginia Geol. Survey Bull. 43, p. 36-37, 1935.

Waynesboro Formation

Definition and Distribution

The Waynesboro is the northern unit of a series of red and variegated shales and sandstones extending throughout the Appalachian region from Alabama to Pennsylvania. Named from Waynesboro,[1] Pennsylvania, this formation passes into the Rome ("Watauga")

[1] Stose, G. W., op. cit., p. 201-220, 1906.

formation[1] south of James River, Virginia.

[1] Woodward, H. P., ..., Age and nomenclature of the Rome ("Watauga") formation of the Appalachian Valley: Jour. Geology, vol. 37, p. 596, 1929.

The Waynesboro outcrop is a continuous belt, about one-third mile wide, extending from the western boundary of the quadrangle through Stanley, Blaineville, Kimball, and Vaughn to a point about one mile south of the northern boundary. (See Pl. .) The formation has only limited exposures, best of which occur (1) west of Stanley, about 2 miles beyond the edge of the quadrangle, and (2) along the road southeast of Stony Man village; it is also exposed (3) near Kimball (Pl.), and (4) at Vaughn. Responsible for no individual topographic effect, the Waynesboro is merely one of many formations whose erosion and weathering produces the valley lowland of Virginia.

Character and Relations

The Waynesboro formation is a shaly aggregate of soft brown shale, grading into soft sub-friable micaceous sandstone, stiff red and purplish shale, and hard blue laminated limestone. All beds weather rusty brown, and the formation decomposes into a yellowish clay-soil through which are scattered fine splinters of the tougher shales.

As the formation is poorly exposed, the Waynesboro thickness must be estimated from the width of its outcrop. Probably it is at least 800 feet thick and may reach 1,200 feet.

Its beds are generally inclined steeply to the southeast. This reversal of dip is a common feature of the central part of Page Valley, where the entire sequence of rocks is overturned. (See also pages .) It is presumed, by analogy with its occurrence in adjacent regions, that the Waynesboro is conformable at both contacts.

Economic materials do not distinguish the Waynesboro formation, although its residual soil was once dug for ocher near Stanley. (See pages .)

Age and Correlation

The Waynesboro formation elsewhere contains rare trilobites (*Olenellus romensis*) and brachiopods (*Acrotreta buttsi*) of early Cambrian age. The formation is broadly equivalent to the Watauga and Rome formations of southwest Virginia and Tennessee. Possibly its upper portion may be of middle Cambrian age.

Elbrook Limestone

General Description

The Elbrook limestone,[1] which overlies the Waynesboro or Rome shales from Pennsylvania to southwest Virginia, locally occupies a continuous belt about one mile wide that extends from the northern to the western margin of this quadrangle. Although it is not uncommonly exposed, it (has neither) a distinctive topography nor produce a prominent soil type.

[1] Stose, G. W., op. cit., p. 209.

This formation is essentially a thick series of light-blue and gray shaly limestones and calcareous shales with scattered benches of more solid blue and blue-gray limestone. There is a rather pure dark-blue massive limestone member at the base. It is finely laminated and contains thin-bedded calcareous shales that weather into shaly plates. The middle of the formation is somewhat massive and contains siliceous limestone and magnesian beds that are responsible for a slightly higher topography than the lower shaly zones. The upper section is composed of light-colored calcareous shales and impure laminated limestones that are also more massive than the lower third of the formation. Some Elbrook limestones are nearly black. Where the rock has been deeply weathered, its typical residual product is a soft yellow ocherous clay similar to that of the underlying Waynesboro shale.

There are several limestone quarries in the Elbrook that apparently utilize the same bed of limestone for road metal and as a source of agricultural lime. All are small and are only seasonally operated. They are more fully described on pages

As the formation has been considerably disturbed in the deformation of this area, its thickness is difficult to estimate; probably it is 1,300 to 1,800 feet thick.

Age and Correlation

Fossils have not been obtained from the Elbrook limestone of the Stony Man area. Specimens of Dolichometopus are known from the base of the formation at Waynesboro, Pennsylvania, and Glossopleura bassleri occurs in the Elbrook near Winchester, Virginia. These fossils indicate, and the stratigraphic position of the Elbrook corroborates, a middle Cambrian age if the overlying Conococheague limestone is considered to be upper Cambrian, and an upper Cambrian age if the overlying formation is placed in the independent Ozarkian system. The latter assignment is made in this discussion. (See also pages .)

The Elbrook is equivalent to the Honaker dolomite and Nolichucky shale of southwest Virginia. It crosses the eastern "panhandle" of West Virginia into Maryland and eastern Pennsylvania, and there may be an Elbrook equivalent in the upper "Kittatiny" limestone of New Jersey.

OZARKIAN AND CANADIAN ROCKS

Discussion

The Appalachian Valley of Pennsylvania, Maryland, West Virginia, Virginia, and other southern states is floored with a thick series of calcareous rocks that present a remarkably uniform appearance from the Cahaba Valley of Alabama to the Hudson Valley of New York. Formerly these rocks were all grouped together under

a single name. Recently, however, detailed studies of the series have enabled stratigraphers to establish a number of independent formations, each with its own distinctive fauna. Of these separate units, those at the bottom of the sequence up to and including the Elbrook limestone are recognized as of Cambrian age, while at the top of the "Valley" limestones, all formations extending down to the bottom of the Stones River group (basal member in this area, the Mosheim limestone) are assigned without question to the Ordovician. Although it is plain that the actual contact, or dividing line, between the Cambrian and Ordovician systems must lie somewhere between the Elbrook and Stones River limestones, stratigraphers have not yet wholly agreed where this boundary should be placed.

For this general portion of the Appalachian region, the sequence of calcareous rocks is as follows:

Ozarkian - Canadian Rocks

(Undoubted Ordovician	Stones River limestones)	Local Occurrence
Canadian or Beekmantown series; probably Ordovician	Upper Canadian (Bellefonte?) dolomite	800-1,000 Feet
	Middle Canadian (Nittany?) dolomite	600 - 700
	Lower Canadian (Stonehenge) limestone	Absent
Ozarkian series; probably Cambrian	Chepultepec limestone	100
	Conococheague limestone	1, 750±
		Total 3,250-3,550 Feet
(Undoubted Cambrian	Elbrook limestone)	

Following the suggestions of Ulrich,[1] many modern stratigraphers separate the post-Elbrook and pre-Stones River beds into 2 units, a lower or Ozarkian division, and an upper or Canadian division.

[1] Ulrich, E. O., op. cit., p. 627-29, 649-50.

Ulrich's proposal to regard each of these divisions as a system coordinate in rank with the Cambrian and Ordovician has never been fully accepted, although it has been followed in many descriptions of both the Appalachian and Ozark regions.

As a result of recent faunal studies, evidence is accumulating (1) that the Ozarkian series of the Appalachian region (at least) is actually equivalent to the Franconia and Trempealeau horizons (late Cambrian) of the central United States, and (2) that it should not be excluded from the Cambrian system. For example, an apparently normal late Cambrian fauna has been recognized some 500 feet below the top of the Copper Ridge formation (middle Ozarkian) of eastern Tennessee. It is also true that many geologists have opposed all efforts to separate the Beekmantown (Canadian) from the Ordovician system. In view, therefore, of the problems which still remain unsolved in the correlations of these calcareous rocks, it has been thought desirable to separate their descriptions from those of the beds below and above pending an ultimate precise allocation.

The reader should recognize that the rocks here grouped as Ozarkian are considered to be latest Cambrian by most authors who similarly treat the Canadian rocks as of early Ordovician age. That these common assignments are not wholly without question has been emphasized by the present separation from the Cambrian and Ordovician sections of this report.

Ozarkian Rocks

Definition

At no point in the Valley of Virginia has it been found possible to recognize more than two Ozarkian formations. In eastern and northern belts, including the Stony Man area, the sequence involves the thick Conococheague limestone overlain by the much thinner Chepultepec limestone. In southwestern outcrops, the Chepultepec overlies a thick dolomitic sequence known as the Copper Ridge dolomite. The Copper Ridge and Conococheague formations appear to be of approximately the same age, and have been traced into the same outcrop around the end of Tinker Mountain, Botetourt County, Virginia.[1]

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[1] Woodward, H. P., Geology and mineral resources of the Roanoke area, Virginia: Virginia Geol. Survey Bull. 34, p. 37, footnote, 1932.

The known fauna of the Conococheague formation is small, consisting mainly of the following species:

Cryptozoon aff. c. steeli (Seely)
C. aff. c. proliferum Hall
Lingulepis walcotti Resser
Tellerina wardi Ulrich and Resser
Solenopleura jerseyensis (Weller)
Dikelocephalus harti Walcott

Similar equally scarce forms are known from the Copper Ridge dolomite. The type locality of the Conococheague formation is along the creek of that name near Scotland, Franklin County, Pennsylvania.[1]

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

The Chepultepec limestone [1] is named from Chepultepec, Murphrees Valley, Alabama, and its presence in the northern Appalachian Valley has only recently been discovered, although it is well developed in the central and southern Valley of Virginia, where the span of Natural Bridge is composed of this rock. The formation is fairly fossiliferous in Alabama, but few fossils are found in Virginia. Near Winchester, Virginia, however, there is a zone of Chepultepec limestone [2] which is crowded with silicified brachiopods identified as Finkelnburgia buttsi Ulrich and Cooper, F. plicata Ulrich and Cooper, and Tetraloba delicatula Ulrich and Cooper. This zone may be traced southward from Winchester for more than 35 miles, and extends northward into Berkeley County, West Virginia.

[1] Ulrich, E. O., idem.

[2] Butts, Charles, in Guidebook, Field conference of Pennsylvania geologists, Virginia--1938: Virginia Geol. Survey Bull., Guide leaflet 1, p. 21, 1938.

The joint stratigraphic horizon of the Copper Ridge-Conococheague and Chepultepec formations of the Appalachian region is readily determinable as post-Elbrook and pre-Beekmantown. The allocation of this horizon to a position in the standard geologic column, however, has not been agreed upon. Ulrich, Butts, and others believe that the horizon can properly be excluded from the Cambrian system, which is materially restricted by this elimination. These authors, especially Ulrich, [1] would place the formations in question within

[1] Ulrich, E. O., and Cooper, G. A., Ozarkian and Canadian brachiopoda: Geol. Soc. Amer., Spec. Paper 13, plate 58, 1938.

the "Ozarkian system" which is conceived by its sponsors as having independent systematic rank of post-Cambrian position. Other authors, recently Resser,[1] believe that "to bring the Cambrian

[1] Resser, C. E., Cambrian system (restricted) of the southern Appalachians: Geol. Soc. Amer., Spec. Paper 15, p. 2, 1938.

sequence of the southern Appalachians more completely in accord with the conditions found elsewhere in North America, it is necessary to regard the Copper Ridge and equivalent strata as Upper Cambrian." At the same time, however, Resser [1] would place the

[1] Resser, C. E., op. cit., p. 20.

Chepultepec in the Canadian, or next younger, group, thus excluding it from the Cambrian system.[1]

[1] It should be noted that this interpretation introduces a new and serious complication. So long as the dividing line between the Ozarkian-Canadian systems and the Cambrian-Ordovician systems are drawn at the same point (i.e., <u>above</u> the Chepultepec and below the Beekmantown), the problem is merely one of assigning the proper chronologic value to the rocks in question. On the other hand, if the Chepultepec limestone can be suspected of a Beekmantown, rather than Ozarkian, age, the problem takes on larger stratigraphic implications than before.

In view of these differences in wholly current interpretations, the writer has refrained from making any allocation of the beds in question. Stated in simplest terms, Ozarkian formations are pre-Ordovician, but whether they belong in, or after, the latest Cambrian is still unsettled.

Conococheague Limestone

Character

The Conococheague limestone, which rests disconformably (?) upon the Elbrook formation, is one of the soluble and easily eroded

rocks that have been responsible for the lowland of Page Valley. (See Pls. .) In the Stony Man quadrangle it crops out in a belt that crosses the middle portion of Page Valley in a northeasterly direction (Pl.) with a width of about 3 miles at the south boundary of the quadrangle; west; it ~~becomes more~~ narrows northward and is scarcely ~~one~~ a mile wide at the north edge of the quadrangle. There are many good exposures along the larger streams and in scattered road cuts. Accessible exposures occur (1) in the valley of Pass Run near Springfield, and (2) along Hawksbill Creek south of Luray.

This formation is a thick mass of limestone containing a lesser volume of dolomite. (See Pl. .) In general it is medium bedded, and the limestone beds are more massive than the dolomites. Distinctive is a thin interbedding of argillaceous and dolomitic bands that are more resistant to weathering than the enclosing limestone layers, and have become intensely crinkled during deformation. On a weathered surface the irregular uneven edges of these contorted bands produce a crinkly lamination that is a diagnostic feature of the Conococheague. (See Pl. .) Most of its limestones are blue, and some are nearly pure calcium carbonate.

The Conococheague formation normally produces a deep residual fertile soil that is, nevertheless, somewhat less rich and less unctuous than soil from Canadian limestones. Most of its outcrop, however, is deeply covered with alluvial debris.

Throughout this formation occur thin zones containing grains of quartz sand. In some localities, the sand is sufficiently abundant to form a lens of sandstone; elsewhere it is loosely

scattered through the limestone. A peculiar residual product marks certain parts of the lower Conococheague outcrop with saddle-shaped masses of brown to reddish sandstone composed of tiny glistening hexagonal quartz crystals.[1] The latter have

[1] Oder, C. R. L., Occurrence of doubly terminated quartz crystals in sandstone in the Shenandoah Valley, Virginia: Am. Mineralogist, vol. 14, p. 382-5, 1929.

apparently been developed by secondary deposition of silica during weathering or exposure. Excellent bodies of this unusual sandstone occur in Conococheague soil about 0.75 miles northeast of Hawksbill Church.

NW of Hawksbill Church, or some other locality is meant ?

Thickness and Relations

North of this quadrangle near Rileyville is an almost completely exposed section of the Conococheague, showing approximately 1,600 feet of limestone. (See section, page .)

No contact of Conococheague and Elbrook limestones was observed, but it is believed to be disconformable, as is the Chepultepec contact.

Age and Correlation

No fossils have been found in the Conococheague limestones of this area. Nearby, however, the formation has afforded a few fossils, mainly *Cryptozooa* (*C.* aff. *C. steeli*) and rare trilobites (*Tellerina wardi*). The Conococheague is regarded as being of early Ozarkian age. It is equivalent to the Copper Ridge formation of southwest Virginia and Tennessee, and occurs at the general horizon of the Hoyt formation of northern New York. By many geologists it is regarded as a late Cambrian unit.

Chepultepec Limestone

General Description

The Chepultepec member of the Ozarkian limestone is a thick-bedded, blue-gray limestone that is not essentially different from beds above and below. Its most distinctive local feature is a fine interlamination of siliceous impure limestone and calcareous limestone which produces a crinkly or wavy surface on ledges that have been eroded at right angles to the bedding. This structure is similar to that developed in the underlying Conococheague, but the alternating laminae of dolomite and limestone are much thinner in the Chepultepec member than in the earlier Ozarkian formation. At other outcrops, the Chepultepec exhibits fairly pure dense blue-gray limestone.

This portion of the Ozarkian is about 100 feet thick, and its distribution approximates that of the lower Beekmantown. It has an excellent exposure about 3 miles southwest of Luray Caverns along the country road which crosses Mud Pike, two miles due south of Hamburg; it is also exposed along Hawksbill Creek immediately north of Luray, and at Springfield.

Although a distinct formation has long been identified above the Conococheague and below Canadian dolomites of northern Virginia, Maryland, and southern Pennsylvania, it has previously been correlated with the Stonehenge limestone of central Pennsylvania. The presence of upper Ozarkian fossils (Finkelnburgia and Tetraloba) in this limestone near Winchester has established the Chepultepec age of this formation. (See also pages .) None of these species was found in the Stony Man area.

Canadian, or Beekmantown, Rocks

Definition

There is a considerable body of pure limestone, magnesian limestone, and dolomite which occurs widely in North America between formations carrying Ozarkian faunas and the earliest definitely accepted Ordovician rocks (Buffalo River series, Stones River group, Chazy group, etc.). Well exposed in the vicinity of Beekmantown, New York, this calcareous series has long been called the Beekmantown group; it constitutes the "Canadian system" of Ulrich [1] and others who believe it represents an independent

[1] Ulrich, E. O., Revision of Paleozoic systems: Geol. Soc. Amer. Bull., vol. 22, p. 627-29, 649-50, 1911.

geologic unit of systematic rank and of pre-Ordovician age. Most authors consider the Beekmantown to be the earliest Ordovician group.

Rocks of Beekmantown or Canadian age occur (1) in northern New York and the Hudson Valley, (2) in New Jersey, Pennsylvania and Maryland; (3) on the Nittany arch of central Pennsylvania; (4) along the Appalachian Valley of West Virginia, Virginia, and Tennessee; (5) in Alabama; and (6) in the Ozark region of Missouri and Arkansas. In each of these areas, the group has been separated into two or more independent geologic units, and geologists are at present engaged in clarifying correlations between the various named units. Although this revision is now in progress, it has not yet reached a point where there is complete agreement as to the particular units which should be identified at all localities; and, specifically in the Appalachian Valley region of northern

Virginia, West Virginia, Maryland, and Pennsylvania, a precise nomenclature has not been determined.

For the Beekmantown outcrops of Virginia and adjacent portions of West Virginia and Maryland, a practice has been followed for about 10 years of recognizing three Beekmantown members, a basal Stonehenge limestone, the medial Nittany dolomite, and an upper post-Nittany member possibly equivalent to the Bellefonte dolomite of Pennsylvania. Of these units, the Stonehenge limestone is most irregular in distribution, and is not extensively present. The main Canadian member, commonly identified as the Nittany dolomite, is universally present; post-Nittany dolomites are usually found only in the eastern and northern Valley belts.

The Stonehenge limestone [1] was named from the town of Stonehenge, situated a short distance east of Chambersburg in southern Pennsylvania. At first it was considered to be a basal unit of the undifferentiated Beekmantown; now it is treated as an independent formation of mappable dimensions. This formation is irregularly present at the base of the Canadian dolomites from southern Pennsylvania at least as far south as Sullivan County, Tennessee. In its absence, middle Canadian dolomites rest directly upon the underlying Ozarkian formations. The latter condition appears to obtain in the Stony Man area of Virginia, where middle Canadian dolomite overlies the Chepultepec limestone, which separates it from the Conococheague limestone. As the Stonehenge limestone has a reputed thickness of more than 450 feet in southern Pennsylvania and Maryland, the formation (if properly identified) must thin rapidly southward from Pennsylvania into northern Virginia.

[1] Stose, G. W., op. cit., p. 6.

From their fauna and stratigraphic position, it is clear that the middle Canadian rocks of the Appalachian region are approximately equivalent (a) to the Roubidoux formation of Missouri and Arkansas; (b) the typical Beekmantown dolomite as exposed at Beekmantown, New York; (c) the Longview limestone of Alabama; and (d) at least the lower portion of the Nittany dolomite of the Nittany arch in central Pennsylvania. Several authors, including the writer [1] following the work of Butts,[2] have trans-

[1] Woodward, H. P., op. cit., p. 39-41.

[2] Butts, Charles, Variations in Appalachian stratigraphy: Wash. Acad. Sci. Jour., vol. 18, p. 367, 1928.

ferred the term "Nittany" dolomite to the middle Canadian beds of the Appalachian Valley of Virginia. This identification is based upon the occurrence of the index fossil Lecanospira, and on the stratigraphic position of the beds correlated. The type Nittany dolomite of central Pennsylvania, however, appears to contain certain upper zones (characterized by late species of Eccyliopterus and Orospira) which are not common to the middle Canadian of the Appalachian Valley, and which are also absent in the Longview limestone of Alabama. It is thus possible that the so-called Nittany dolomite of Virginia is more closely allied with the Longview limestone of Alabama than with the more inclusive Nittany dolomite of Nittany Valley, Pennsylvania. If this is verified, the name Longview would be more appropriate than Nittany for the middle Canadian, or Beekmantown, of this quadrangle.

Upper Canadian formations are also present in the Appalachian Valley of Virginia, West Virginia, Maryland, and southern Pennsylvania. In more southern regions, the upper Canadian beds are

thinner than those of the middle Canadian; north of Augusta County, Virginia, the upper Canadian beds constitute nearly two-thirds of the entire Canadian. Fossils are more abundant in the upper Canadian than elsewhere in the group, and the curious form Ceratopea is typical of this horizon. From its fauna and general stratigraphic position below the Stones River group, the upper Canadian of this area must approximately represent the horizons of the Axemann and Bellefonte dolomites of central Pennsylvania, as well as some portion of the Jefferson City, Cotter, and Powell formations of Arkansas and Missouri. No single stratigraphic name is at present wholly appropriate for the upper Canadian dolomite of northern Virginia.

In view of the unsettled status of correlations at this general horizon in the geologic column, it is considered unwise to apply any precise stratigraphic names to the Canadian, or Beekmantown, subdivisions of Page Valley, although its two units may be tentatively called Nittany (?) and Bellefonte (?) dolomites.

That the Massanutten synclinorium occupies an important stratigraphic boundary line is apparent in a comparison of the Canadian and post-Beekmantown sections east and west of this structure. There are no important variations on opposite sides of this structure in beds below the Beekmantown, but from this horizon upward, differences become marked between the Ordovician and Silurian rocks of Page and Shenandoah valleys. These differences, manifest in lithologic character, thickness, and internal sequence of such formations as the Beekmantown, Athens, Chambersburg, and Martinsburg, reveal that the present synclinorium must hold the site of some early Paleozoic environmental axis, which was responsible for different types of sedimentation on its opposite sides.

Nittany (?) Dolomite

Character

The lower portion of the Beekmantown formation crops out in a continuous belt, about one-half mile wide, which extends from the western margin of the quadrangle through Luray and Oak Hill to the northern border of this area. Best exposures are those (1) at Rileyville, a short distance north of the quadrangle; (2) at Oak Hill; (3) in Luray Caverns; and (4) along Dry Run. The rocks produce low ground except for local areas thickly strewn with cherty debris (see Pl. .) The Nittany member develops a characteristic red clay-soil that is more favorably located for cultivation than soil of the older Ozarkian limestones. Characteristic of many Nittany exposures is a step-like arrangement of tiers, or ledges, of bedrock that protrude conspicuously where the soil has been partially stripped off by erosion.

The Nittany (?) member of the Beekmantown mainly contains gray or blue dolomite interspersed with zones of limestone and of vaughanite.[1] At most exposures it is more or less thinly

[1] Vaughanite is a dense crypto-crystalline pure limestone, generally dove colored or blue gray; it breaks with a conchoidal fracture.

bedded, and is commonly very dense. Much of the rock is somewhat laminated although the dense purer beds break with a sub-conchoidal fracture. Weathered Nittany surfaces are commonly chalky; where the rock is eroded or dissolved are found smooth, water-worn, or furrowed surfaces.

Much chert is developed upon local portions of the Nittany outcrop. This gray or white chert is dense, massive, and commonly jagged. It occurs in greatest abundance where the bedrock is

nearly horizontal, and is well developed near Luray on Cave Hill and elsewhere. The chert fragments, which range from a few inches to several feet in diameter, appear to have been produced during weathering. Poorly preserved fossils (mainly Lecanospira) occur sparsely in the cherty residue.

Thickness

The Nittany (?) member of the Beekmantown is 600 to 700 feet thick. A typical Beekmantown section measured at Rileyville, about two miles north of this quadrangle, follows:

Rileyville Section

Section along Nelson Run, measured from Shenandoah River to a point one-half mile east of Rileyville. The rocks are well exposed, almost vertical, and strike N. 30° E. The Mosheim limestone is exposed along Shenandoah River, and the Chepultepec limestone crops out near the railroad crossing over the creek.

Lenoir dark knotty limestone.....Not measured
Mosheim limestone..... 18 Feet
1. Pure dove-colored vaughanite in beds 3-4 feet thick..... 18
Beekmantown dolomite.....1,347
Bellefonte (?) member.....760
2. Dark gray thinly laminated dolomite, weathering brown..... 73
3. Interbedded crinkly dolomite and vaughanite.....163
4. Massive dove vaughanite..... 11
5. Dense gray dolomite..... 13
6. Crinkly dolomite and limestone; some dark vaughanite.....135
7. Massive vaughanite..... 10
8. Crinkly dolomite and limestone; some dark vaughanite.....355
Nittany (?) member.....587
9. Gray dolomite, with bands of cavernous black chert.....195
10. Dolomite and very light-gray vaughanite..... 72
11. Interbedded gray dolomite and dark vaughanite..... 70
12. Blue limestone and dolomite; some bluish vaughanite.....250
Chepultepec limestone..... 105
13. Finely laminated rather heavy-bedded dolomite.....105
Conococheague limestone.....Not measured
14. Interbedded limestone and dolomite; thickness estimated to be 1,600 feet.

Economic Material

The Nittany dolomite was formerly burned for lime near Hamburg, not far from the western border of the quadrangle. The few small abandoned quarries along its outcrop suggest that attempts to obtain material for road construction have not proved more than locally successful.

Age and Correlation

The Nittany (?) member of the Beekmantown corresponds broadly to the formation bearing this name in Nittany Valley, Pennsylvania, where it is the middle unit of the Canadian system. (See also pages .) It is one of the most extensively developed dolomites in North America, and is spread from the St. Lawrence Valley to Alabama, and extends westward to Texas and Oklahoma. The horizon universally carries the sinistral gastropod Lecanospira (Ophileta) compacta, as well as Roubidouxia depressa and Coelocaulus cf. C. linearis. Sections of these fossils are visible on the weathered surfaces of many Nittany ledges, and also occur in fragments of Nittany chert.

Bellefonte (?) Dolomite

Character

The Bellefonte (?) member, 600 to 1,000 feet thick, occurs at the top of the Beekmantown dolomite where it directly underlies the Mosheim limestone in an outcrop that closely follows those of the overlying and underlying beds. It crops out in a continuous belt which extends from the western edge of the Stony Man quadrangle through Kibler Hill to Compton, north of the quadrangle, where its exposure forms a precipitous bluff along Shenandoah River. The width of this outcrop is about ~~one-~~half mile except in the area immediately north of Luray Caverns, where the Bellefonte has been

duplicated by folding (and a wider outcrop is shown / occurs in a wider territory). It is well exposed along the South Fork of Shenandoah River near Ruffner Ferry, Bixler Bridge, and Kibler Hill; there are good exposures in the lower gorge of Hawksbill Creek, and the formation is exposed along Nelson Run, east of Rileyville. (See Pl. , and section, pages .)

The Bellefonte is essentially similar to the underlying beds, and its chief distinction is a greater abundance of vaughanite in beds that range in thickness from a few inches to zones nearly 50 feet thick. The following section, measured near Bealer Ferry, shows the general character of the upper Beekmantown:

Bealer Ferry Section

Section along Shenandoah River and a northward-flowing tributary, one-half mile east of Bealer Ferry, one mile northwest of Oak Hill. The rocks are continuously exposed and strike about N. 30° E. Dips are steep, in places overturned to the southeast.

(For the upper part of this section, see pages .)

Mosheim limestone..... 32 Feet
1. Light and dark dense vaughanite..... 32
Beekmantown dolomite.....1,350
Bellefonte (?) member.....660
2. Thin-bedded dense dark magnesian limestone.....200
3. Same, more massively bedded..... 65
4. Heavy-bedded coarse and fine dolomite 87
5. Dense gray dolomite..... 38
6. Massive-bedded crinkly dolomite and limestone..... 96
7. Dense dark-gray wavy vaughanite..... 9
8. Crinkly dolomite and interbedded limestone..... 86
9. Dove-colored fractured vaughanite... 8
10. Gray dolomite in heavy bed..... 13
11. Interbedded dolomite; some vaughanite and limestone..... 42
12. Massive bed of gray dolomite..... 16
Nittany (?) member.....700
13. Largely covered; massive gray dolomite and typical Nittany chert...250
14. Dolomite; much cavernous chert on outcrop..... 50
15. Largely covered; scattered dolomite ledges.....400

(Bealer Ferry Section, continued)

Chepultepec limestone.....100
16. Largely covered; dense limestone and dolomite ledges.....100
Conococheague limestone.....Not measured
17. Interbedded limestone and dolomite, producing Ozarkian-type chert.....

dolomite

The Bellefonte member contains much pure pearl-gray dolomite as well as considerable limestone (which is) interbedded with the dolomite and vaughanite. The rock weathers to a satiny-brown color, is medium bedded, and, not uncommonly, (is) finely laminated. Its weathered surfaces are usually water-worn and show evidence of considerable solution, solutional activity, with ~~while~~ sink-holes and solution depressions marking its outcrop (Pl.). Although it contains no arenaceous material, certain parts of the Bellefonte outcrop--especially east of Ruffner Ferry--are well supplied with chert residuals.

The general lithologic character and topographic expression of the Bellefonte closely resemble those of the underlying Nittany dolomite ~~member~~, and any uniform separation of the Beekmantown outcrop (Beekmantown group) into two belts is difficult (to maintain) in view of a general absence of continuous exposures and the usual rarity of fossils. Indeed, except for purposes of detailed correlation, the entire Beekmantown is largely a homogenous unit.

Soil (of) (from) the Bellefonte soil is red and rich if unpolluted (unmixed with) (free from) with alluvial debris and free from chert. Although no economic materials are now obtained from the Bellefonte, (quarries favorably located could supply) ample quantities of stone for roads, foundations, and other rough construction, could be obtained from favorably locatis quarries quarries favorably locatis in the belt of Bellefonte

Age and Correlation

Fossils are rather rare in the Bellefonte, where the most common forms are Hormotoma artemisia and Syntrophia lateralis. The most distinctive fossil is Ceratopea keithi, which is commonly silicified, and may be found loose in Bellefonte soil.

ORDOVICIAN SYSTEM

General Features

Although the Ordovician system is amply represented in this area, the sparseness of its exposures--as in the case of earlier "Valley" limestones--hinders examination of its bedrock. Earliest Ordovician sediments are those of the Stones River group--specificially the Mosheim and Lenoir limestones--which follows the Bellefonte dolomite of Canadian age. As the two members of this early Ordovician group are both thin, a single symbol designates their outcrop on the accompanying geologic map (Plate 1). Elsewhere in Virginia, especially in southwestern sections, the Mosheim rests upon a still lower Stones River member--the Murfreesboro limestone--which is absent in the Stony Man region.

Throughout the central and southern Valley of Virginia, the Lenoir limestone is followed by the Blount group, to which belong the Holston, Whitesburg, Tellico, and Ottosee limestones, and the Athens and Sevier shales. Here, where the limestone members of the Blount are wholly wanting, the Athens is its only representative and is directly overlaid by the thin knobby chambersburg limestone of Black River age. The thick Martinsburg shale, forming the upper portion of the Ordovician system, includes horizons of Trenton, Eden, and Maysville age; no Richmond equivalent is

present. Of a total Ordovician thickness amounting to about 3,500 feet, at least three-fourths is contained in the Martinsburg shale.

The Ordovician of this report is restricted to post-Beekmantown horizons, an interpretation which thereby excludes several thousand feet of dolomitic Beekmantown or Canadian limestones. (See also pages .) By some authors, the rocks here treated as Canadian are considered to be lowermost Ordovician; this alternate interpretation would considerably amplify the thickness of the local Ordovician sequence, which is indicated in the following table:

Ordovician Rocks

Standard Sequence			Local Occurrence	
Upper - Cincinnatian	Richmond		absent	
	Maysville			
	Eden		Martinsburg shale	3,000± Feet
Middle -	Trenton			
	Black River		Chambersburg limestone	100
Lower or Chazy	Blount Group	Sevier, Ottosee, Tellico	absent	
		Athens	Athens shale	300
		Whitesburg, Holston	absent	
	Stones River Group	Lenoir	Lenoir limestone	70-100
		Mosheim	Mosheim limestone	30
		Murfreesboro	absent	
				3,500± Feet

Mosheim Limestone

Character

The Mosheim limestone[1] is the earliest, or lowest, Ordovician

[1] Ulrich, E. O., op. cit., p. 413-14, 538, 543-7, plate 37, 1911.

rock of this area; it lies upon the Bellefonte (?) member of the Beekmantown ~~dolomite~~ and is overlaid by the Lenoir limestone. As its scant outcrop is adjacent to that of the equally narrow Lenoir outcrop, a single symbol is used to designate the Stones River belt on the accompanying geologic map. (Plate 1.) The Mosheim limestone crops out along a very narrow belt in the northwestern corner of this quadrangle, where it is crossed many times by meandering South Fork of Shenandoah River. Exposures in the river banks are common and readily accessible. Near Bixler Bridge, the outcrop has been duplicated by faulting; elsewhere its narrow belt is continuous. The best Mosheim exposures occur at (1) Bealer Ferry, (2) Bixler Bridge, (3) along Shenandoah River immediately north of Kibler Hill.[1] The formation has no effect on local topography and its outcrop is too limited to produce a distinct soil type.

[1] Kibler Hill is a low elevation near Shenandoah River, about 3 miles west of Vaughn, not to be confused with Kibler Knob, a much higher summit in the Blue Ridge foothills, about 1 mile northeast of Kimball, and 2 miles south of Vaughn.

Most of the Mosheim is a dense structureless dove-colored rock that ranges from massive gray limestone to pure dove-gray or dark-gray subcrystalline vaughanite. It weathers bluish and its exposed ledges are usually covered with tiny flutings or other solution markings. As it is rather massively bedded, many of its members are 3 to 4 feet thick. The vaughanite beds are thickest, one zone reaching 20 feet. The upper Mosheim contains dark-gray medium-bedded limestone that is finely laminated. Probably the Mosheim averages 30 to 50 feet in thickness in this area.

Economic Importance

The Mosheim limestone has not been locally developed for economic use, although a small quarry was formerly operated for agricultural lime near Hamburg, 3 miles west of this quadrangle. Elsewhere in northern Virginia and still more extensively in Berkeley and Jefferson counties, West Virginia, the Mosheim has been exploited for chemical, agricultural, and furnace lime. In the northern continuation of its outcrop near Potomac River, it is one of the purest limestones in North America. It is Probably ~~its~~ that the zone of Mosheim ~~outcrop~~ in the Stony Man region is too limited in extent and too poorly located for commercial development.

Age and Correlation

The Mosheim is sparingly fossiliferous. Its most ubiquitous fossil is Tetradium syringoporoides, which may be seen as quadrilateral shreds and stringers of translucent calcite in the Mosheim vaughanite. Leperditia cf. L. fabulites is also fairly common, as are cross-sections of various gastropods including several species of Lophospira, Liospira americana, and Helicotoma subquadrata. The latter appear on eroded or weathered ledges of the purer limestones.

Lenoir Limestone

Distribution and Character

The Lenoir [1] limestone, named from Lenoir City, Tennessee,

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[1] Safford, J. M., and Killebrew, J. B., Elementary geology of Tennessee; p. 108, 123, 130-31, 137, Nashville, Tennessee, 1876.

overlies the Mosheim, and, in this quadrangle, is overlaid by the Athens shale. Throughout central and southern Virginia, various other members of the Blount group intervene between the Lenoir and the Athens, which is here the sole Blount representative. This upper Stones River formation occupies a narrow outcrop that is repeatedly crossed by South Fork of Shenandoah River; in an area immediately east of Bixler Bridge, it has been partially deleted by faulting. The best Lenoir exposures are in the bank of Shenandoah River a short distance east of Oak Hill Ferry, and in banks of tributary streams that cross the limestone belt. Where the Lenoir outcrop is free from transported debris, its natural soil is chocolate red and slightly cherty. As Beekmantown dolomite produces somewhat more elevated topography than that of the Athens and lower Martinsburg shales, the belt of Lenoir limestone is located at a slight topographic break produced by differential erosion of these adjacent formations.

Most of the Lenoir is a knobby granular to crystalline black limestone carrying numerous nodular zones of black knotty chert. Fairly coarse grained and thin bedded, Lenoir ledges weather into irregular slabs that have no uniform shape or thickness. A few dark coarsely crystalline zones are free ~~from~~ chert, but the latter is present in sufficient quantity in much of the bedrock to supply considerable cherty debris to the Lenoir outcrop. In an exposure on Mill Creek west of this quadrangle, there is a 5-foot bed of coarsely crystalline dark limestone at the top of the Lenoir. The total Lenoir thickness ~~varies between~~ 70 to 105 feet. A section on Shenandoah River near Bealer Ferry follows:

Bealer Ferry Section

Section along south bank of Shenandoah River one-half mile east of Bealer Ferry.

Athens shale.....Not measured
1. Dark calcareous shales with graptolites...
Lenoir limestone..... 69 Feet
2. Dark knobby rather coarse limestone; some black chert..... 11
3. Dark-gray medium-bedded crystalline limestone..... 6
4. Dark thin-bedded knobby limestone, weathering blue-gray; both coarse and fine; trilobites..... 38
5. Massive dark dense blocky limestone; trilobites; welded contact with beds below..... 14
Mosheim limestone..... 32
6. Light and dark dense vaughanite..... 32
Beekmantown dolomite.....1,350
7. Dark fine-grained limestone and dolomite..

(For lower beds of this section, see page .)

Structural Relations

Like other Paleozoic rocks, the Lenoir is overturned in Page Valley where its exposed ledges dip toward the southeast. A minor fold and small fault are responsible for the development of a secondary outcrop (between Hawksbill Creek and) the west on edge of the quadrangle, where an outlying area of Mosheim, Lenoir and Athens has been partly separated from their main belts. The contact of the Lenoir and Mosheim formations is conformable; the contact of the Lenoir limestone with the overlying Athens shale is slightly unconformable in the exposure near Bealer Ferry.

X about half a mile SE Bealer Ridge near

Age and Correlation

The Lenoir contains many broken brachiopod and trilobite fossils as well as other fragmental debris of organic origin; unbroken fossils are difficult to find. A partial list of Lenoir species follows:

Solenopora cf. S. compacta (Billings)
Rhinidictya trentonensis (Ulrich)
Receptaculites biconstrictus Ulrich
Hebertella vulgaris Raymond
Hesperorthis tricanaria (Conrad)
Plaesiomys platys (Billings)
Pianodema subaequata (Conrad)
Dinorthis pectinells (Emmons)
Maclurea cf. M. magna (Le Sueur)
Illaenus fieldi Raymond
Remopleurides canadense Billings
Leperditia fabulites (Conrad)

It is believed that the Lenoir is approximately equivalent to the Pierce and Ridley formations of central Tennessee; it is also a broad correlate of the Chazy limestone of northern New York.

Athens Shale

Character

The Athens shale, [1] named from Athens, Tennessee, crops out in a belt, about 800 feet wide, along the meandering course of South Fork of Shenandoah River. The belt is widened by folding and faulting between Ruffner Ferry and Bixler Bridge. (It) underlies rolling river country that has a dark soil through which are scattered tiny shale splinters. The soil furnishes good pasture and is readily cultivated. (See Pl. .) Where the formation is unusually calcareous, there are sinks that reveal excellent underground drainage.

The main body of the Athens is a dark-gray to black shale that weathers chocolate brown. The shale is soft, mostly non-fissile, and commonly reveals black graptolite fragments where freshly split. Where it has been excessively deformed, the shale is more platy and assumes a pseudo-cleavage resembling that of

[1] Hayes, C. W., U. S. Geol. Survey Geol. Atlas, Kingston folio (No. 4), p. 2, 1894.

true slate. This stiffer rock is more abundantly exposed than the softer unaltered shales. The formation is essentially thinly bedded, containing few strata more than 8 inches thick. (See Pl. .) Most of the thicker beds are black limestones that weather blue gray and are dense and fine grained. In weathering they produce platter-shaped fragments that have rounded edges and are commonly covered with tiny "chatter" marks which develop during exposure. When broken, Athens limestones have a prominent conchoidal fracture. Some portions of the formation show thin limestone bands, one-half to one inch thick, that are regularly interbedded with bands of dark shale; a few somewhat crystalline or granular limestones are present in the lower Athens.

Outside S.M. quad

Probably the best Athens exposures are those along ~~Virginia~~ State Route 266, near Trinity Chapel, 3 miles northwest of Luray.

Thickness

As the Athens shale of this region is closely folded, its thickness is difficult to determine. Possibly it attains 300 feet, but it may well be somewhat thinner. Traced northward from central Virginia, the Athens outcrop is divided by Massanutten Mountain. In Shenandoah Valley, west of the Massanutten range, the Athens thins out in the latitude of Page Valley and disappears in southern Shenandoah County. The eastern Athens outcrop, of which the Stony Man belt is part, extends as far north as Warren County, but does not reach Potomac River, where in Clark County, Virginia, and Jefferson County, West Virginia, the Chambersburg limestone rests directly upon the Lenoir with no Blount representative.

Economic Use

Athens shale has been quarried for road metal along Shenandoah River, one mile east of Alma, one-half mile south of Lee Highway. Its slaty phase was once prospected for slate near Trinity Chapel, 3 miles northwest of Luray, but was found to be unsuited except for extremely local use.

Age and Correlation

The Athens is readily distinguished by an abundance of graptolites which occur in its dark-shale facies. Most diagnostic is the graceful Nemagraptus gracilis Hall; rarer brachiopods and trilobites occur in Athens limestones. Most common Athens fossils are:

Climacograptus bicornis Hall
Dicellograptus sextans Hall
Dicranograptus ramosus Hall
Diplograptus foliaceous Murchison
Nemagraptus gracilis Hall
Triarthrus cf. T. becki (Eaton)
Ampyx americanum Safford and Vogdes

This formation is a member of the Blount group which is more than 8,000 feet thick in the south-central Appalachians. Traced northward from eastern Tennessee, however, the various Blount members disappear one by one, and the Stones River group below and Black River group above progressively come closer together. In this region, they are separated only by the Athens shale which has diminished from a known maximum of more than 3,000 feet to one tenth of this thickness. Thirty miles north of Luray, the Athens, likewise vanishes, and the Stones River and Black River beds are in contact with one another. The Athens fauna is directly correlated with that of the Normanskill shale of New York and the Glen Kiln shale of Scotland; it is of lower Ordovician age.

Chambersburg Limestone

General Description

Although the Chambersburg limestone,[1] which is named from

[1] Stose, G. W., Sedimentary rocks of South Mountain, Pennsylvania: Jour. Geology, vol. 14, p. 211, 1906.

Chambersburg, Pennsylvania, is widely displayed in Maryland, West Virginia, and Shenandoah Valley in northern Virginia, its occurrence in Page Valley is limited to a narrow belt that follows the general course of Shenandoah River adjacent to the Martinsburg shale outcrop of the southeast flank of Massanutten Mountain. The Chambersburg ~~is exposed~~ occur near Bixler Bridge and Bealer Ferry, where it is a thinly bedded blue-black limestone not unlike the calcareous members of the Athens below or the Martinsburg (Trenton member) above. It is irregularly laminated (Pl.) and some beds are nodular or knotty in a phase that strongly resembles Lenoir limestones. Characteristic is a wavy bedding that is produced by thin argillaceous seams which interweave between nodular masses of dark dense limestone. Chambersburg limestone produces neither distinctive soil nor a unique topographic expression, and its beds contain no material of special economic importance. Thin beds of metabentonite (altered volcanic ash) are known from the Chambersburg limestone of Shenandoah Valley at this latitude.

At the latitude of Page Valley west of Massanutten Mountain, the Chambersburg is more than 450 feet thick; in this area, its total thickness does not reach 100 feet.

Age and Correlation

As originally defined, the Chambersburg included the Lowville limestone which elsewhere occurs at its base; now the formation is

restricted to the upper, or post-Lowville, Black River beds of middle Ordovician age. Chambersburg fossils, although fairly common, are difficult to extract whole from the bedrock, in which they occur mostly as broken fragments. The following fossils are typical of this limestone:

Echinosphaerites cf. E. aurantium (Hisinger)
Nidulites pyriformis Billings
Solenopora compacta Billings
Christiania trentonensis (Ruedemann)
Plectambonites pisum (Ruedemann)
Pianodema subaequata (Conrad)
Tretaspis reticulata (Ruedemann)
Illaenus cf. I. fieldi Raymond

No Lowville limestone, which underlies the Chambersburg limestone in western Virginia, is present in this belt.

Martinsburg Shale

Distribution

The thick Martinsburg shale,[1] named from Martinsburg, West

[1] Darton, N. H., Notes on the stratigraphy of a portion of central Appalachian Virginia: Am. Geologist, vol. 10, p. 13, 1892.

Virginia, crops out in a belt, about two miles wide, that reaches from the summit of Massanutten Mountain southeastward to the outcrop of the Chambersburg formation along Shenandoah River. It is limited to the northwest corner of the quadrangle, where it is involved in the Massanutten synclinorium that occupies the middle portion of the Valley of Virginia. Exposures are common along the flanks of ~~this~~ Massanutten Mountain, and the Martinsburg is readily accessible in road and stream cuts, where its sandy shales protrude through the thin soil of the mountain slopes. There is a good exposure along the creek which enters Shenandoah River, ~~one~~ a quarter

of a

mile east of Long School; abundant exposures mark the county road following the northwest bank of Shenandoah River. Light-brown Martinsburg soils are fairly fertile but occupy slopes too steep for cultivation. The Martinsburg outcrop, still extensively forested, is wholly within the George Washington National Forest.

The Martinsburg is a thick aggregate of dark-colored evenly laminated shale (Pl.), in which are interbedded lenses of thin flaggy sandstone. In its lower and upper portions, sandstones are more abundant and thicker than in the middle portion where thin-layered shales are common. On faunal evidence the Martinsburg is divisible into Trenton, Eden, and Maysville members.

Trenton Member

The lowest third of the Martinsburg is of Trenton age. This member begins at the base with calcareous gray shales interbedded with thin impure evenly laminated limestones. It disintegrates rapidly under the attack of the weather to produce an unctuous yellow, clay-soil. The remainder of the Trenton division consists of several hundred feet of gray-green sandstone close to greywacke. The even-grained sandstones are cross-bedded and contain lenses, or zones, of thin arenaceous green shales. Good Trenton exposures flank the base of Massanutten Mountain; its green sandstone is well exposed on State Highway 266 at the edge of this quadrangle, and in road cuts on U. S. 221 (Lee Highway) between New Market and the southeast base of Massanutten Mountain.

The Trenton member of the Martinsburg is at least 800 feet thick, and may reach 1,000 feet. Some zones are abundantly fossiliferous, containing the common Trenton species Cryptolithus

tessallatus, Prasopora orientalis, Dinorthis pectinella, Dalmanella rogata, Sowerbyella sp., and Diplograptus amplexicaulis.

Eden Member

The middle Martinsburg is shale that becomes increasingly sandy upward. These shales occur between the green Trenton sandstones and sandy beds of the Maysville member. They are thin and fissile, and, although dark colored, weather rapidly to a light-buff color. Some sandy beds and lenses of gray shale that weather into pencil-shaped fragments are also present. The Eden crumbles readily and is exposed only in gullies or creek beds. Its yellow-brown soil is meagerly fertile. In the main, this is the weakest Martinsburg member, and has no distinctive topographic expression in its outcrop along the middle slope of Massanutten Mountain. Typical Eden fossils include Rafinesquina alternata, Zygospira modesta, Callopora cf. C. sigillaroides, and Dalmanella multisecta.

Maysville Member

The upper Martinsburg, or Maysville member, is a thick body of fine-grained even-bedded green sandstone and sandy shale. Its thickness must approximate 1,000 feet, and it occurs immediately below the resistant Tuscarora sandstone which caps Massanutten Mountain. Although the Maysville is sparingly fossiliferous, its topmost beds invariably contain Orthorhynchula linneyi, Byssonichia radiata, and Modiolopsis modiolaris.

Thickness and Relations

The Martinsburg thickness in the Massanutten syncline--estimated to be about 3,000 feet--is a maximum for western Virginia.

The Maysville member of the Martinsburg dips northwestward below Tuscarora sandstones at the top of Massanutten Mountain; at its basal contact with the Chambersburg limestone, the Martinsburg dips southeastward. This divergence suggests that the overturned structure, which characterizes Page Valley, gives way to close folds within the mass of the weak Martinsburg shales. (See also pages .) The Martinsburg - Chambersburg contact is disconformable; the Tuscarora contact is slightly disconformable, but shows no trace of the profound diastrophism which marks the close of Ordovician deposition in eastern Pennsylvania, New Jersey, and southern New York.

No products of economic importance are derived from the Martinsburg shale of this region.

Age and Correlation

The Martinsburg shale includes Trenton, Eden, and Maysville horizons of middle and late Ordovician age. As it may be traced continuously from New Jersey to southern Virginia, it makes an easily recognizable unit throughout the central and northern Appalachian region. It is the youngest Ordovician deposit of the Stony Man region, there being no Richmond, or uppermost Ordovician, representation in this area. A difference may be noted between the Martinsburg shale of the Massanutten synclinorium and the equivalent shale of the mountainous region west of Shenandoah Valley. This difference involves variations in both thickness and lithologic content, the eastern belt containing a much thicker section, as well as more arenaceous and less fossiliferous beds. To a similar degree are differences in many of the early

Paleozoic formations on opposite sides of the Massanutten range, and the conclusion must be drawn that this deep fold occupies the position of an important line of demarcation between conditions of sedimentation on opposite sides of the main Appalachian geosyncline. These differences become greater toward the north, where the early Paleozoic section of Clarke County is markedly different from that of Frederick County.

Neither the Juniata formation nor the coarse Oswego sandstone has been recognized in the Massanutten range, although both are conspicuously displayed at this latitude along the West Virginia border.

The Martinsburg shale of southwest Virginia and Tennessee may be separated into a distinct calcareous Trenton division, and a shaly Eden-Maysville member known as the Reedsville shale. The latter was erroneously called "Sevier" shale in early reports.

SILURIAN SYSTEM

General Features

Silurian rocks, which comprise approximately 1,400 to 1,600 feet of the Paleozoic section in the Stony Man quadrangle, are restricted to the extreme northwest corner of this area, where the following units are recognized:

Silurian Rocks

Tonoloway limestone.....	380-415 Feet
Wills Creek formation.....	150-225
Bloomsburg redbed facies.....	185-235
McKenzie-Clinton formations..	65 - 80
Tuscarora sandstone.....	600-700
Total.....	1,380-1,655 Feet

Except for the Tuscarora sandstone, exposures of which are common on Massanutten Mountain near Kennedy Peak, Silurian formations have few if any exposures within the actual limits of this quadrangle, and their presence is inferred mainly by projecting their outcrop along the main Massanutten ridge. In the absence of local exposures, the character of Silurian rocks in this area must be determined from nearby sections, most of which occur on the west rim of Fort Valley, beyond the limits of the Stony Man quadrangle.

There is no more easterly Silurian exposure in the north-central Appalachians than in Massanutten Mountain, and the nearest exposure of these rocks lies across Shenandoah Valley in or west of North Mountain. Because of its isolated position distant from other Silurian outcrops, the local section shows many variations from the normal Silurian sequence of Virginia.

Tuscarora Sandstone

Distribution

The Tuscarora sandstone,[1] named from Tuscarora Mountain in central Pennsylvania, crops out along the crest of Massanutten Mountain and forms the conspicuous summit of Kennedy Peak. Many excellent exposures occur near this peak while ledges of the sandstone are visible along the main Massanutten ridge. Large boulders and other Tuscarora debris choke all streams that descend on either side of the mountain. The length of the Tuscarora outcrop in this quadrangle is scarcely 2 miles.

[1] Darton, N. H., U. S. Geol. Survey Geol. Atlas, Piedmont folio (No. 28), 1896.

Width of belt ± - 3 to .5 mile. The width being due to duplication by faulting.

Character

This formation is a thick aggregate of sub-quartzitic sandstone and conglomerate; mainly white or gray, its beds are commonly pink-stained after weathering. At the base are massive ledges that carry quartz pebbles up to one inch in diameter. Cross-bedding is prominent at many levels, and the formation as a whole is massively stratified. The uppermost portion is less thickly bedded and contains numerous reddish sandstone members. The more resistant lower portion exerts a topographic control scarcely exceeded by early Cambrian quartzites or pre-Cambrian crystalline rocks.

The Tuscarora is essentially a homogeneous sandstone containing no prominent lithologic break. Ledges that have been long exposed become secondarily hardened by redeposition of silica during weathering--a feature which gives their rock a sub-quartzitic character wherein a fragment breaks across the constituent grains rather than around them as in the case of unaltered sandstone. The most prominent member is a massive conglomeratic zone about 450 feet above the base. This bed, which is the chief ridge-maker, occurs at the summit of most Tuscarora ridges.

The general character of the Tuscarora and overlying formations is shown in the following section measured about 8 miles north of Kennedy Park:

Section between Dietrich and Woodstock

Section along Virginia 261 between Dietrich and Woodstock on west rim of Fort Valley. Strike N. 40° E., dip about 45° NW. Section extends across the west limb of subsidiary fold in the main Massanutten anticline.

Keyser limestone..... 12 Feet
1. Clifton Forge brown limonitic sandstone... 12
2. Lower Keyser limestone; concealed
Tonoloway limestone; concealed } 384

(Section between Dietrich and Woodstock, continued)

Wills Creek formation.....150
3. Largely covered; yellow and red sandy shale.....150
Bloomsburg redbed facies.....235
4. Yellow and red sandy shales; red sandstone 85
5. Covered..... 90
6. Dense red sandstone; some thin shale laminae..... 39
7. Largely covered; some reddish-orange sandstones..... 21
Clinton formation..... 78
8. Dense gray sandstone..... 8
9. Red sandstones and gray sandy shales..... 31
10. Slabby red shaly sandstones..... 21
11. Largely covered; some reddish sandy shales 18
Tuscarora sandstone.....660+
12. Covered; gray sandy debris.....133
13. Coarse gray cross-bedded sandstone, some pebbly zones..... 47
14. Massive conglomerate..... 2
15. Pink and white coarse sandstone; partly covered.....168
16. White coarse cross-bedded sandstone.....128
17. White and pinkish quartzitic sandstone.... 30
18. Covered..... 14
19. Brown cross-bedded shaly sandstone..... 40
20. Heavy bed white sandstone..... 10
21. Coarse pinkish-gray quartzitic sandstone.. 39
22. Sandstone, weathering brown..... 35
23. Coarse heavy-bedded gray sandstone..... 14
(Base of Tuscarora not exposed)

Thickness

The Tuscarora sandstone of Massanutten syncline is much thicker than in its outcrops in the main valley ridges west of Shenandoah Valley. It is reported to be 800 feet thick along Passage Creek at the northeast end of Fort Valley, and is estimated to be nearly 700 feet thick near Woodstock Gap. Probably it thins southwestward and may be no more than 600 feet thick as it crosses the Stony Man quadrangle.

Elsewhere in Virginia the Tuscarora and equivalent Clinch sandstones are rarely more than 250 feet thick.

Relations

This formation occurs above soft Ordovician shale and below equally weak Silurian rocks in a position advantageous for the development of mountain ridges and summits. It has acted as a competent member during deformation of the bedrock, and is now a ridge-maker of the first magnitude. Its mountains are steep sided, sharp crested, and heavily wooded.

There is no indication at its base of the strong unconformity which occurs below the Tuscarora of eastern Pennsylvania, although in the absence of any Richmond beds (latest Ordovician), the Tuscarora rests upon the Maysville member of the Martinsburg with evidence of slightly disconformable relations. The base of the formation is well exposed at the point where the Edinburg road (in Fort Valley) crosses Kerns Mountain. Here, the lower 20 feet is composed of cross-bedded pebbly sandstone which rests directly upon heather-colored medium-bedded soft Maysville sandstone. The upper Tuscarora contact is difficult to determine, for the formation grades without major break into Clinton beds (?) above.

Edinburg-Seven Fountains or Edinburg-Fish

In the Stony Man quadrangle, the Tuscarora sandstone dips northwestward at an angle of about 45° beneath the valley of Passage Creek. Its inclination is uniform and reveals little or no minor folding; the outcrop has been slightly offset by faulting directly east of Kennedy Peak. (See pages .)

Good map shows dip of 35°

Age and Correlation

No fossils are known from the Tuscarora of this area where the formation is identified mainly on the basis of stratigraphic position.

The considerable Tuscarora thickness in the Massanutten Mountain syncline (600 - 800 feet) as compared with its lesser thickness (100 to 250 feet) in the ridges west of the main Valley, indicates that the source of its deposition was east of the general Appalachian belt. This eastern increase of Tuscarora deposition is accompanied by an analogous diminution of Clinton beds, which are 400 to 500 feet thick at this latitude in eastern West Virginia, but fail to reach 100 feet in the Massanutten area. It is possible that the joint variation in thickness indicates some interfingering of Clinton and Tuscarora members, but the evidence for this is not conclusively demonstrated.

In all of the Appalachian area north of this latitude, there is no more easterly belt of early Silurian sandstone except in central-northern New Jersey, where the Green Pond conglomerate occupies a synclinal position in the crystalline rocks of the New Jersey highlands. Here, too, occur certain differences between the Green Pond conglomerate and the analogous early Silurian sandstone (Shawangunk) of the western ridges.

There is no indication that the base of the Tuscarora occurs at any different level in Massanutten Mountain than in outcrops west of the main Shenandoah Valley. If it should be subsequently found that the eastern sandstone ranges somewhat higher (into the lowermost Clinton) than its western namesake, it might be appropriate to redefine and apply the older name Massanutten[1] sandstone

[1] Geiger, H. R., and Keith, A., Structure of the Blue Ridge near Harpers Ferry: Geol. Soc. Amer. Bull., vol. 2, p. 156-163, p. 4, 1891.

which at present is not in use.

Scolithus verticalis and Arthrophycus alleghaniensis, common to the Tuscarora sandstone elsewhere, were not observed in the Stony Man region. It is believed that this sandstone occupies the approximate stratigraphic position of the Albion sandstone of western New York. Tuscarora ridges of western Virginia may be traced continuously southward into those underlaid by Clinch sandstone, an apparently exact equivalent.

Clinton - McKenzie Formations

General Description

No outcrops of Clinton or McKenzie beds are available for study in this quadrangle. Elsewhere in the Massanutten area, their joint horizon is poorly exposed, and the character of any Clinton or Niagaran representatives--if present in the local region--must be determined by inference only.

In the gorge of Passage Creek near the northeast end of the Massanutten range, there is approximately 200 feet of greenish gray sandstone and arenaceous shale directly above gray-white Tuscarora sandstone. Included also are one or more thin brownish-red ferruginous beds resembling the Cacapon-type Clinton sandstone of western Virginia. This assemblage is thought to be an eastern non-marine facies of the Rose Hill formation of Maryland and eastern West Virginia. There are no fossils except thin carbonaceous layers that may represent macerated plant fibers; and neither the common olive-buff shales of the Rose Hill nor the conspicuous red Cacapon sandstones are present. For these reasons, except on the basis of stratigraphic position it is difficult to establish any correlation with the known Clinton which occurs west of the Shenandoah Valley.

Along Virginia 261 east of Woodstock, the Clinton horizon is occupied by 60 to 80 feet of greenish-gray partly conglomeratic sandstone that contains one or more zones of redbeds, chiefly reddish sandy shales. This material, which is believed to be of Clinton age, is somewhat transitional between the Tuscarora below and the red Bloomsburg facies above. (See section, page .) The Clinton horizon, if present, was not observed on Virginia 266 in the Stony Man quadrangle.

There is no indication of any Keefer or Rochester horizons in the Silurian sections of Massanutten Mountain, although both are present in eastern West Virginia at this latitude.

Approximately 200 feet of thin-bedded buff-weathering sandy shale and thin tough dark limestone, comprising the McKenzie formation of Niagaran [1] age, occurs in eastern West Virginia at

[1] Some authors, as Butts, assign the McKenzie to the basal Cayugan.

the latitude of Massanutten Mountain. These beds overlie the Keefer-Rochester formations at the top of the Clinton group, and are overlaid by redbeds of the Bloomsburg facies. There is no analogous material in the Silurian sequence of Massanutten Mountain, where the entire section between the Tuscarora below and the Bloomsburg above is scarcely 80 feet thick. If the beds assigned above to the Clinton (on Passage Creek and east of Woodstock) are properly allocated, the McKenzie has no representation in this syncline. However, in the absence of any fossil evidence to the contrary, there may be McKenzie equivalents in the uppermost portion of the section assigned to the Clinton. At present, whatever interpretation is made must be based wholly upon inference.

As discussed below (see pages), the redbed facies which overlies the Clinton (or Clinton-McKenzie) horizon of the Massanutten syncline is not a true geologic formation of constant stratigraphic level, but a phase of nonmarine deposition that varies in horizon from place to place. It is suggested in the apparent absence of other McKenzie strata in this region, that the local Bloomsburg facies has descended downward across marine McKenzie rocks and has replaced in this syncline the normal McKenzie horizon of the belts west of Shenandoah Valley with a nonmarine succession of red sandstones and shales. (See also pages .)

Bloomsburg Redbed Facies

Definition

Traced eastward and northward from the Cumberland region of Maryland and the Keyser region of West Virginia, the McKenzie, Wills Creek, and Tonoloway limestones interfinger with a redbed facies of nonmarine sandstone and shale. This red facies thickens northeastward to its type locality in eastern Pennsylvania, where, more than 2,000 feet thick, it represents, it is believed, almost the entire Cayugan (and Niagaran). The gradation into, and replacement by, redbeds, as the Cayugan limestones are traced eastward, are indicative of a change in the character of Cayugan deposition; western marine facies are thin-bedded ostracode limestones, eastern nonmarine facies are thin red sandy shales and chunky red sandstones.

When first described, the red Bloomsburg [1] shales were assumed

[1] White, I. C., Pennsylvania 2d Geol. Survey Rept. G7, p. 106, 1883.

to hold a constant stratigraphic level; now the red color is known to occupy various horizons which, when traced southwestward from Delaware River, grow calcareous and become limestones of the Tonoloway, Wills Creek, and McKenzie formations.

Inasmuch as the red color is a phase of deposition rather than a time unit of stratigraphic continuity, the phrase Bloomsburg redbed facies is here employed for the red nonmarine rocks of Niagaran and Cayugan age. It is probable that they displace the upper McKenzie and early Wills Creek formations of other areas. (See pages .)

Character

The local Bloomsburg facies, no exposure of which is known in the Stony Man quadrangle, is a series of red and green shales with blocky red and orange-red sandstones. All members are brightly colored and break into chunky or hackly fragments. Some sandstones are coarse textured, porous, and attain several feet in thickness. An alternation of sandstone and shale characterizes the facies. Its rocks are mainly thin bedded and its weak resistance to erosion provides few natural exposures. The best exposures occur in streams on the west side of Fort Valley and along the headwaters of Passage Creek. There is a fine exposure on the southeast side of Powell Mountain, beginning near the fire tower, 3 miles east of Woodstock; here, the Bloomsburg facies is 235 feet thick. (See section, page .)

The Bloomsburg facies lacks sharp upper and lower delineation. It is somewhat gradational downward into beds assigned to the lower McKenzie or Clinton; and, although it is sharply overlaid by the basal Tonoloway limestone, the presence of a red member (Indian

Spring redbed) about 100 feet above the main Bloomsburg facies, indicates an interfingering with the overlying Cayugan horizon. (See pages .)

The Bloomsburg of Massanutten Mountain varies in thickness from 185 to 235 feet.

Age and Correlation

The Bloomsburg facies of this quadrangle is without fossils. From the apparent absence of any marine upper McKenzie or lower Wills Creek representatives, it is believed that the facies has replaced these units which elsewhere occur as marine rocks. As a facies in distinction to a stratigraphic formation, the Bloomsburg holds no constant chronologic level.

Wills Creek Formation

General Description

The Wills Creek [1] formation of Maryland and West Virginia is

[1] Uhler, P. R., The Niagara period and its associates near Cumberland, Maryland: Maryland Acad. Sci. Trans., vol. 2, p. 20-25, 1905.

a thick succession (500 feet) of thin dark calcareous shales and thin-bedded argillaceous limestones. It overlies a thin sandstone (Williamsport sandstone) [1] throughout much of West Virginia, and

[1] Reger, D. B., Mineral-Grant counties: West Virginia Geol. Survey, p. 396, 1924.

is overlaid by the Tonoloway limestone. This formation is known to be present in eastern Hardy County, West Virginia, about 30 miles west of Massanutten Mountain. It is about 175 feet thick on State Route ~~Virginia~~ 250, near Crabbottom, Highland County, Virginia, and is 150 feet thick near Gore, Frederick County.

It is represented to a thickness of 150 to 225 feet in Massanutten syncline by yellowish and reddish sandy shales that overlie the Bloomsburg facies and occur below the Tonoloway limestone. (See section, page .) There are a few calcareous lenses in its main shale body, but the tough black ostracode limestones of more westerly exposures are conspicuously absent. The presence of red lenses in the Wills Creek indicates its partial replacement by, or interfingering with, the red Bloomsburg facies.

No fossils were obtained in the local Wills Creek formation, which is here identified solely on the basis of its stratigraphic position. The formation is not exposed in the Stony Man quadrangle.

Tonoloway Limestone

General Description

The Tonoloway [1] limestone is one of the most persistent, if

[1] Ulrich, E. O., Revision of Paleozoic systems: Geol. Soc. Amer. Bull., vol. 22, pl. 28, 1911.

poorly exposed, formations of the Appalachian Valley, occurring from eastern Pennsylvania as far south as Sneedsville, Tennessee. Although its projected outcrop crosses the extreme northwest corner of the Stony Man quadrangle, there is no known exposure of the formation in this quadrangle.

The Tonoloway is well displayed at several exposures in the central and northern portion of the Massanutten range, where its measured thicknesses range from 350 to more than 400 feet. Possibly its best exposure is near Seven Fountains, 8 miles northeast of Kennedy Peak, where the following section occurs:

Seven Fountains Section

Section [1] on farm of William Lichliter, about one-third mile north of Seven Fountains, 8 miles northeast of Kennedy Peak.

Romney black-shale facies, and
Onondaga shale.....Not measured
Keyser limestone..... 21.5 Feet
1. Clifton Forge sandstone member..... 1.5
2. Uneven-bedded limestone; *Chonetes jerseyensis*..... 20
Tonoloway limestone.....409
3. Argillaceous limestone and calcareous shale..... 50
4. Thick-bedded crystalline mostly crinoidal limestone; *Hindella congregata* and other fossils at various levels..... 72
5. Concealed..... 14
6. Calcareous sandstone at crest of hill..... 6
7. Arenaceous limestone and some sandstone; very fossiliferous uneven-bedded limestone; *Spirifer fontinalis* etc. 13-40 feet above base; *Beyrichia tonolowayensis* at 5 feet above base..... 67
8. Calcareous sandstone..... 4
9. Laminated limestone with *Leperditia* sp. below; exposed in small quarry..... 12
10. Calcareous shale; some impure limestone and sandstone; mostly concealed..... 36
11. Indian Springs redbed member; exposed..... 8
12. Concealed to base of Tonoloway; estimated.140

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[1] Swartz, F. M., *in* Guidebook: Field conference of Pennsylvania geologists, Virginia, 1938: Virginia Geol. Survey, Guide leaflet 1, p. 26, 1938.

There is another good Tonoloway exposure along the Edinburg road, 3.5 miles west of its junction with the main road following Fort Valley. This section is analogous to that at Seven Fountains, and both show more than 400 feet of Tonoloway limestone; the red Indian Springs member occurs near the base of the formation at both sections.

Edinburg Road Section

Section along road leading from Fort Valley to Edinburg, about 3.5 miles west of the main road in Fort Valley.

Onondaga buff fissile argillaceous shale..Not measured
Coeymans limestone..... 10 Feet
1. Coarsely crystalline gray crinoidal limestone..... 10
Keyser limestone..... 32
2. Thin-bedded limestone with thin crystalline lenses..... 18
3. Knobby reticulated irregularly bedded limestone..... 14
Tonoloway limestone.....426
4. Thin-bedded calcareous shale, mostly covered..... 9
5. Largely covered; some irregularly bedded dark limestone..... 40
6. Knobby to thin-bedded gray argillaceous limestone, some crystalline zones..... 25
7. Covered..... 52
8. Coarse crystalline gray cronoidal limestone; Hindella congregata..... 8
9. Covered..... 10
10. Blue finely reticulated dense limestone... 8
11. Covered; some platy laminated calcareous shale..... 20
12. Thin-bedded thin-laminated mud-cracked limestone..... 20
13. Covered..... 6
14. Same; some sandy and argillaceous thin platy limestone..... 20
15. Knobby limestone, somewhat arenaceous; weathering red..... 18
16. Chiefly covered; shaly float..... 55
17. Sandy buff shale; Leperditia alta..... 15
18. Covered; some red shale (Indian Springs member) at top.....120
Wills Creek formation.....Not measured

The Tonoloway limestone consists mainly of dark thin-bedded thin sandstones and arenaceous horizons; at its top occur gray calcareous shale and slightly knotty argillaceous limestone. The second 50 feet below the top commonly contains a considerable body of fairly coarse gray crinoidal limestone, some parts of which are dense and crystalline. A wine-red shale and hackly red sandstone, 8 to 40 feet thick, occurs about 120 feet above the base of the

Tonoloway. This member, apparently equivalent in position to the Indian Spring redbed member [1] of the Tonoloway of eastern Maryland,

[1] Swartz, C. K., and others, Silurian: Maryland Geol. Survey, p. 46, 1923.

represents a penetration of the eastern red Bloomsburg facies into the western marine Tonoloway. Many Tonoloway limestones are strongly marked with mud-cracks that give evidence of shallow-water deposition. (See Pl. .)

The formation weathers rapidly, and its outcrop is covered with soil from the adjacent Silurian sandstones. Where cleared, the outcrop affords good pasture and fair agricultural land; its natural soil is yellow-red.

Age and Correlation

The Tonoloway limestone is the uppermost Silurian formation of the Stony Man region where it forms the top of the Cayugan group. Sparingly fossiliferous at any locality, the Tonoloway affords few fossils. The following forms have been identified in the Tonoloway of the Massanutten area:

Stropheodonta bipartita Weller
Chonetes sp.
Camaratoechia litchfieldensis (Schuchert)
Hindella congregata (Swartz)
H. rotundata (Whitfield)
Spirifer fontinalis (F. M. Swartz)
Hormotoma cf. H. rowei (Swartz)
Beyrichia tonolowayensis Ulrich & Bassler
Leperditia alta (Conrad) Jones
L. scalaris var. praecedens U. & B.

Traced northeastward from Virginia, West Virginia, and Maryland into central and eastern Pennsylvania, the Tonoloway limestone becomes partly nonmarine, and its middle and lower portions are replaced by the Bloomsburg redbed facies. In eastern Pennsylvania and New Jersey, only the uppermost beds of the Tonoloway horizon--

locally called the Bossardsville limestone--are marine. The middle and lower Tonoloway, is represented along the Delaware by the uppermost beds of the red High Falls (Bloomsburg) facies.

DEVONIAN SYSTEM

General Statement

Devonian rocks in this quadrangle occupy the smallest area of any Paleozoic system, being limited to about one square mile in the extreme northwest corner. (See Pl. 1 .) Their outcrop, which is wholly within Fort Valley (Pl.), contains very few bedrock exposures within the bounds of the Stony Man quadrangle. (See Pl. .)

In view of its limited outcrop, the local Devonian system is separated into but three units for descriptive purposes. These are (1) Helderberg limestone, represented by Keyser and Coeymans members; (2) Onondaga shale; and (3) the Romney black-shale facies. The last is not a true stratigraphic formation but rather a phase of middle and late Devonian deposition that includes Marcellus, Hamilton, and Naples horizons. Not more than 800 feet of Devonian rocks (actually) occurs in the quadrangle, although the full thickness of all Devonian units of this area is at least 1,800 feet. No economic products are found in local Devonian rocks whose topographic expression is also negative.

beds of M., H. and N. ages

(??) what area appl. rocks?

Helderberg Limestone

Distribution

Throughout Maryland, West Virginia, and adjacent portions of Virginia, the Helderberg is represented by four formations, in ascending order, the Keyser limestone, the Coeymans limestone, the New Scotland

shale, and Becraft limestone. Of this succession, only the two lower members are present in the Massanutten region, where it is most convenient to discuss them under a single heading. The local Helderberg outcrop is exceedingly limited, being only a narrow band, possibly ~~one~~ a quarter of a mile in length long, crossing the extreme northwestern corner of the quadrangle. This outcrop is part of a belt that bounds Fort Valley and may be traced in a long oval around the axis of the Massanutten Mountain syncline. As no Helderberg exposure is known within this quadrangle, its local presence can be inferred only.

Keyser Limestone

The Keyser limestone of Massanutten Mountain varies in thickness from 20 to about 50 feet. At most exposures, it is separable into (1) an upper mealy or friable brown fossiliferous sandstone, and (2) a lower knotty or cherty crystalline limestone. The sandstone, believed to be the Clifton Forge member [1] of middle

[1] Swartz, F. M., Helderberg group of parts of West Virginia and Virginia: U. S. Geol. Survey Prof. Paper 158, p. 29, 1929.

Keyser age, varies from 1 to 23 feet thick, and has been mistaken for the Oriskany sandstone which it lithologically resembles. F. M. Swartz [1] reports Chonetes jerseyensis, Camaratoechia gigantea, and

[1] Swartz, F. M., in Guidebook: Field conference of Pennsylvania geologists, Virginia--1938: Virginia Geol. Survey, Guide leaflet 1, p. 26, 1938.

Merista typa from these sandstones near Boyer Furnace, west of Dilbeck. The lower Keyser limestone, from 14 to 30 feet thick, has the normal Keyser lithologic character, being cherty and nodular,

and containing irregularly bedded grainy or crystalline dark-blue limestones. Chonetes jerseyensis, Merista typa, Atrypa "reticularis," and Cladopora rectilineata were observed in the lower beds.

The Keyser limestone is poorly exposed. It weathers readily, and its outcrop is covered with a deep yellow soil in which minor quantities of black chert are present. The contact of Keyser and Tonoloway limestones is wholly conformable, and the lithologic gradation between the knobby lower Keyser and the irregularly bedded upper Tonoloway is far from sharp.

The following section on the abandoned road leading from Fort Valley to Mt. Jackson along the headwaters of Passage Creek, shows the character of the Keyser limestone at its exposure nearest the Stony Man quadrangle:

Mt. Jackson Road Section

Section along abandoned road from Fort Valley to Mt. Jackson, along headwaters of Passage Creek, 1.5 miles east of Moreland Gap.

Onondaga yellow fissile shale; ostracodes (estimated)		100 Feet
Coeymans limestone		5
1. Coarse-crystalline coralline gray crinoidal limestone	5	
Keyser limestone		45
2. Clifton Forge sandstone member	23	
a. Buff mealy sandstone, Chonetes jerseyensis	3	
b. Sandy shale, mostly covered	20	
3. Lower Keyser member	22	
a. Dark subcrystalline cherty limestone, Chonetes jerseyensis, Cladopora rectilineata	5	
b. Finely knobby dense thin-bedded gray limestone	11	
c. Coarsely crystalline crinoidal gray limestone	2	
d. Dense gray crystalline limestone	4	
Tonoloway limestone		387
4. Knotty calcareous gray shale	4	
5. Mainly thin-bedded knotty limestone	28	
6. Covered	57	
7. Fine thin-bedded dark limestone	8	
8. Covered	25	

(Mt. Jackson Road Section, continued)

9. Dense pink cross-bedded subquartzitic sandstone..... 4
10. Fissile buff calcareous shale..... 33
11. Thin-bedded calcareous slabby shale..... 35
12. Hard thin-bedded plattery dark limestone, *Leperditia alta*..... 4
13. Yellow-buff sandy shale..... 3
14. Thin-bedded thin-laminated shaly limestone 20
15. Somewhat sandy thin-bedded limestone..... 4
16. Very platy thin-laminated dark limestone.. 17
17. Indian Spring redbed member..... 45
    a. Thin-bedded wine-red shale..... 45
18. Buff-weathering calcareous shale; some brown friable sandstone members near base.....100

Wills Creek sandstone and shale.....Not measured

Introduction of the Keyser limestone into the Helderberg group is not wholly in accord with the time-honored interpretation of the well-known New York section in which the Coeymans limestone has long been regarded as the earliest Devonian formation. However, the fossils, lithologic character, and stratigraphic position of the Keyser limestone of the Appalachian region are such that it is believed impossible by stratigraphers logically to exclude the Keyser from the same assignment as the overlying Coeymans, New Scotland, and Becraft formations. Acceptance of this view has come from careful studies of Reeside[1] and F. M. Swartz[2]

[1] Reeside, J. B. jr., Helderberg limestone of central Pennsylvania: U. S. Geol. Survey Prof. Paper 108, p. 185-225, 1918.

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

in Pennsylvania and the Virginias, respectively. Complications which arise from the apparent equivalence of the Keyser limestone of the Appalachians with the Decker Ferry-Manlius limestones of New Jersey and New York--long regarded as upper Silurian rocks--have not yet been composed.

Coeymans Limestone

Above the brown Clifton Forge member of the Keyser limestone is a coarsely crystalline gray crinoidal limestone 5 to 40 feet thick. This member is a single massive dense bed, whose weathering indicates a somewhat arenaceous content. The limestone is fairly fossiliferous, supplying *Favosites* sp., *Atrypa "reticularis,"* *Schuchertella woolworthana*, *Uncinulus abruptus*, and *Spirifer* cf. *S. cyclopterus*. Except that they indicate a Helderberg age, these fossils are not diagnostic, and no specimens of *Gypidula coeymanensis*, the most typical Coeymans species, were found. Nevertheless, on the basis of a position directly above the Keyser, and because it has the lithologic character which Coeymans limestone consistently exhibits, this member is tentatively assigned to the Coeymans.

No indication of any New Scotland shale nor Becraft limestone was observed in the Massanutten area, where the overlying Oriskany sandstone is also absent.[1] The Coeymans member of the Helderberg appears to be directly overlaid by Onondaga shale.

[1] Sandstone reported as "Oriskany" is now identified as Keyser.

Onondaga Shale

General Description

Thin shales at the base of the thick Devonian black-shale facies represent the Onondaga limestone of New York and Pennsylvania. These rocks are sparse yellow clay-shales that weather rapidly and are relatively unconsolidated. They vary from buff to green and grade upward into the dark or black shales of the basal Romney sequence. Although the Onondaga is not exposed within

the Stony Man quadrangle, its projected outcrop is assumed to cross the extreme northwestern corner of the quadrangle, where it is undifferentiated on the geologic map (Plate 1) from the wider Romney outcrop. Possibly it is 100 feet thick. There is a good Onondaga exposure in a shale pit along ~~Virginia~~ State Route 266, about ~~one-~~ a quarter of a mile south of C. C. C. Camp Roosevelt, where typical Onondaga fossils--including Amphissites favulosus, Bollis ungula, and Leptocoelia flabellites--have been found.

So far as known, the Onondaga shale rests directly upon the Coeymans limestone with a hiatus representing Oriskany, Becraft, and New Scotland horizons.

Romney Black-shale Facies

Definition

A thick black-shale facies constitutes a large body of the Devonian between Onondaga and Portage horizons in West Virginia and Virginia. At different localities, this facies includes one or more horizons of Marcellus, Hamilton, Genesee, or Naples age. Varying in stratigraphic content from place to place, the facies does not maintain a constant stratigraphic level, although it holds a fairly uniform lithologic character. Until more detailed field work provides separation of its several members, a group name is appropriate, and the term Romney [1] is a convenient, but

[1] Darton, N. H., Notes on the stratigraphy of a portion of central Appalachian Virginia: Am. Geologist, vol. 10, p. 17, 1892.

not precise, appellation for local Devonian black shales.

As herein used, Romney has the connotation of a black-shale lithologic facies, and does not carry the precise implication of

definite stratigraphic horizons. Use of the term may be compared with that of the Bloomsburg redbed facies, or with recent use of Catskill for all upper Devonian redbeds. It is possible that the Romney facies of Massanutten Mountain actually contains the constituent members of the original Romney shale (Marcellus-Hamilton-Genesee) at its type locality at Romney, Hampshire County, West Virginia.

Character

The Romney facies of Massanutten Mountain is black fissile shale that lacks any calcareous material and commonly weathers to buff colors. The rock disintegrates readily to a sterile splintery soil that is mainly uncultivated and supports a meager growth of small trees. The Romney is extensively folded and it is impossible to find a continuous exposure of any major sequence of the shales. Most of the material is fine-grained, and its bedrock colors range from chocolate brown to true black. Middle and upper portions contain thin-bedded slabby sandstones. It is estimated that the total thickness of this black-shale facies may reach 1,600 feet in Fort Valley.

Age and Correlation

The Romney black-shale facies of Fort Valley contains a lower member of Marcellus age, which may be identified by the presence of *Styliolina fissurella* and *Leiorhynchus limitare*; a middle member of Hamilton age, identified by *Spirifer mucronatus*, *Athyris spiriferoides*, and *Atrypa spinosa*; and an upper member of Naples age, identified by *Buchiola retrostriata*, *Paradardium doris*, and *Probeloceras lutheri*. The Marcellus member is visible near the

bridge at the intersection of Virginia 266 and a side road north of Camp Roosevelt; the Hamilton member is well exposed at the great bend in Virginia 266 near Detrick.

Probably only the lowest portion of the formation enters the Stony Man quadrangle. This is the Marcellus member which is the thickest portion of the facies; the joint Hamilton-Naples thickness is less than 600 feet. Elsewhere in Virginia, the Naples is overlaid by the Brallier, Chemung, and Hampshire formations of upper Devonian age. These are absent in the Stony Man region, where the black Romney facies is the youngest element of the bedrock.

QUATERNARY DEPOSITS

Quaternary rocks of this region are unconsolidated surficial materials that are widely distributed over all other rock systems. Most of them are gravels, sands, clays, and associated deposits of recent origin (Pl.) separable into three main types: (1) transported gravel and sand; (2) residual chert, clay, and loam; and (3) calcareous fluvial deposits.

Gravels and sands are the insoluble residue of older rocks together with stream debris that has not been reduced to fine size or washed away in suspension. Most of the gravels, which occur mainly in alluvial fans, are fragments of sandstone, greenstone, and other igneous rocks of the Blue Ridge; in the northwestern corner of the quadrangle, they are derived from the Tuscarora sandstone. Commonly half-round or sub-round--although some are angular--their shape depends upon length of transportation and the inherent hardness of the rock. Streams along the west foot of

the Blue Ridge are choked with boulders of granite and sandstone, and the quantity of their alluvial material is tremendous (Pl.).

The sand deposits are chiefly pure quartz grains produced during weathering and erosion of sandstones or siliceous igneous rocks. Magnetite is a common accessory in sands from the crystalline rocks, and black grains of this heavy mineral form tiny placer-like accumulations on the surface of these deposits; none is found in sands derived wholly from Paleozoic sediments. Smaller quantities of fine detrital material occur on the floodplains of Shenandoah River and its larger tributaries, as on the wide fluvial plain along Hawksbill Creek, directly south of Luray.

Residual Quaternary soils, chert, clay, and loam are widely developed in the broad area of Page Valley, where they are products of bedrock decomposition. Where free from chert or other foreign debris, they form fertile and productive areas. The limestone residues vary in thickness from a few inches to ten or more feet, and grade imperceptibly downward into a sub-soil that merges with the bedrock. On portions of Ozarkian and Canadian outcrops, there are large quantities of chert, which impairs the fertility and productiveness of such soils. Upon Silurian and Devonian shales, the residual materials are thinner and contain tiny shale splinters that make their sterile soil readily subject to drought.

Calcareous fluvial deposits are chiefly varieties of "marl" or travertine, which are secondary accumulations of calcium carbonate deposited from solution by ground and surface waters. The surficial varieties ("marl") are frothy and characterize those streams that flow across limestone outcrops. Subsurface forms include stalagmites and stalactites in caves and caverns. The "formations" of Luray Caverns belong to this group. (See Pls. .)

Few fossils are known from Quaternary deposits. Recent snail shells and plant leaves fill the "marl" of surface origin, and rare bones of ancient mammals are dug from residual clays or transported surface deposits of northern Virginia. None, however, has been reported from this region. Flints made by the Indians, which are occasionally found in Quaternary deposits, are of comparatively recent origin.

GEOLOGIC STRUCTURE

GENERAL FEATURES

The geologic structure of any region is the pattern of its bedrock, most elements of which escape casual observation. To the economic geologist or mine operator, the structure of a region has active significance, and no development of natural resources should be undertaken without careful study of local geologic structures.

The Stony Man region reflects the general structure of the main Appalachian Valley, wherein a thick series of sediments, once laid down in horizontal layers, covers a basement of ancient crystalline rocks. Long after the formation of the sediments--indeed, after they had been hardened into sedimentary rocks--the entire succession of sediments and crystalline materials was folded and otherwise deformed during a long epoch of crustal disturbance. Great arches (anticlines) and troughs (synclines) were folded in the formerly horizontal bedrocks, and a later epoch of erosion beveled the entire series of folds. At many points, as in the Blue Ridge, the sediments were largely stripped off by a denudational

formed
developed

localities
places

removed

attack that laid bare the ~~twisted structures of the~~ older crystalline rocks. Other folds, deeper than erosion could reach, were planed flat but not cut down to their roots; in them still remain the down-folded sediments whose upturned edges are now etched into irregular relief as differential erosion has worked upon rock belts of alternating hardness. In briefest form, the structural elements of this region consist of (a) an eastern ~~anticlinorium~~ [1] of crystalline ~~material~~ (Blue Ridge), and (b) an irregular lowland (Page Valley) underlaid by hardened sands, muds, and limy muds that have been folded and overturned and are now deeply eroded.

[1] The term anticlinorium applies to a broad arch irregularly wrinkled into numerous anticlinal axes; there is an analogous term, synclinorium, which is appropriate for the synclinal, or down warped counterpart.

Large parts of these ancient folds have been removed by erosion. Indeed, only where they have been deeply infolded, are higher members of the sedimentary series preserved, and even the underlying basement rocks have been deeply bared. The magnitude of the folds is measured in miles; the original height from the top of the anticlines to the bottom of adjacent synclines must have been several thousand feet.

The tremendous pressure which produced the folds was exerted from the southeast, and at many points exceeded the resistance of the rocks. In consequence, bodies of rock miles across were thrust, or faulted, some distance northwestward, while many folds were crowded forward so that their rocks became overturned. Two types of structure were thus produced, (a) rock folds and (b) dislocations or faults. Both are well represented in the Stony Man quadrangle.

The folds are of two types that differ only in magnitude. One type is a great open fold, represented by Massanutten syncline, wherein dimensions are measured in miles. The other type is much smaller, (occurring in) soft clay-shales which yielded pliantly to compression. Small(er) folds of this occur in Harpers, Waynesboro, and Martinsburg and Romney shales.

There are two classes of faults; those caused by pressure, and those resulting from tension. In this region, all known faults belong to the former group (having resulted from pressure) they are (called) overthrust faults. Minor structures, such as joints and (rock) cleavage are (also) common.

FOLDS

MASSANUTTEN SYNCLINE

The Massanutten Range (Pl.) is the most prominent topographic feature of the northern Valley of Virginia, which it bisects into two parallel sections. Structurally, it is a great synclinorium, which may be traced in the bedrock far beyond the northeast and southwest ends of the mountain block. Indeed, a synclinal structure occupies the Valley of Virginia from Botetourt County northeastward to the Potomac, (thence) across the eastern "panhandle" of West Virginia and east-central Maryland, into southern Pennsylvania--a (total) distance of more than 175 miles. The width of this structure--as measured by the infolded formations--is more than 12 miles. Named from its main ridge, Massanutten Mountain, the fold is known as Massanutten syncline.

The most striking topographic feature of this structural basin is its central mountain range, which forms the boundary be-

mountainous mass
lone mountain area

tween Rockingham, Page, Warren and Shenandoah counties. This mountain upland has a length of about 50 miles, and is rudely separated by New Market Gap into (a) a southwestern portion, about 20 miles long, consisting of a double or triple ridge with intervening deep narrow subsequent valleys; and (b) a northeastern portion about 30 miles long, consisting of two or more parallel ridges which enclose surround a wide flat-floored interior valley (Fort Valley[1]).

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[1] John Powell once had a fort in this valley which was first called Powell's Fort Valley, and later (merely) Fort Valley.

The southwestern division of the range ends sharply near McGaheysville, Rockingham County, in the Peak, a knob that rises from 1,600 to 1,700 feet above the adjacent valley to an ~~elevation~~ altitude of about 2,950 feet. Extending northeastward from this peak is a main ridge that is bounded on the southeast and northwest by smaller and more discontinuous ridges that are huddled together but divided from the main mountain and from each other by narrow ravines. The width of this portion of the range is nowhere greater than four miles.

Directly east of New Market, New Market Gap and (now) occupied by the Lee Highway, U. S. Route 211 severs the range into its two ~~segments~~ parts. In the floor of this gap, elevation 1,800-1,900 feet, the mountain crest is only 750 feet above the adjoining valleys, and there are no flanking ridges opposite the gap.

Gap = 1800-1850'

Valleys ± 900-1000'
Diff = ± 800-900

Northeast of New Market Gap, begins a double line of ridges that spread apart to bound the wide inner lowland of Fort Valley, which lies between the main Massanutten Mountain on the southeast and the Kerns-Powells-Three Top ridge on the northwest. The floor of Fort Valley is but slightly higher than Shenandoah and Page valleys, and drains northeastward through Passage Creek. At its

broadest section, Fort Valley occupies about four of the seven miles of the total width of the range. (See Pl. .) The highest summit north of New Market Gap is a little more than 2,800 feet above sealevel. The highest peak of the entire range is Lairds Knob, due east of Harrisonburg, with an elevation of more than 3,300 feet. Massanutten Mountain and its associated ridges end abruptly at Waterlick, Warren County.

Northeast of Waterlick, (in the absence of) Massanutten Mountain, the undivided Valley of Virginia is nearly 25 miles across at the latitude of Winchester, where its level floor is but slightly dissected. The Valley-floor peneplane (see pages) rises southwestward from (the) 500-foot in Frederick County, to 600-700 feet above sealevel near Waterlick, where Massanutten range begins. Page Valley, (east of Massanutten Mountain), is about 5 miles wide, and Shenandoah Valley, (northwest of Massanutten Mountain), is 10-12 miles wide. Southwest of McGaheysville, Page and Shenandoah valleys merge near the Peak which terminates the Massanutten range at the south. (Their joint width is about 20 miles) near the Rockingham-Augusta county-line, and about 14 miles near Greenville, Augusta County,

In the latitude of Massanutten Mountain, Shenandoah Valley is drained by North Fork of Shenandoah River; South Fork occupies Page Valley; Passage Creek drains Fort Valley within the range. These three rivers converge northeastward and join in central Warren County, Passage Creek entering North Fork at Waterlick; South Fork meeting North Fork at Riverton. Northeast of Riverton, ~~the~~ Shenandoah flows north to meet the Potomac near Harpers Ferry.

The Massanutten synclinorium is a broad structural basin wherein Silurian and Devonian rocks are downfolded into the Ordovician and Cambrian rock sequence of the Great Valley. The main central valley occupied by Passage Creek is located approximately upon the axis of the fold. There is a subsidiary synclinal axis west of this valley in the section directly northeast of New Market Gap, and a third similar axis is crossed by the road from Dietrich to Woodstock. Short Mountain, east of Mt. Jackson, is a fourth syncline containing Tuscarora sandstone that is wholly separated from other Tuscarora outcrops. East of Dietrich, there is another minor syncline.

Resistant Tuscarora sandstone everywhere forms the ridge of the synclinorium and dips below Fort Valley at angles of 20-40°. The outer ridge has been cut through by Passage Creek near Waterlick in a gorge wherein the creek descends from Fort Valley to meet North Fork of the Shenandoah. Fort Valley is floored with the Romney black-shale facies of upper Devonian rocks. The soft shales are intimately crumpled at most exposures, and their erosion has led to the development of the inner lowland. A belt of Helderberg and Cayugan limestones bounds the valley athwart its limiting ridges, where their outcrop adjoins that of the Clinton-McKenzie and early Silurian rocks. If projected across Shenandoah Valley west of the range, these Silurian and Devonian sediments would reach a height of several thousand feet above the present floor of that lowland. In any such reconstruction, it would be necessary likewise to project them over Page Valley at the east, but there are no data to reveal how far east of this syncline these rocks once extended. Presumably they covered the Blue Ridge itself, but they now have no more easterly outcrop than in the Massanutten range.

The Massanutten Mountain syncline dominates the structure of the northern Valley of Virginia, and to a large extent controls the structure of the Paleozoic rocks in the Stony Man quadrangle. It is the largest individual fold in the area of this report and one of the most prominent geologic structures in Virginia. Study of Paleozoic sections in Shenandoah and Page valleys reveals that the syncline lies along what was (once) an important environmental axis at the time of rock deposition. The (Its) effect of the structure was most marked during Ordovician time. As an example of its control may be cited the thickness of the Chambersburg limestone, which is 500 feet thick in Shenandoah Valley, but is less than (fails to reach) 100 feet thick in Page Valley, east of the central fold. The Massanutten Mountain syncline is of special stratigraphic importance in that it contains the easternmost outcrop of many critical Paleozoic formations, including the Tuscarora, Clinton, Cayugan, and Helderberg.

Only a small part (section) of the syncline lies (falls) within the Stony Man quadrangle. Kennedy Peak (Pl.), which is the highest local portion of the main ridge, reaches 2,552 feet above sea level. It is underlaid by Tuscarora sandstone in a small projection that has been slightly offset from the main belt by a close fold or a small linear strike-fault. The main Tuscarora outcrop follows the Massanutten ridge across the northwest corner of the quadrangle. Not more than one square mile of the latter extends into Fort Valley.

PAGE VALLEY

The geologic structure of Page Valley is more (than usually) unusually complicated--even for a section of the disturbed bedrock of the Appalachian region. When originally deposited, ~~its~~ rocks were forming now undergoing

approximately horizontal and rested evenly upon a basement of pre-Cambrian materials. During deformation in the Appalachian revolution, more easterly areas were buckled into the Blue Ridge anticlinorium, which may have had some sort of synclinal trough at its western foot. Continued compression from the east thrust this anticlinorium westward against the softer rocks of what is now Page Valley, and these were elevated into a complex anticline that ultimately transmitted the pressure westward to produce various westerly folds, of which the Massanutten syncline was next adjoining. Crowded between the latter and the westward-pressing Blue Ridge anticlinorium, the bedrock of Page Valley was remarkably close-folded, and no portion of it now retains any semblance of a previous horizontal structure.

With the present exceptions of (a) the early Cambrian sandstones, which dip northwestward at steep angles, and (b) the Tuscarora sandstone, which also dips toward the northwest, the inclination of nearly every rock ledge in Page Valley is southeastward. As one crosses the valley from Blue Ridge to Shenandoah River, he passes successive outcrops of Tomstown, Waynesboro, Elbrook, Ozarkian, Beekmantown, and early Ordovician formations in normal ascending stratigraphic order. However, as all dips are toward the southeast, each successively higher formation appears to dip southeastward below the rock upon which it normally rests--a fact which indicates that the entire rock sequence may be overturned, and that observed dips to the southeast are actually inclinations which have been carried beyond 90°. Thus, an observed southeast dip of 45° must represent an overturn through an arc of 135° (90° plus 45°).

There are two possible explanations for this nearly constant southeastward dip. One is the simple hypothesis that the entire Paleozoic sequence up to the Tuscarora sandstone is wholly overturned with~~out much~~ little internal crumpling within each formation. This hypothesis would assume that a deep well drilled in the valley lowland should penetrate downward successively younger--rather than older--rocks than those exposed at the surface. The other explanation assumes a great deal of internal folding within each rock formation, and calls for a series of tight folds--anticlines and synclines--in which all axial planes dip southeastward; thus, both limbs of all structures would contain rocks that dip to the southeast. This hypothesis is somewhat more probable than the overturning of a thick section of the earth's surface, and readily accounts for the apparently conformable southeastward-sloping contacts of the many formations in Page Valley.

The latter hypothesis is partially confirmed by the excessively wide outcrops of many rocks. If the strata in Page Valley are merely overturned, each formation would have an outcrop whose width would be proportional to the thickness of the formation and the angle of its inclination. Such a proportion does not exist. The Elbrook limestone, which has a probable thickness of about 1,800 feet, occupies a belt about 6,000 feet wide; the Ozarkian system, with an analogous thickness, has an outcrop 5,000 to 13,000 feet wide. Variation in width between outcrops of these approximately equal formations reveals that the Ozarkian ~~is~~ formations are considerably crumpled internally, a fact which is compatible with the hypothesis that many tightly compressed folds are responsible for the constant southeastward dips.

The Tuscarora-Martinsburg contact on Massanutten Mountain dips steeply to the northwest; the Chambersburg-Martinsburg contact along Shenandoah River, about 2 miles to the southeast, dips toward the southeast; the former is normal, the latter, overturned. These relations indicate a reversal of dip within the body of the Martinsburg shale--either a tight synclinal structure with an axial plane that is inclined toward the southeast, or a fault. The position and character of this reversal is not determinable within the Stony Man quadrangle.

In general, Page Valley represents a highly compressed and telescoped anticline, only the crumpled roots of which now remain. Beveled by the Valley-floor peneplane and blanketed with residual and alluvial soil, the contorted bedrock reveals little indication of its complexity save to the student of geologic structure.

BLUE RIDGE

A long relatively narrow mountainous tract bounds the Appalachian Valley on the southeast and separates it from the broad Piedmont plateau. The continuous chain of elevations which marks this belt also forms the geomorphic unit known as the Blue Ridge physiographic province. (See pages .) A similar tectonic province may be recognized in the same belt. This province, known as the "Blue Ridge" is largely coextensive with its physiographic analogue. The western borders of the two provinces exactly coincide, the topographic boundary reflecting a sharp lithologic contrast between the weak rocks of the eastern Valley and Ridge belt and the hard siliceous and crystalline rocks of the Blue Ridge that have been overthrust upon them. The eastern boundaries of the Blue Ridge provinces, however, are somewhat divergent. Whereas the physiographic province is restricted to the mass of

the Blue Ridge and its allied ranges, the tectonic province has a more easterly boundary. South of James River in central Virginia, it extends more than 15 miles beyond the east slope of the Blue Ridge. proper

The Blue Ridge crystalline complex occupies a medial position in the present Appalachian Mountains. East of its western border, igneous bodies of the intrusion and both progressive and retrogressive metamorphism have been prominent factors features of several epochs of deformation. West of the Blue Ridge where both intrusion and metamorphism are almost wholly absent, folding and overthrusting are the visible evidences of Appalachian deformation. West of the Blue Ridge occurs the thick unaltered Paleozoic column of the Appalachian geosynclinal tract. East of the Blue Ridge, Paleozoic sediments are less commonly recognized or differ considerably in character and sequence from their western counterparts. It has been suggested that the original Appalachian geosyncline was composed of two troughs, in which the site of the present Blue Ridge then occupied a medial, or dividing, position. Of more probable validity is the suggestion that marginal differences are now thrown into sharp contrast by the telescoping of a single geosyncline. ∠ ¶ here –

The structure of the Blue Ridge is best shown in its northern portion, from Maryland southwestward to central Virginia. The central core is chiefly formed by Catoctin metabasalt or greenstone (pages), which has been variously intruded by younger igneous rocks, and is flanked on either side by quartzites. The latter form Catoctin and Bull Run mountains on the east, and the Blue Ridge foothills (Hershberger, Piney, and Varner hills, etc.) on the west of the main Blue Ridge. In the vicinity of James

River, the greenstone and eastern quartzites disappear, and the anticlinorium continues southwestward as a tract of disturbed metamorphic and igneous rocks bounded only at the northwest by a border belt of early sediments. The general strike of the main axis of the anticlinorium, as well as the trends of its subsidiary folds, seems to hold a slightly more southerly direction than either the Valley and Ridge province, the Piedmont province, or the Blue Ridge tract itself. Thus the Martic overthrust, which overlaps the southeastern edge of the Blue Ridge anticlinorium, progressively conceals in a southwestward direction the various linear elements of the massif.

The western border of the Blue Ridge mass is marked by the Blue Ridge overthrust, which may be followed without essential interruption from Pennsylvania to Georgia. Along this fault, which differs little if any from overthrusts in the Valley and Ridge region, crystalline and early Paleozoic rocks have been overthrust upon the sedimentary rocks of the Great Valley, or locally Page Valley. Actually, the Blue Ridge overthrust is a complicated line of imbricating faults arranged <u>en échelon</u>. Probably its many local thrusts are shear planes of a continuous "master fault," although there is marked variation in the amount of forward movement from place to place. The pre-Cambrian rocks are involved in small sharp folds along the fault margin, suggesting a rolling, or even plastic, yielding of the crystalline anticlinal core. Displacements of the Blue Ridge overthrust become increasingly complex toward the southwest. Northeast of Roanoke, Virginia, the major displacement lies chiefly between the main mass of the Blue Ridge and the Cambrian foothill belt that bounds the Appalachian Valley on the southeast. From Roanoke

southwestward, the main line of thrusting gives way to two major belts of displacement; an eastern one which separates the crystalline rocks of the fold from the more western arenaceous sedimentary belt, and a western fault zone along which the quartzites and sandstones are, in turn, thrust westward upon still younger Paleozoic sediments.

The eastern border of the Blue Ridge ~~anticlinorium~~ Province is less sharply marked than the western border. From Pennsylvania southward nearly to James River, ~~the anticlinorium~~ it is bounded by the Catoctin Mountain border fault which is a high-angle displacement having an estimated throw of at least 6,000 feet at South Mountain, Pennsylvania. Along this fault, which is probably of Triassic age, Triassic sediments, ~~relatively~~ down dropped on the east, conceal the southeastern continuations of the ~~anticlinal structures~~ crystalline mass as well as the local trace of the Martic overthrust. Narrow linear belts of ~~Cambrian rocks~~ metasediments in sharply compressed synclines occur in a disconnected zone along the east margin of the anticlinorium. These belts are strongly overturned toward the northwest, probably as a result of the thrusting along the Martic block (now partially concealed beneath the Triassic basin). From central Virginia southwestward, the Blue Ridge anticlinorium is bounded on the east and southeast by the Martic overthrust fault block.

block is fault along fault

In this quadrangle, the Blue Ridge ~~anticlinorium~~ occupies the eastern half portion, in which outcrops of Catoctin greenstone, hypersthene granodiorite, and granite are widespread. ~~Scattered [illegible] liers lie on the southeast [illegible] axis.~~

southeastern half of the area

occur

OTHER FOLDS

The Paleozoic rocks of Page Valley crop out in linear belts that vary but slightly from a true northeastward strike. Directly south of Shenandoah River, between Hawksbill Creek and the west margin of the quadrangle, is a small area of Athens shale largely separated from the main Athens outcrop. The detached belt, which is about ~~one~~ a mile wide, is truncated on the northwest by a small overthrust fault. Mosheim, Lenoir, and Chambersburg limestones bound the shale ~~at~~ area on the south~~west~~east, but have been partially deleted by faulting along the northwest~~ern~~ edge of the Athens area. This structure is crossed by State ~~Highway~~ Route 266, along which the duplication of beds may be seen one mile southwest of Bixler Bridge.

A small syncline occurs one mile east of Marksville, south of Hershberger Hill. This structure is a shallow fold wherein Tomstown dolomite lies in a~~n~~ of Antietam sandstone basin. The southeast~~ern~~ limb of the syncline has been broken by an overthrust fault that extends northward from the Blue Ridge overthrust east of Marksville. The syncline plunges southwestward, and is cut by the main Blue Ridge overthrust near Little Hawksbill Creek. Several minor folds occur in lower Cambrian formations elsewhere in the foothills belt. A small fold, probably accompanied by strike-faulting, slightly offsets the Tuscarora outcrop near Kennedy Peak ~~of~~ on Massanutten Mountain. The sinuous Loudoun outcrop between Dark Hollow and Robertson rivers indicates a type of folding which does not mark the Weverton outcrop west of the Blue Ridge.

FAULTS

BLUE RIDGE OVERTHRUST

One of the most conspicuous structures of the Blue Ridge anticlinorium is the large overthrust fault that parallels its western front across most of its Virginia extension. Along this fault, resistant pre-Cambrian and early Paleozoic rocks have been overthrust mainly upon weaker Cambrian limestone and shale. Throughout much of its length, the structure is a single overthrust, but at some outcrops, there are several parallel faults en échelon.

The Blue Ridge overthrust enters the Stony Man quadrangle about one-half mile southwest of Stanley, at the north end of Round Head Mountain. Thence, it may be traced northeastward between the Blue Ridge foothills. It is crossed by State Highway 279 near Luray Reservoir; by Lee Highway (U. S. 211) near Brick Church; and by Jeremys Run 0.7 miles east of Vaughn. It crosses the middle of the north border of the quadrangle, and continues northward about 1.5 miles east of Rileyville, Compton, and Bentonville. Its general strike is northeast. The trace of this fault is poorly exposed, for it lies beneath a thick accumulation of alluvial material that conceals its exact location save at rare isolated exposures. The line of the break is roughly marked by low country.

Throughout most of its local extent, the Blue Ridge overthrust carries lower Cambrian arenaceous rocks against other Cambrian formations. West of Stanley, the fault-trace is at right angles to the strike of its overthrust block but is nearly parallel to the strike of the overridden block. Northeast of Stanley and elsewhere

in the foothill belt, it does not diverge far from the general trend of the Cambrian outcrop.

Several smaller overthrusts emerge beneath or branch from the main displacement. The largest diverges near Marksville to run parallel with the main displacement along the west edge of an Antietam belt, which is partially thrust northwest upon Tomstown dolomite. A brecciated zone impregnated with limonite occurs along this fault directly south of Mt. Calvary Church. Along the road from Vaughn to Jeremys Run, quartzite beds of the Antietam are cut out by this fault.

Another displacement occurs southwest of Piney Hill, it bears eastward past Rattleburg School and Morning Star between hypersthene granodiorite and the lower Cambrian sediments. Furcron, who believes this displacement disappears within the crystalline rocks east of Morning Star, finds no trace of its continuation northeast of that point. (See also page .)

Production of the Blue Ridge overthrust is assigned to the Appalachian revolution.

OTHER FAULTS

Several small dislocations are indicated on the accompanying geologic map. (See Pl. | .) A small fault occurs at the edge of an Athens outcrop near Bixler Bridge. The fault enters the quadrangle one mile southwest of the bridge, and strikes northeastward for at least 3 miles, into an outcrop of Beekmantown limestone.

The Tuscarora has been duplicated along a small dislocation on the southeast slope of Massanutten Mountain directly below

Kennedy Peak, a spur of which extends southwestward and is underlaid by sandstone that is separated from the main outcrop. A minor fracture within the Conococheague limestone has been traced from a point one mile east of Alma across Hawksbill and East Hawksbill creeks to a point about one mile south of Luray, where it disappears within Ozarkian limestones.

The Blue Ridge crystalline massif does not clearly reveal any important folds or faults; and if major faulting has taken place in the range, it is not marked by extensive shear zones. Its uniformly massive rock suggests that the Blue Ridge acted as a unit during the Appalachian revolution, and that it was thrust en masse against the Paleozoic rocks of the Great Valley.

Lovingston gneiss at the east base of the Blue Ridge, much altered by regional metamorphism, may contain overthrusts of late Paleozoic or pre-Cambrian age whose locations are now obscured.

The hypothesis has been suggested [1] that two prominent cross

[1] Personal communication to the Virginia Geological Survey by Drs. Anna Jonas Stose and George W. Stose.

faults of normal type strike northeast-southwest across the Blue Ridge front east of Luray. One displacement is projected along a straight line from Beahms Gap on the Blue Ridge summit, down Kemp Hollow and Rocky Branch, to Brick Church, where it is supposed to be crossed by U. S. 211; thence it is projected southwest to Fairview. The second fault-line is assumed to extend in a straight line from Thornton Gap through Morning Star; projected southwestward, it would pass a short distance south of Mt. Calvary School. Evidence for these faults is derived chiefly from an assumed dislocation in the foothills belt between Pumpkin Hill and Valleyburg School, and from an alignment of certain topographic features such as Kemp Hollow, Rocky Branch valley, and Beahms Gap.

A displacement of the Blue Ridge overthrust may be traced from a point south of Mt. Calvary Church northeastward past Morning Star and, according to the author ~~Woodward~~, Shenks School to Thornton Gap, where he ~~one author (Woodward)~~ believes a fault contact exists between the hypersthene granodiorite of the Marys Rock area and the Catoctin greenstone north of U. S. Route 211 ~~281~~. This displacement occupies the supposed position of the southernmost normal fault hypothecated above. For the other, more northern, cross fault, the present authors can find no corroborating evidence. They are, furthermore, doubtful of the existence in this quadrangle of any northeast-southwest trending displacements of the type suggested by Jonas and Stose.

GEOLOGIC HISTORY

The geologic history of an area is recorded in its bedrock formations and topography, for each rock formation, mineral deposit, and feature of its landscape reveals some ancient historic event; even its present rock structures discloses additional evidence of geologic history. Not all past events have left tangible records, for many data once available are now destroyed. For ~~its~~ The most ancient history of any area or region, the geologist turns to the underlying bedrock of ~~a~~ that region; more recent history is recorded in its surface features. Both must be studied to obtain a connected story of the geologic development of the rocks and the area land. Whereas recorded human history is a matter of a few tens of centuries, geologic history is measured in hundreds of millions of years, and the reader must appreciate the immensity of geologic time intervals before he can properly understand the events of the long geologic past.

PRE-CAMBRIAN EVENTS

INSERT

Editor:

As I do not have any draft originally prepared for this section by Dr. Furcron, I have inserted a statement of my own, which follows.

H. P. Woodward, Jan. 1, 1940

The geologic history of the Stony Man country stretches far back into pre-Cambrian time--indeed so far into the past that few data are now obtainable to reveal the true sequence of its geologic history. One of the earliest events in this region was the production of an ancient series of sediments. Possibly these rocks occupied a basin similar to the Appalachian geosyncline of Paleozoic time, but its details are now unrecoverable, and it is not even known whence the rocks came. Now greatly altered into a biotite gneiss, they stand as an undecipherable monument of the great past. That they were later invaded by igneous rock (Lovingston gneiss) is known, for this almost equally metamorphosed intrusive still penetrates these ancient biotite gneisses to form a unit complex as old, if not older, than any other materials of this part of the Blue Ridge.

A pre-Cambrian event of approximately equal antiquity was the out-pouring of vast series of basaltic lava flows (now Catoctin greenstone). The vents from which these flows were extruded are not now known, but were probably many rather than few. Tremendous volumes of lava, possibly in several distinct flows, were exuded upon this part of the earth's crust; but if any portion of the

basement upon which the flows came to rest is now exposed in this area, it has been unrecognized. ~~If the biotite gneiss and intrusive Lovingston gneiss were of more ancient age than the extrusives, one would expect to find the volcanic rocks somewhere at rest upon the older basement. That no such exposure is known does not invalidate a theory that the flows are younger than the Lovingston, but until evidence is at hand to the contrary, it may as well be suspected that the flows antedated production of the gneisses, or were of contemporaneous age.~~ See

Probably long after the volcanic activity producting the Catoctin basalts had grown quiet, intrusive bodies of molten rock welled upward into the basement below the volcanics and into the flows themselves. These intrusions range themselves into two sequences, an older invasion of hypersthene granodiorite, ~~and~~ followed by a later intrusion of Old Rag and possibly other granites. Absorption of basement material by the rising intrusions has destroyed all vestige of this supporting rock, and at many places, the granites and granodiorite have replaced or "floated" ~~huge~~ blocks of the basalt itself, extensively altering it to greenstone. Interesting contact facies, involving the peculiar association of green epidote, pink feldspar, and blue quartz, occur near contacts of the volcanic rocks and the materials which invade them, and are responsible for the unakite and pink granite previously described. (See pages .)

The invasion of these igneous rocks was itself an ancient event, possibly of late-middle, or late pre-Cambrian time. It was not followed for a long time by any rock formation; and during an epoch of uplift and erosion, the crystalline terrane was

weather~~ing~~ed and denuded to a more or less level basement that was to form the floor upon which Paleozoic rocks were later deposited. The effects of this long erosion are now emphasized by the great unconformity that everywhere separates the crystalline pre-Cambrian basement from sedimentary rocks of Paleozoic and Mesozoic systems.

During this epoch of erosion at the close of pre-Cambrian time, the basic elements of North American geography came into existence; and most events which followed were direct functions of the new geography.

PALEOZOIC AND LATER EVENTS

GEOLOGIC SETTING

The Paleozoic rocks of this area were assembled in the Appalachian geosyncline, a great structural trough that once extended southward from the Acadian region of Canada. Its central axis is thought to have been slightly west of the present site of the Blue Ridge; its eastern limit is problematical. The nature of its floor is unknown, although it is thought that there were irregularities which produced long narrow troughs within the larger basin. Possibly these irregularities were low anticlines that were more or less proscribed by an earlier orogenic cycle or were the parent folds which later developed into great zones of overthrusting in the Appalachian revolution at the close of the Paleozoic era. As the geosyncline was not uniformly depressed but seems gently to have oscillated from time to time, these minor basins produced many faunal and stratigraphic provinces within the Appalachian region.

The total thickness of sediments that accumulated in the geosyncline is not less than 40,000 feet, and it is probable that this entire thickness was actually in superposition at a few localities, involving a depression of the geosyncline in such places of more than 7 miles. In the Stony Man region at least 15,000 feet of rock were deposited in the incomplete local Paleozoic section. Although this basin was more or less completely drained many times, it persisted as a geographic unit from earliest Cambrian to mid-Pennsylvanian. Possibly it occupied the site of a former pre-Cambrian geosyncline. Its dimensions are not clearly known. Its width may have reached 300 miles, although this figure may be considered a maximum. Formerly it was assumed that the basin was never deeper than 1,000 feet, but suggestions of its greater depth have recently been made.

West of the Appalachian geosyncline at the beginning of the Paleozoic era lay the low continental mainland, which was, perhaps, the original nucleus of North America. To the east of the geosyncline was a borderland that separated it from the open Atlantic Ocean. At the northeast, the trough connected with the Atlantic in the latitude of the present Gulf of St. Lawrence; at the southwest it may have opened to the Pacific.

The eastern borderland, known as Appalachia, was a long narrow body separating the geosyncline and the Atlantic. Probably it was a rugged land, for active streams descended its eastern and western slopes during most of the Paleozoic, to pour immense quantities of rock debris into the Atlantic at the east and the geosyncline at the west. No record exists of the deposits on the east side of Appalachia, but those of its western flank are the sedimentary rocks which now underlie Page Valley and other parts of the Appalachian region. In the main the continental

interior was a low country from which no coarse clastic debris was furnished. Its slight subsidence, or a rise in sealevel occasionally permitted the interior to be flooded by shallow epeiric seas, in the warm clear waters of which were deposited limestone and dolomite, while many kinds of marine life flourished abundantly.

During this era, the geosyncline received coarse silt and gravel from Appalachia at the east and calcareous material from the open waters of the western epeiric seas. Thus, fragmental debris from the rivers of Appalachia became interbedded with marine calcareous deposits in a sequence of sediments wherein sandstone and shale alternate with limestone and dolomite. Waters invading the geosyncline often brought a great abundance and diversity of marine animals, whose fossil shells may now be found in the bedrock of this area.

The details of the filling, subsidence, and ultimate collapse of the Appalachian geosyncline constitute the Paleozoic history of eastern North America. During at least 6 geologic periods, the geosyncline persisted as a seaway, but, in the closing period of the Paleozoic, it was elevated into a range of lofty mountains--the ancestral Appalachians. The disturbance producing these mountains is known as the Appalachian revolution, and it initiated a long era of erosion which has ultimately led to the development of present topography. In the following pages, brief paragraphs are devoted to the important divisions of the Paleozoic and to post-Paleozoic time.

ORIGIN OF THE ROCKS

It is believed that the first Cambrian event in the Stony Man region was a recurrence of the vulcanism that had been so prominent a part of pre-Cambrian history. The evidence for this is found in an amygdaloidal lava flow which occurs below the earliest marine Cambrian rocks and above many units of the pre-Cambrian massif. Early Cambrian vulcanism may not have been extensive--indeed, the irregular distribution of the flow suggests only local activity--yet it is clear that the period of uplift and erosion preceding initial Cambrian sedimentation had not been sufficiently long for all volcanic activity to become quiescent.

Deposition of sand and gravel in early Cambrian time soon followed the spasmodic vulcanism to mark the first major event of the Paleozoic era. These sediments were derived from Appalachia and were washed westward into the geosyncline where they accumulated on the floor and near the shore of that basin shortly after the era began. Their coarseness and cross-stratification indicate derivation from a region of high relief; the deposits themselves are fragmental debris from pre-Cambrian materials of nearby Appalachia. They now compose the Weverton-Loudoun, Harpers, and Antietam formations of the early Cambrian arenaceous group.

Little by little, Appalachia became reduced by continued erosion; possibly it was actually depressed by earth movement. The result was to widen the geosyncline and halt all deposition of coarse material. Warm shallow waters fostered the development of life, and for the first time, the Appalachian area was inhabited by an abundant fauna whose fossils have been preserved.

Lack of clastic debris led to the deposition of clays and fine lime muds which now compose the Tomstown, Waynesboro, and Elbrook formations of the later Cambrian calcareous group.

Throughout succeeding Ozarkian and Canadian time, Appalachia was deprived of most of its former elevation. Its marginal rivers brought little terrigenous material into the geosyncline, where a thick succession of calcareous muds slowly accumulated to form the present Conococheague, Chepultepec, Nittany and Bellefonte limestones and dolomites. The history of this part of the Paleozoic has a monotonous uniformity, and the various deposits differ but little from one another. Only the life materially changed, and the fossil forms in the various deposits are the only basis for differentiating members within the massive sequence of Ozarkian and Canadian rocks.

At the beginning of the Ordovician, the purity of the calcareous deposits increased, for Stones River limestone reveals an almost complete absence of magnesia which had been common in the earlier limestones and dolomites. Its earliest member, the Mosheim limestone, purest of all Paleozoic limestones in Virginia, is more than 95 percent calcium carbonate. The overlying Lenoir limestone, although less pure, is still rich in lime. Both rocks contain fossils of animals different from those of earlier epochs, and the new life was more replete with bivalved forms.

The middle of the geosyncline was soon muddied by an increased quantity of land-derived material, possibly indicating an uplift in Appalachia. These dark muds, now the Athens shale, extend along a wide front, suggesting that analogous conditions were present in the basin from the Potomac southward to what is now Alabama.

Deposition of limestone (Chambersburg) soon ceased, and in the late Ordovician, quantities of fragmental debris grew thicker to form the sandstone and shale now comprising the Martinsburg formation. This change in character of deposition indicates the growing activity of those streams which drained the west slope of Appalachia; while a more abundant and complex fossil fauna reveals that the life of the time was greatly expanded under marked evolutionary changes. A thin bed of volcanic ash (metabentonite) is widespread in the middle Ordovician (Chambersburg) of Virginia, and may reveal a mild renewal of a phase of geologic activity that had been dormant since the beginning of the Cambrian period.

Rising Appalachia furnished its streams with vast quantities of coarse sand that soon spread far and wide across the geosyncline; in early Silurian times vigorous streams were at work sorting and sifting this sand (Tuscarora-Clinton formations) over Ordovician sediments. During middle and late Silurian, thin sandy shales (McKenzie-Wills Creek) and thin limy muds (Tonoloway) settled in more quiet waters, while the active erosion at the beginning of the Silurian gave way to a more leisurely denudation that supplied less terrigenous material to the stream of a lower Appalachia.

These conditions continued into the Devonian period, and its earliest sediments (Helderberg limestones) resemble those upon which they rest. The thick middle and late Devonian shales (Romney) represent part of a delta-like deposit that was widely distributed over the marine sediments of the geosyncline. Broad

rivers, flowing westward from Appalachia, transported large quantities of terrigenous debris, and their floodplains and deltas are recorded by the thick Devonian materials of the present Appalachian region. The sediments became more clastic toward the close of the period, and uppermost Devonian rocks--although not present in this quadrangle--are sandstones and conglomerates.

Although they do not occur in this area, it is possible that Mississippian and Pennsylvanian rocks were once deposited here. They are present in Virginia and West Virginia, west of Shenandoah Valley, but if ever laid down in the Stony Man quadrangle, they were long ago eroded away.

MOUNTAIN BUILDING

The Paleozoic was a time of subsidence and rock deposition in an era when epigene, or destructive, geologic forces were dominant, and when the process of denudation controlled major events. During this long era, the Appalachian geosyncline was filled with sediment--debris transported laterally across the earth's surface and brought to rest some distance from its source. Surface transfer of such vast quantities of rock overburdened the earth's crust beneath the geosyncline, as it must also have lightened the mass of Appalachia. Crustal equilibrium was upset, and eastern North America became a region of increasing instability. Gradually the constructive forces of uplift and mountain building took precedence over the forces of erosion, and the Paleozoic came to a close with profound modifications of surface topography and a mountain uplift on a vast scale.

At some time, probably near the close of the Pennsylvanian period, the Appalachian revolution began. It was not a sudden

beginning, but rather the culmination of a series of events that had started well toward the middle of the era. A compressive force began to thrust northwestward against the oldland of Appalachia and the sedimentary rocks recently deposited in the geosyncline. This irresistible pressure gradually compressed the crystalline materials of Appalachia into a coherent but greatly deformed block that was thrust laterally northwestward against the weaker sediments of the geosyncline. The thick section of Paleozoic rock was crushed, but it was also elevated into a folded tract of high relief--the ancient Appalachians--of which the present linear ridges comprise little more than the denuded roots.

The uplift of the original Appalachian Mountains occurred over an area extending from Newfoundland at the northeast to Alabama at the southwest--a linear distance of nearly 1,500 miles. Throughout this entire belt Paleozoic rocks were folded and faulted as a result of pressure which was exerted from the southeast and directed westward or northwestward by the thrusting of Appalachia against the geosyncline. In much of the belt the rocks were crumpled and overthrust on a tremendous scale--sufficient, indeed, to shorten the earth's crust by as much as 100 miles. The folds were most intense on the eastern side of the basin, and gradually died out in the more or less horizontal rocks of the Alleghany Plateau. Faults were of the overthrust type, having low angles of displacement. Some of them, including the Blue Ridge and Martic overthrusts, may be traced continuously for more than 500 miles. Along some was a horizontal movement of at least 10 miles.

There are many indications of this revolution in the Stony Man quadrangle. The pre-Cambrian rocks of the Blue Ridge are now faulted upon the contorted sediments of Page Valley along the Blue Ridge overthrust, which is one of the great shear zones produced during the revolution. Massanutten Mountain is the east limb of a syncline that formed a trough in the local succession of wave-like folds into which the Paleozoic sediments were thrown. In the floor of Page Valley, still overturned and contorted, are the deeply embedded roots of an anticlinal structure whose crest has long ago been eroded away. The revolution was responsible for almost all crushing and dislocation of the rocks of this quadrangle; it produced the various geologic structures that have been elsewhere described. At no time previous nor since, has this region been involved in a crustal disturbance of such magnitude.

LAND SCULPTURE

In the Mesozoic and Cenozoic eras, which followed the Appalachian revolution, the dominant process was erosion, and there were many long epochs of land sculpture before the present scenery was produced. Except for rare dikes of basic igneous rock that were intruded during the Triassic period, the events of these two eras are not recorded in the bedrock, but must be interpreted from study of the land surface. A general statement of this sculpture has been previously made (see pages), but any detailed account must take into consideration the geographic effects of the Appalachian revolution.

It is quite clear that the deforming force of the main Appalachian orogeny acted from the east westward; and it is equally

clear that the source of the pressure was located well to the east of any disturbed rocks now exposed. With these considerations in mind, one must assume that first deformational effects were in those easternmost belts toward which the pressure was first directed. Not until these eastern areas had yielded to the fullest degree--that is, until they had been deformed into a relatively stable or coherent block--would any force be transmitted to more westerly belts, where, in turn, it would be absorbed until maximum structural compliance was attained before being transmitted to still more distant belts. This interpretation calls for a westward migration of the zone of active orogeny with, possibly, a considerable time variation between the deformation at the east and its cessation at the west.

When the first upfolds began to corrugate the rocks of the eastern half of Appalachia, its east-coast streams were obviously affected. Woodward believes that growth of the upfolds was sufficiently slow that the rivers were able to defend antecedent positions at least along their lower portions where the first effects of the westward-moving zone of maximum deformation occurred. Coincident with this subsurface zone of active compression must have been a general uplift of the land--uplift caused primarily by the arching of anticlinal structures which, because of an immediate attack by erosion and weathering, may never have actually attained the topographic height suggested by their (now) eroded stumps. Probably for a time, there was a double divide between the east-coast streams and interior drainage--(a) the new west-moving uplift caused by the migrating deformation, and (b) the old axis of the borderland. Gradually, however, these more or less

parallel watersheds must have coalesced, as mechanical recession of the zone of folding progressively involved more and more westerly areas.

This hypothesis [1] thus invokes a slow but gradual migration

[1] Woodward, H. P., Interpretation of Appalachian geomorphic history: Geol. Soc. Amer. Bull., vol. 49, p. 1965, 1938.

of the belt of deformation, which is believed to have crept westward under a land surface that bowed upward as folds grew larger and thrust blocks sliced northwestward. The divide between Atlantic and interior drainage correspondingly receded inland from its original position along the spine of Paleozoic Appalachia. Kept active by uplift of their headwater areas, the pre-revolution streams of eastern Appalachia maintained their general positions in the wake of the orogenic front. Possibly new consequent drainage also developed on this area, which now sloped eastward to the sea with an inclination arising from (a) an original consequent gradient, (b) the eastern dip-slope of asymmetric folds, and (c) the eastern inclination of fault-block surfaces. As the divide at the head of these streams pressed westward, the latter lengthened and developed by headward erosion of the retreating upland, at the same time increasing in volume and gaining maturity in their lower portions. By planing their interstream areas with enlarging lateral tributaries, and by coalescing their several areas of planation, these streams caused the development of a land surface of low relief that likewise crept westward as the rivers forced maturity to higher portions of their headward-lengthening courses.

The present Blue Ridge occupies a more or less central belt in the deformed Appalachian area, and makes a convenient and well-known line of orientation. When the westward-moving topographic divide reached the line of the present Blue Ridge, it was carried west of that meridian as the zone of active deformation wrinkled the top-heavy clastic section of central Maryland and Pennsylvania into broad, open folds. Probably this divide ultimately assumed relative stability in (or above) the folded country west of the Great Valley, and it is believed that it thus extended the head-waters of the master streams (Potomac, etc.) beyond (west of) the rocks now exposed in the Appalachian Valley and Blue Ridge. Attendant upon the westward migration of the Atlantic-Interior divide, must have also been the complete disorganization and ultimate obliteration of the west-flowing drainage which had formerly attacked the inner slopes of Appalachia and had been responsible for the deltaic deposits of the late Paleozoic. No trace of these streams now exists.

When the Appalachian revolution was over, the eastern water-shed stood, possibly, west of the Virginia border. A few master streams, including the Susquehanna, Potomac, and James, flowed eastward to the sea. They were even then of ancient origin, for they had been east flowing on the Atlantic slope of Appalachia before they became elongated backward across the folded Appala-chian belt by retreat of the divide at their heads. The Appalachian geosyncline was gone. In its place was a region of irregular relief partially beveled by east-flowing streams, and partially in a stage of increasing dissection by tributaries that were jockeying for favorable positions on belts of easily eroded sediments.

Appalachia, as a borderland, was likewise gone, its place taken by a broad eastward-sloping piedmont ready for dissection by new streams.

During the middle and late Mesozoic, land sculpture was pushed at a fast pace, incited by the relatively high stand of the land and by the alternating weak- and hard-rock strata that were being revealed as each fold of the Paleozoic basement was attacked. It is believed during this period, when drainage changes of a local character were constantly in progress, that development of the various windgaps occurred, and that the ridge-and-valley type of country was established. Probably the land itself contributed to the drainage reorganization by periods of minor uplift with or without warping. Ultimately, the softer rock belts became deeply eroded into the narrow valleys of the Appalachian ridge region, while separating ridges remained where resistant rock retarded the erosional process.

Following this period of readjustment came a time of sufficient stability for the broadening of valley bottoms into the various Valley-floor peneplanes. Where the weak rock belts were widest, as in Shenandoah and Page valleys, the peneplane surface was best developed; in narrower belts, little or no widening occurred.

Production of the Valley-floor peneplane came to an end with another stage of uplift and warping that again rejuvenated drainage by increasing stream gradients. As a result of this recent uplift, the drainage pattern was sunk deeply into the valley floor, where present incised stream courses, after many minor adjustments in drainage, were developed. That capture and stream diversion were common may be observed at many points throughout the Appalachian Valley. At some time during the Valley-floor cycle, or immediately

following its termination, an extensive series of underground channels was produced in the soft soluble limestone of the Valley floor. As more of the limestone was exposed to erosion and weathering, underground water had increasing opportunity to select, enter, and follow open zones in the bedrock. By enlargement of these zones into channels, caves and caverns were produced; and the solution-pitted surface of the Valley-floor peneplane now reveals many sinkholes through which one may actually enter the enlarged underground cavities. Continued uplift of the land lowered the water-table until it is now some distance below the larger caves; this has had the effect of freeing them from streams which originally formed them, and permitting access to their subterranean passages.

The Stony Man region has passed through at least two great cycles of erosion and is at present in a third cycle. The area has been more or less constantly in uplift since the end of Mississippian time, and this uplift has been vigorous from the Cretaceous to the present. In large part, the uplifts are recorded by depths of valleys and by differences in elevation between various erosion levels. Intervening periods of crustal rest are recorded by peneplanes that reveal long epochs of unhindered erosion.

MINERAL RESOURCES

Mineral resources [1] obtainable from the bedrock of this

[1] It should be noted that the field survey upon which this report is based was concluded in 1934; all descriptions of mineral properties are as of that date.

quadrangle are mainly limited to small quantities of iron and manganese ore; lime, limestone, and crude rock; ocher; and underground water for domestic or local industrial use. Copper although long prospected has had no active mining. Neither gold, silver, oil, nor gas may be expected in appreciable quantities, and their search is specifically discouraged.

~~At present, there is little indication of any future increase in mineral output for this district. Local iron and manganese ores are of too poor grade and are in too meager quantity to warrant further development save under forced or unusual conditions of demand. Only local need for limestone and crude rock can be expected to stimulate their commercial production. Unless other materials are found to have economic values now not anticipated, the mineral production of this quadrangle will remain negligible.~~

IRON AND MANGANESE

Introduction

Page County in general and this quadrangle in particular have contain some ~~few~~ metallic deposits of economic importance ~~and almost~~ especially ~~no workable~~ beds of iron or manganese ore.

The earliest iron development in this area led to the erection of Isabella Furnace, one mile north of Luray, about 1760, and Redwall Furnace on Hawksbill Creek in 1781. There was very little prospecting or mining for iron until about 1880, when several mines and prospects were discovered and exploited during the period from 1880 to 1905. At the time of the World War,

renewed search for American deposits of manganese stimulated local prospecting and encouraged many temporary mining operations along the Blue Ridge. Since 1920, however, demand for manganese has been insufficient to support the small local operations begun about 1916, and at present writing (1935) only the Eureka mine, southwest of Stanley, is active.

All iron and manganese ore of this region occurs above the bedrock in residual soil or alluvial debris. Ore of this type is called "Valley" ore. Blue Ridge hematite, elsewhere present along the Blue Ridge as a member of the Unicoi formation, does not here occur in Weverton sandstones which are the northern equivalent of the Unicoi. No iron ore is found in the Clinton formation of this area.

Character of Ore

Valley ore is an accumulation of brown iron and manganese oxide at the foot of the Blue Ridge. Mostly it occurs on the gravel-covered benches of the Valley-floor peneplane along the northwest slope of the sandstone foothill ridges. Deposits are rarely large, although they are numerous and irregularly scattered along the Valley margin. The most common ore-type, occurring mainly in brown or variegated clays, is an irregular concentration produced by downward-circulating surface waters. The ore consists of hydrated iron oxide commonly intermixed with manganese oxides. Iron minerals range from limonite to goethite, and contain up to 40 percent metallic iron; manganese oxides are psilomelane, pyrolusite, manganite, and wad. Most prevalent is a brown earthy amorphous mixture of oxides of both metals. Much of the

purer manganese ore is black, glossy, and hard; it accumulates in nodules and botryoidal or mammillary masses.

Brown Valley ores are commonly found along or near the Antietam-Tomstown contact. They are of irregular size, and grade downward into brecciated zones wherein quartzite blocks, limestone residuals, and alluvial gravel are partially replaced or cemented by ore minerals. Valley ore is also known from a Weverton-Catoctin contact, and the Compton mine shows considerable ore within the body of the Antietam sandstone.

Prospects

Dry Run, or Compton, Mine

This mine, slightly north of the Stony Man quadrangle, is situated on the north side of Dry Run, about 1.5 miles southeast of Compton. It is one mile east of the Norfolk and Western Railway, and 4.5 miles northeast of Vaughn. Operated intermittently between 1916 and 1920 by the Compton Manganese Corporation (Pittsburgh, Penna.), the workings include (a) an open cut on a small hill-top near the east side of a low Antietam ridge, and (b) a 300-foot tunnel at the foot of the ridge which was drilled to intersect the open shaft. A small mill nearby was used in crushing and concentrating the ore. This mine has not been active for many years.

Compton manganese ore is a good grade of psilomelane containing manganite, which occurs in cracks and crevices of the brecciated Antietam quartzite; some ore is also found along joints and bedding planes. A small fault revealed by the open cut may have been responsible for the brecciated rock. Where encountered in the tunnel,

the orebody is reported to have been nearly 100 feet wide; many rich pockets of solid ore have been reported. The rock was broken by blasting and was crushed and concentrated at the company mill nearby. Ore was carried by wagons and trucks to the railroad station at Compton.

An ore shipment in 1918 was sampled as follows:

Analysis of Manganese Ore, Compton Mine, Page County, Virginia[1]

Metallic manganese....	43-48 percent
Metallic iron.....	1
Silica.....	8-11

[1] Stose, G. W., and others, Manganese deposits of the west foot of the Blue Ridge, Virginia: Virginia Geol. Survey Bull. 17, p. 62-3, 1919.

When this locality was operated as an iron mine--prior to 1903--the ore was hauled in wagons to Rileyville. A sample of Compton iron-ore was reported to show 37 percent of metallic iron, 25 percent of silica, and 1.8 percent phosphorus.[1]

[1] Watson, T. L., Mineral resources of Virginia: p. 432, Virginia-Jamestown Exposition Commission, Lynchburg, Virginia, 1907.

Mine Run Bank

This prospect[1] is located near the head of Moody Creek (Mine

[1] Stose, G. W., and others, op. cit., p. 63.

Run), 1.1 miles northeast of Knob Mountain, 2.2 miles northeast of Vaughn. It occurs near a contact of Weverton sandstone and Catoctin greenstone which crops out a short distance east of the prospect pits. Workings consist of an old open cut and a tunnel now largely caved. Sandy brown ore, now exposed in the old dumps, shows a poor grade of limonite with manganese oxide coating cavities and

crevices of the ore. The rock is brecciated and the metallic ores were apparently deposited by circulating surface waters. The locality has been inactive for many years.

Vaughn Prospect

This prospect is 1.5 miles north-northeast of Vaughn, near the Heiston mine [1] which was operated during the War between the

[1] Watson, T. L., op. cit., p. 433.

States. It is reported that ore from the latter mine was fired in Isabella Furnace built about 1760, north of Luray.

The Vaughn prospect [1] occurs on the crest of a low hill

[1] Stose, G. W., and others, op. cit., p. 63.

which extends due north from Kibler Knob; operations consist of several shallow open pits along the top of this ridge. The older Heiston working was a shallow pit 300 x 400 feet. Bedrock on this ridge is Antietam sandstone which is broken and partially brecciated. Manganese and iron oxides occur in small quantities in the breccia. The locality is reported to have produced 20 tons daily of limonitic ore during a short period in the 1890's, but no operations have been active in more recent times.

Jeremy Run Prospect

This prospect [1] is 0.5 to 0.7 miles northeast of Vaughn,

[1] Stose, G. W., and others, op. cit., p. 64.

east of Jeremy Run. There are several shallow pits near the base of the Antietam ridge which bounds the Blue Ridge at this locality. The Antietam is brecciated and the ore is a quartzite-breccia cemented by metallic oxides. It has never been actively mined.

Fronk, or Brown, Prospect

The Fronk prospect is 1 mile northeast of Kimball P. O. (Elgin station of the Norfolk and Western Railway). Several shallow prospect pits have been opened in residual Tomstown clays near the Antietam contact. The ore is nodular psilomelane and there are a few small seams of manganese oxide and clay. Brecciated zones in the nearby Antietam quartzite are cemented by manganese oxide.

Marksville Prospect

East of Marksville, south of Hershberger Hill, is a syncline of Tomstown dolomite above a shallow Antietam basin. Many fragments of iron-cemented breccia crop out along Chub Run, 0.7 miles northeast of Marksville. The ore is a loose mixture of limonite and various manganese oxides.[1]

[1] Stose, G. W., and others, op. cit., p. 65.

Ore from the nearby Round Head tract is reported as follows:

Analysis of Manganese Ore near Marksville, Page County, Virginia[1]

Metallic manganese.....	51.46 percent
Metallic iron.....	2.94
Phosphorus.....	0.23
Silica.....	4.17
H_2O.....	4.97

[1] Watson, T. L., op. cit., p. 245.

The structure of the shallow syncline is believed to favor accumulation of ore at this locality, and it has been recommended that the Marksville area be more fully prospected if an increased demand for manganese warrants local operation of small deposits of

this type. A small quantity of float ore, chiefly nuggets of limonite, was found on a low hill near the road intersection, 1.2 miles northwest of Long Store, 4 miles north of Marksville.

Eureka Mine

This mine [1] is located on the north flank of Round Head

[1] Stose, G. W., and others, op. cit., p. 65-67. Watson, T. L., op. cit., p. 245.

Mountain, 1.3 miles southwest of Stanley. Operations are on a terrace which overlooks Page Valley at an elevation of about 1,550 feet above sealevel. The mine dumps and openings make scars on the mountainside that are conspicuous from many points in Page Valley.

The workings are in thick alluvial gravels that form the inner edge of one of the broad alluvial fans spreading westward from the Blue Ridge escarpment (Pl.). Most of the cobbles are Antietam quartzite that average 2-3 inches in diameter. They are compacted with yellow clay into a stiff mixture that stands vertically when dry but slumps readily when wet. The workings cover two or more acres at three different levels. Several shafts up to 25 feet deep and numerous side tunnels have been dug from the main open cuts. Formerly the mine was worked by steam shovel; operations in 1934 were entirely by pick.

The ore is mammillary psilomelane and wad in rounded masses which may reach one foot in diameter but are commonly less than 3 inches across. They are scattered irregularly in thin zones or seams through the clay and residual debris. There are many small pockets, and the ore slopes in conformity with the local

watertable. Alluvial material in which the ore occurs is more than 50 feet thick, for bedrock is not encountered by any mine operations.

The ore bodies are near the contact of the Tomstown and Antietam sandstone. Fragments of chert in the residual debris indicate a limestone basement beneath the alluvial material; and Stony Run, directly west of the mine, washes fine exposures of Antietam sandstone. (See section, page .) The ore is of fair grade, but is of too meager distribution for intensive operation. When visited in 1934, it was being worked by four men with pick and shovel.

COPPER

Introduction

Copper ores have been unsuccessfully prospected at many localities in the Blue Ridge of this region. They were discovered long ago and have furnished many fine specimens, but although much time and money have been spent in fruitless prospecting, all attempts to discover an ore body of economic value have so far failed.

In this district, the deposits occur in the Catoctin greenstone where they are found near its base, or at intrusive contacts. Ores are principally native copper and cuprite with small amounts of chalcopyrite and bornite. The minerals occur in joints, cracks, and quartz stringers that replace the greenstone. In all operations examined, a great quantity of greenstone had been moved to obtain very small quantities of ore. The mines were worked before the

War between the States, and were again prospected shortly before 1900. They have been discussed by Weed and Watson[1] and by Phalen.[2]

[1] Weed, W. H., and Watson, T. L., Virginia copper deposits: Econ. Geology, vol. 1, p. 317-323, 1906.

[2] Phalen, W. C., Copper deposits near Luray, Virginia: U. S. Geol. Survey Bull. 285, p. 140-145, 1906.

At present little ore can be found on the abandoned dumps except for malachite, which coats a few joint surfaces.

Developments

The Dark Hollow mines, developed by the Blue Ridge Copper Company, are situated in the east wall of a tributary of Dark Hollow Creek, 0.7 miles southeast of Fisher Gap. Much preliminary work was done about 1905, when 4 shafts and tunnels were sunk in the greenstone at considerable expense. Phalen[1] states that

[1] Phalen, W. C., op. cit., p. 141.

a few tons of ore were shipped out, and local reports indicate that only one carload of ore was shipped before mining was abandoned. Much prospecting has been done nearby, and some copper was mined near the top of the Blue Ridge east of Stony Man Peak. At present the openings are largely filled in and no ore shows.

The Virginia Consolidated Copper Company operated a mine at the top of Hoak Hill, one mile northwest of Ida. There was an inclined shaft, 306 feet deep, which had drifts at the 80-, 120-, and 260-foot levels.[1] Work was suspended in January, 1905. The

[1] Watson, T. L., Mineral resources of Virginia: Virginia-Jamestown Exposition Commission, Lynchburg, Virginia, p. 503-511, 1907.

ores are reported to be native copper, cuprite, malachite, and azurite. Now (1934), the shaft is in bad repair. Greenstone fragments on the dump are coated with copper carbonates.

Origin of the Ores

Watson and Weed [1] attribute these ores to local concentra-

[1] Watson, T. L., and Weed, W. H., op. cit., p. 323.

tions from downward-circulating meteoric waters. Subsequently, Watson[1] suggested that some primary ores may have been deposited

[1] Personal communication to A. S. Furcron, 1921.

by a reaction between magmatic waters and the ferric oxide of the greenstone.

Phalen [1] believed the ores at Ida were deposited from meteoric

[1] Phalen, W. C., op. cit., p. 142-3.

waters, but that ascending magmatic waters may have been responsible for bringing such sulphides as chalcopyrite into the quartz veins that are associated with shear zones at other localities. The conclusions of previous workers is that most of the ore is secondary, but that some sulphides may be primary or genetically related to intrusive bodies.

An inspection of the above localities in 1933-1934 disclosed no evidence to contradict these interpretations. As mining operations practically ceased more than 35 years ago, ore specimens are difficult to find. At Dark Hollow and Stony Man, the ore is near granite. The ore-bearing greenstone adjoining the granite in Dark Hollow is chloritized, sheared, and brecciated, and the shaft near Ida is in greenstone of Hoak Hill, probably close to

underlying granite. A specimen of granite at the greenstone contact in Little Devil Stairs contains chalcopyrite.

NON-METALLIC MATERIALS

Ocher

A small abandoned ocher mine is located 1.2 miles west of Stanley, at the bridge of the Norfolk and Western Railway over Stony Run. It was originally operated by the Oxford Ocher Company (Detroit) which opened a mill in 1876. More recently, the locality was worked by the Walline Ocher Corporation, but has been idle since 1925. The ocher is light brown, has good quality, and is comparatively deep, being a residual clay from weathering of Waynesboro shales. Soft and readily worked, it is easily accessible because of its location near the railroad. Production in 1877, one year after the mill was erected, is reported to be 350 tons; the mine annually produced about 1,000 tons of ocher prior to 1910.

An analysis of the ocher from this location is as follows:

Analysis of Ocher near Stanley, Page County, Virginia [1]

Iron peroxide.....	39.0	percent
Allumina.....	15.0	
Silica.....	33.0	
Alkalines.....	0.5	
H_2O.....	11.5	
	99.0	

[1] Watson, T. H., op. cit., p. 228.

Lime, Limestone, and Road Metal

Practically every county in the Appalachian belt west of the Blue Ridge is amply supplied with excellent quantities of limestone bedrock, and, therefore, is nearly independent of all other areas for this valuable material. In a few regions, such as the Potomac area of northern Virginia and West Virginia, local grades of limestone may be superior to varieties obtainable elsewhere, and large-scale exportation of limestone may be possible.

In this quadrangle, Page Valley has a bedrock floor that is dominantly calcareous, yet little of its stone has been put to commercial use. The reason for this failure to utilize local limestones stems from many angles. The bedrock is mostly covered either with deep residual soils or with thick alluvial debris, and is thus relatively inaccessible beneath much of the lowland country. As the network of roads is fairly complete, local need for crude stone is relatively small. The fertility of the Valley soils is such as to demand little agricultural lime; and, finally, the chemical purity of local limestones is no greater than average for Valley counties. In view of these and other reasons, Page Valley limestones have had scant development.

The purest of all local stone is the vaughanite of the Mosheim and Bellefonte limestones, which normally contains less than 2 percent silica and more than 95 percent calcium carbonate. This stone makes excellent agricultural lime when properly burned, and if very low in silica is of value as a furnace flux. Local quantities are meager, however, and it is unlikely that they can attract outside attention or deserve other than local exploitation. Either

stone is desirable if agricultural lime is needed. Other good limestones include beds of the Nittany, Chepultepec, Conococheague, and Elbrook limestones.

Local development of limestone has been scant. Near Hamburg, north of Lee Highway, east of the bridge over Mill Creek, are kilns (now in ruins) where Beekmantown vaughanite was once burned for agricultural lime. Although the stone is of good grade and is locally abundant, the kilns have not been operated for a long time. Other kilns, also in ruins, are on the lower reaches of Mill Creek, 0.7 miles northwest of Hamburg, 0.2 miles from Shenandoah River. A similar stone was used at these kilns. It is reported that Helderberg and Cayugan limestones were once burned for lime along the Edinburg road in Fort Valley.

A small limestone quarry was operated in 1933 by W. L. Woodward 0.5 mile northwest of Antioch Church, 1.5 miles south of Luray. (See Pl. .) This quarry is located in a small bluff northeast of East Hawksbill Creek, where a dark platy Conococheague limestone is extracted for road metal. There is a small crusher which is fed by hand. In 1934, Mr. Woodward was also operating a small quarry on Dry Run near its junction with Hawksbill Creek. This quarry is in Chepultepec and upper Conococheague limestones.

There is a small quarry on the west bank of Dry Run directly south of Lee Highway. The quarry rock is Conococheague limestone which shows excellently preserved impressions of prismatic mudcracks. (See Pl. .) Stone from this quarry was used in surfacing Lee Highway. Another quarry is located north of Pass Run, 0.8 mile northeast of Kimball P. O. This exposure is of Elbrook limestone. Beekmantown limestone has been quarried (a) on the

northwest side of Mud Pike, 1 mile southwest of Leaksville, and (b) along Lee Highway, directly east of the bridge over Mill Creek. All quarries mentioned in this paragraph are temporary, supplying stone only while surfacing of nearby roads was in progress.

A quarry in Athens shale is located east of Shenandoah River, one mile east of Alma. A similar small quarry in the same rock occurs 0.2 miles south of Lee Highway on the east bank of Shenandoah River. Both were small and were inactive in 1934.

WATER RESOURCES

Surface Water

General Description

The average annual rainfall for the Stony Man region--about 35 inches--is fairly evenly distributed throughout the year. The run-off, which amounts to about one-third of the total precipitation, makes its way into two basins, for the crest of the Blue Ridge separates Potomac from Rappahannock drainage.

South Fork of Shenandoah River crosses the northwest corner of the quadrangle near the east base of Massanutten Mountain. No important tributaries enter it from the west, but Hawksbill Creek and Dry, Pass, and Jeremy runs rise in the Blue Ridge and flow into the Shenandoah from the east. At the west foot of the Blue Ridge, open hollows are clogged with pebbles and gravel, so that many streams flow far below their surface channels in dry seasons. The bed of Jeremy Run east of Vaughn is frequently dry in summer, although the stream is clear in the upper part of its valley above the belt of alluvial debris.

South Fork of Shenandoah River has a drainage area of about 1,380 square miles above the highway bridge, 4 miles southwest of (above) Luray.[1] Its elevation at the bridge is about 750 feet

[1] Dirzulaitis, J. J., and Stevens, G. C., Water resources of Virginia: Virginia Geol. Survey Bull. 31, p. 38-41, 76-78, 1927.

above sealevel. Records for the period from April 1925 to September 1927 show a maximum flow of 15,100 second-feet on November 17, 1926, and a minimum flow of 74 second-feet on September 28, 1925. A discharge of 20,300 second-feet is recorded for April 1929, when the gage-height was 13.2 feet. The mean monthly discharge of the river (1,340 second-feet) during the period between 1925 and 1927, represented an average of 0.971 second-feet per square mile of drainage basin and 13.16 inches of runoff.

Shenandoah River enters this quadrangle at an approximate elevation of 700 feet above sealevel, and drops about 50 feet in the 9.5 miles of its course across the area; its average fall is 5 feet per mile. Although it is not available for navigation, it was an important line of intercommunication in colonial time. Hawksbill Creek has a drainage basin of 52 square miles above the mouth of Dry Run. Between June 1905 and July 1906, a gaging station near the mouth of Dry Run, 1.5 miles north of Luray, indicated a maximum recorded discharge of 430 second-feet on April 15, 1906, and a minimum stage of 24 second-feet in September 1905. The highest reported stage of this creek prior to 1905 was on October 13, 1893, when the creek rose nearly 20 feet above the zero of the gage.

Thus far there have been no water supply problems in the area underlaid by crystalline rocks because towns and villages are absent there. Most of the inhabitants derive domestic supplies from springs, although wells are common in the extreme southeastern corner of the quadrangle. Deep wells are not recommended where water is desired in any quantity. Thornton River can supply Sperryville on U.S. Highway 211 just east of the quadrangle with an abundant supply of excellent water. Other large creeks and rivers of the area will afford water supplies if utilized. The ground waters of this crystalline area are soft in contrast with ~~similar~~ waters of the limestone country west of the Blue Ridge.

Rose, Hughes, and Thornton rivers, tributaries of the Rapidan and Rappahannock rivers, head near the east top of the Blue Ridge and flow east. Most of the upland surface drains into these streams, which carry a small volume of cold clear water.

Relatively slight use of surface water has been made in this region. A power plant is located 5 miles southwest of Luray to utilize the flow of South Fork of Shenandoah River, and another plant near Ruffner Ferry, 2 miles above Luray, furnishes electricity to the town. Two streams heading in Stony Man Mountain supply water to Luray. The water flows by gravity to two open earth-fill reservoirs of 3,500,000-gallon and 6,500,000-gallon capacity. A spring in the Blue Ridge 7 miles east of Luray is also used. Its overflow is impounded in a small concrete reservoir 0.5 miles below the spring, whence it is piped into the reservoir. The main Luray reservoir is located on the flank of Piney Hill, 4 miles southeast of town.

Subsurface Water

Wells

Page Valley is well supplied with ground-water, and its many sinks, caverns, and springs reveal abundant subsurface circulation. Much of the ground-water makes its way directly through the bedrock in channels and enlarged cavities in the soluble limestones and dolomites. Few wells yield large quantities of water, but many have a moderate volume and steady supply. The thick alluvial gravels of the east side of the valley make drilling difficult. In many places the gravel contains a "fluid mud" which clogs the casing and contaminates the water unless completely cased off. Elsewhere an ocherous silt, or mud, appears below the upper surface of the bedrock. On the other hand, some wells are thoroughly

satisfactory and derive their water directly from the gravel.

The average drilled well in Page Valley is about 100 feet deep and supplies about 10 gallons of water per minute. [1] The

[1] Cady, R. C., Ground-water resources of the Shenandoah Valley, Virginia: Virginia Geol. Survey Bull. 45, p. 77-82, 1936.

watertable varies in depth from as little as 17 feet to more than 200 feet in one limestone well. It is nearer the surface in shale than in limestone bedrock and its seasonal fluctuations are less marked. The water from bedrock is hard; that from gravel is soft but likely to be high in iron. Most of the wells in Massanutten Mountain (Fort Valley) are less than 50 feet deep and yield little water. They are located chiefly on the Romney black-shale facies of middle and late Devonian rocks.

Springs

The largest reported spring of this area is Yager Spring, located on the west bank of Hawksbill Creek, one mile northeast of Luray. The water emerges from a low limestone cliff on the Beekmantown outcrop, and its flow is reported to be 12 second-feet. From the location of this spring and its relation to known underground circulation, it is suggested that the spring releases drainage originating in or near Luray Caverns.

Hite Spring is on the east side of Dry Run, 0.5 miles north of Lee Highway, between the Norfolk and Western Railway and the old turnpike. Its flow is reported to be 4,300,000 gallons daily, or about 7 second-feet. Water of this spring was formerly bottled and sold as "lithia water"; part of the flow is now retained in a

mill pond. Although the spring emerges in low ground on the Conococheague outcrop, it is probable that the water is the subsurface flow of Dry Run emerging beneath the gravel and sand of its dry channel. An analysis of water from this spring is in the table on page .

There are several large springs (Harnsberger Springs) near the old Luray Caverns power plant, east of Hawksbill Creek, 0.2 miles south of Luray. The total flow is estimated to be about 2 second-feet, and the springs emerge from the Conococheague formation 200 yards downstream from Saltpeter Cave. Price Spring is located 0.5 miles northwest of Antioch Church, 1.5 miles southeast of Luray. Hudson Spring is 0.5 mile west of Antioch Church; Big Spring is one mile southwest of Vaughn. All emerge from Conococheague limestone. Lewis Spring, which is the source of Hawksbill Creek, is located on the Blue Ridge summit, near the edge of Big Meadows.

No mineral spring occurs in this area.

The following table shows the chemical character of various types of water in Page Valley:

Analyses of Water, Page County, Virginia[1]

	A	B	C	D	E	F	G
Iron (Fe)			5.0[a]	0.04			
Calcium (Ca)	75[b]	173	74	28	22	80	48
Magnesium (Mg)		44	18	9.5			
Sodium and potassium (Na-K)[c]	4.6	31	15	3.6	90	16	12
Bicarbonate (HCO_3)	284	458	82	117	90	278	190
Sulphate (SO_4)	4[b]	72	211	7.8	12	10	5
Chloride (Cl)	5.0	73	3.0	2.0	50	1.0	0.5
Nitrate (NO_3)	0.0	156[d]	0.0	1.3	0.43	3.2	1.2
Dissolved solids[c]		775	361	120		252	168
Hardness as $CaCO_3$	234	613[c]	259[c]	109	100[c]	208	137

A. Well water, John Huffman well, Rileyville. Total depth 223 feet; yield when drilled 16 gal. per minute. 50 feet of gravel above Beekmantown limestone.

B. Well water, Bud Harrison well, Luray. Total depth 244 feet; yield when drilled 15 gal. per minute. Clay, sand, and boulders (80-100 feet) above Conococheague limestone.

C. Well water, W. E. Burner well, 6 miles west of Luray. Total depth 72 feet; yield when drilled 1 gallon per minute. Bedrock Martinsburg shale.

D. River water, South Fork of Shenandoah River, at highway bridge 4 miles southwest of Luray.

E. Spring water, Hite Spring, 0.5 miles north of Lee Highway, 1.5 miles northeast of Luray.

F. Spring water, C. E. Fristoe Spring, 4 miles northeast of Rileyville at Overall. Water temperature 55°F.; bedrock Elbrook limestone.

G. Spring water, S. G. Davis Spring, near above on north bank of Overall Creek, 200 feet east of Shenandoah River. Water temperature 64°F.; bedrock Elbrook limestone.

a. Turbid with precipitated iron when collected.
b. By turbidity.
c. Calculated.
d. The large amount of nitrate in this well indicates serious pollution at the time of sampling. (H.P.W.)

---

[1] Analyses A, B, C, from Ground-water resources of the Shenandoah Valley, Virginia, by R. C. Cady: Virginia Geol. Survey Bull. 45, p. 80-82, 1936. Analysis D from Chemical character of surface waters of Virginia, preliminary report, by W. D. Collins and others: Virginia Commission on Conservation and Development, Div. of Water Resources and Power, Bull. 2, p. 10, 1930. Analysis E furnished by F. K. Zirkel of Luray. Analyses F and G from Springs of Virginia, by W. D. Collins and others: Virginia Commission on Conservation and Development, Div. of Water Resources and Power, Bull. 1, p. 54, 1930.

GEOLOGY AND MINERAL RESOURCES

OF THE STONY MAN QUADRANGLE, VIRGINIA

By Furcron, A.S., and Woodward, H.P.

1935

PHOTOGRAPHIC ILLUSTRATIONS

to accompany

report on the

STONY MAN QUADRANGLE

H.P.WOODWARD
A.S. FURCRON

117
55
162

Aeroplane
Views available?
N Pks Service
VS Fr "

1. Stony Man Mountain, from Fairview in Page Valley.

(Frontispiece)

2. Hershberger Hill from a point one mile northeast of Marxville.

3. Foothills of the Blue Ridge at eastern margin of Page Valley. View ~~taken~~ from Thornton Gap.

Poor Cut

Substitute?

4. Page Valley. View from Tanners Ridge.

5. The Blue Ridge Front, showing sharp contrast in elevation between the Valley-floor Peneplane and the upland level.

6. The Blue Ridge Front east of Stony Man.

Omit

7. View along Lee Highway as it descends eastern slope of Blue Ridge.

8. The Blue Ridge ~~Massif~~ upland. View looking westward toward Sperryville from Skyline Drive.

? Loc etc

9. Franklin Cliffs, from Fishers Gap. Photograph shows the steep western slope of the Blue Ridge and low mountains upon the surface of the Upland Peneplane.

Omit

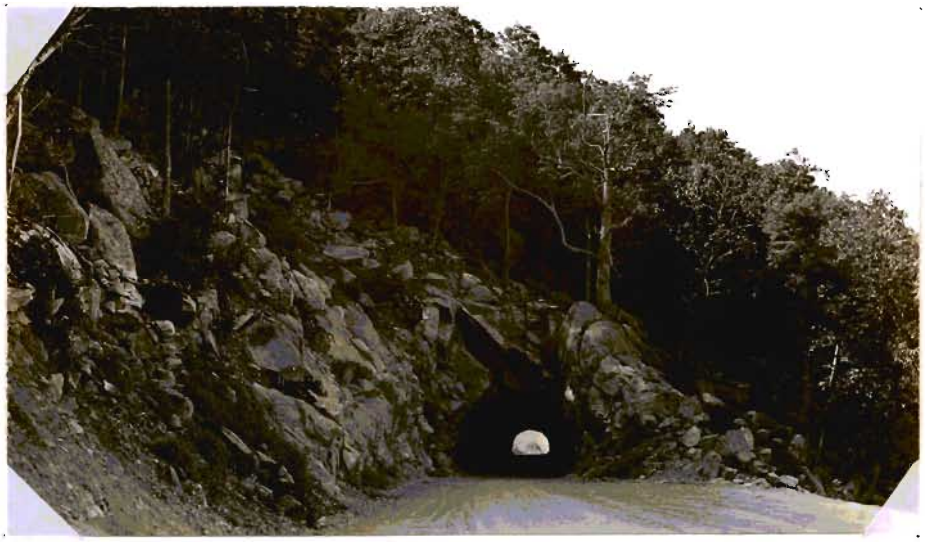
10. The Lee Highway east of Thornton Gap. View looking west from the Skyline Trail near the tunnel through Marys Rock. The main range of the Blue Ridge is in the background.

11. View of level summit of Blue Ridge along ~~proposed~~ Skyline Drive.

12. The Upland Peneplane, elevation 3,500 feet above sea-level, near Lewis Spring.

13. The contrasting level Page Valley and rugged Blue Ridge. View looking southwest from Fairview.

14. Marys Rock. Elevation 3,514 feet ~~above sea-level.~~ Tunnel entrance of Skyline Drive in left (of view).



15. Southwest entrance of tunnel along Skyline Drive through spur of Marys Rock.

Describe features

~~Poor cut~~
~~Substitute?~~
omit
Duplicate
4

omit

16. Page Valley. View looking northward from Tanners Ridge.

17. Page Valley, developed on the Valley-floor Peneplane.

18. View looking toward Stony Man Mountain. Ex-President Hoover's community school in foreground.

Omit or use in place of 1

Loc?

19. Stony Man Mountain. Elevation 4,010 feet above sea-level.

Omit - duplicate of 13 & 5

20. Stony Man Mountain. View looking east from Fairview near Stony Man.

Substitute photo PATC

21. The profile of Stony Man. View looking southwest from the Skyline Drive at Hughes River Gap.

22. Hawksbill Mountain. Elevation 4,049 feet above sea-level.

23. New Market Gap in Massanutten Mountain. Looking W ?

omit

24. Laurel thicket on top of the Blue Ridge near the Conservation Camp east of Crescent Rock. December 24, 1933.

✓ ?

25. Forested slope of Basin Hollow, from crest of Tanners Ridge.

omit
use
B-35

26. Page Valley. View looking eastward
from Massanutten Mountain.

omit

27. View looking northeastward across the fertile floor
of Page Valley. The Neighbor, elevation
2,736 feet above sea-level, in background.

omit

28. Cave Hill, one mile west of Luray.
Luray caverns are developed below this hill.

29. The Blue Ridge, view looking southwestward
from Lee Highway near Thornton Gap.

Get Better View

omit

30. The Upland Peneplane surface at Big Meadows.
View looking northeast toward the Conservation Camp.

See 48

omit

31. The Upland Peneplane surface at Big Meadows.

32. The Three Sisters, showing the straggly growth of vegetation on the sterile quartzite soil.

Omit

33. A cultivated clearing near the top of the Blue Ridge.

omit

34. Kennedy Peak, highest elevation along Massanutten Mountain in Stony Man Quadrangle.

35. Broad valley of Jeremys Run, looking southward toward The Three Sisters.

omit

36. Sink holes in Beekmantown limestones north of Trinity Chapel. Note the level skyline of Massanutten Mountain in the distance.

37. Limestone sinks near Cave Hill, west of Luray.

omit
use
B-35

38. The Blue Ridge Front, view looking eastward from Lee Highway, north of Luray.

39. The Blue Ridge Front. View looking northeastward from Tanners Ridge.

40. View in the rugged Blue Ridge near the President's camp immediately south of the quadrangle.

omit
Too poor
cut

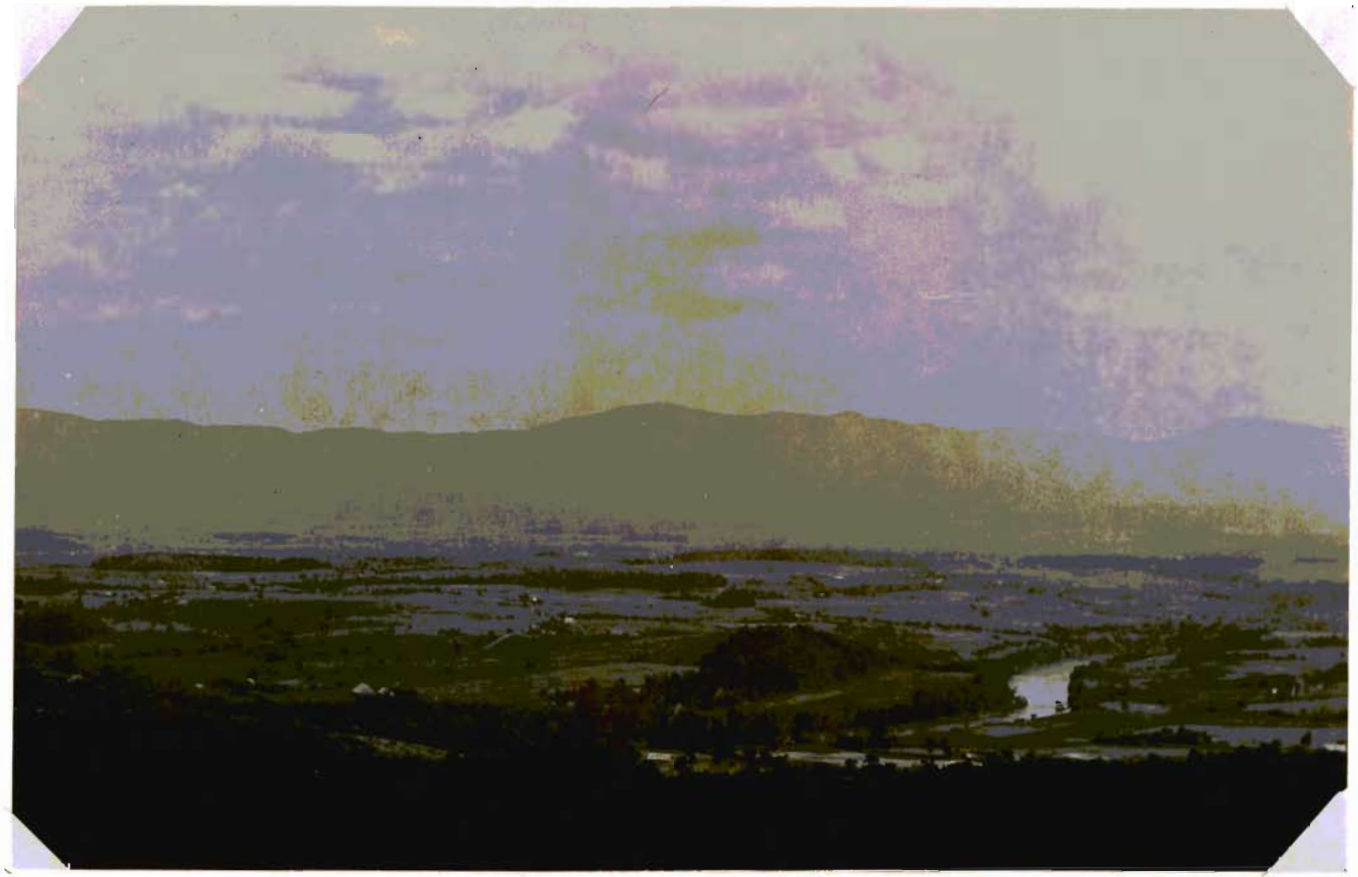
41. View looking across Page Valley from Skyline Drive above Timber Hollow.

omit = repetition

42. View looking down West Branch of Naked Creek from point near St. Luke Mission.

√?

43. View looking northward across foothills of the Blue Ridge at the eastern margin of Page Valley.



omit use B-30

44. Page Valley. View looking eastward from Massanutten Mountain.

omit

45. Floodplain gravels of Shenandoah River near Lee Highway bridge.

46. Contact of stratified gravels, same locality.

print

47. Pine Mountain, a foothill of the Blue Ridge. View looking westward from Thornton Gap.

48. The Upland Peneplane, developed at Big Meadows along crest of the Blue Ridge.

49. Page Valley, showing flat Valley-floor Peneplane north of Luray.

omit

50. The Blue Ridge Front from Kimball.

omit & duplicate

51. Valley-floor Peneplane, as developed north of Luray.
View looking north from Lee Highway.

use Pl 2
Bull 30

52. Massanutten Mountain, showing its level, peneplaned surface.

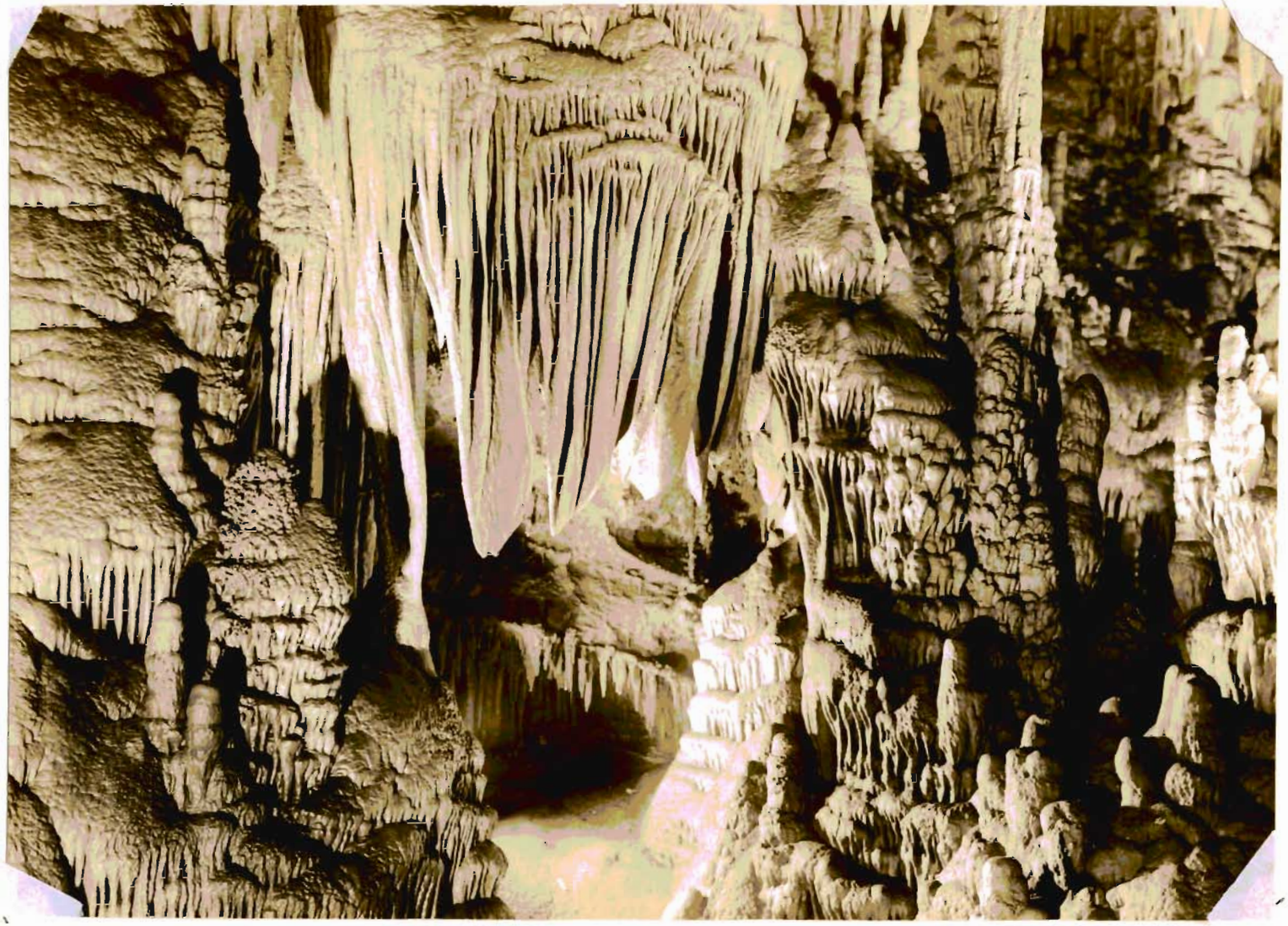
53. Floodplain of Hawksbill Creek south of Luray.

? omit
not in area

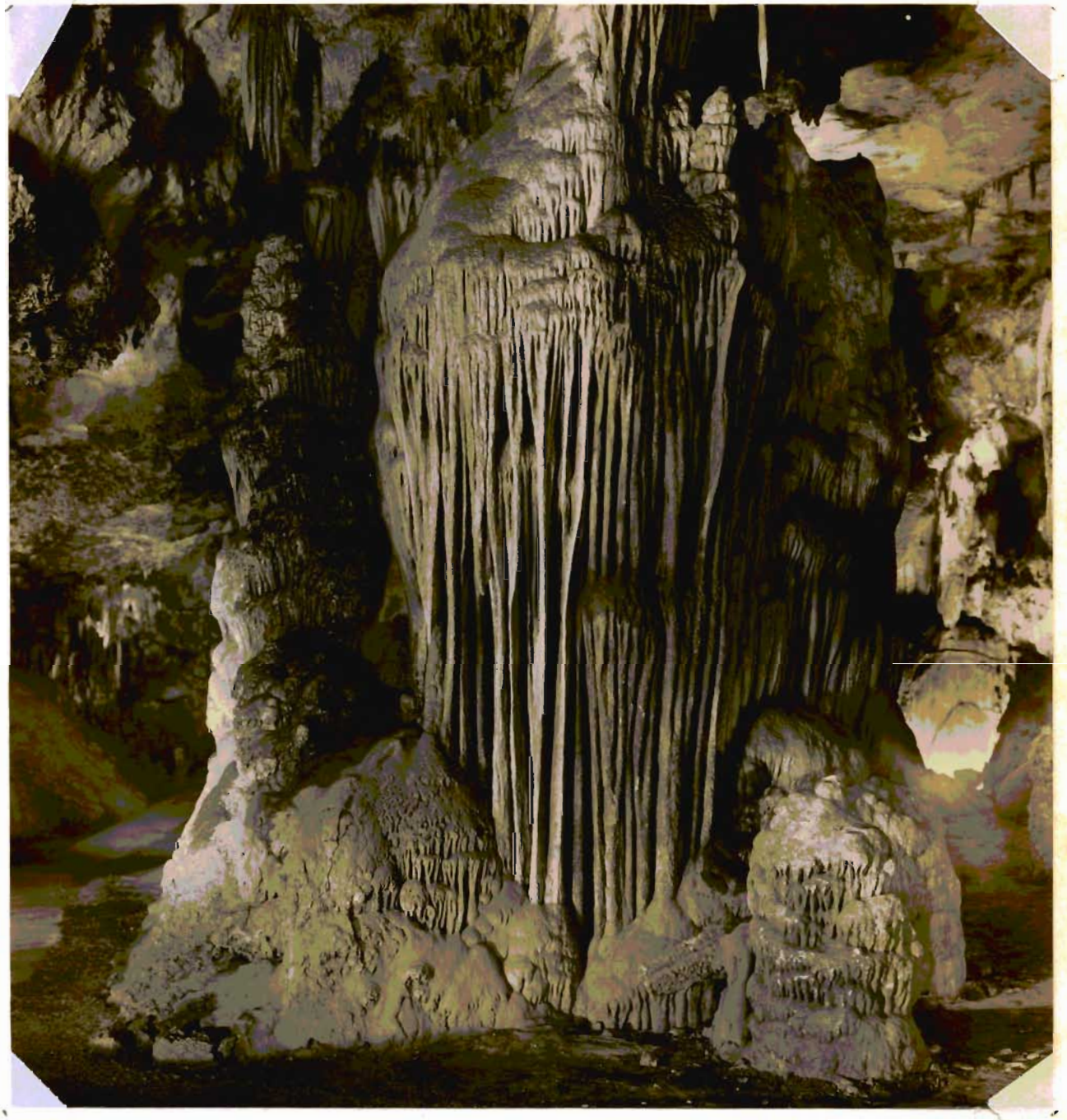
54. Meanders of North Fork of Shenandoah River opposite Woodstock in Shenandoah Valley.

? omit

55. Dissected alluvial fans near Eureka manganese mine southwest of Stanley.



56. View in Luray Caverns showing massive stalactite, drip stone, stalagmites and columns. (Copyrighted by Luray Cavern Corporation)



57. Intergrowths of stalactites and stalagmites to form a massive and complex pillar of secondary cave deposit. The fluted, drapery-like stalactites form a striking contrast to the stubby, coral-like stalagmites on the cave floor. Luray Caverns. (Copyrighted by Luray Caverns Corporation).

not for cut & repetition

58. Typical view of ceiling of Luray Caverns, showing the profusion of stalactites. Several massive stalagmites rise from the sloping floor of this part of the cave. (Copyrighted by Luray Caverns Corporation).

59. A mass of coalescing stalactites, Luray Caverns. (Copyrighted by Luray Caverns Corporation)

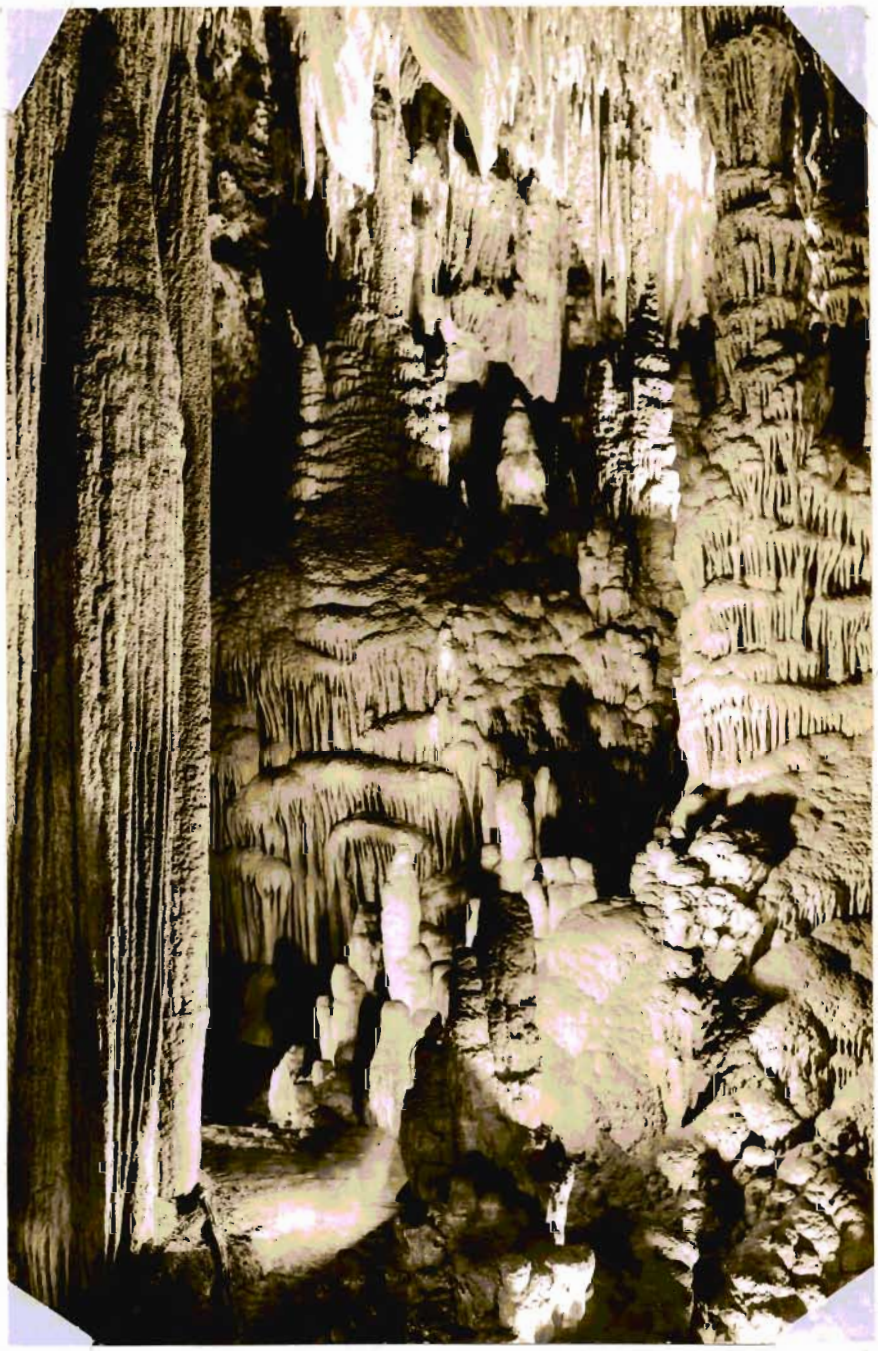
60. Fluted stalactites, Luray Caverns. (Copyrighted by Luray Caverns Corporation.)

61. The "Totem Pole," a tall stalagmite, Giant's Hall, Luray Caverns. For scale, note railings. (Copyrighted by Luray Caverns Corporation)

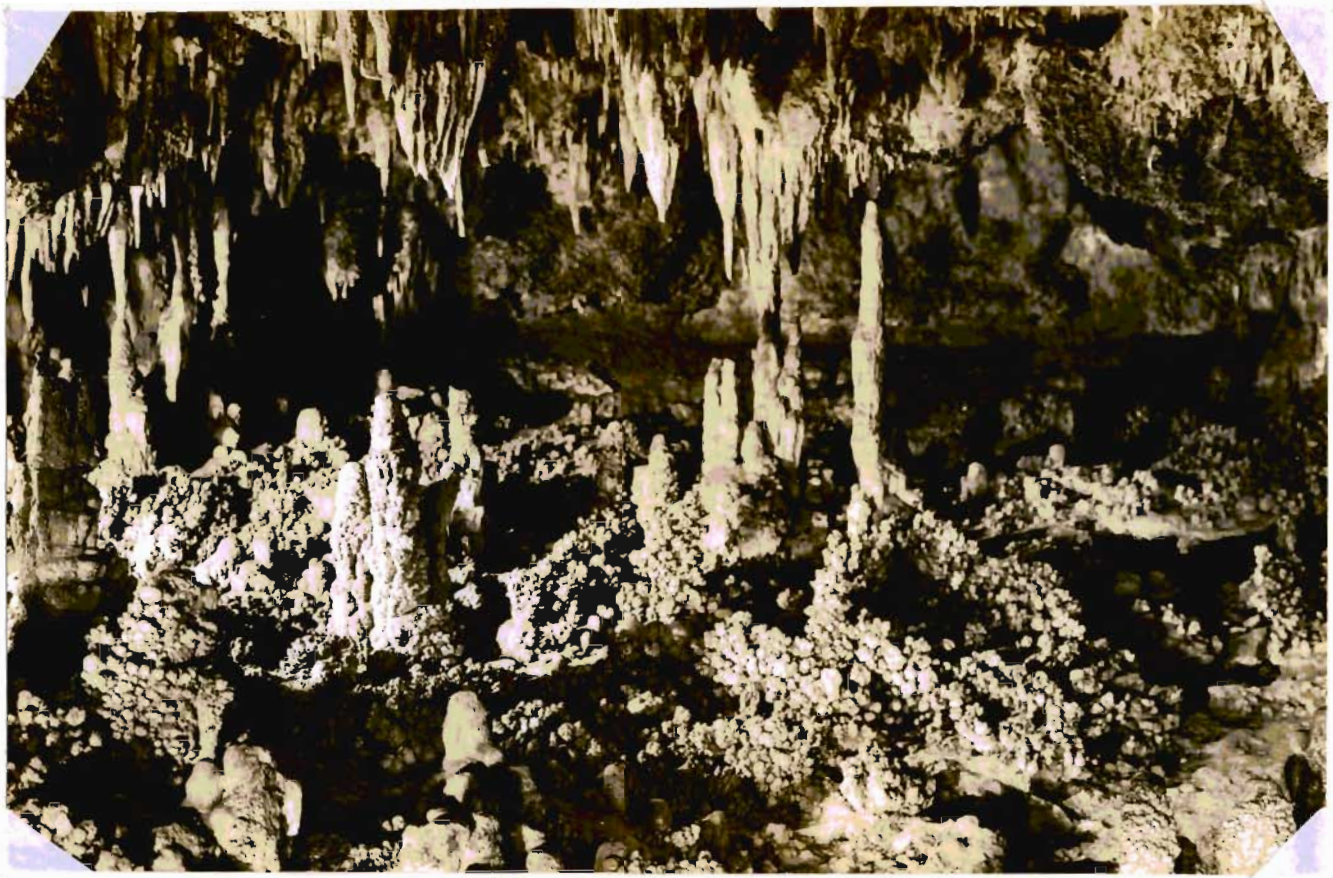
62. Group of stalagmites, Luray Caverns. (Copyrighted by Luray Caverns Corporation)

Draft use 64

63. Cascade-like flowstone surrounded by shallow pool. Streamer-like staladtites above. Luray Caverns. (Copyrighted by Luray Caverns Corporation).

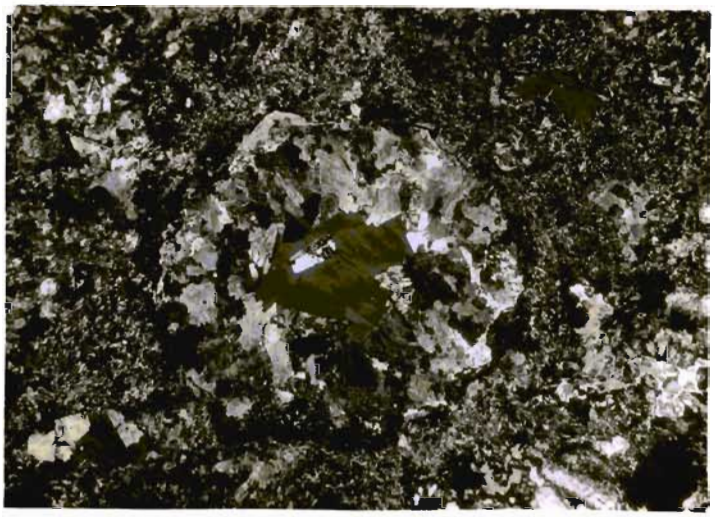


64. View in Luray Caverns showing the variety of cave deposits present. In their natural colors of brown, yellow, and red, these stalactites, stalagmites, and columns give the impression of bizarre and ornate workmanship. (Copyrighted by Luray Caverns Corporation).



65. "The Vegetable Garden," Luray Caverns. Normal stalactites occur on the roof of this opening, but the stalagmites and floor are encrusted with pebble-like concretionary forms. (Copyrighted by Luray Caverns Corporation)

66. Columnar jointing in Catoctin greenstone, Little Devil Stairs.



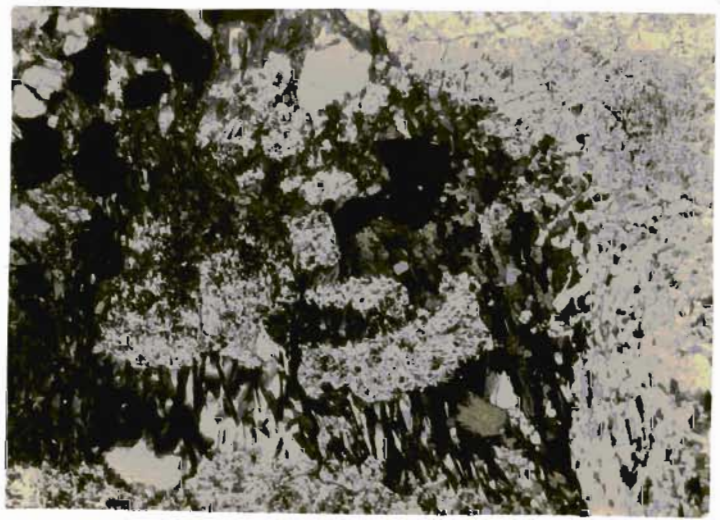
Photomicro

67. Amygdaloidal greenstone on Dry Run just north of the Stony Man Quadrangle. Groundmass consists of epidote, quartz, magnetite, etc.; and the amygdaloidal filling is of pink quartz. Crossed nicols; X20.

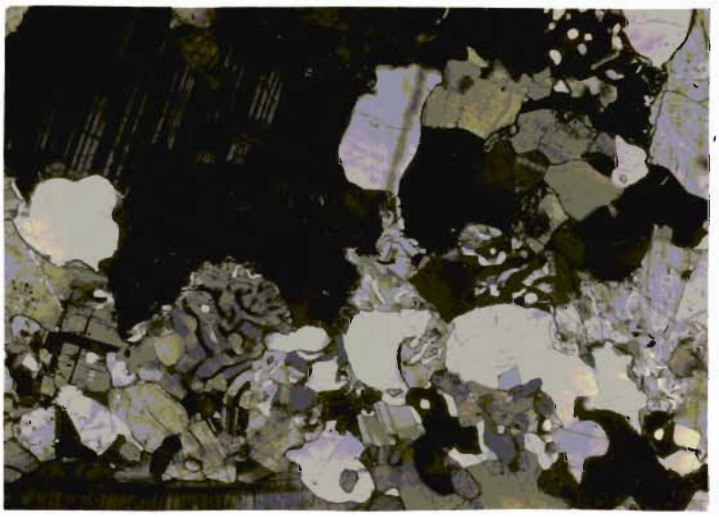
Choose!

Photoniere

68. Lovingston gneiss about three-fourths mile southeast of Etlan showing crushed feldspar partly altered to muscovite and enwrapped with wisps of biotite, quartz, and feldspar to form an augen gneiss. Crossed nicols; X 15.



69. Lovingston gneiss from the east side of Dulaney Mountain. Plagioclase quartz and brown biotite and titanite from the alteration of titaniferous magnetite or ilmenite. Plane polarized light; X15.



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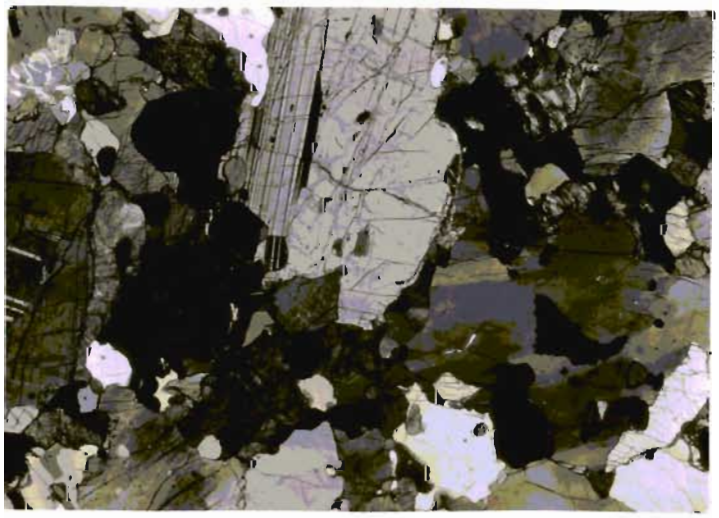
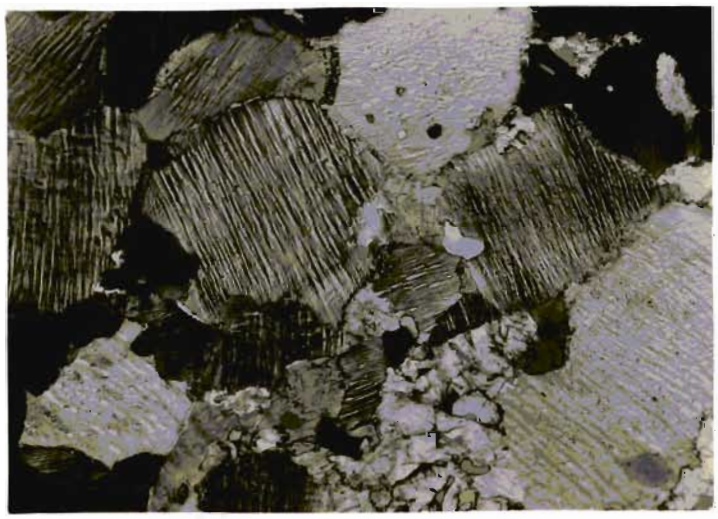
70. Granodiorite at the mouth of Mink Hollow on Hawks Bill Creek showing oligoclase-andesine, quartz and micrographic intergrowths of quartz and plagioclase. Crossed nicols; X20.



Photomicr

71. As above showing also hypersthene. Crossed nicols; X15.

72. Boulders produced by weathering of Old Rag granite, Nicholson Hollow.



Photomicro

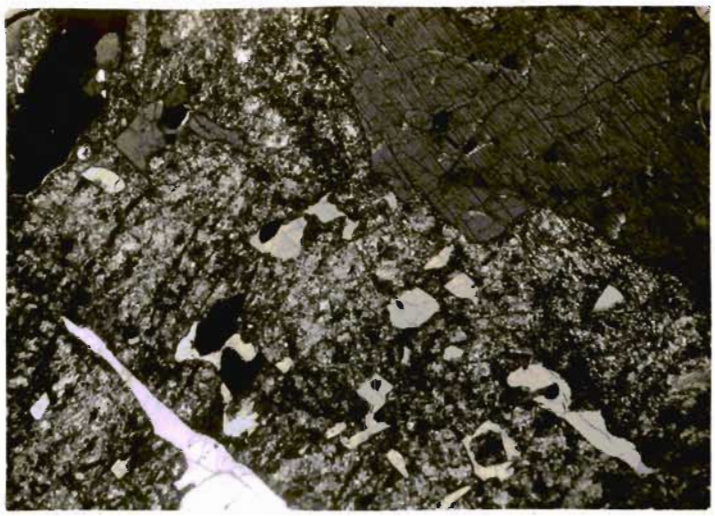
73. Old Rag granite from the northeast side of Old Rag Mountain near Nethers. Coarse grained microperthite. Crossed nicols; X^{30}.

Pro cut

74. Hypersthene granodiorite injected by narrow dikes and stringers of Old Rag granite. Skyline Drive, southwest of the tunnel through Mary's Rock.

?

75. Pink epidote-bearing granite one-half mile north of Hughes River Gap. Crossed nicols; X30.

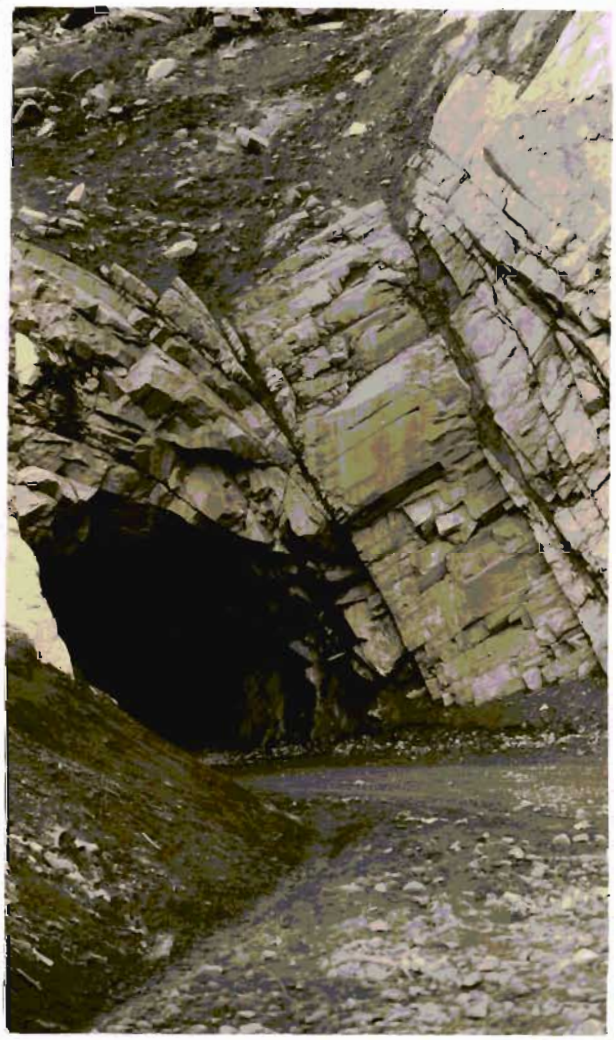


76. Granodiorite altering to unakite north of Franklin Cliffs. Plagioclase is considerably altered to epidote. Brown hornblende occurs in the upper right-hand corner of the illustration. Marginal secondary quartz is shown which has grown into the feldspars to produce a pseudo-micropegmatitic structure. Crossed nicols; X20.

77. Quartz amygdaloid at the base of the Cambrian on Knob Mountain. Crossed nicols; X20.

omit

78. Dike of Triassic diabase (to the left of the hammer) intruding granite and granodiorite on the Skyline Trail just east of Stony Man.



79. Dike of Triassic diabase cutting granite and granodiorite. East end of the tunnel through Marys Rock, Skyline Drive.

??

80. The Neighbor and the Three Sisters, foothills of the true Blue Ridge. View looking northeast from the Lee Highway.

omit?

81. Knob Mountain, capped by Loudoun sediments; viewed from Jeremy Run.

82. Loudoun sandstone along Lee Highway near Pumpkin Hill.

83. Lower Cambrian sandy shales, exposed in Pumpkin Hill.

Photomicro

84. Sandy bed in Lower Cambrian phyllite, Pine Hill Gap, showing crushed and partly oriented quartz and feldspar. Crossed nicols; X20.

omit
Poor cut

85. Quartzite breccia, developed in talus deposits of Antietam sandstone on Jeremys Run.

86. Ledges of Antietam sandstone above the dam near Ureka Mine, southwest of Stanley.

87. Large talus accumulations along Round Head Mountain, three miles southwest of Stanley. This talus is derived from the Antietam sandstone. (Note the figure in center of view.)

88. Waynesboro shale near Kimball.

89. Interbedded limestone and dolomite in Conococheague formation, one-half mile northwest of Rileyville.

90. Massive bed of vaughanite interbedded in Conococheague formation near Rileyville.

Omit 2 detail lost in cut

91. Sun-cracked surface of Conococheague limestone exposed in quarry along Dry Run near Lee Highway. (See Fig. 92)

Don't see 154

92. Closer view of sun cracks.
(See Fig. 91)

Print!

93. Pot holes developed in Conococheague formation near Big Spring Church.

94. Typical exposure of Stonehenge limestone one-eighth mile south of Mud Pike immediately west of the Stony Man Quadrangle.

95. Massive ledge of Nittany dolomite near Deford Leather Company, Luray.

omit ?

96. Massive ledge of vaughanite, Bellefonte member of Beekmantown, northwest of Rileyville.

97. Laminated Beekmantown dolomite near railroad cut immediately north of Luray.

98. Typical exposure of limy beds in the Athens shale half a mile northwest of Trinity Chapel along State Highway 821.

omit?

99. Quarry in Athens shale near Alma, immediately west of Shenandoah River.

100. Thinly laminated Chambersburg limestone near Trinity Chapel.

101. Martinsburg shale along Virginia State Highway 821 west of Bixler Bridge.

omit

102. Tuscarora sandstone as exposed along southeastern face of Massanutten Mountain.

✓?

103. Sandstone member of Bloomsburg shale along road from Fort Valley to Edenburg.

104. Tonoloway limestone, showing sun-cracked surface, along road leading toward Edinburg.

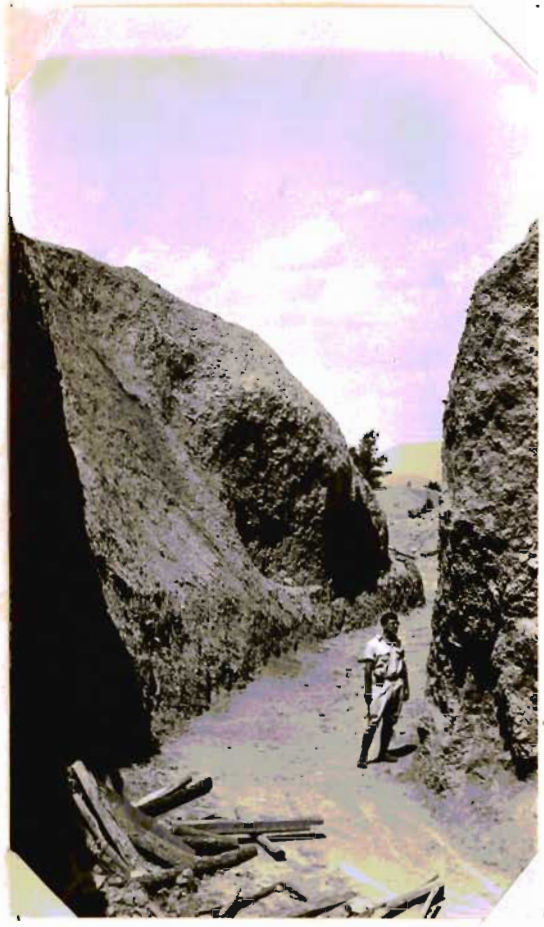
105. Romney shale along Passage Creek in Fort Valley.

omit
Duplicate
use
B-35

106. Massanutten Mountain from Page Valley. The crest shows the level Upland Peneplane; the Valley-floor Peneplane is in the foreground.

omit
Duplicate

107. New Market Gap in Massanutten Mountain.



108. Deep cut in alluvial material at contact of Antietam and Tomstown formations near manganese mines south of Stanley.

109. Opening of shaft in alluvial gravels at the Eureka manganese mine, southwest of Stanley.

Omit

Fort Valley too obscured

110. Fort Valley and northwestern ridges of Massanutten Mountain, from a point near Kennedy Peak. Edinburg Gap is in the right background.

111. Conococheague limestone exposed in quarry operated by W. L. Woodward on Stony Man Creek.

omit

112. Tanners Ridge, from crest of Blue Ridge.

omit
duplicate

113. Page Valley from Tanners Ridge.

omit
± duplicate

114. Hawksbill Mountain and the Blue Ridge Front. View looking southwestward from a point along U.S. Highway 211 near Thornton Gap.

omit ?

115. View looking northeastward along the Blue Ridge Front east of Luray.

omit
poor cut
& ± dup

116. Page Valley from Massanutten Mountain.

omit

117. New Market Gap. Viewed from Lee Highway near Hamburg.

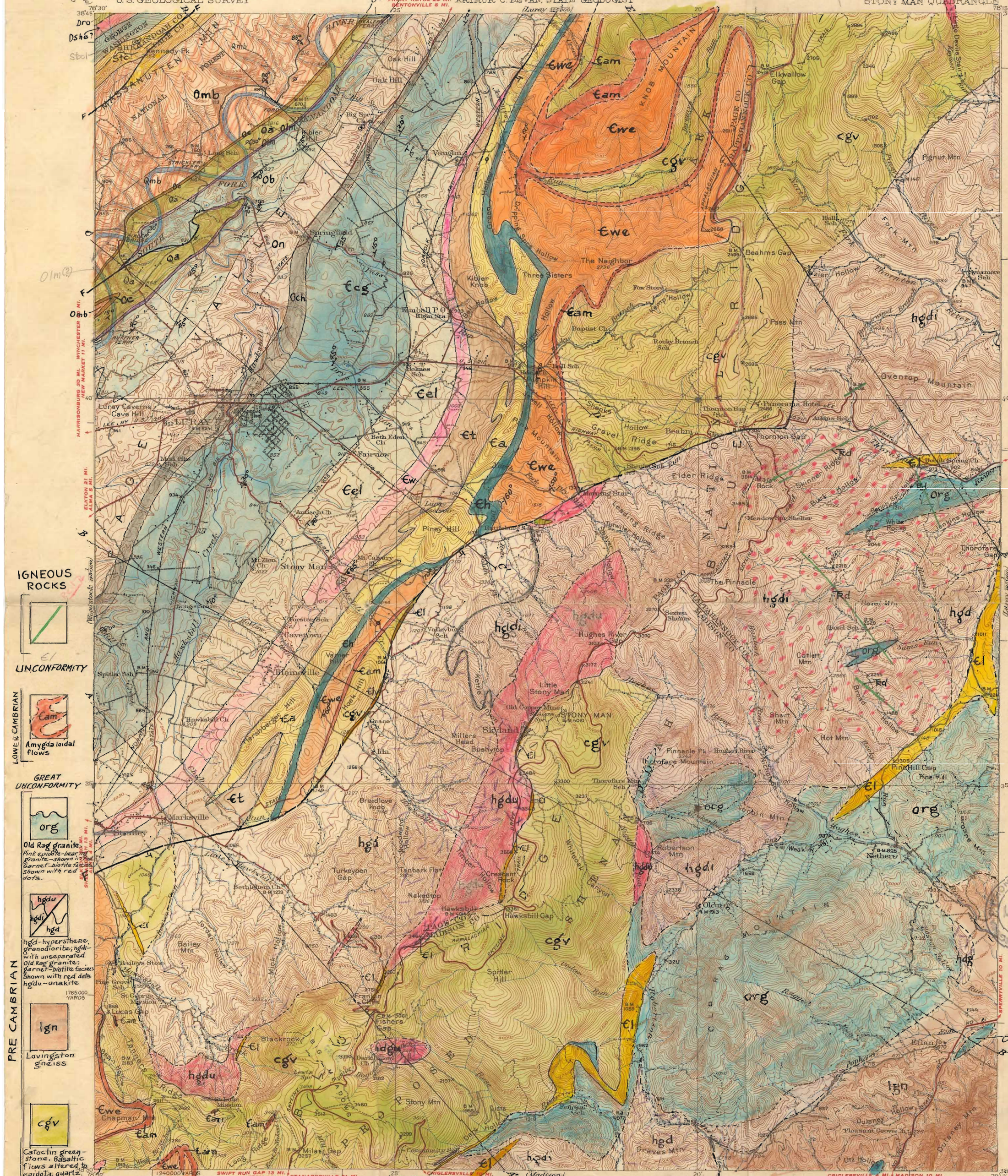
Plate 1

Copied by hand 1-1942 from original office map

DEPARTMENT OF THE INTERIOR
U.S. GEOLOGICAL SURVEY

STATE OF VIRGINIA
CONSERVATION AND DEVELOPMENT COMMISSION
VIRGINIA GEOLOGICAL SURVEY
ARTHUR C. BEVAN, STATE GEOLOGIST

VIRGINIA
STONY MAN QUADRANGLE



Credit to U.S. Geol. Survey for base map