COMMONWEALTH OF VIRGINIA
DEPARTMENT OF CONSERVATION AND ECONOMIC DEVELOPMENT
DIVISION OF MINERAL RESOURCES

GEOLOGY AND MINERAL RESOURCES OF PAGE COUNTY

RHESA M. ALLEN, JR.

BULLETIN 81

VIRGINIA DIVISION OF MINERAL RESOURCES

James L. Calver
Commissioner of Mineral Resources and State Geologist

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Commonwealth of Virginia
Department of Purchases and Supply
Richmond
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GEOLOGY AND MINERAL RESOURCES OF PAGE COUNTY

By

RHESA M. ALLEN, JR.[1]

ABSTRACT

Page County is located in the northwestern part of Virginia in the Blue Ridge and Valley and Ridge physiographic provinces. Its boundaries enclose an area of 316 square miles which extends from the crest of the Blue Ridge on the east to Massanutten Mountain on the west. The South Fork of the Shenandoah River, the major stream, passes through the central part of the county.

Bedrock in the county consists of Precambrian to Devonian rocks, with one known occurrence of Triassic igneous rock. Quaternary terrace gravels cover much of the bedrock in the central part of the county, and river flood-plain alluvium is present along the margins of the South Fork and its major tributaries and in scattered places on the upland surface of the valley. The oldest Precambrian unit, the Pedlar Formation, occurs in the Blue Ridge area and consists of granitoid and gneissic rock of essentially granodioritic composition. The Pedlar is overlain in part by metamorphosed sedimentary rocks of the Swift Run Formation, and this unit is conformably overlain by the altered basaltic flows of the Catoctin Formation, both having an age of late Precambrian or Early Cambrian. Along the western slope of the Blue Ridge and in the foothill belt immediately to the west, the predominantly clastic rocks of the Loudoun, Weverton, Hampton, and Erwin formations of Cambrian age hold up higher elevations. The central part of the county is underlain by a sequence of carbonate rocks, with a few shale units, of Cambrian and Ordovician age. The western part of the county consists of a highland area of ridges and narrow valleys known as Massanutten Mountain. The Martinsburg Formation makes up much of the western slope, and the Massanutten Sandstone holds up the ridge crests. Silurian to Devonian clastic rocks, with a few carbonate units, are also present in Massanutten Mountain. Quaternary terrace gravels and flood-plain deposits cover much of the bedrock, especially in the southwest three-fourths of the central part of the county.

The major structures in the Page County area include from east to west: the western flank of the Blue Ridge-Catoctin Mountain anti-

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clinorium, the faulted and intensely folded anticlinal structure of the central part of the county, and the synclinal complex of the Massanutten Mountain area. The Cambrian and Ordovician rocks in Page Valley form a large fold overturned to the northwest. The Massanutten Mountain region, comprising Ordovician, Silurian, and Devonian rock, has been deformed into a synclinorium. A major fault structure in the area, the north-northeast trending Stanley fault, appears to have essentially vertical movement with the east-southeast side upthrown. In the northern part of the county the Vaughn fault zone consists of several closely spaced thrust faults that border the west front of the Blue Ridge. Several small faults occur in the Ordovician rocks in the central part of the county, and two well-developed thrust faults transect the Silurian and Devonian rocks in Massanutten Mountain.

The mineral resources of Page County that are of current or potential interest consist of the gneissic and granitoid rocks and greenstone that can be used for construction purposes, the carbonate rocks, sand and gravel, quartzose rocks, and clays. The copper ores of the Blue Ridge have been worked in the past but appear to be of poor quality and limited quantity. Iron and manganese ores were mined, milled, and smelted in the past, especially in the area east of the town of Shenandoah. Surface water is plentiful, and generally sufficient quantities of ground water are available for present needs.

INTRODUCTION

Page County, formed in 1831 from portions of Rockingham and Shenandoah counties, is in the northern part of Virginia (Figure 1),

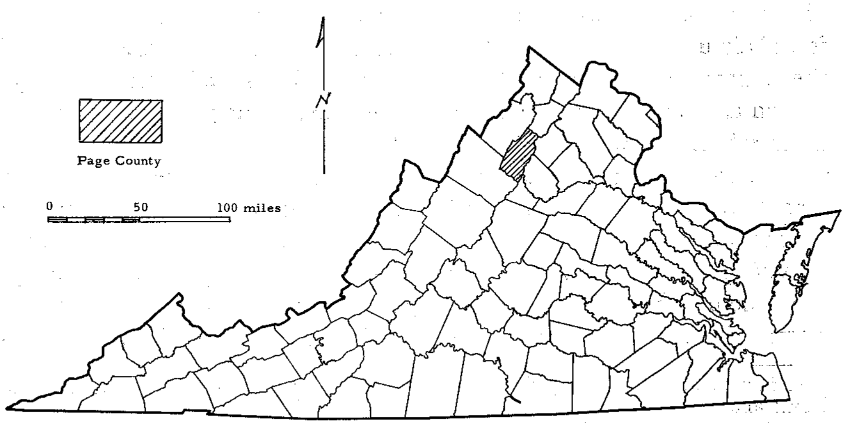

Figure 1. Index map showing location of Page County.

and includes an area of 316 square miles. The eastern boundary is along the crest of the Blue Ridge, and the county is chiefly within the Valley and Ridge physiographic province. Counties bordering Page on the east are Greene, Madison, and Rappahannock; on the north, Warren; on the west, Shenandoah; and on the southwest and west, Rockingham. The county lies between lines of longitude 78° 17′ and 78° 40′ W. and lines of latitude 38° 25′ and 38° 50′ N. and is shown on parts of five 15-minute quadrangle maps: Madison, Stony Man, Strasburg, Mt. Jackson, and Elkton.

The primary purpose of this report is to provide a guide to the geology of Page County, and to present a geologic map of the major rock units. Previous publications have descriptions of some rocks that crop out within the county, and contain details on small areas within the county. This report, prepared using a modern topographic base, has sections on the stratigraphy, structure, geologic history, and geomorphology of the area with an outline of the mineral resources of past, present, and possible future interest.

PREVIOUS INVESTIGATIONS

The Valley and Ridge province of Virginia has been of great interest to geologists, beginning with the report of W. B. Rogers (1836). Reports by Lesley (1859), Hotchkiss (1878), Prime (1880), McCreath (1884), Benton (1886), Phalen (1906), Watson (1907), Harder (1910), and Stose and others (1919) considered the iron, copper, and manganese ores of the area. Spencer (1897) described the geology of Massanutten Mountain. Some mention of the cement resources was made by Bassler (1909). Clay materials of the area were noted by Ries and Somers (1920), and a general description of ground-water resources was made by Cady (1936).

Of a more recent date are the studies by Butts (1933, 1940-41), the work of Edmundson (1945) on the limestones and dolomites, the works of King (1943, 1949, 1950), stratigraphic studies in Page and adjoining counties by Cooper and Cooper (1946), studies on the igneous rocks of the Blue Ridge by Furcron (1934), the study of the Catoctin Formation by Reed (1955), and the presentation by Bevan and others (1938) on the geology of the area from Luray, Virginia, to Panorama and Front Royal, Virginia.

The geology of the Elkton area was described in detail by King (1950), and the geology of the Mt. Jackson quadrangle was described by Thornton (1953). The report on the geology of Rockingham County was made by Brent (1960), and the geology of Greene and Madison counties was reported on by Allen (1963). Many of these publications have been utilized in the preparation of this report.

PRESENT INVESTIGATION

Field work by the writer in Page County was done during the summers of 1961, 1962, 1963, and 1964, at which times the writer was in the employ of the Virginia Division of Mineral Resources. Aerial photographs and sheets of the 15-minute topographic quadrangles were utilized for mapping. Along with mapping of surface exposures, examinations were made of mineral deposits of past and present economic value and of those deposits of potential value, including water resources.

Particular attention was given to the stratigraphy and structure of the rocks of the area. In the preparation of the geologic map of Page County (Plate 1), the work of King (1950) and Thornton (1953) was used; and although no new stratigraphic terms were introduced, the descriptions of the lithologic units have been used along with those made by the writer. Structures mapped by King (1950) and Thornton (1953) were slightly modified. The work of R. S. Edmundson done along the eastern edge of Massanutten Mountain and within the Strasburg quadrangle was utilized for the compilation of that part of the geologic map.

ACKNOWLEDGEMENTS

Mapping of the areas (Plate 1) credited to C. P. Thornton, R. S. Edmundson, and the writer was done under the auspices of the Commonwealth of Virginia. A report on the Elkton area was written by P. B. King (1950) and published by the U. S. Geological Survey. The writer is indebted to Dr. James L. Calver, Commissioner of Mineral Resources and State Geologist of Virginia, for assistance of many kinds in the conduction of the field work and preparation of the report. The aid and assistance of the staff members of the Virginia Division of Mineral Resources is greatly appreciated. Mr. Merrick Whitfield assisted in the field in the summer of 1961, and the writer's son, Rhesa M. Allen, 3rd, assisted during parts of the summers of 1963 and 1964. These men rendered valuable service and the writer is especially grateful for their aid.

Numerous persons in Page County, especially county officials and officials of the National Park Service were most cooperative and helpful. In particular, the writer expresses his heartfelt appreciation to Mr.

Frank Kiblinger of Stanley, Virginia, who spent many days in the field with the writer, guiding him to many of the more inaccessible areas of geologic interest and to several of the old mines and prospects, and acquainting him with the geography, history, and lore of the region. Mr. Kiblinger spent many years as an employee of the National Park Service in the Shenandoah National Park, and his aid has been of inestimable value. The aid and courtesies, and the genuine interest, shown to the writer by the residents of Page County are greatly appreciated, and it is unfortunate that space does not permit the listing of their individual contributions.

GEOGRAPHY

CLIMATE

Climatic conditions of Page County are summarized from the climatographic data published by the U. S. Weather Bureau (Rice, 1959). During the period 1941-52, the weather station at Luray, Virginia, indicated for precipitation an annual high of 49.43 inches in 1942, an annual low of 27.28 inches in 1943, and an average annual precipitation of 39.96 inches for the period. Temperature data for Luray for the same period indicated an average low of 35.7° F during January and an average high of 73.2° F during July. The average annual temperature for Luray for the period was 54.6° F. Also for Luray the mean maximum temperature indicated was 24.6° F during December. For the period 1935-52 the weather station at Big Meadows on the crest of the Blue Ridge indicated for precipitation an annual high of 67.07 inches in 1952, an annual low of 36.35 inches in 1941, and an average annual precipitation of 52.38 inches for the period. Temperature data for Big Meadows for the same period show an average low of 29.8° F during January and an average high of 66.6° F during July. The average annual temperature for Big Meadows for the period was 48.0° F. Also for Big Meadows the mean maximum temperature indicated is 76.1° F during July and the mean minimum temperature indicated is 20.3° F during both January and February.

For the period 1921-50 at Woodstock, the mean date of the last spring freeze is April 26, and the mean date of the first fall freeze is October 13; the average number of days between dates is 170. Data are for temperature of 32° F. Although this part of Virginia normally has abundant rainfall, the frequency of dry periods and droughts greatly affects agricultural activity. The drought of 1930 is thought to have been the most serious of the past century, and the period from

1952 through 1957, with the exception of 1955, and the years 1962 through 1964 were times of notable rainfall deficiency.

TOPOGRAPHY AND DRAINAGE

Page County lies in the Blue Ridge and Valley and Ridge physiographic provinces (Fenneman, 1938, p. 165-171, 245-265). The greatest relief is along the east margin of the county, and the highest point, 4049 feet, is Hawksbill. Other high elevations are Stony Man, 4010 feet; Hazeltop, 3816 feet; Nakedtop, 3726 feet; Blackrock, 3721 feet; The Pinnacle, 3720 feet; and Marys Rock, 3514 feet. Relief is high in the western part of the county in the Massanutten Mountain area with elevations of 2955 feet on Big Mountain and 2822 feet on Duncan Knob.

The lowest elevation in the area is approximately 590 feet where the South Fork of the Shenandoah River leaves Page County and enters Warren County. The elevation of the town of Luray (bench mark location) is 824 feet. Where the South Fork enters Page County at its southern boundary (at the confluence of Naked Creek), the elevation is approximately 890 feet. The area is drained by the South Fork of the Shenandoah River and its major tributaries: Naked Creek, Cub Run, Stony Run, Mill Creek, Hawksbill Creek, Jeremys Run, and Overall Run.

Topography in the extreme eastern and western parts of the county includes steep-walled valleys with fast-flowing streams and heavily wooded slopes. In the southeastern area is the Shenandoah salient, an extremely rugged part of the Blue Ridge that extends 6 to 8 miles westward from the Page-Greene-Madison boundary almost to the South Fork of the Shenandoah River at Ingham. Hershberger Hill, Varner Hill, Piney Hill, and Pine Mountain are the features that mark the edge of the Blue Ridge highlands. Massanutten Mountain occupies a width of slightly over 2 miles along the western boundary of the county with a low divide at New Market Gap at an elevation of 1807 feet.

The central part of the county is a dissected upland or valley floor traversed by the South Fork of the Shenandoah River. The widest part of the valley, approximately 7 miles, is just north of Stanley; the narrowest part, about 1 mile, is at Overall. The valley floor, generally about 100 to 125 feet above river elevation, is for the most part covered with a gravel veneer. The area enclosed by the towns of Leaksville, Hamburg, and Luray has a moderate karst development. The present flood plain of the South Fork is a modest one, approximately 0.75 mile wide just north of Alma, narrowing to small scrolls on the inside of meander bends downstream. For the most part, throughout its length in Page County, the South Fork is entrenched below the upland surface.

INDUSTRY AND ECONOMIC DEVELOPMENT

The 1960 census recorded a population of 15,572 persons in Page County for a density ratio of approximately 50 persons per square mile. The county had a gain of 420 persons between 1950 and 1960, whereas Luray, the largest town and county seat, had a population of 3014 persons in 1960, a gain of 343 persons over 1950 and making up the great majority of the county increase. Per capita income of Page County increased from $902 in 1950 to $1100 in 1957, with the State average in 1957 being $1660.

At the time of the field investigation, mining or quarrying operations were active at two localities (Plate 1), although in the past numerous quarries were in operation as were mines for iron, manganese, and copper ores. Industrial activities, primarily those engaged in manufacturing men's and work clothing, manufacturing yarn and thread, leather tanning and finishing, poultry dressing and packing, seasonal peach canning, and other enterprises, employ approximately 1443 persons. In 1954 there were 1185 farms with a land total of 102,183 acres, for an average-size farm of about 86 acres. Livestock, poultry, and field crops make up the most common types of farm activity.

Recreation has come to play an important role in the area. The facilities of the Shenandoah National Park with its scenic Skyline Drive attract more than one million visitors each year, and the George Washington National Forest on the western margin of the county offers facilities for camping, hiking, fishing, and hunting. Just west of Luray are the well-known Luray Caverns that attract many tourists.

Page County contains approximately 82,064 acres of commercial forest land in addition to 46,800 acres of non-commercial forest, a large part of which is in the Shenandoah National Park. Over one-half of the commercial acreage is in oak-hickory type.

TRANSPORTATION FACILITIES

The area is served by a network of excellent roads. U. S. Highway 211 is a direct route from Luray to Washington, D. C., and connects with U. S. Highway 11 at New Market; it also connects with the Skyline Drive at Thornton Gap (Panorama). The Skyline Drive follows closely the eastern boundary of Page County along the crest of the Blue Ridge. U. S. Highway 340 also serves Page County, entering the county at its southern margin near Shenandoah and essentially paralleling the South Fork of the Shenandoah River to the Warren County boundary at Overall. Many hard-surfaced State roads provide easy access to the central part of the county, but in the Massanutten Mountain area and in the area adjacent to the Shenandoah National Park, roads are few and not suitable for bad-weather travel.

Page County is on the Norfolk and Western Railway's Shenandoah Valley Division main line from Roanoke, Virginia, to Hagerstown, Maryland, with freight service only available. Airline connections are available at the Harrisonburg-Staunton-Waynesboro (Shenandoah Valley) Airport at Weyers Cave, approximately 20 miles south of Page County. Flights are operated daily by Piedmont Airlines.

ROCKS IN THE AREA

The rocks in the area are mainly sedimentary, with igneous and metamorphosed igneous and sedimentary types along the eastern margin of the county. Bedrock in Page County ranges in age from Precambrian to Devonian and is in part covered by unconsolidated deposits of Cenozoic age; one mafic dike of Triassic age is also shown on Plate 1. The Precambrian and Paleozoic rocks, exclusive of the Pedlar Formation, have an aggregate thickness of approximately 23,000 feet and have been greatly deformed. From east to west the major rock units are: (1) the westernmost edge of the Virginia Blue Ridge Complex (Brown, 1958) which consists of sialic and intermediate igneous rocks and gneisses; the Swift Run Formation of sedimentary origin; and the Catoctin Formation that contains altered basalts and tuffaceous rocks; (2) a highly deformed unit of Cambrian to Ordovician sedimentary rocks that make up the valley of the South Fork of the Shenandoah River; and (3) the west margin of the county which contains Ordovician, Silurian, and Devonian sandstones, shales, and limestones.

The unconsolidated rocks in the valley of the South Fork consist of clay, sand, and gravel that lie unconformably over the bedrock units. Much of the clay represents residual deposits derived from the weathering of the Paleozoic rocks, mainly the carbonate units. Sands and gravels were deposited during post-Paleozoic time on older and higher valley floors. The South Fork is depositing similar materials on its valley floor at the present time. Table 1 summarizes the stratigraphic sequence in Page County.

Table 1.—Geologic formations in Page County.

AGE	NAME	MAP SYMBOL	CHARACTER	THICKNESS IN FEET
Quaternary	River flood-plain deposits	Qal	Gravel, sand, and clay	0–100
	Terrace gravels	Qg	Gravels, mainly quartzite	0–200
Triassic	Dikes of mafic igneous rocks	₹d	Mafic igneous rocks	
Devonian	Devonian undivided	Du	Limestone, claystone, and shale	30–200
Silurian	Cayuga Group	Scy	Shaly limestone, siltstone, and shale	200–600
	Massanutten Sandstone	Sm	Quartzite and sandstone	400–650
Ordovician	Martinsburg Formation	Omb	Shale, calcareous and silty in part; greenish and gray sandstone	1000–3000
	Edinburg Formation	Oe	Black to gray fissile shale; slabby black limestone	500–1500
	Lincolnshire Formation and New Market Limestone	Oln	Dark-gray limestone with black chert; dove-gray compact limestone; conglomerate and breccia at base	50–200
	Beekmantown Formation	Ob	Dolomite and limestone; abundant chert	2000–3000
	Chepultepec Formation	Och	Limestone; some chert	300–500?
Cambrian	Conococheague Formation	Ꞓco	Dolomite and limestone; some white sandstone	2000–2500?
	Elbrook Formation	Ꞓe	Dolomite and limestone; some chert	2000–2500?
	Rome Formation	Ꞓr	Limestone and shale	2000?
	Shady Formation	Ꞓs	Dolomite and limestone	1000–1500?
	Erwin (Antietam) Formation	Ꞓer	Quartzite and sandstone	800

Table 1.—(Continued)

AGE	NAME	MAP SYMBOL	CHARACTER	THICKNESS IN FEET
Cambrian	Hampton Formation	Ꞓh	Sandstone, siltstone, and shale	900
	Weverton Formation	Ꞓw	Conglomerate, sandstone, and shale	1000–1500
	Loudoun Formation	Ꞓl	Slate and phyllite	0–200
Cambrian or Precambrian	Catoctin Formation	ꞒpꞒc	Altered basalt and tuff	0–2000
	Swift Run Formation	ꞒpꞒs	Conglomerate, slate, and phyllite	0–100
Precambrian	Pedlar Formation	pꞒp	Granodiorite and gneiss	?

PRECAMBRIAN ROCKS

Pedlar Formation

The Pedlar Formation is a heterogeneous assemblage of granitoid and slightly gneissic rocks consisting of many lithologic types including granite, syenite, granodiorite, quartz diorite, and unakite. On the Geologic Map of Virginia (Virginia Geol. Survey, 1928) it was indicated as chiefly hypersthene granodiorite and was described by Jonas (1935). Bloomer and Werner (1955, p. 582) suggested the name Pedlar Formation for the unit and cited the exposures of granitoid rocks along the upper part of the Pedlar River in northwestern Amherst County as typical of the formation. The name Pedlar has been used in the Page County area to include a number of somewhat similar rock types that appear to have a generally common origin under a single heading. Distribution of the Pedlar Formation is shown on Plate 1. Along the east margin of Page County the Swift Run and Catoctin formations occur unconformably above the Pedlar. The greatest exposure of the Pedlar is in southeastern Page County, southeast of the Stanley fault, where it crops out over an area of approximately 30 square miles. Smaller exposures occur southwest of the Harris Cove fault and in the center of the Shenandoah salient.

The most prevalent rock type in the Pedlar Formation in Page County is a coarse-textured, dark greenish-gray, quartz monzonite. Fresh exposures are characteristically greenish gray; slightly weathered rock surfaces are light gray to brownish white, and after prolonged exposure the surfaces generally are rusty brown. Generally, the Pedlar has a poorly to well-defined gneissic structure. In hand specimen, feldspar, quartz, and minor quantities of ferromagnesian minerals are evident. Feldspar crystals may be as large as 1 cm; quartz grains are generally smaller, and both clear and bluish to violet quartz are common. The dark-green color of fresh Pedlar exposures is caused by the presence of chlorite. Scattered grains of ilmenite are commonly present.

In the area along the west front of the Blue Ridge, along the old road from the village of Stony Man to Skyland and in Kettle Canyon, the Pedlar is a fine-grained, dark-gray quartz diorite. Small outcrop areas of diorite and granodiorite of the same color and texture are also present. Locally, exposures of granodiorite contain pink feldspar, green epidote, and gray to bluish quartz; this rock type, known as unakite, is especially prevalent in the vicinity of Fishers Gap.

Petrographic examination of rock specimens from the Pedlar Formation indicates the most common variety has a granitoid texture with some foliate structure. Orthoclase, microcline, and plagioclase (commonly calcic oligoclase to andesine) make up 60 to 70 percent of the rock; the potassic feldspar and plagioclase occur in approximately equal amounts, although some specimens contain about twice as much plagioclase as potassic feldspar and the rock may be classed as granodiorite or quartz diorite. Much of the potassic feldspar is perthitic. Quartz is present in amounts ranging from 15 to 25 percent. Hornblende and olive-brown biotite are generally present in amounts less than 10 percent. Hypersthene and monoclinic pyroxenes are rare, although on Millers Head, west of Skyland, pyroxene may make up as much as 8 percent of the rock. Wisps of chlorite between feldspar masses and patches of small epidote grains in plagioclase are responsible for the gray to green color of most of the Pedlar. Small blebs and rims of fresh albite replace potassic feldspar, and myrmekitic intergrowths of albite and oligoclase with quartz are common.

CAMBRIAN OR PRECAMBRIAN ROCKS

There is a lack of agreement as to the precise placement of the boundary between the Precambrian and Cambrian rocks in the Blue Ridge area (King, 1950; Bloomer and Werner, 1955; Reed, 1955; Whitaker, 1955). In Greene and Madison counties, Gooch (1958, p. 574) and Allen (1963, p. 37-40) suggested age and lithologic equivalence of the Swift Run, Mechum River, and Lynchburg formations. From the preceding views and varied opinions, the Swift Run and Catoctin formations are designated Cambrian or Precambrian.

Swift Run Formation

The name Swift Run was applied by Stose and Stose (1946, p. 18-20) to a heterogeneous unit of sedimentary material that unconformably overlies the Pedlar Formation and is overlain by the Catoctin Formation. The type locality is in Greene County about 1 mile southeast of Swift Run Gap on the old U. S. Highway 33 and about 200 feet above the present highway location. King (1950, p. 9-12) used the term Swift Run Formation for sedimentary and pyroclastic rocks lying between the Pedlar and the Catoctin. Reed (1955, p. 880-881) did not recognize the Swift Run as a formation, but included sedimentary material at the base of the Catoctin as a basal sedimentary member.

In Page County the Swift Run generally crops out in a narrow belt between the Pedlar and Catoctin formations. A continuous band can be traced southwestward along the west slope and crest of the Blue Ridge from south of Thornton Gap to Tanners Ridge. A small exposure is present along the east side of Hoak Hill, and a narrow belt crops out above the Pedlar in the Long Ridge-Weaver Hollow area north and east of Jollett. It is interesting to note that the Swift Run is absent, as is the Catoctin, within the Shenandoah salient at the heads of Dovel, Lucas, and Cubbage hollows, where either the Loudoun or Weverton formation rests unconformably on the Pedlar.

The character of the Swift Run is varied. Generally it is a vitreous, well-bedded, green, gray, or pinkish arkosic quartzite. The quartz is commonly colorless, but locally blue or violet; other minerals are pink and white feldspar, rare ferromagnesian minerals, and minor epidote. In many places conglomeratic layers are present. Phyllitic and slaty beds are common, and much tuffaceous or altered pyroclastic material is generally present in the upper part of the unit. The contact with the overlying Catoctin is gradational. Seldom does the thickness of the Swift Run exceed 50 feet, although King (1950, p. 10) notes that thicknesses may exceed 100 feet.

Catoctin Formation

Keith (1894a, p. 306-309) applied the name Catoctin schist to exposures in Catoctin Mountain, Maryland, and Jonas and Stose (1939) termed similar rock in Virginia, metabasalt. King (1950, p. 12), from his work in the Elkton area, gave preference to the term Catoctin greenstone as was used on the Geologic Map of Virginia (Virginia Geol. Survey, 1928). Reed (1955), who has made the most comprehensive study of the Catoctin in northern Virginia, used the term Catoctin Formation and included within that unit the underlying Swift Run and overlying Loudoun. Allen (1963) in the report on Greene and Madison counties designated the Swift Run and Loudoun formations as separate rock units and mapped as Catoctin Formation the flows and associated volcanic rocks that overlie, and are younger than, the Virginia Blue Ridge Complex and the Swift Run and underlie the Loudoun. The Geologic Map of Virginia (Virginia Division of Mineral Resources, 1963) also incorporates the term Catoctin Formation.

The Catoctin Formation crops out along the crest and northwest slope of the Blue Ridge in the eastern part of Page County (Figure 2). A portion of the Catoctin extends northwestward from the crest of the Blue Ridge along Tanners Ridge to just south of the Stanley fault in the vicinity of Marksville, and a small outcrop of Catoctin is present along the crest of Hoak Hill west of the Stanley fault (Figure 3). In the northern part of Page County, excellent exposures of Catoctin occur in the valley of Jeremys Run and along the headwaters of Dry Run, Overall Run (Figure 4), Rocky Branch, and Pass Run. Thornton Gap (Panorama) and Pass Mountain to the north are also underlain by Catoctin. Dikes of Catoctin greenstone cut the underlying granitic rock at a number of places in the Blue Ridge area. One such dike, about 15 feet thick, with columnar jointing can be seen at the north end of the tunnel on Skyline Drive about 0.5 mile south of Thornton Gap.

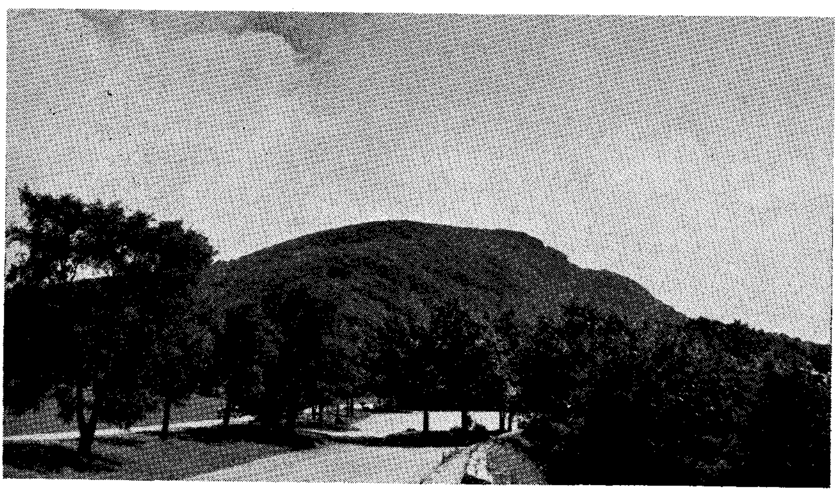

Figure 2. View of Stony Man from nearby overlook on Skyline Drive. The profile of Stony Man, along the ridge line to the right, is in the Catoctin Formation.

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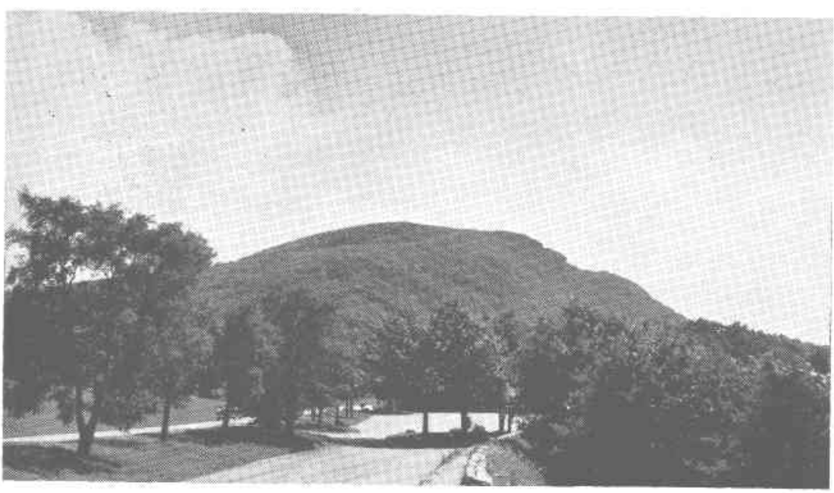

Figure 2. View of Stony Man from nearby overlook on Skyline Drive. The profile of Stony Man, along the ridge line to the right, is in the Catoctin Formation.

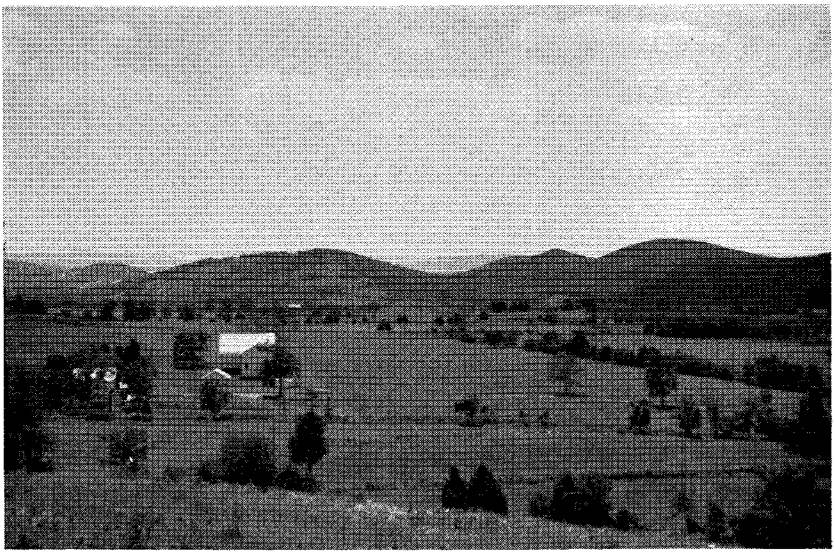

Figure 3. View of Hoak Hill in the left foreground; the Catoctin Formation is in the cleared area, and the Ida copper mine is near the crest of the hill. The Weverton Formation is present on the right side of Hoak Hill; Hampton Formation is in the low area between Hoak Hill and Varner Hill to the right which is underlain by Erwin (Antietam). The beds are overturned.

King (1950, p. 12-14) has described the Catoctin along the northwest slope of the Blue Ridge in the Elkton area, and an excellent and comprehensive description of the facies of the Catoctin Formation in the Luray area is given by Reed (1955). Allen (1963) described the Catoctin along the crest of the Blue Ridge in Greene and Madison counties. In Page County the Catoctin consists of altered basaltic flows and associated volcanic agglomerate and pyroclastic sedimentary rocks. The flows are generally dense, massive, and dark green to grayish green, and the rock is commonly referred to as "greenstone." Many flows contain amygdules composed of feldspar, epidote, quartz, and zeolites. Much of the rock is massive; a southeastward-dipping cleavage is present in most of the flows, and some layers have a slaty or schistose texture. Columnar jointing, although relatively uncommon, is present in the Fishers Gap area and along the headwaters of Overall Run.

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The thickness of the Catoctin Formation varies considerably. On the crest and upper west slope of the Blue Ridge in Page County the Catoctin is 1000 feet or more thick. In the upper part of the valley of Overall Run the thickness exceeds 1500 feet. Reed (1955, p. 880-883) gives a thickness of 1800 feet at Big Meadows. Allen (1963, p. 46) suggests that the total thickness of the flows may have been about 2500 feet. In the area between Ingham and Lucas Gap, the Catoctin wedges out, and as noted previously, the clastic Cambrian sedimentary rocks rest directly on the Pedlar. On the other hand, the thickness of the Catoctin in the Hoak Hill area, just west of the Stanley fault where the unit is in a vertical to slightly overturned attitude, is approximately 1800 feet.

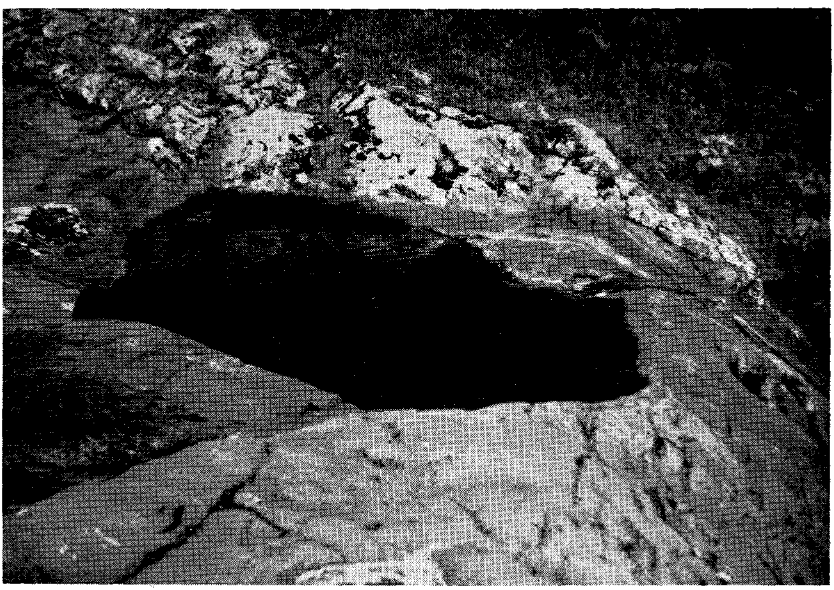

Figure 4. Plunge pool formed in the Catoctin Formation along Overall Run.

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CAMBRIAN SYSTEM

Loudoun Formation

Keith (1894a, p. 324-329) named the Loudoun Formation from outcrops in Loudoun County, Virginia, near the confluence of the Potomac and Shenandoah rivers, but a specific type locality was not described. The unit described by Furcron and Woodward (1936, p. 45-61) as a "basal Cambrian lava flow" that rests unconformably on the Catoctin and is overlain by the Loudoun Formation in the Blue Ridge of Page and Rappahannock counties appears to be slaty and schistose rocks of pyroclastic origin and corresponds to the Loudoun in the Elkton area as described by King (1950, p. 16). In Page County the Loudoun is exposed in a nearly continuous narrow band between the Catoctin and the Weverton formations. The Loudoun crops out along the eastern and southern margins of the inlier of Pedlar in the Shenandoah salient east of Ingham where it rests directly on the Pedlar and also in the area southwest of the Harris Cove fault. In the valley of Hollow Run, in the Hoak Hill-Hershberger Hill area, the Loudoun is present as a narrow band, directly above the Catoctin. The Loudoun also crops out in the Knob Mountain-Jeremys Run area and crosses the Skyline Drive just north of Beahms Gap and just west of Elkwallow Gap.

The Loudoun characteristically is a purple or reddish soft slate or phyllite, containing many oval or round light-green spots. Light-gray to green, soft, sericitic slates and phyllites are intercalated with the purple, green-spotted slates. Cleavage is generally well developed and bedding is commonly evident on cleavage surfaces. In Page County the thickness of the Loudoun is about 100 feet or slightly less, although King (1950, p. 17) states the thickness in the vicinity of Long Ridge northeast of Jollett is possibly 200 feet.

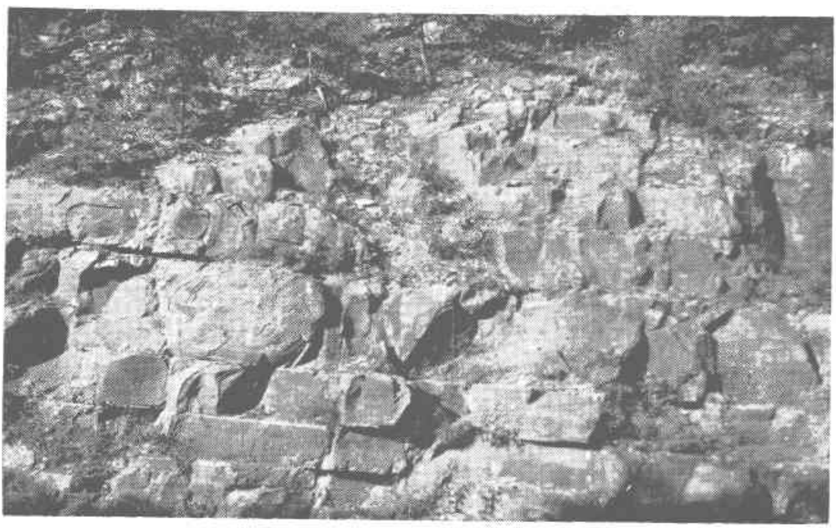
Weverton Formation

The name Weverton sandstone was given by Keith (1894a, p. 329-333) to sandstone beds exposed on South Mountain near Weverton, Maryland. King (1950, p. 17) used the term Weverton Formation for a heterogeneous unit of clastic rocks in the Elkton area and divided the formation into lower, middle, and upper members. On Plate 1 the Weverton is mapped as a single unit.

In Page County the Weverton overlies the Loudoun in outcrops along the northwest slope of the Blue Ridge, in Hoak Hill-Hershberger Hill, and in Pine Mountain. An excellent exposure can be seen in the roadcut of U. S. Highway 211 through Pumpkin Hill, just west of Shenandoah National Park headquarters. Good exposures of the Weverton Formation are present on Neighbor Mountain, Knob Mountain, Beecher Ridge, and between Beahms Gap and Elkwallow Gap (Figure 5), but the best sections occur in the valleys of Dry Run (both forks) and Overall Run.

Figure 5. Exposure of the lower part of the Weverton Formation near Milepost 27 along the Skyline Drive.

The heterogeneous lithology of the Weverton is characteristic of the unit, although coarse clastic rocks appear to predominate. The lower part of the unit is composed of conglomeratic beds grading upward into coarse-grained feldspathic (arkosic) sandstones. Silty shales overlie the sandstones and are overlain by fine-grained, ferruginous sandstones. Coloration of the Weverton on fresh exposure varies from a dark greenish gray to light brown. Good exposures of conglomerate can be seen immediately overlying the Pedlar Formation in Lucas Hollow, and in the valley of Overall Run where the Weverton overlies the Loudoun. The shaly beds and sandstones are well exposed in a roadcut of State Road 629 along Hollow Run southeast of Cavetown. Traces of *Scolithus* are noted by King (1950, p. 19) in the upper part of the Weverton within the Shenandoah salient. Total thickness of the Weverton in Page County ranges from 1000 to 1500 feet. A measured section (Geologic Section 1) along State Road 629 southeast of Cavetown roadcut of U. S. Highway 211 through Pumpkin Hill, just west of Shenandoah National Park headquarters. Good exposures of the Weverton Formation are present on Neighbor Mountain, Knob Mountain, Beecher Ridge, and between Beahms Gap and Elkwallow Gap (Figure 5), but the best sections occur in the valleys of Dry Run (both forks) and Overall Run.



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Geologic Section 1.—Along State Road 629 from a location about 0.5 mile northwest of Ida to a location 0.2 mile southeast of Cavetown (measured by Clark Jones, August 1962).

	Thickness Feet
ROME FORMATION (at first roadcut along State Road 629 southeast of Cavetown)	
2. Covered	45
1. Clay, varicolored (white, red, gray, maroon, buff, purple, and green) but predominantly shades of red; silt content variable; few layers of fine-grained, unconsolidated quartz sand; some clay layers have very little or no silt	115
ROME-SHADY FORMATION (?)	
1. Covered, probably Rome and/or Shady formations	885
ERWIN (ANTIETAM) FORMATION	
7. Quartzite, white, almost pure quartz, consolidated but brittle, breaks with sharp, subconchoidal fracture; bedding largely obscured by jointing	30
6. Covered	55
5. Quartzite, white, severely fractured and jointed but bedding is locally recognizable	167
4. Covered	85
3. Quartzite, same as above	18
2. Covered	20
1. Quartzite, pale-lavender but otherwise similar to quartzite above; few jasperoid surfaces on joint planes; interbedded layers of sandy clay	35
HAMPTON FORMATION	
6. Sandstone, nearly white to rust-brown; beds 1 to 3 feet thick; alternates with thin beds of hard, sandy clay and medium-grained friable sandstones; clay is greenish-gray to buff with iron oxide stains along bedding	16
5. Sandstone, similar to above, but interbedded with quartzite similar to consolidated Antietam quartzite above	16
4. Covered	80
3. Quartzite, similar to Antietam quartzite; bedding obscured by joints	119
2. Covered	154
1. Quartzite, similar to Antietam quartzite; interbedded with friable sandstone and sandy clay layers	55
WEVERTON FORMATION	
5. Covered	205
4. Sandstone, light- to dark-gray, friable, arkosic, grain size larger in darker layers; few thin layers of hard, fine-grained sandstone; pronounced cleavage and random jointing; iron oxide stains along joints	180
3. Sandstone, dark purplish-gray, fine-grained, clayey, cleaved and jointed	3

	Thickness Feet
2. Sandstone, gray to greenish-gray, buff, and green, fine-grained, shaly to schistose, arkosic, cleaved and jointed; few 1- to 2-foot-thick layers of indurated, fine- to coarse-grained sandstone consisting almost entirely of quartz; intersected by random milky quartz veins up to 0.5 inch thick	67
1. Covered	155
LOUDOUN FORMATION	
1. Shale, purple, with green elongate spots along partings, slaty, very fissile; little silt; thin layers of milky quartz along bedding; iron oxide stains along shaly partings; silky luster on surfaces; jointed	85
CATOCTIN FORMATION	
10. Metabasalt, greenish-gray to olive-green, weathered, shaly to clayey, cleaved and jointed; manganese stains on cleavage surfaces	60
9. Metabasalt, purple, schistose to clayey, distinctly cleaved along bedding, jointed; few concentrations of porphyroblasts (about 0.1 inch in diameter)	15
8. Metabasalt, greenish-gray to olive-green, weathered, shaly to clayey, cleaved and jointed; manganese stains on cleavage surfaces	20
7. Metabasalt, light-brown to olive-green, similar to lithology above but contains epidosite and seams of serpentine asbestos (fibers about 0.5 inch long)	16
6. Metabasalt, weathered, jointed; manganese stains along joint surfaces; reddish residual clay; epidosite boulders in residuum	50
5. Metabasalt, weathered, brown and olive-green; manganese stains on joint and cleavage surfaces; contains epidosite boulders; alternates with purple slaty layers containing very little epidosite	420
4. Metabasalt, brown to greenish, consolidated and slaty; contains epidosite seams up to 3 feet thick; manganese stains along joint and cleavage surfaces	242
3. Metabasalt, deeply weathered, buff to red; scattered thin, hard, cleaved and jointed, olive-green beds; small epidosite fragments in residuum; largely shaly and friable	1055
2. Metabasalt, greenish-gray to olive-green, weathered, shaly to clayey, cleaved and jointed; manganese stains on cleavage surfaces	35
1. Metabasalt, deeply weathered, reddish, clayey, friable and shaly; contains a few thin epidosite seams	95

Hampton Formation

The Hampton shale was named by Campbell (1899) from Hampton, Carter County, Tennessee. The Hampton overlies the Weverton wherever the latter formation is present in Page County. Well-exposed sections of the Hampton are somewhat rare as the formation is generally covered by talus from the overlying Erwin (Antietam) Formation. A fair exposure of Hampton is present along State Road 629 in the valley of Hollow Run.

In general the Hampton occurs as thin beds of dark greenish siltstone and rusty, fine-grained sandstone. True shaly material is absent in Page County, but lenses of brown, ferruginous quartzite occur locally. King (1950, p. 20) states that the Hampton maintains a rather constant thickness of about 900 feet in the Elkton area. The section along Hollow Run southeast of Cavetown is approximately 450 feet thick.

Erwin (Antietam) Formation

The Erwin was named from Erwin, Unicoi County, Tennessee (Keith, 1903, p. 5). The term Antietam sandstone was used by Keith (1893, p. 68) for exposures along Antietam Creek in Maryland, and King (1950, p. 20) used the term Antietam quartzite for the unit in the Elkton area. The Erwin Formation is well exposed in Page County, especially in the Shenandoah salient where it forms the tops of many high crests and ridges. A number of the ridges stand as cuestas or hogbacks with dip slopes of Erwin extending westward into the valley of the South Fork of the Shenandoah River. The Erwin also holds up the crests of Hershberger Hill, Varner Hill, Piney Hill, and Pine Mountain in the Blue Ridge. North of U. S. Highway 211 the Erwin is present on Kibler Knob and can be traced northward to the Vaughn fault zone near Vaughn. The Erwin is also exposed north of Jeremys Run holding up the high ridge immediately east of Rileyville, Compton, and Overall. The Erwin ridges and slopes are partially covered by talus blocks or colluvium derived from the weathering of the quartzite ledges. These areas of talus or scree have been described by Hack (1960).

King (1950, p. 22-23) divided the formation in the Elkton area into a lower member and an upper member, having about equal thicknesses. In general, the lower part of the Erwin is a massive- to thick-bedded white quartzite consisting of white, well-rounded, well-sorted, quartz grains cemented with silica. The upper part consists of thinner beds of less well cemented quartzite that weathers to rusty, friable blocks. King (1950, p. 21) indicated a thickness of about 800 feet in the Elkton area, but the writer found that thicknesses seldom exceed 450 feet in the central and northern parts of Page County. *Scolithus* tubes are common in the lower units, but less abundant in the upper part of the formation.

Shady Formation

Keith (1903, p. 5) named the Shady limestone from Shady Valley, Johnson County, Tennessee, and King (1950, p. 24) used the name

Tomstown dolomite for the unit in the Elkton area but noted that the latter term may well be discontinued because the Shady and Tomstown are probably the same formation. The Shady overlies the Erwin but is poorly exposed in Page County; it is deeply weathered and covered by a mantle of residual clay and gravel. A recent roadcut along State Road 611 just east of Vaughn indicates what is very likely a contact (Figure 6) between the Shady and Erwin formations. King (1950, p. 24) noted exposures in two localities, one near Fultz Run and one near Crooked Run, southwest of Ingham, and also expressed the opinion that the Shady ". . . is probably present across the entire Elkton area."

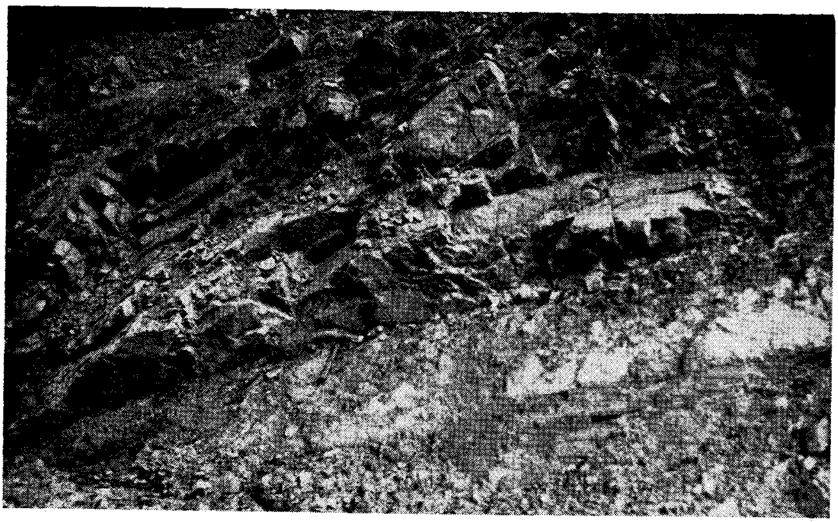

Figure 6. Contact (at hammer) between the Erwin (Antietam) Formation (above) and Shady Formation (below) along State Road 611 near Vaughn. The beds are overturned.

The Shady consists principally of intercalated layers of dolomite and limestone, with dolomite predominant. The color is generally described as blue, with light gray to white also common. Shaly and argillaceous material is present which may account for the thick mantle of residuum. King (1950, p. 25) indicated that the formation is about 1000 feet thick in the Elkton area, which he noted agrees with the estimate of 1000 to 1500 feet for the Shady made by Edmundson (1945, p. 180) in Clarke County. No fossils were found in the Shady in Page County by the writer, although King (1950, p. 25) reported finding a single reefy mass which he suggested may be a cryptozoon.

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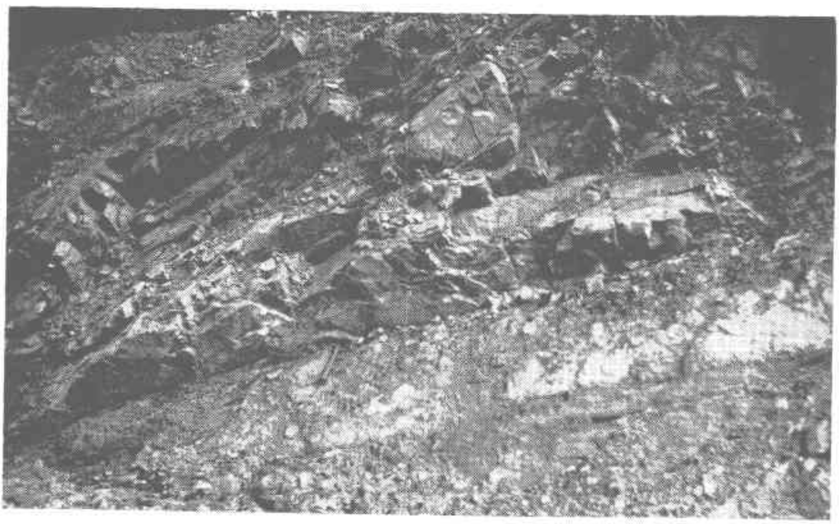

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Rome Formation

The name Rome Formation is used for the rock unit overlying the Shady in Page County to correspond with the usage of Brent (1960, p. 23) in Rockingham County, although King (1950) and Thornton (1953) used the term Waynesboro formation. The name Rome was initiated by Hayes (1891) for exposures at Rome, Georgia. The Rome is exposed in the valley of Crooked Run 0.5 mile north of Comertown, in Steam Hollow south of Ingham, and in a small exposure along U. S. Highway 340 northwest of Marksville. A small exposure of Rome can be seen in the valley of Hollow Run, just east of Cavetown along State Road 629. The Rome crops out in a band about 0.25 mile wide from Kimball P. O. northward to Overall Run, with the best exposures along Dry Run east of Compton and along Overall Run.

The Rome has a varied lithology, with red and greenish shale being the most characteristic; the red shales are usually criteria for recognizing the presence of Rome. Thick beds of dolomite and dolomitic limestone may also be present. King (1950, p. 30-31) cited a section of Rome measured on Crooked Run with an aggregate thickness of 1685 feet with about 400 feet of carbonate rock. An overturned section of Rome along Dry Run east of Compton includes roughly 1000 feet of shale, limestone, and shaly limestone, with dolomitic shale and blue limestone at the top of the section.

Elbrook Formation

Stose (1906, p. 209) named the Elbrook dolomite for outcrops near Elbrook, Franklin County, Pennsylvania. The unit named by Stose was predominantly a limestone, but has been called Elbrook dolomite in Virginia. In Page County the unit consists of both dolomite and limestone and the term Elbrook Formation is preferred. Exposures of Elbrook occur along Crooked Run and along the South Fork of the Shenandoah River near Ingham and along East Hawksbill Creek, southeast of Luray. The contact relationship between the Elbrook and overlying Conococheague is well exposed near the mouth of Crooked Run and on Dry Run northeast of Luray. Good exposures of Elbrook are present in a cut along the Norfolk and Western Railway between Vaughn and Rileyville.

Dolomite is the principal rock type in the Elbrook in Page County, but beds of blue limestone and argillaceous limestone are common. The dolomite is generally light gray, fine grained, and variable in thickness of beds. Limestone is blue to blue gray, and the argillaceous beds weather to a soft, yellow, crumbly shale that gives the rock surface a yellowish coating. Chert and cherty bands produce a ribbed appearance on the weathered surfaces. King (1950, p. 32) estimated the thickness of the Elbrook to be about 3000 feet in the valley of Crooked Run. In the belt of Elbrook trending northeastward from the vicinity of Luray to Rileyville, the thickness is estimated to be at least 3500 feet, although the close folding of the section makes accurate measurement difficult. Cryptozoon "heads" were found (King, 1950, p. 32) near the base of the Elbrook in the valley of Crooked Run. No other fossils have been reported from the Elbrook in Page County nor were any found by the writer. Butts (1940, p. 78-79) reported that at other localities in Virginia, the lower part of the formation has yielded fossils of Middle Cambrian age, and the upper part may be of Late Cambrian age.

Conococheague Formation

The Conococheague limestone was named by Stose (1908, p. 701) from outcrops along Conococheague Creek in Franklin County, Pennsylvania. The unit in this report is designated Conococheague Formation because additional lithologies are present: dolomite, limestone, sandstone, siliceous oolites, and chert masses. The Conoco-

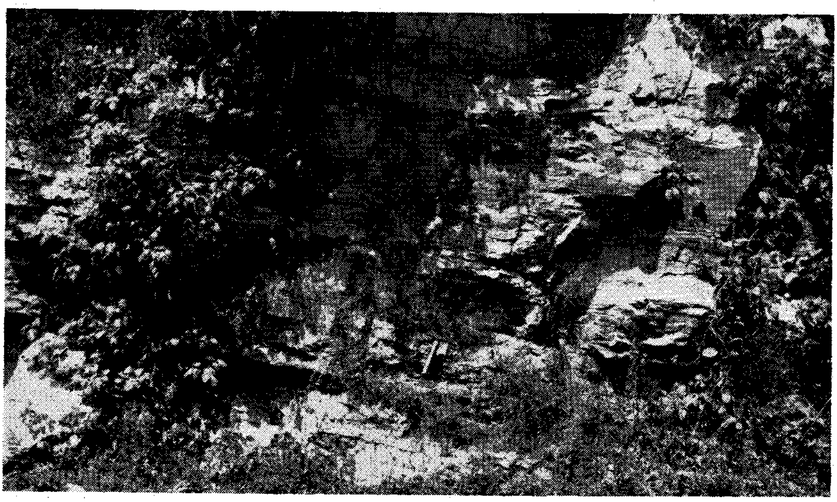

Figure 7. Exposure of Conococheague Formation along U. S. Highway 340, 0.25 mile south of Luray. The position of a bed of white quartzose sandstone is indicated by the hammer. Intraformational conglomerate is also present in the Conococheague at this locality.

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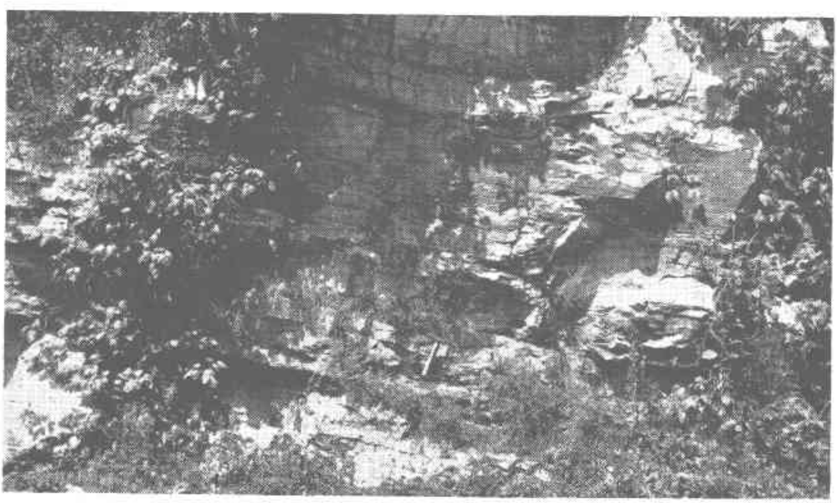


Figure 7. Exposure of Conococheague Formation along U. S. Highway 340, 0.25 mile south of Luray. The position of a bed of white quartzose sandstone is indicated by the hammer. Intraformational conglomerate is also present in the Conococheague at this locality.

cheague overlies the Elbrook Formation in Page County, and excellent exposures are present east of Grove Hill along the Norfolk and Western Railway, along Hawksbill Creek south of Luray (Figure 7), and in the valleys of Dry Run (northeast of Luray), Pass Run, Jeremys Run, Dry Run (east of Compton), and Overall Run. The variation in width of the belt of Conococheague from Grove Hill northeastward to Overall Run is caused by structural changes.

The Conococheague in Page County consists generally of dense, light blue-gray limestone, thin beds of dolomite, and lens-like layers of medium-grained sandstone (Figure 7). Thin layers of intraformational conglomerate are locally present, and such a layer can be seen along U. S. Highway 340 in the south part of Luray. One common characteristic of the Conococheague noted in the central and northern parts of Page County is the ash-gray schistose appearance of the weathered surface. This condition appears to be evidence of flowage of the limestone units in tight folds, and this effect has also been noted by King (1950, p. 53). It was not possible to ascertain the thickness of the Conococheague in Page County because of folding and discontinuous exposures. However, in the Luray area the formation appears to be at least 2500 feet thick.

No fossils were seen in the Conococheague Formation in Page County. Brent (1960, p. 26) reported cryptozoon in Rockingham County, and Butts (1940, p. 89-90) reported that elsewhere in Virginia Late Cambrian fossils are present.

ORDOVICIAN SYSTEM

Chepultepec Formation

The Chepultepec limestone was named by Ulrich (1911, p. 638) from outcrops near Chepultepec (now Allgood), Blount County, Alabama. In Rockingham County, Brent (1960, p. 26-29) mapped the Chepultepec as a separate unit. King (1950) and Thornton (1953) included the Chepultepec as a lower unit or member of the Beekmantown Formation. In Page County the aphanitic, dark-gray limestone below the Beekmantown dolomite is designated the Chepultepec Formation and is mapped as a separate unit to conform with usage in Rockingham County. In general, the Chepultepec crops out as a relatively narrow band from south of Luray northeastward to Overall Run, and the greatest width of exposure is in the vicinity of Luray. A small quarry was developed in the Chepultepec in the valley of Dry Run (Plate 1, No. 6), and the rock was burned for lime.

The Chepultepec is generally a dense, blue-gray limestone, with dolomite in thin layers near the top. Irregularly layered black chert is common. In the Luray area the unit appears to be about 600 feet thick; it thins to the northeast. Edmundson (1945, p. 15, 143) estimated the thickness at 300 to 500 feet, and from a section 0.3 mile east of Rileyville, reported a thickness of approximately 321 feet. Fossils are rather common in the Chepultepec. The characteristic fauna is composed of cephalopods and gastropods. Brent (1960, p. 29) noted that species of *Dakeoceras* and *Levisoceras* are dominant among the cephalopods and *Helicotoma* among the gastropods.

Beekmantown Formation

The Beekmantown Formation was proposed by Clarke and Schuchert (1899, p. 874-878) for rock units known as Calciferous Sandrock in Beekmantown Township, Clinton County, New York. In Page County the term is used for the unit composed predominantly of dolomite that overlies the distinctive, fossiliferous, relatively pure limestone of the Chepultepec and underlies the pure, fine-grained limestones of the New Market. The Beekmantown can be traced in almost continuous outcrop from Shenandoah on the South Fork of the Shenandoah River northeastward to Overall Run. Excellent exposures can be seen at Grove Hill, in the vicinity of Alma, at Leaksville, between Hamburg and Luray, and at many places along U. S. Highway 340 between Luray and Overall. Luray Caverns are in the Beekmantown Formation.

In Page County the Beekmantown consists essentially of gray, fine- to medium-grained dolomite with a considerable amount of limestone. The dolomite is generally well bedded, with beds commonly ranging from 1 to 3 feet in thickness. The beds weather to a very rough, coarse surface. Black, fine-grained chert is generally present in the dolomite, as are layers of intraformational breccia (Figure 8). Discontinuous beds of limestone are common and the upper part of the Beekmantown contains more limestone than the middle and lower parts of the unit. Limestone and dolomite may occur side by side in the same bed with a sharp lateral contact separating the two, as can be seen at the west abutment location of the dam on the South Fork of the Shenandoah at the old Ruffner Ferry site (Figure 9). Much of the limestone is compact, sublithographic, blue or dove gray, fossiliferous, and resembles the overlying New Market Limestone. Edmundson (1945, p. 147-149) described sections of the Beekmantown at Rileyville and near Shenandoah, and estimated the thickness near Rileyville to be 3360 feet. King (1950, p. 35) estimated the thickness of the Beekmantown in the Shenandoah-Grove Hill area to be about 3000 feet.

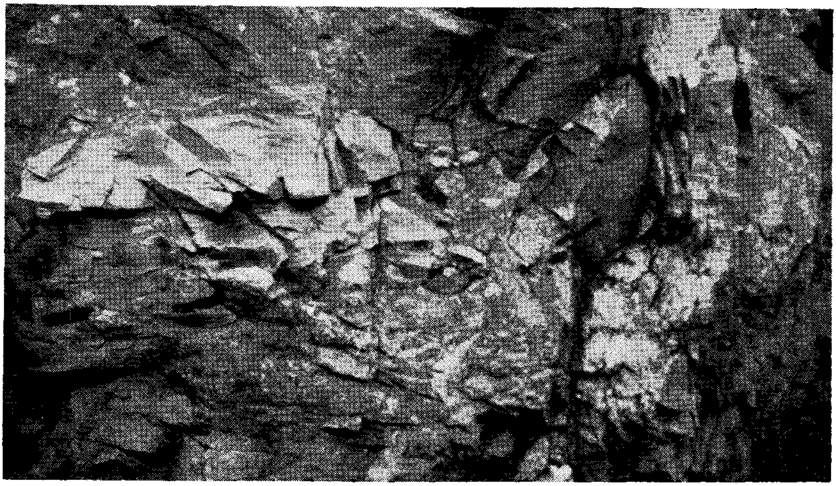


Figure 8. Intraformational breccia containing fragments of black chert in the Beekmantown Formation along U. S. Highway 340, 1.5 miles north of Luray.

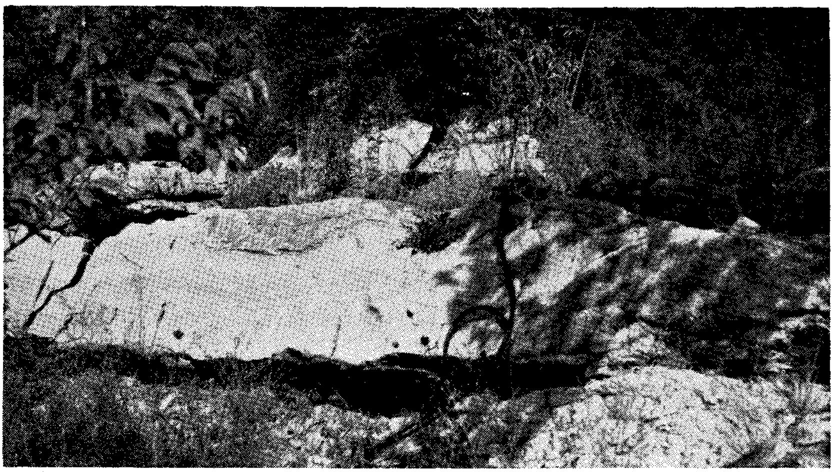
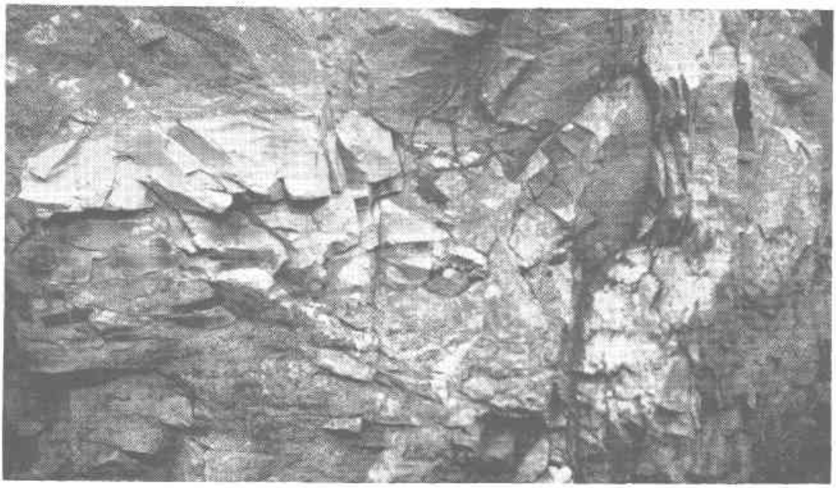


Figure 9. Beekmantown Formation with sharp lateral contact between fine-grained limestone (white, to left of cable) and dolomite (darker, to right of cable and above limestone) at the end of State Road 654 near the old Ruffner Ferry site.

The Beekmantown is somewhat more fossiliferous than any of the older formations in Page County. The lower part of the formation contains *Lecanospira*, *Roubidouxia*, and *Hormotoma*, and the upper part



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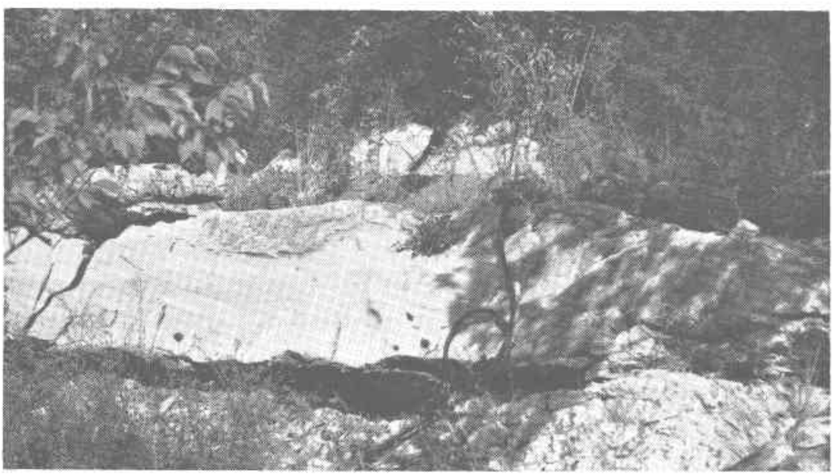

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The Beekmantown is somewhat more fossiliferous than any of the older formations in Page County. The lower part of the formation contains *Lecanospira*, *Roubidouxia*, and *Hormotoma*, and the upper part contains species of *Ceratopea* and *Lophonema*. Just north of the bridge over the South Fork of the Shenandoah at Grove Hill and in the cut on the east side of the road, excellently preserved gastropods can be seen.

The top of the Beekmantown is characterized by an unconformity that is evidenced by a karst-type erosion surface in the upper part of the unit which is filled with conglomeratic beds of the overlying New Market. Variations in thickness of the New Market are also evident, and there are some areas where the presence of the New Market is in doubt.

New Market Limestone

Cooper and Cooper (1946) named the New Market limestone for the blue to dove-gray, pure, fine-grained limestones exposed near New Market, Shenandoah County, Virginia. The unit is essentially the same as the Mosheim recognized by Butts (1940) and Edmundson (1945). Excellent exposures of the New Market can be seen overlying the Beekmantown 0.5 mile west of Leaksville and in the valley of Hawksbill Creek about 1 mile above the point where that stream enters the South Fork of the Shenandoah. Because of the irregular upper surface of the Beekmantown, the continuity of the New Market is broken by distances of several hundred feet along the strike where the unit is absent.

The New Market consists mainly of dark-blue to dove-gray, pure limestone. The weathered surface acquires a white color with a faint bluish tinge. The lower part of the New Market is generally characterized by a conglomeratic rubble of blocks and fragments, in many places quite angular, of limestone and dolomite from the underlying Beekmantown. One of the best exposures of the rubble bed is present in the valley of the small stream to the north of the bridge on State Road 646, about 0.5 mile west of Leaksville. Cooper and Cooper (1946, p. 98, Geologic Section 27) described a section at or near this locality. Thickness of the New Market ranges from 0 to over 250 feet, with a general thickness of not over 50 feet. Edmundson (1945, p. 138-142) reported sections (designated in his report as Mosheim limestone) of New Market ranging from 32 to 55 feet in thickness. Fossils are common in the New Market but are difficult to identify. The most prevalent is the coral *Tetradium syringoparoides*, and cross sections of brachiopods and gastropods can be readily seen on weathered surfaces.

Lincolnshire Formation

Cooper and Prouty (1943, p. 863) named the Lincolnshire limestone from a stream in Tazewell County, Virginia. The term was redefined and extended to the northern Virginia area by Cooper and Cooper (1946, p. 75), and in this report it is used in the sense of the redefinition and designated as the Lincolnshire Formation. The unit is essentially the same as the Lenoir used by Butts (1940) and Edmundson (1945) for rocks in northern Virginia. The distribution of the Lincolnshire in Page County is essentially the same as that of the New Market, and on the geologic map (Plate 1) the two are shown as a single map unit. One of the better exposures of Lincolnshire can be seen near the junction of Hawksbill Creek and Pass Run along the valley of Hawksbill Creek. Another good exposure is located east of Bixler Bridge on the northwest side of the South Fork of the Shenandoah River.

The characteristic lithology of the Lincolnshire is dark bluish-gray to black, medium-grained limestone with layers of black chert. A definite nodular structure is present in many places in the Lincolnshire, and in some places the unit appears to be made up of masses of fragmental fossil material. Lenses of fine-grained, blue to dove-gray limestone, much like the underlying New Market, are common and the contact between the two units is generally poorly defined. In Page County the thickness of the Lincolnshire ranges from 50 to 135 feet. Edmundson (1945, p. 138-144) described measured sections of the Lincolnshire (Lenoir) near Compton, Rileyville, Hamburg, and at Bixler Bridge. The formation is fossiliferous, although whole recognizable forms are scarce. Brent (1960, p. 35) noted that *Dinorthis atavoides* and species of *Sowerbyella* are useful in identifying the formation.

Edinburg Formation

The Edinburg Formation was named by Cooper and Cooper (1946, p. 78) from Edinburg, Shenandoah County, Virginia. In Page County, the Edinburg is equivalent to the Chambersburg and Athens formations recognized by Edmundson (1945, p. 135-136). In Rockingham County, Brent (1960, p. 36) noted that ". . . the Edinburg consists of a basal member, the Botetourt limestone, and two facies, the Liberty Hall and the Lantz Mills." Only the Liberty Hall facies has been recognized by the writer in Page County, and this was also noted by Cooper and Cooper (1946, p. 78). The Edinburg is exposed in an almost continuous outcrop from Shenandoah northeastward to the Page-Warren county boundary. Small outcrop areas are covered by gravels and alluvium between Shenandoah and the vicinity of Leaksville, and in small areas along the South Fork of the Shenandoah River. One of the best exposures of the Edinburg is in the area along State Road 675 south of Bixler Bridge.

The Edinburg Formation in Page County consists essentially of thick beds of dense black to gray limestone grading upward into thinner limestone layers with shale partings, and near the top black shale predominates. Some black shale occurs in the lower part of the formation, but the lower shales appear lenticular and thin out along the strike. The limestone units are generally dense, black and slabby. Quarrying operations are facilitated by the presence of the shale partings, and limestone slabs have been used as local building stone, as in the case of the Methodist Church in Luray.

Local deformation of the Edinburg (Figures 10, 11) renders precise thickness measurements difficult, however, measurements made along the belt of Edinburg from Bixler Bridge northeastward to the Warren County boundary indicate a thickness of not over 1000 feet. Fossils appear confined to the shaly beds, and graptolites, *Nemagraptus gracilis* and species of *Dicellograptus*, *Climacograptus*, and *Diplograptus*, are common. Brent (1960, p. 39) and Cooper and Cooper (1946, p. 78-86) summarized the fauna of the Edinburg in detail.

Figure 10. Small fold with well-developed vertical slaty cleavage in the Edinburg Formation along State Road 684 near Bixler Bridge.

Martinsburg Formation

The Martinsburg shale was named by Geiger and Keith (1891, p. 161) for Martinsburg, West Virginia. In Page County the unit is called Martinsburg Formation because of its heterogeneous character. It is

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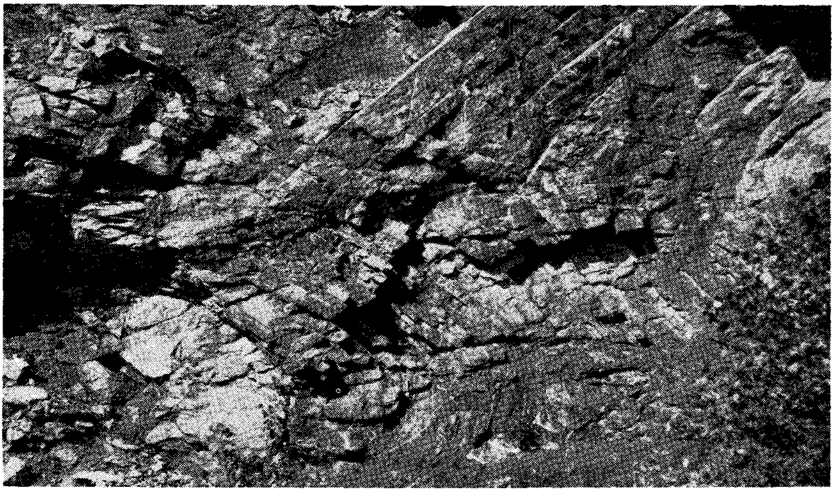
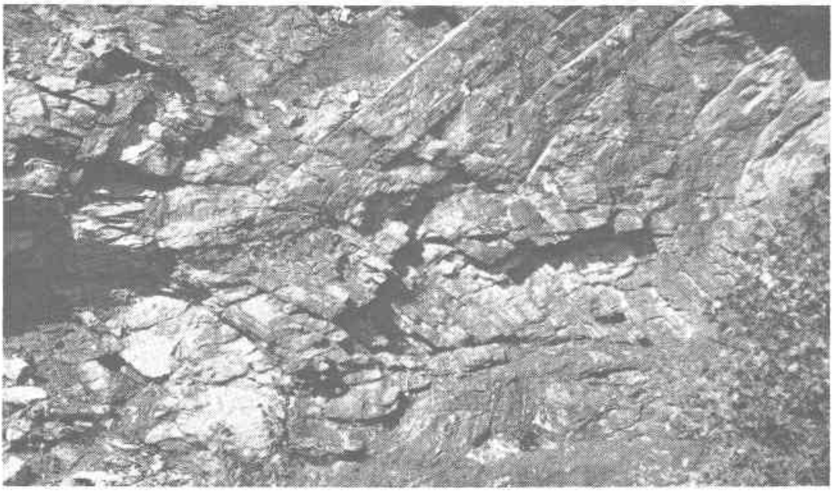


Figure 11. Recumbent fold in Edinburg limestone in the Woodward quarry along State Road 646 near its junction with U. S. Highway 211.

present in the western part of the county in an outcrop belt from 2 to 4 miles wide. The unit underlies Massanutten Mountain in a large synclinal structure and also forms the crest of Massanutten Mountain-Kerns Mountain at New Market Gap where erosion has removed the younger formations.

The Martinsburg consists predominantly of shale, but layers of calcareous shale and thin limestone beds are present near the base; siltstone and sandstone occur at irregular intervals throughout the unit. The beds in the Martinsburg are generally thin, but massive siltstone layers are common. Along the east slope of Massanutten Mountain the unit is well jointed and is closely folded. Ripple marks and ill-defined mud cracks are locally present in the shaly siltstones. Because of close and isoclinal folding along the east margin of the formation, accurate thickness measurements cannot be made. Spencer (1897, p. 9) estimated a thickness of about 2800 feet. Butts (1940, p. 209) suggested a maximum thickness of 4000 feet in the Massanutten Mountain area, and Thornton (1953) estimated a thickness in excess of 1000 feet. The writer is of the opinion that a minimum thickness of 3000 feet of Martinsburg is present in Page County.

The Martinsburg is divided into three parts on the basis of paleontology: Trenton, Eden, and Maysville. Brent (1960, p. 41) noted that "*Diplograptus amplexicaulis* and *Sinuites cancellatus* may be used to distinguish the lowest zone (Trenton), and species of *Cryptolithus*



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SILURIAN SYSTEM

Massanutten Sandstone

In Page County the term Massanutten Sandstone (Geiger and Keith, 1891, p. 156-163) is used for the massive sandstone beds, overlying the Martinsburg and underlying rocks of the Cayuga Group, that hold up the ridges of Massanutten Mountain. The rock unit named "Massanutten" by Geiger and Keith was later mapped by Keith (1894b) as Antietam. Butts (1940, p. 202, 233, 237) considered that the Massanutten Sandstone corresponded to the Tuscarora-Clinch-Clinton formations of the Appalachians. Thus the lower part of the Massanutten Sandstone is a Tuscarora-Clinch equivalent and the upper part correlates with the Clinton, but the exact division is not known.

Thornton (1953, p. 66) noted the presence of a sandstone between the Martinsburg and the Massanutten, and considered its age as Late Ordovician or Early Silurian. In Massanutten Mountain the Ordovician Oswego Sandstone and Juniata Formation (Butts, 1940, p. 219-229) are missing, and the sandstone may represent an equivalent of these units. In this report, the sandstone is grouped with the Massanutten Sandstone.

The Massanutten consists of white, silica-cemented sandstone with layers of quartz-pebble conglomerate in discontinuous lenses at the base. Lenses of siltstone and shale are locally present, as is pronounced cross-bedding in the sandstones. Thornton (1953, p. 73) measured a section at Burners Gap and indicated a thickness of 700 feet, and Brent (1960, p. 46) reported the thickness to be 646 feet at Runkles Gap. No fossils were found by the writer in the Massanutten Sandstone in Page County, although a few specimens of *Arthrophycus alleghaniensis* and *Scolithus verticalis* have been reported by other workers.

Cayuga Group

Clarke and Schuchert (1899) named the Cayuga Group from Cayuga County, New York. Butts (1940) noted that in Virginia the group includes in ascending order the McKenzie, Bloomsburg, Wills Creek, and Tonoloway formations. The Bloomsburg red shales, siltstones, and sandstones possibly include in part the McKenzie and Wills

Creek units in Massanutten Mountain. The Tonoloway shaly limestone overlies the Bloomsburg, and both it and the Bloomsburg are shown on Plate 1 as one unit. The rocks of the Cayuga Group crop out in Massanutten Mountain along the western margin of Page County, and are shown on Plate 1 in the areas mapped by Thornton and Edmundson. There are good exposures along Roaring Run in the Catherine Furnace area and along State Road 671 where it descends into Duncan Hollow west of the crest of Massanutten Mountain.

The Bloomsburg Formation is composed of red shales, red siltstones, and reddish to buff sandstones. Because of the poor resistance to weathering, outcrops of the Bloomsburg are generally covered, and thicknesses are difficult to determine. Butts (1940, p. 255) suggested a thickness for the Bloomsburg of 340 feet in the Harshberger Gap-Runkles Gap area of Rockingham County, about 5 miles southwest of the Page County boundary.

The Tonoloway Formation overlies the Bloomsburg as a thin, fine-grained, gray, shaly limestone, approximately 35 to 50 feet thick. Mud cracks are generally present, although exposures of the Tonoloway are uncommon. Thornton (1953) noted approximately 80 feet of limestone in the Catherine Furnace area, and indicated that this unit overlies 35 feet of Tonoloway (?) limestone. These limestone units are best exposed along National Forest Road 274 about 5 miles northeast of New Market Gap and along Pitt Spring Run west of its confluence with Cub Run near Catherine Furnace. Thornton (1953) indicated a Late Silurian age for the Tonoloway and a possible Late Silurian and Early Devonian age for the overlying limestone.

DEVONIAN SYSTEM

Devonian Undivided

On the geologic map (Plate 1) the Paleozoic units above, and younger than, the Cayuga Group are indicated as undivided Devonian. In this unit are included Thornton's (1953) post-Tonoloway limestone, the Needmore Formation, and the Millboro Shale. These units crop out in the synclinal valleys of Massanutten Mountain along the western margin of Page County. Exposures are present in the valleys of Cub Run and Pitt Spring Run west of Catherine Furnace and in Crisman Hollow and Duncan Hollow on the headwaters of Passage Creek west of Burners Gap.

The post-Tonoloway limestone consists of approximately 80 feet of fine- to medium-grained, dove- to dark-gray limestone, coarse-grained limestone, and minor shaly and claystone layers in a section measured along Pitt Spring Run (Thornton, 1953). Some black chert and fragments of brachiopods and crinoid stems were reported (Thornton, 1953, p. 53).

Overlying the post-Tonoloway limestones is a section of dark-green to olive-gray, subfissile shale that weathers to a yellowish, chalky rock. This unit is generally designated the Needmore Formation; and good exposures are rare. The thickness probably does not exceed 100 feet. Brent (1960, p. 52) listed some of the fossils that have been identified and suggested that the Needmore is a partial equivalent to the Onondaga Formation. A black fissile shale of undetermined thickness, designated the Millboro Shale (Butts, 1940), overlies the Needmore. Fossils reported by Brent (1960) and Butts (1940) indicate a correlation of the lower part of the Millboro with the Marcellus, and the upper part with rocks of Naples age.

TRIASSIC SYSTEM

A dike of mafic igneous rock, approximately 1 mile long and of indeterminate width, cuts the Catoctin and Loudoun formations at the east end of Chapman Mountain. Residual boulders of the dike rock can be seen on the surface, and a discontinuous outcrop can be traced for short distances. The finely crystalline, almost aphanitic, black rock is composed essentially of augite, labradorite, and minor olivine and magnetite. Secondary chlorite, serpentine, and biotite are also present, and the rock can be classed as a diabase. The intrusive rock noted above, as well as those mentioned by Brent (1960, p. 56-60) in Rockingham County, and by Butts (1940, p. 435) in other parts of the Valley of Virginia, correlate in texture and composition with the Triassic intrusives of the Virginia Piedmont. It may be that the dike is also Triassic in age.

QUATERNARY SYSTEM

Deposits of Quaternary age in Page County include terrace gravels of probable Pleistocene age and the more recent river flood-plain deposits. The most complete study of the Cenozoic deposits in the area is that of King (1949; 1950, p. 52-63). Plates 1 and 6 of King's report (1950) on the Elkton area illustrate the distribution of residuum resulting from the decay and weathering of the rocks in the area, the several gravel units, the talus deposits on the flanks and foothills of the mountains, and the river flood-plain deposits.

The geologic map (Plate 1) shows all of the terrace gravels as a unit and the more recent river flood-plain deposits as a younger unit. The gravel deposits constitute the most extensive formation in Page County. For the most part the gravels are located east of the South Fork of the Shenandoah River and extend from Rockingham County northeastward to the vicinity of Big Spring Church, about 4.5 miles northeast of Luray. The gravels also constitute many of the large alluvial fans that emerge from valleys on the northwest side of the Blue Ridge. The oldest gravel (King, 1950, p. 57) is reported at an elevation of 1350 feet; lower and next younger gravels occur at elevations as high as 1200 feet. Intermediate gravels range in elevation from 1000 to 900 feet, and the youngest gravels occur from river level to 900 feet in elevation. Gravel thicknesses range from a thin veneer of less than 25 feet to as much as 260 feet (King, 1950, p. 59). For the most part the gravels consist of rudely stratified pebbles, cobbles, and boulders in a sandy clay matrix. Gravels along the west front of the Blue Ridge are mostly quartzite from the Erwin (Antietam) Formation (Figures 12, 13) with minor amounts of Catoctin greenstone. The gravels west of the South Fork of the Shenandoah River in the Shenandoah-Alma area (Figure 14) contain materials derived from the Massanutten Sandstone.

The river flood-plain deposits, or alluvium, occupy small areas along the present course of the South Fork of the Shenandoah River

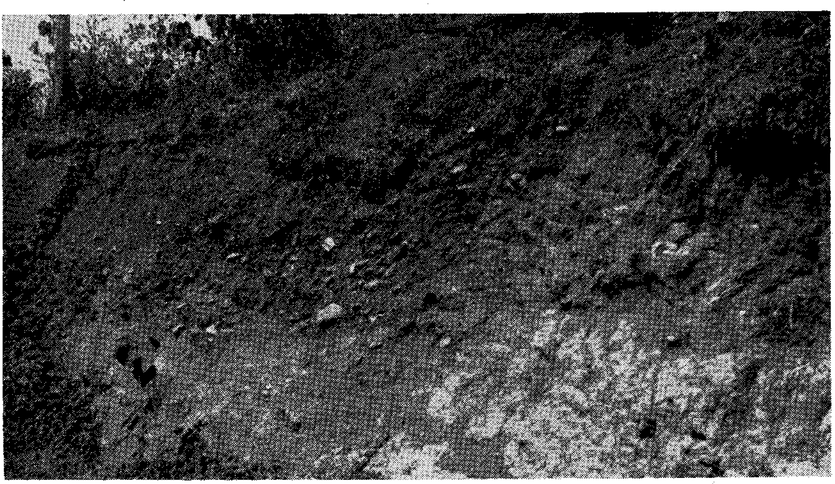

Figure 12. Quaternary gravel overlying residual clay formed by weathering of the Elbrook Formation along State Road 640, 2 miles southeast of Luray.

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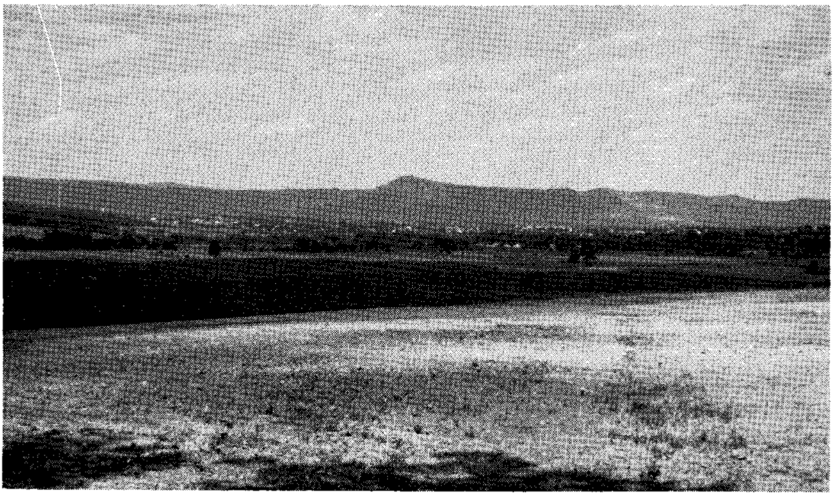


Figure 13. Quaternary gravel veneered surface in foreground, town of Luray in distance, and Massanutten Mountain in background. View from village of Stony Man along State Road 640.

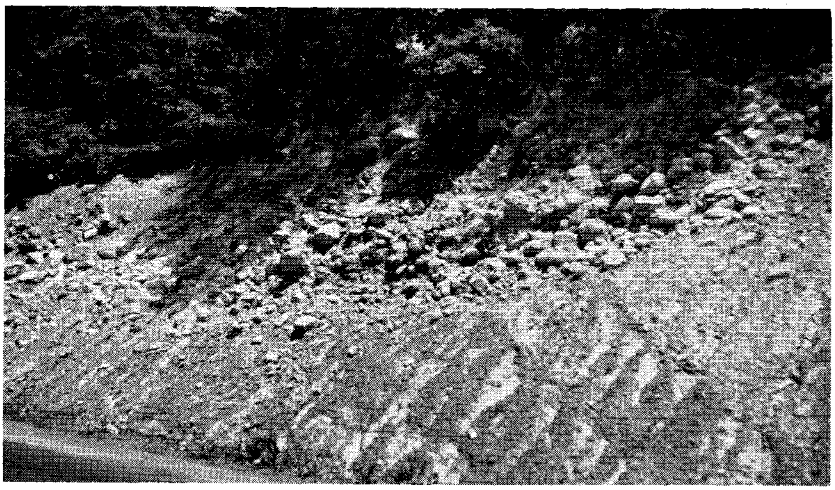
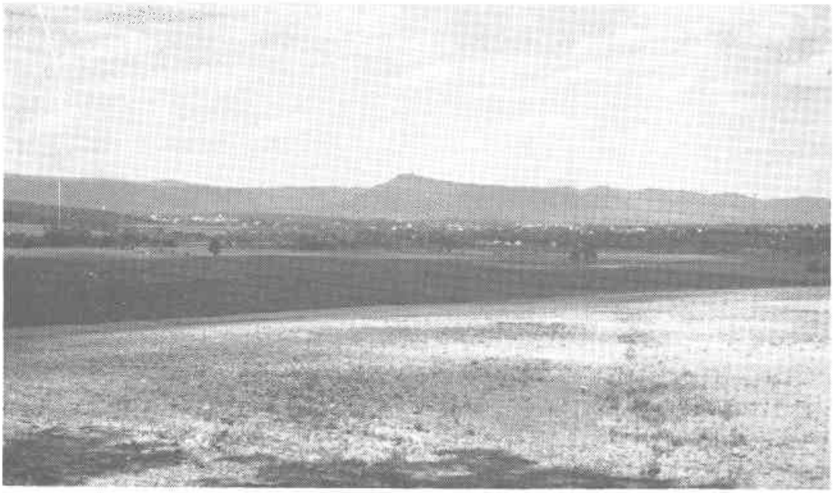


Figure 14. Quaternary gravel in an old eroded channel on Martinsburg Formation along State Road 615 near Battle Creek.

and in the valleys of the larger tributary streams such as Hawksbill Creek, Dry Run, Pass Run, and Jeremys Run. The alluvium consists of gravel, sand, and silt, and appears for the most part to be reworked



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and in the valleys of the larger tributary streams such as Hawksbill Creek, Dry Run, Pass Run, and Jeremys Run. The alluvium consists of gravel, sand, and silt, and appears for the most part to be reworked older terrace material. Thickness of the alluvium along the South Fork and the larger tributaries appears to be less than 10 feet in most places.

Mention should be made of the extensive unconsolidated accumulation of colluvium or talus and scree along the slopes of the Blue Ridge and also present on the flanks of the Massanutten Mountain ridges. Most of the talus is on relatively steep slopes (20 degrees or more), and supports no vegetation other than lichen. Blocks of talus or scree are angular; some are more than 10 feet on a side, with much of the block material from 1 to 3 feet on a side. King (1950, Plate 1) mapped talus fields in the Blue Ridge part of the Elkton area, and Hack (1960, 1965) has made an excellent study of the distribution and origin of the talus. Hack (1965, p. 32) cited evidence that the talus or scree is presently forming in the Shenandoah Valley area and that it is constantly moving downslope; therefore, periglacial climates are not necessary for talus formation although an intensely cold climate would favor the production of such material.

Also considered as Quaternary (Recent) deposits are the tufa terraces or dams formed on several of the streams in the Shenandoah Valley. Tufa, or travertine, is chemically deposited and is composed of calcium carbonate. Streams carrying high concentrations of calcium carbonate in solution may deposit tufa as the water is aerated by riffles and small waterfalls and loses carbon dioxide. The tufa observed in several of the streams is brown to buff, porous, and punky. The lower part of Mill Creek, especially that part downstream from Hamburg, contains the greatest accumulations observed.

STRUCTURE

Page County contains three major northeastward-trending structural features, each of which consists of several subsidiary structural elements. From southeast to northwest the major features are: the west margin of the Blue Ridge-Catoctin Mountain anticlinorium (King, 1950, p. 7); the strongly folded and faulted Cambrian and Ordovician rocks in the valley of the South Fork of the Shenandoah River which form what is essentially a nappe structure; and part of the Massanutten Mountain synclinal complex that involves rocks as young as Devonian.

BLUE RIDGE-CATOCTIN MOUNTAIN ANTICLINORIUM

The eastern part of Page County is underlain by Precambrian and Cambrian rocks that form the western margin of the Blue Ridge-

Catoctin Mountain anticlinorium, the axis of which lies to the east of the Blue Ridge crest. Rocks of the anticlinorium exposed in Page County include the Pedlar, Swift Run, Catoctin, Loudoun, Weverton, Hampton, and Erwin (Antietam) formations, all of which show the effects of deformation.

The northwesterly projection of Precambrian and Cambrian rocks, almost to the South Fork of the Shenandoah River, in the southeast part of Page County (Plate 1) has been described as the Shenandoah salient (King, 1950, p. 42-43). In the core of the salient is the Pedlar granodiorite gneiss, and the younger units generally form a folded, outward-dipping rim on the north, northwest, and west sides. The eastern part of the salient is predominantly Catoctin greenstone with capping rocks of Weverton on the higher elevations. The Catoctin is not present above the Pedlar in the Dovel, Lucas, and Cubbage hollows area. A series of open folds, plunging outward and away from the core of the salient, exist in the Cambrian rocks, and the axial traces of several of the folds are shown on Plate 1. Within the core of the salient are two broad domes that are represented by the two inliers of Pedlar: the northern one in Dovel, Lucas, and Cubbage hollows and the southern one in Weaver Hollow. The southern inlier is cut off on its northeast side by the Harris Cove fault that strikes northwestward and is downthrown to the northeast. The fault surface appears to be nearly vertical and it is probably a normal fault. The fault appears to die out in the Weverton northwest of Devils Tanyard, and to the southeast it passes through a shallow gap between Bearfence and Lewis mountains at the crest of the Blue Ridge and ends in the Pedlar in Greene County.

Another normal fault that trends northwestward and is downthrown to the northeast passes through Milam Gap and appears to be restricted to the Catoctin in both Page and Madison counties. Two small normal faults, both with northwesterly trends and downthrown to the southwest, are located in Allen Hollow, just southwest of Meadows School. Plate 1 shows two thrust faults with northerly trends and easterly dips crossing Naked Creek into Rockingham County, and a northward-trending thrust fault with easterly dip lies entirely within the Weverton Formation along the west margin of Chapman Mountain.

In relation to the structure of the main anticlinorium to the east and the structures in the valley of the South Fork of the Shenandoah River and Massanutten Mountain to the west, the Shenandoah salient appears to have developed as a rise or culmination that formed a flattened bench or structural terrace. King (1950, p. 42-43, Figure 13) analyzed the structure of this area in greater detail.

Northeast of the Shenandoah salient, the rocks of Page Valley are flexed into an arc convex towards the Blue Ridge. Although the eastern part of this arc is part of the western margin of the anticlinorium, a veneer of Cenozoic gravels covers much of the bedrock, and the rocks are cut by the Stanley fault, which is the major structural feature in the area. The Stanley fault has its southwest terminus in the vicinity of Grove Hill, follows a northeasterly trend around the northwest extremity of the Shenandoah salient, continues about due east through Stanley, and just east of Marksville it changes trend and follows the general strike of the Cambrian rocks north-northeastward through the east end of Piney Hill where it passes in an east-northeasterly direction into Rappahannock County through Thornton Gap. King (1950, p. 43, 47) indicated that movement along the Stanley fault was complex, although the apparent movement indicated a down-dropping of the rocks to the west along a more or less vertical fault surface as is evidenced by the older rocks now present on the east side of the fault. The rather unusual S-shaped trace of the fault renders the mechanics of a great amount of strike-slip movement difficult to resolve. However, some strike-slip movement must have occurred because the regional pattern indicates a possible westward movement of the Shenandoah salient mass. There is also a possibility, as noted by King (1950, p. 47), that the west and north side of the fault could be the upthrown side and that:

> "By this interpretation, the rocks south of the fault, on the margin of the Shenandoah Salient, would form the upper flank of the great anticline, and the syncline would be beneath the surface. North of the fault, the syncline would lie at the surface, and the overlying anticline would have been removed by erosion. The north side of the fault would be upthrown about 7,500 feet with respect to the south side. Moreover, extensive rotational movements would be necessary, as the fault terminates about 4 miles to the southwest of this section."

From evidence northeast of the Shenandoah salient, the most reasonable explanation of movement along the Stanley fault is that of upthrown movement of the south and east block. In the valley of Chub Run east of Marksville, and along the southwest crest of Hoak Hill, cemented breccia in the Erwin (Antietam) appears to be of fault origin. On the east flank of Hoak Hill the fault is wholly within the Pedlar Formation for a short distance which obviates the possibility of any great upward movement of the west block. On the northeast extremity of the fault near Rattleburg School the presence of a small mass of Swift Run and Catoctin on the southeast side of the fault also makes it unlikely that this side has moved downward. Between Morning Star and Thornton Gap the Stanley fault separates the Pedlar from the Catoctin, and such a relationship is more reasonably explained by the upward movement of the southeast (Pedlar) block.

West of the Stanley fault Hershberger Hill-Hoak Hill and Piney Hill occur in the westernmost margin of the anticlinorium. Cambrian beds are overturned to the southeast and have dips of 30 to 80 degrees. To the west beyond Luray, the beds are overturned to the northwest, having steep southeasterly dips, indicating the large-scale nature of the anticlinal fold or nappe that makes up the central part of Page Valley.

North of the Stanley fault and north of Dry Run, the rock units trend to the northwest through Kimball to the vicinity of Vaughn where they revert to a north-northeasterly trend. North of Vaughn the valley becomes increasingly narrower, and the more resistant Catoctin and overlying Cambrian rocks hold up the higher elevations. The Knob Mountain-Neighbor Mountain area is a synclinal structure on the upper limb of a large recumbent anticline. The Pedlar Formation in the core does not crop out in the northern part of Page County but is exposed at the surface east of Bentonville in Brown Hollow a few miles north of the Page County boundary. The rocks have moved westward over the rocks of the valley along a zone of thrust faults, designated in this report as the Vaughn fault zone, as evidenced by the extensive brecciated zone of Erwin (Antietam) in the valley of Jeremys Run east of Vaughn. The major fault in the zone appears to extend from just north of Pass Run in a northerly direction through Broadus Mountain to the Page-Warren county boundary about 1 mile east of Overall. The main fault and the several subsidiary faults are of a rotational type with the pivot at the south end. Displacement in the Three Sisters area appears to be minor, but to the north the Weverton is in contact with the Rome, and the Hampton, Erwin (Antietam), and Shady are absent. North of Jeremys Run the main fault develops into five thrusts and the most complex structure is present in the area southeast of Compton where an overturned synclinal wedge of Cambrian and Ordovician rock has been preserved. In the Compton-Overall area the Shady Formation is absent, and along Overall Run the Rome is thrust onto the Conococheague. Northeast of the Page-Warren county boundary about 4.3 miles northeast of Bentonville (Warren County), near the confluence of Gooney Run with the South Fork of the Shenandoah River, the Pedlar is faulted against the Beekmantown (Figure 15), which indicates the increased magnitude of fault displacement northward.

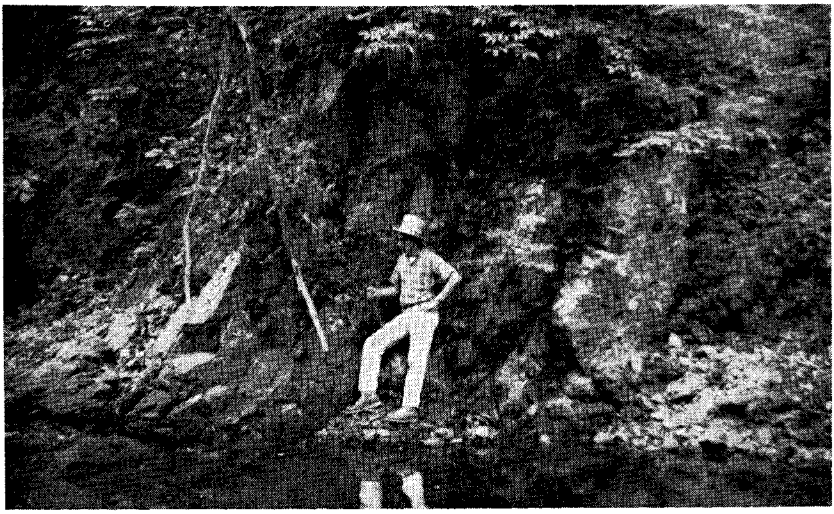
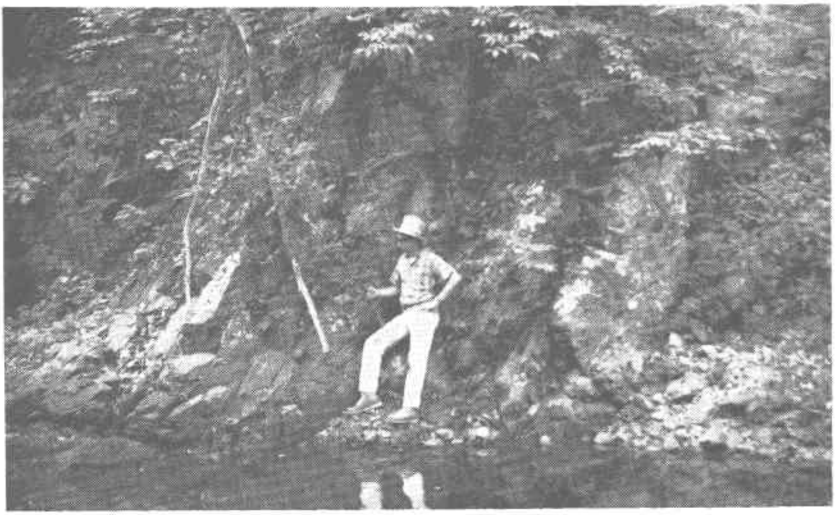


Figure 15. Thrust fault in the Vaughn fault zone beside Gooney Run (Warren County) near its confluence with the South Fork of the Shenandoah River. Assistant is standing at the contact between the Beekmantown Formation on the left and the Pedlar Formation on the right.

VALLEY OF THE SOUTH FORK OF THE SHENANDOAH RIVER

West of the overturned and faulted western margin of the Blue Ridge-Catoctin Mountain anticlinorium and east of the Massanutten Mountain structural complex, the Cambrian and Ordovician rocks underlie the central valley of Page County as the deformed lower limb of a large overturned anticlinal structure or nappe. Although much of the southern and central parts of this area is covered by a veneer of terrace gravel and alluvium, sufficient outcrops are available to determine the major structural configuration. The northern third of the valley area is essentially free of gravel and alluvial cover, and bedrock exposures are plentiful. The prevailing attitudes of the rock units are steep to moderate southeasterly dips of overturned beds, vertical attitudes, and steep dips to the northwest.

Exposures of bedrock in the area covered by the Elkton and Mt. Jackson quadrangles (Plate 1) were mapped by King (1950) and Thornton (1953), and sections C-C′ and D-D′ have been modified from their work. In general, the Cambrian and Ordovician rocks have been deformed into an anticlinal arch, slightly asymmetrical to the northwest. The Stanley fault has not been traced southwest of Grove Hill,



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From Alma northeastward to Hamburg, the Beekmantown is the bedrock unit with the greatest exposed width, and intraformational folding is widespread. A well-developed fault, mainly within the Beekmantown can be traced for a distance of about 3 miles from about 1 mile west of Leaksville northeastward to north of Hamburg. Offsetting of the New Market, Lincolnshire, and Edinburg beds indicates that this is probably a normal fault, with the upthrown block to the west. A good exposure of the fault trace can be seen in the valley of Mill Creek downstream from Hamburg.

A klippe (Plate 1) lies about 1 mile northwest of Hamburg, and the interpretation given by Thornton (1953, p. 117) is:

> "The klippe is thought to be an 'erratic block,' that is, a mass of rock that has broken off some higher topographic feature and slid down into its present position. It is, essentially, a landslide block. Its source may have been the overturned anticline to the east which probably marked a topographic high before it was so extensively eroded."

The area from Grove Hill to Alma is structurally complex, as evidenced by the few available outcrops, however, the extensive veneer of gravel covering the bedrock makes a detailed interpretation of the structure impossible. King's (1950) mapping has generally been followed for this area, but it is possible that additional faults other than those noted may be present (Thornton, 1953, p. 110-112).

That part of Page Valley from Hamburg to Oak Hill and extending westward from Hershberger Hill and Piney Hill to Massanutten Mountain contains rock units, including the Shady through much of the Beekmantown, which are overturned with steep southeasterly dips. This structure is evident in the belt of rock from upper Mill Creek to northeast of Oak Hill. The Beekmantown in the vicinity of Luray Caverns is part of an overturned fold (Hack and Durloo, 1962, p. 8; Butts, 1940, p. 445). Northwest of Luray the Beekmantown, covered in part by alluvium and some terrace gravel, occupies a belt approximately 2 miles wide which is characterized by many small, tight folds, all apparently overturned to the northwest. A small syncline of Ordovician rocks (New Market, Lincolnshire, and Edinburg) borders the Beekmantown on the northwest. The synclinal structure plunges to the southwest and is cut by a strike fault along its northwest flank that thrusts the Edinburg over the overturned Beekmantown. The beds northwest of the fault are overturned to the northwest with steep southeasterly dips. The Beekmantown northwest of the fault is cut out on the southwest by a tear fault that is just east of Bixler Bridge, and the associated thrust fault appears to terminate to the southwest within the Edinburg. Movement along the strike fault has produced an apparent displacement of a normal or gravity type, but it is probable that a considerable amount of strike-slip movement is involved. However the major thrust movement occurred along the upper limb of an overturned anticline, and subsequent erosion has removed that limb of the structure.

A fault of minor displacement and probably of a thrust type is present in the Conococheague in the valley of Pass Run about 1 mile east of Springfield. A brecciated and silicified zone cuts across the Conococheague in a local flattening of that unit along the lower limb of a large overturned (recumbent) fold. The Conococheague outcrop along Pass Run increases in width of surface exposure although there is a possibility that part of the lower section mapped as Conococheague may be Elbrook Formation. Irregular attitudes of dips were recorded in this area, indicating intraformational folding, and the fault appears to be a thrust along the lower part of the overturned (recumbent) anticline.

From Oak Hill northeastward to the Page-Warren county boundary, the major structural unit west of the Vaughn fault zone is a tight anticline overturned to the northwest. East of Oak Hill and Rileyville an overturned syncline contains a narrow belt of Conococheague within the Elbrook. Southwest of Rileyville, east of U. S. Highway 340, a small subsidiary fold is responsible for an easterly protuberance of the New Market, Lincolnshire, and Edinburg. Two small, strike-slip faults offset the Ordovician rocks west of Compton. The offset position of the New Market and Lincolnshire beds is indicative that the southwest blocks of these two northwestward-trending faults have moved northwestward. The northeasterly fault has a right-lateral separation of about 0.7 mile. Movement along these faults does not appear in harmony with the regional structural pattern. That is, the expected movement resulting from the regional deformation should be that of the northeast blocks being moved to the northwest.

A possible explanation is that the two faults also have a component of dip-slip movement and are normal faults with southwest sides upthrown, perhaps the result of regional tension that followed the compressional forces responsible for thrusting along the Vaughn fault zone. The decrease in width of the Beekmantown outcrop belt between Compton and Overall results from the almost vertical attitude of the beds in this area.

MASSANUTTEN SYNCLINORIUM

The Massanutten synclinorium lies to the west of the valley occupied by the South Fork of the Shenandoah River, and extends along the western margin of the county in a northeasterly direction. In western and southwestern Page County ridges along Massanutten Mountain are held up by the Massanutten Sandstone, and the valleys are cut in the Martinsburg Formation, rocks of the Cayuga Group, and Devonian shales. A series of folds constitute the synclinorium, and dips are generally steep along the flanks of the folds. Along the east margin of First Mountain and Massanutten Mountain the Silurian beds are overturned to the northwest with steep southeasterly dips. The axial traces of the major folds are shown on Plate 1, and structural highs along the anticlinal axes are notable in the small outcrop of Martinsburg west of Catherine Furnace and in the broad outcrop of Martinsburg in the headwaters of Big Run and at New Market Gap. Structural lows along the synclinal axes are recognized in the areas of Devonian outcrops. A tight, overturned syncline is present along the steep eastern slope, near the crest of Massanutten Mountain, from Kennedy Peak northeastward to Ross Pass.

Two thrust faults are present in Massanutten Mountain. The easternmost fault extends northeastward from Strickler Knob to the west flank of Kennedy Peak and continues northeastward into Shenandoah County. The fault trace at Burners Gap lies immediately to the northwest of the ridge crest, and the fault surface essentially parallels the bedding on the east side of a tight syncline overturned to the northwest. The overturned east limb of the synclinal fold has been thrust up, and the Massanutten Sandstone and a small section of the Cayuga form the crest of the ridge. Where State Road 675 crosses Massanutten Mountain, the fault trace is on the ridge crest and a small wedge of Massanutten Sandstone of the hanging-wall block is thrust over an exposed remnant of the Massanutten Sandstone that is part of the overturned limb of the syncline in the footwall block.

The westernmost fault may be seen in the roadcut of National Forest Road 274 in Crisman Hollow on the headwaters of Passage

Creek. Along the trace of the fault for most of its extent in Page County, the Massanutten Sandstone has been thrust diagonally across a syncline of Silurian and Devonian rock. The fault appears to terminate in the Cayuga Group close to the county boundary.

GEOMORPHOLOGY

Page County is within the Blue Ridge and the Valley and Ridge physiographic provinces (Fenneman, 1938, p. 165-171, 245-265). Recent definitive work on the geomorphology of the Shenandoah Valley is contained in the report by Hack (1965). The geomorphic elements of Page County correspond to the major structural elements: the western margin or west flank of the Blue Ridge, that part of the Shenandoah Valley represented by the valley of the South Fork of the Shenandoah River, and part of the eastern ridges of Massanutten Mountain.

Early workers on the geomorphology of the Shenandoah Valley region (Hayes and Campbell, 1894; Keith, 1896) applied the cyclic theory of Davis (1889, 1890a, 1890b) to landform development of the southern Appalachians and the Shenandoah Valley, and somewhat later other workers (Stose and Miser, 1922; Wright, 1934) proposed the existence of several peneplains in the Valley region. Hack (1965, p. 4-5) suggested that the cyclic concept with peneplain formation was not the mode of geomorphic development of the region, but that:

> "The entire landscape could have evolved through long-continued erosion of a thick sequence of rocks, during which an approximately balanced condition of the slopes was maintained throughout. The landforms and surficial deposits have a complex but close relation to the geologic structure, and as both forms and deposits can be accounted for by this concept, the necessity to postulate a peneplain is eliminated."

Within Page County there is suggestion of an old erosion surface on the valley floor that is cut on Cambrian and Ordovician rocks. The present drainage of the South Fork of the Shenandoah River is below this level. From close examination of the area the suggested mechanism of geomorphic development proposed by Hack (1965) seems a reasonable and valid approach to an explanation of the landforms and surficial deposits.

BLUE RIDGE AREA

North of the Stanley fault the crest of the Blue Ridge is composed of the altered basaltic rocks (greenstone) of the Catoctin Formation and the Cambrian sandstones. Cliffs of Catoctin are common and slopes are steep. South of the Stanley fault Pedlar granodiorite and

Catoctin greenstones make up the crest and western slope of the ridge. Slopes are steep, but the weathering of the granodiorite tends toward smoother slopes covered with a loose, thin colluvium in contrast with the rough and clifflike forms of the Catoctin outcrops. The sandstones and quartzites of the Weverton and Erwin (Antietam) formations in the Shenandoah salient hold up ridges and are responsible for the very irregular topography of the salient area. Stream gradients are high, and the stream channels contain coarse gravels. Talus and scree are abundant on the steep slopes of the Cambrian sandstones in the Shenandoah salient. Valleys on the flank of the Blue Ridge tend to open up headward, as the several stream tributaries cut headward and outward and the main stream emerges from the valley through a relatively narrow opening. Waterfalls are common in the headwaters of streams crossing the Catoctin. Alluvial fans of gravel are generally present at the mouths of the streams where the streams leave the mountain front and pass into the valley of the South Fork of the Shenandoah River, and such fans are especially conspicuous in Hawksbill Creek, Dry Run, and Pass Run. Two prominent features, Hershberger Hill and Piney Hill, are on the west side of the Stanley fault that separates them from the main mass of the Blue Ridge.

VALLEY AREA

The central part of Page County constitutes a large valley containing as its major stream the South Fork of the Shenandoah River. The South Fork meanders in a north-northeasterly direction for a distance of approximately 50 miles and falls in elevation from about 890 feet above sea level at Verbena on Naked Creek to about 590 feet above sea level at the mouth of Overall Run, for an average of approximately 6 feet per mile. The width of the meander belt is about 3 miles in the Ingham area and about 2 miles in the Rileyville-Compton area. The stream valley is characterized by steep cut-in bluffs along the outside of the meander bends and gentle slip-off slopes on the inside of the bends. At the present time the river elevation is about 150 to 200 feet below the upland valley floor which indicates entrenchment of the present course of the river below the old valley floor that is cut on Cambrian and Ordovician sedimentary rocks. Meander scrolls of alluvium are generally present on the inside of the meander loops, and the older, higher valley floor contains successively higher, and older, gravel, sand, and silt terraces.

A conspicuous feature in the central part of Page Valley is the modified karst-type topography developed in areas underlain by carbonate rocks. Sinkholes, caves, and caverns are numerous in some areas underlain by the Beekmantown Formation as is evident in the broad outcrop of that unit southwest, west, and northwest of Luray. Surface drainage in this area is confined to major streams, and the greater part of what normally would be surface runoff is carried underground through sinkholes to emerge along stream courses as springs. The contact between the Beekmantown and the New Market-Lincolnshire unit is especially susceptible to sinkhole and cave formation, and numerous karst features are also present in the Edinburg Formation. The only commercial cavern in the county is Luray Caverns, located on the west side of Luray in the Beekmantown Formation. Hack and Durloo (1962) have written a comprehensive report on the geology of Luray Caverns. A cavern of modest size is located in the Beekmantown-New Market contact zone just west of State Road 685 in the community of Newport.

MASSANUTTEN MOUNTAIN AREA

The several ridges of Massanutten Mountain extend from east-central Rockingham County northeastward to the vicinity of Strasburg, Shenandoah County. North of the Rockingham-Page county boundary the bulk of the Massanutten ridges are within Page County. North of State Road 675, west of Bixler Bridge, the Massanuttens are mainly within Shenandoah County, and the crest of the ridge of Massanutten Mountain (the easternmost ridge) forms the boundary between Page and Shenandoah counties. The high ridges of Massanutten Mountain within Page County are composed of Massanutten Sandstone that has been folded into a synclinal complex, or synclinorium, and on Plate 1 this feature is indicated as the Massanutten synclinorium. The topographic lows are long, narrow valleys, following the regional structure, which have been cut in shales. The valleys of Cub Run, Pitt Spring Run, Passage Creek, and Duncan Hollow have been cut along synclinal axial traces in Silurian and Devonian rock. The valleys of Brown Hollow and the headwaters of Mountain Run have formed along an anticlinal flexure in the Martinsburg Formation. Differential erosion, following regional uplift of the entire Shenandoah Valley area, has been responsible for the formation of Massanutten Mountain, with the more resistant Massanutten Sandstone holding up ridges. The location of wind gaps, especially New Market Gap, seems to have been controlled by local structure.

The streams in the Massanutten Mountain area, by headward erosion, have been responsible for valley development on the less resistant shale beds. Valleys that cut across the strike of beds, such as the valley of Cub Run at Catherine Furnace, appear to have formed by local superimposition of an ancient stream as that stream was lowered onto the Massanutten Sandstone through a cover of overlying shale and the stream maintained sufficient volume and velocity to maintain its course. Both Cub Run and Big Run may have experienced some measure of stream piracy in the past, Cub Run by the headwaters of Smith Creek (Shenandoah County), and Big Run by headwaters of Passage Creek (Page and Shenandoah counties).

GEOLOGIC HISTORY

The bedrock in Page County ranges in age from Precambrian through Triassic. Quaternary terrace gravels and river flood-plain deposits are also present. In general the bedrock units become younger from east to west across the county. One Triassic diabase dike is present in the southeastern part of the county within the Catoctin and Loudoun formations. The Pedlar Formation, a part of the Virginia Blue Ridge Complex consisting for the most part of igneous and metamorphic rocks of granitoid and gneissic texture and of sialic and intermediate composition, is the oldest rock exposed in Page County. From studies made to the east in Greene and Madison counties (Allen, 1963), the Pedlar appears to be a late, magmatic phase of a series of igneous and metamorphic activities in what is now the Blue Ridge and Piedmont areas in late Precambrian time. Radiometric age determinations (Tilton and others, 1958, p. 1473) on the Pedlar granodiorite gneiss at Marys Rock (about 0.5 mile south of Thornton Gap) indicated an age (time of crystallization) of 1170-1150 million years before the present from zircon and an age of 890-840 million years from biotite. The age determination for zircon may represent the time of primary crystallization and the one for biotite, a later metamorphic recrystallization. Kulp and Eckelmann (1960, p. 1912) indicated a primary age of 1100 million years, or older, for the basement rock in the southern Appalachians and also suggested that widespread metamorphism may have affected the southern Appalachians about 850 million years ago.

From these data it may be inferred that the Pedlar Formation had its origin about 1150 million years ago and that the changes that occurred in the rock approximately 850 million years ago were most likely accompanied by processes of deformation, uplift, and erosion. A long period of erosion was accompanied by contemporaneous deposition in a basin area east of the Blue Ridge in the Virginia Piedmont. As erosion lowered the surface of the Pedlar and related rocks in the Precambrian igneous and metamorphic complex, the onlap of clastic sediments from east to west occurred over part or all of the denuded surface. In the Blue Ridge, the relief on the eroded surface may have been 2000 feet or more, and the coarse clastic sediments of the Swift Run Formation were deposited in the form of surface washes, alluvial cones and fans, and stream-channel fillings. The almost complete absence of the Swift Run in the northern part of the Shenandoah salient suggests that this area may have been the western limit of Swift Run deposition.

In late Precambrian or Early Cambrian time, volcanic flows and pyroclastic material were deposited over what is now the Blue Ridge and Piedmont region. In the Blue Ridge the Swift Run Formation contains altered tuffaceous and pyroclastic material, and east of the Blue Ridge the unit contains thin flows of altered basaltic rock. The Catoctin flows, originally basaltic but subsequently altered to greenstones, contain interbeds of pyroclastic material and tuff breccia. The original basaltic material flowed onto the surface from fissures in the basement rocks and may have reached a total thickness of 2500 feet although the aggregate thickness in the Blue Ridge at present is about 1500 feet. The flows and pyroclastic material were deposited on a surface that may have exceeded 1000 feet in relief in the Blue Ridge area. The absence of the Catoctin in the northern part of the Shenandoah salient and the thinning of the flows along the west margin of the Blue Ridge indicate that this area was possibly the westward limit affected by Catoctin volcanism.

Catoctin flows appear to be conformable with the underlying Swift Run Formation. Relationships between the Catoctin and the overlying Cambrian sedimentary rocks are somewhat more complex. King (1950, p. 41) stated that along the northwest flank of the Blue Ridge: "The northwestward truncation of the Catoctin greenstone and Swift Run Formation, and the southeastward thickening of the Catoctin are interpreted as being due largely to tilting before Cambrian time and to erosion before the Chilhowee group was deposited."

It is apparent that minor volcanic activity in the form of pyroclastic ejections continued into earliest Cambrian time along with an extensive depression or downwarping of the entire Appalachian region. The continued depression, and eventual submergence, of the Appalachian region developed a long, relatively narrow trough that became the site of deposition of perhaps 30,000 feet of sediment during Paleozoic time, and the structure has become known as the Appalachian geosyncline. Approximately 600 million years ago, the beginning of Cambrian time, the depression in the Page County area was accompanied by concurrent filling of clastic sediment. The lowest (and oldest) rock unit of this sequence is the Loudoun Formation which is composed essentially of slates and phyllites of pyroclastic origin and which appears to lie unconformably over the Catoctin. As subsidence and deposition continued, the sequential deposition of the sediments of the Loudoun, Weverton, Hampton, and Erwin (Antietam) formations took place. The source area of the sediments that formed these units probably lay to the northwest and represented the old Precambrian landmass. Changes in the relief of the source area and changes in the environment of the basin of deposition resulted in the accumulation of carbonate rocks as evidenced by the Shady Formation. Continual changes in sedimentation led to the deposition of red muds that became part of the Rome Formation, and then a long period of renewed carbonate deposition resulted in the development of limestones and dolomites in the Rome, Elbrook, and Conococheague formations. At times throughout deposition of the Conococheague, quartz sand was carried into the area, and the sands are now represented by sandstone beds in that formation. Deposition of the Conococheague sediments brought to an end the Cambrian Period.

There appears to have been continuous sedimentation from Late Cambrian to Early Ordovician times because the Conococheague is conformably overlain by the Chepultepec Formation, the oldest Ordovician unit in the region. Essentially, conditions of deposition must have been similar throughout times of formation of the Elbrook, Conococheague, Chepultepec, and the next younger unit, the Beekmantown. The presence of black chert in the Conococheague, Chepultepec, and Beekmantown indicates a contemporaneous deposition of silica or a replacement of parts of the carbonate material by silica, or perhaps both processes were operative and the cherts are of different ages.

The top of the Beekmantown is characterized throughout Page County by an unconformity caused by uplift, erosion, and by groundwater action that developed a karst-type topography. Overlying the Beekmantown, the dense, pure, New Market Limestone in many places contains at its base a coarse rubble of underlying Beekmantown fragments, some of which appear to have been sinkhole fillings; much of the rubble conglomerate represents a veneer of rock fragments covered by the return of marine waters during the time of New Market deposition. In the upper part of the Beekmantown, beds of pure limestone occur with dolomite (Figure 9), and the deposition of lime sediments continued into New Market and Lincolnshire times. The Lincolnshire is a dark, medium-grained, cherty limestone that may well be classed as a clastic limestone. Interbedded with clastic material are layers of fine-grained, dense limestone of the "New Market type," indicating fluctuation of the environment of deposition.

The Lincolnshire beds are succeeded by black to gray, graptolite-bearing shales marking the base of the Edinburg Formation. The change from essentially carbonate deposition to fine clastic deposition indicates a change in the source area. It is probable that the source area may have changed at about this time from the northwest to the southeast. This change was very gradual, and the new source area may have resulted from the rising of volcanic islands or a discontinuous landmass to the southeast of the geosynclinal trough. Beds of altered volcanic ash, or metabentonite, have been reported in the Edinburg (Cooper and Cooper, 1946).

In general, the Edinburg Formation in Page County has a lower black shale unit, a middle section essentially of limestone, and an increasing amount of shale in the upper part of the formation. Clastic sedimentation that began in Edinburg time continued into Martinsburg time; the thick section of Martinsburg consists essentially of shales and siltstones with medium-grained sandstone in the upper part of the formation. Uplift and perhaps other forms of tectonic activity in the source area were probably responsible for the great amount of clastic material.

In Page County the lowermost Silurian formation is the Massanutten Sandstone, which is probably a nonmarine beach sand and gravel deposit. The coarse debris forming the Massanutten reflects the increased size of material contributed by the source area. Overlying the Massanutten are nonmarine red shales and sandstones, and above these beds are fossiliferous limestones of the Cayuga Group. This lithologic sequence is indicative of a gradual lowering of the source area. Deposition of lime sediments, succeeded by the development of shales and siltstones, continued into Devonian time, and the remnants of these beds are present in Massanutten Mountain. No younger Paleozoic units are now exposed in the Page County area, although it is very likely that deposits younger than the mapped Devonian units were once present and that subsequent erosion has removed them.

The close of the Paleozoic Era was accompanied by mountain building, with initial movements starting perhaps in Mississippian time and certainly during Pennsylvanian time. By the close of the Permian Period, the entire rock section, Precambrian and Paleozoic, was deformed. The Pedlar, Swift Run, and Catoctin formations attained their present textural, structural, and mineralogic characteristics during the Paleozoic deformational cycles. Major structures, such as the folds in the Precambrian and Paleozoic rocks and the faults cutting these rocks, also developed at this time. Contemporaneous with deformation and metamorphism, uplift and erosion occurred in the area, and the initiation of present drainage patterns took place. The late Paleozoic deformation and uplift is the prime geologic activity in the history of development of the Appalachian Mountains; however, erosion accompanying and following mountain building may have been so active that the first cycle, or ancient, Appalachian Mountains reached only moderate heights.

During Triassic time the Page County area underwent continuous erosion, and remnants of transported Triassic sedimentary materials can be seen in the Triassic deposits of eastern Madison County, east of the Blue Ridge. Igneous activity took place, probably during late Triassic time, in the Piedmont and in the Valley and Ridge area. One Triassic dike is present in Page County, and several have been recognized in adjacent Rockingham County. During the Jurassic and Cretaceous periods extensive erosion in the area occurred; it has been suggested (Johnson, 1931) that much of the Appalachian region was so reduced by erosion and that Cretaceous seas may have penetrated into the region and left a blanket of Cretaceous sediment. However, no remnant of Cretaceous marine deposits has been found in the Appalachian highland area (Hack, 1965, p. 65).

The Page County area, and the Appalachian region in general, underwent continued erosion and periodic uplift during the Cenozoic Era. Continued adjustment of stream drainage to lithology and structure developed the present topography. It was during the Quaternary Period that the terrace-gravel deposits were laid down and terraces formed through lowering of the bed of the South Fork of the Shenandoah River. It is likely that most of the terrace formation took place during Pleistocene time, along with the development of the talus and scree on the ridge slopes. At present the South Fork of the Shenandoah River and its tributaries appear to be in erosional equilibrium with the lithology and structure, and they are slowly lowering their valleys in equilibrium with the lowering of the regional topography.

MINERAL RESOURCES

The mineral resources of Page County consist of a variety of materials, although during the time of field investigation only deposits of sand, gravel, and stone were being commercially worked. In the past, ores of copper, iron, and manganese were exploited, and quarries were opened in limestone and dolomite formations. Recently some attention has been given to the clays and related materials of the area. Mineral resources of interest are: the granitic rocks, especially the variety known as unakite; the carbonate rocks, limestone and dolomite; sand, gravel, and quartzose rocks suitable for crushed stone and dimension stone;

copper, iron, and manganese minerals; clay and shale; and the water resources which are becoming a matter of increasing interest. Plate 1 shows the major occurrence of rocks and minerals of economic interest in Page County.

CARBONATE ROCKS

The carbonate rocks, limestone and dolomite, have many uses in industry. Several quarries have been opened in Page County for road material although none was operating at the time of the field investigation. Quarries in the Beekmantown are shown on Plate 1 (Nos. 5, 22). Stone from a small quarry in the Chepultepec (Plate 1, No. 6) was apparently used for burning lime. Rock from a quarry in the Elbrook (Plate 1, No. 7) was used for road material. The quarries opened in the Edinburg (Plate 1, Nos. 13, 14, 16) were for road material, and the old quarry southwest of Leaksville on the bank of the South Fork of the Shenandoah River (Plate 1, No. 15) supplied building stone for the construction of the Methodist Church in Luray. Edmundson (1945, p. 135-152) gave a very comprehensive discussion of the economic aspects of the carbonate rocks in Page County, including a table showing chemical compositions of selected samples.

High-calcium limestone (containing more than 95 percent calcium carbonate) in Page County includes the local occurrences of the New Market and thin layers or beds in the upper part of the Beekmantown. The New Market is generally not more than 50 feet thick and locally may be absent; the lower part commonly contains rubble composed of dolomite and, in many places, chert, both of which affect the grade of the rock. Edmundson (1945, p. 140) noted that one of the best exposures of New Market (Mosheim) is along Mill Creek about 0.5 mile northwest of Hamburg and 3 miles southwest of Luray, and presented a chemical analysis of rock from that locality.

The Chepultepec, Lincolnshire, and the limestone beds in the Edinburg are classed as impure limestones. Several of the thin limestone layers in the Beekmantown and older formations could be placed in this category, but they are intercalated with dolomite and are classed with magnesian limestone and dolomite. The Chepultepec contains from 84.10 to 93.03 percent calcium carbonate, and the Lincolnshire (Lenoir) from 76.93 to 92.76 percent calcium carbonate (Edmundson, 1945, p. 151-152). There is an excellent exposure of Edinburg limestone in the quarry (Plate 1, No. 14) along State Road 646, 4 miles southwest of Luray. Edmundson (1945, p. 145-146) referred to this as the Woodward quarry (Figure 11) and noted that 60 feet of limestone exposed in the quarry contains 86.56 percent calcium carbonate, 4.35 percent magnesium carbonate, and 8.86 percent noncarbonates.

The carbonate beds in the Rome, Elbrook, Conococheague, and Beekmantown consist chiefly of dolomite, with intercalated limestone and variable quantities of siliceous and argillaceous impurities. These units generally contain from 50 to 90 percent calcium carbonate (Edmundson, 1945, p. 146-152). The carbonate rocks in the Silurian and Devonian formations are generally impure limestones containing variable quantities of siliceous and argillaceous materials.

CLAY AND SHALE

The clays in Page County that may have economic potential can be classified as residual clays overlying the calcareous and argillaceous Cambrian and Ordovician rocks, and transported clays present in terraces and flood plains. Shales of possible economic value are present in the Hampton, Rome, and Martinsburg formations, although shales and other argillaceous rocks are not limited to these formations.

Residual clay, or residuum, is derived from the decay or weathering of impure calcareous and argillaceous rocks and consists of insoluble material, principally clay with admixed sand, silt, and chert fragments. The origin of this material can be attributed to solution of limestone or dolomite or to the kaolinization of potassic micas in shale. Residuum appears thickest over the Shady and Rome formations and may be as much as 200 feet thick (King, 1950, p. 55), although generally it is much thinner. Most of the residuum in Page Valley is overlain by gravel deposits. Transported clays are dispersed in relatively thin layers in terrace deposits and river flood-plain deposits and may be considered of doubtful economic potential. A detailed discussion of the residual deposits in the southern part of Page County was reported by King (1950, p. 54-58). Hack (1965, p. 30-49, 66-76) presented a detailed description of the residual deposits in his study of the geomorphology of the Shenandoah Valley. King (1950, p. 70) noted that between 1930 and 1940 the Smith bank (Plate 1, No. 26) was worked for white kaolinitic clay, but only a small amount was produced.

The localities of several samples of clay taken in Page County are shown on Plate 1. Sample R-650 and sample R-673 were reported by Calver and others (1961, p. 102-105). Sample R-650 was taken from the northwest side of State Road 654 approximately 2.75 miles northwest of Luray. Test data indicate a potential use as common red brick. Sample R-673 was taken from the west side of State Road 615 about 0.5 mile north of Battle Creek at an outcrop of Martinsburg shale.

The test data indicate potential uses as common brick, tile, and lightweight aggregate.

Potential uses of other samples shown on Plate 1 are as follows. Sample R-1676, clay from the Stanley manganese mine (Plate 1, No. 17), has possible use as quarry tile; sample R-1677, clay from the Watson tract manganese mine (Plate 1, No. 32), has possible use as quarry tile. Sample R-1678, clay from the old Atwood-Bolan workings for iron and manganese, has potential use as decorative brick and tile.

COPPER ORES

The Catoctin Formation in the Blue Ridge of northern Virginia has long been noted for the occurrence of copper minerals. Since the earliest settlement of the region, native copper and copper sulfide minerals in the greenstones and altered flows have aroused interest. From what can be learned through published material on the Blue Ridge copper ores, court land records, and from conversations with the older inhabitants of the area, the mining of copper ores in this area was not a profitable venture. The early literature (Rogers, 1836, p. 134; Keith, 1894a, p. 309) makes mention of copper in the Catoctin greenstones, and considerable mining activity during the period 1890-1910 received attention in the publications of Watson (1907, p. 503-511), Phalen (1906, p. 140-145), and Weed (1911, p. 14-16, 104-107).

From field investigations of the old copper workings in Greene and Madison counties (Allen, 1963, p. 81-85) and in Page County, the writer has concluded that copper mineralization in the Catoctin is generally restricted to the lower part of the greenstone unit, usually within a few hundred feet above the contact with the underlying granitoid and gneissic rock of the Pedlar. This is true of the occurrences at Hightop mine and Tunnel Tract mine in Greene County, Dark Hollow mine in Madison County, and Stony Man mine located on the Madison-Page boundary line. In Page County, the Ida mine on Hoak Hill (Plate 1, No. 12) and the copper prospect on State Road 662 (Plate 1, No. 2) are respectively located in the middle and upper parts of the Catoctin sequence. The copper minerals are disseminated in the greenstone and also occur in local pods or segregations, or in small veinlets and stringers associated with gash fractures in flows and feeder dikes. It appears that the copper mineralization was originally distributed throughout the Catoctin and that low-grade regional metamorphism and downward-moving meteoric waters recrystallized and concentrated local accumulations of copper minerals. Weed (1911, p. 15-16) and Brophy (1960, p. 1325) have commented on the role of epidotization and serpentinization in the concentration of the copper minerals. Volume changes induced in the basalt flows by serpentinization and the small openings formed by regional deformation and metamorphism developed a structural framework for the concentration of copper minerals, and the epidotization processes facilitated the redistribution of these minerals in the fractured rock.

Copper Ore Prospect

A shallow shaft now filled with debris to within a few feet of the surface, along with a shallow surface cut, is located about 100 feet west of State Road 662, on a low ridge between Mine Run and Molden Hollow, approximately 3 miles by road southeast of Compton (Plate 1, No. 2). Local inhabitants of the area stated that the excavation for copper ore at this locality took place between 1910 and 1920, and call the prospect the "Mine Run mine." The workings are in the upper part of a tuffaceous, slaty facies of the Catoctin, although thin altered flows are also present. The overlying Loudoun Formation crops out about 200 to 300 yards west of the location, and a thrust fault associated with the Vaughn fault zone occurs in the lower part of the Weverton a short distance west of the Loudoun outcrop. The only evidences of copper mineralization observed were thin films of malachite and small specks of a black, sooty mineral tentatively identified as chalcocite. The small size of the dump indicates that only a small amount of prospecting was done.

Stony Man Mine

The Stony Man mine (Plate 1, No. 11) is located just to the east and below the crest of Stony Man, placing the site in Madison County. Undoubtedly some of the operations and mining activities at this site took place on the Page County side of the ridge. The Shenandoah National Park has developed the Stony Man nature trail in this area, and stop number 26 is designated as the copper mine area. Phalen (1906, p. 141) reported that at the time of his visit (1905) there was an old shaft, reportedly 60 feet deep but water filled. Weed (1911, p. 109-111) noted that at the time of his visit there was an open cut trending northwest-southeast which was 50 to 60 feet long, 30 feet deep at its highest point, and from 10 to 15 feet wide. About 0.5 mile to the west of the Stony Man mine and 0.25 mile north of Skyland along the Appalachian Trail is the site of an old furnace known as Furnace Springs which is located in Page County. Weed (1911, p. 110) indicated that the ore from the mine was carried to the furnace for reduction.

The Catoctin Formation on Stony Man is a massive flow containing an amygdaloidal facies and layers of slaty tuffs. The rock is highly fractured and has at least two well-defined joint sets, one with a strike of N. 20° E. and a steep southeasterly dip and another with a strike of N. 60° W. and a steep northeasterly dip. Joints and cleavage surfaces contain small lenses and veinlets of quartz and secondary epidote. Weed (1911, p. 109) reported that the ores consisted of native copper and copper oxide, with films of carbonate in fractured epidotized rock. The writer was able to find only malachite-stained rock surfaces in the area.

Ida Copper Mine

The Ida copper mine (Plate 1, No. 12) is located on the crest of Hoak Hill; from 1900 to 1904, it was operated by the Virginia Consolidated Copper Company. According to Watson (1907, p. 509) and Weed (1911, p. 106-107) the workings consisted of an inclined shaft 308 feet deep, with lateral workings at 80, 120, and 280 feet below the surface, and with the levels extending for distances of 60, 170, and 150 feet respectively. At the time of this investigation all that remained of the former activity was the remnant of the shaft, approximately 15 feet deep, and an extensive dump (Figure 16). The writer observed only malachite stains and a few specks of azurite on the walls of the old shaft and on broken rock in the dump; no sulfides were observed. The mine was located in the upper part of the Catoctin Formation in a sequence of fine-grained flows and amygdaloidal flows. The rocks are well jointed, and the shaft is in a zone of sheared and jointed epidotized rock with numerous small quartz veinlets. Weed (1911, p. 106-107) reported the presence of rare specks of native copper, but this mineral was not seen by the writer either in the shaft or on the dump.

GRANITIC ROCKS

Although outcrop areas of granitic rock (granodiorite gneiss and similar rock types) are numerous along the west slope of the Blue Ridge from Thornton Gap southward to the headwaters of Hawksbill Creek and in the core of the Shenandoah salient, to the best of the writer's knowledge this rock has not been used for industrial or commercial purposes. Granitic rock of good quality could be readily quarried

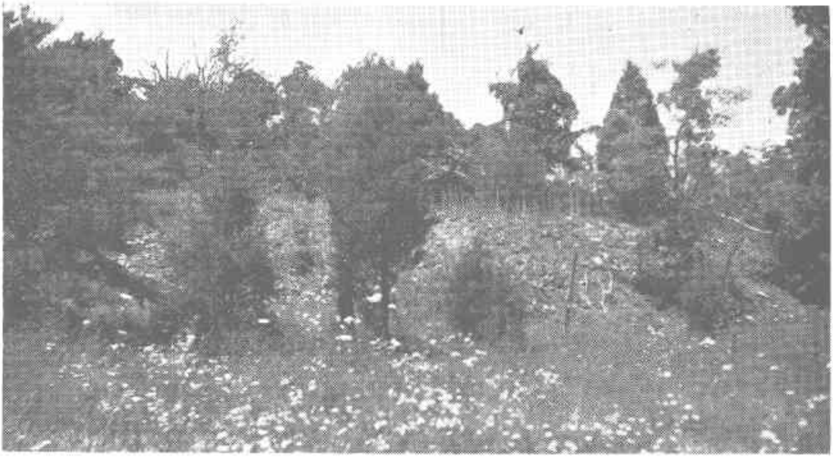
Figure 16. Mine dump at the site of the Ida copper mine. The old shaft is located behind the dump.

at many places along the west foothills of the Blue Ridge such as at St. George Mission on Hawksbill Creek, at Ida, east of Piney Hill, and at Morning Star should the need arise for such rock material. Steidtmann (1945, p. 83-85, 131, 142-143) described granitic rocks from three localities in Page County and also gave chemical analyses of unakite and syenite from Milam Gap.

The occurrence of unakite, a rock containing pink potassic feldspar, green epidote, and blue-gray quartz, has for some time been a matter of interest to rock and mineral collectors. Many collectors have recovered quantities of this rock which, when cut and polished, makes attractive ornaments and costume jewelry. As rock and mineral collecting is not permitted within the Shenandoah National Park, the search for unakite must be made outside the park boundaries. Outside the park boundaries, unakite occurs as stream cobbles in the lower reaches of such streams as Jeremys Run, Rocky Branch, Pass Run, Dry Run, and Hawksbill Creek.

IRON AND MANGANESE ORES

Mining, milling, and smelting of iron ores once was an active industry in western Virginia. Along the west flank of the Blue Ridge the search for deposits of iron ore began in colonial times, and manganese ore mining began in the 1880's. An investigation of the iron and manganese ore deposits in the Elkton area (Rockingham and Page counties) was made by King (1943, 1950), and the origin of the



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Manganese ores and manganiferous iron ore were mined intermittently between 1884 and 1941 in the Elkton area, and it is estimated that approximately 23,000 tons of concentrates were produced. World War II and the period 1950-59 saw a resurgence of manganese activity and some ore was produced during that period. Iron ore was mined in the Elkton area, including the southern part of Page County, almost continuously between 1836 and 1905, and an estimated 350,000 tons of concentrates were produced. Three iron furnaces once operated in the Shenandoah community; two in the town of Shenandoah, and one on the south side of Naked Creek (Rockingham County). In addition, Catherine Furnace, 5 miles north of Shenandoah on Cub Run, was used to smelt iron ore from several workings in Massanutten Mountain, especially the Pitt Spring mine which Holden (1907, p. 433) reported to be in the Oriskany Formation (Devonian) on the north side of Middle (Big) Mountain. The more active iron operations were located in the area around the Shenandoah salient and between Naked Creek and Stanley. Many of the old workings are now obscure, and those that were visited by the writer gave little indication of their former size and extent of operation; surface evidence consists only of small, scattered amounts of ore. The easily located deposits of high-grade iron ore were mined out long ago and the known deposits of high-grade manganese ore have been exhausted.

The deposits of iron and manganese minerals in Page County consist of iron and manganese oxides that were formed by concentration and replacement as a direct result of weathering processes. Ground water undoubtedly was an active agent in the process. The most important deposits are associated with residual material resulting from weathering of the Shady and Rome formations, although some iron and manganese oxides occur in fractured Erwin (Antietam) siliceous beds, and one iron oxide occurrence is in the Weverton. Most of the deposits are in areas of homoclinal or synclinal structure (King, 1950, p. 64).

The ores are embedded in residual clay, generally in the more silty units, and consist of limonite, goethite, and manganese oxides generally described as psilomelane. They occur in the form of hard spherical or botryoidal masses, 0.5 inch to 8 inches in diameter, and in some places as larger, irregular masses. The questions as to the origin of the ores are discussed in detail by King (1950, p. 65-66) and Hack (1965, p. 67-70) and differences of opinion do exist. The weight of evidence indicates that the iron and manganese ores are syngenetic and that original sources were iron and manganese carbonates in the Shady and Rome formations, although some workers have thought that the manganese, although syngenetic, originated in beds either higher or lower than the Shady or Rome. An additional problem regarding the origin of the ores concerns the processes that have concentrated the iron and manganese in the form of oxides in the clayey residuum. It is evident that the oxides occur in residuum on carbonate rocks (Shady and Rome) at various topographic levels. Most of the deposits occur in residuum that overlies basal beds of the Shady, and these beds appear to be the principal control. The general and steady lowering of the topography along the foot of the Blue Ridge provided, and continues to provide, mechanical and chemical processes wherein the supergene oxides of iron and manganese are formed and preserved in the insoluble residues while the soluble constituents are dissolved and carried away by both surface and ground waters. The gravel veneer over the residuum acts as a cover and protects the underlying residuum from subsequent removal. The process is continuous, although past conditions may have at times been more favorable for concentration of the oxides.

Compton Manganese Corporation Mine

The Compton Manganese Corporation mine (Plate 1, No. 1) was in operation during the 1950's. The mine was opened on a fractured zone in the Erwin (Antietam) that is cut by a thrust fault associated with the Vaughn fault zone and that is stratigraphically below residuum of the Shady Formation. The operation has also been identified by local residents as the Mineral Products Company mine and the Shenandoah Mining Company mine. The workings are located on the side of Broadus Mountain and on the south side of Mine Run. Remnants of a washing plant and jigs are still present on the property (1964), and small quantities of psilomelane nodules are present at the site of the washing plant. From what can be determined at the open cut, manganese ore was obtained from fractures in the Erwin (Antietam) and from the overlying residual clay of the Shady. An examination was made of the ground surface along the Erwin-Shady contact between the two segments of State Road 662 connecting Rileyville and Compton and a few scattered pieces of manganese oxide float were observed.

Moody Creek Prospect

The Moody Creek prospect (Plate 1, No. 3) is located on the south side of a dirt road ascending the valley of Moody Creek. The prospect consists of surface cuts that were made for iron ore. Local residents indicated that the work was done sometime before World War I. Surface debris taken from the pits and trenches contains masses of limonite, but no manganese oxides were seen. The excavations are in a shattered zone of the Weverton Formation adjacent to a thrust fault that is part of the Vaughn fault zone. This operation may be the one described by Holden (1907, p. 432) as the Rileyville mine, ". . . located 2.5 miles south of Rileyville at the west base of the Blue Ridge. It was operated about 1903 and the ore hauled in wagons to Rileyville. The ore differs from most of the Blue Ridge limonite in that it is associated with sandstone."

Stanley Mine

The Stanley mine (Figure 17) is located on the northwest slope of Roundhead Ridge about 1 mile south of Stanley (Plate 1, No. 17). King (1950, p. 66-67) has given a detailed description of the history and extent of this operation, and information presented here is from his report. Although manganese oxide ores were identified at the location before 1880, the first production was in the 1890's when the first cuts, known as the Eureka mine, were made. During the period 1918-19 the mine was operated by the Shenandoah Valley Manganese Corporation, and from 1928 to 1936 the mine was worked by a firm from Washington, D. C. King (1950, p. 67) reported that the concentrates averaged 46 percent manganese, 3 to 5 percent iron, 6 to 12 percent silica, and 0.15 percent or less phosphorus.

The operation is in clayey residuum overlying the lower beds of the Shady Formation and is on the northward projection of a synclinal structure with a strike-slip fault of right-lateral separation located south of the mine. The mine workings at the time of operation consisted of open cuts, pits, and shafts that are now generally filled. Scattered small pieces of manganese oxide and limonite are present in the old workings and at the site of an old washer on the east slope of the valley of Stony Run. A number of large masses of siliceous manganese oxide, bypassed in the mining operation because of the high silica content,

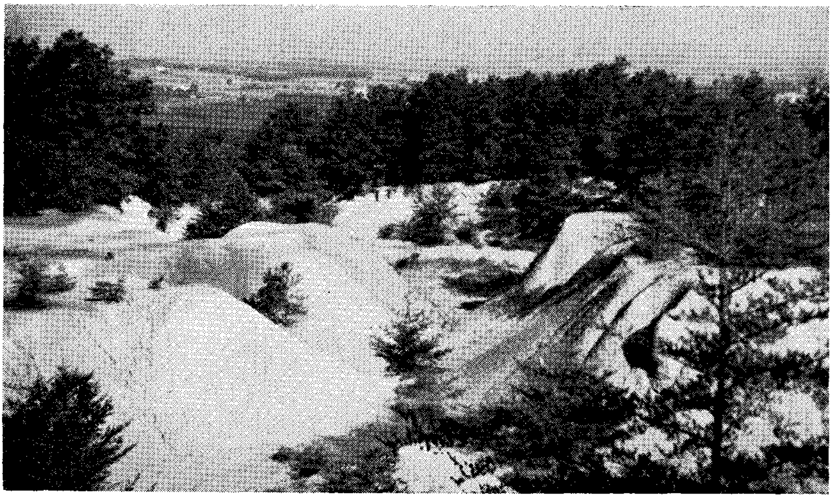
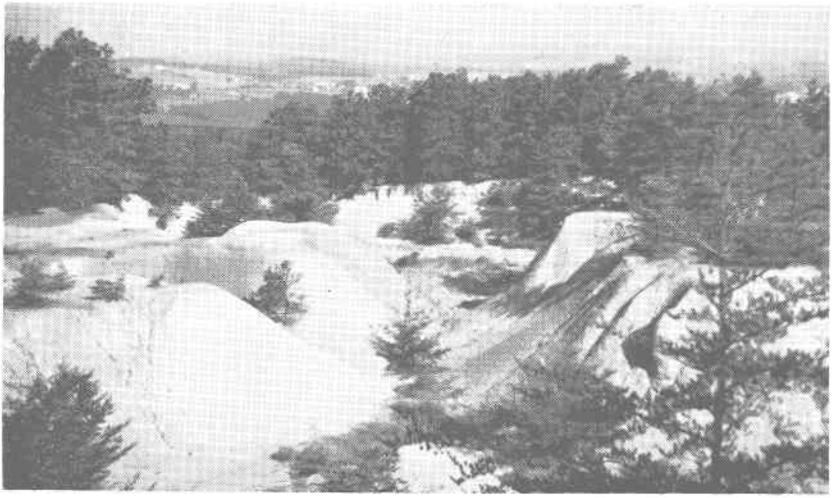


Figure 17. Extraction site at the Stanley manganese mine near Stanley. The manganese ore occurred in clayey residuum overlying the lower part of the Shady Formation.

are associated with lenses of sand and gravel in the pits. Gravels and fanglomerate material overlie residual clays on the margins of the workings, and it is evident that much of this material covered the deposits prior to mining.

Ocher Prospect

Ocher deposits that are incorporated in residual clay from the Rome Formation are located along Stony Run about 1 mile southwest of Stanley (Plate 1, No. 18). This prospect, designated by King (1950, p. 76) as the Stanley deposit, is described in his report of the Elkton area. According to King (1950, p. 76) the deposit was opened in 1876; operations may have continued until after 1907, and shipments were made during many of those years. As the ocher is a residual material formed by weathering of the Rome, the material may well be present beneath the gravel cover bordering the stream, but recovery operations would be expensive. King (1950, p. 76-77) also reported a deposit of ocher along the southwest bank of Naked Creek, about 0.5 mile east of Furnace in Rockingham County. The writer observed low-grade ocher in clay overlying the Rome Formation in a recent roadcut at the junction of U. S. Highway 340 and State Road 624, about 1 mile northeast of Stanley.



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Honey Run Mine

Approximately 1.75 miles southeast of Honeyville, there are a group of old workings (Plate 1, Nos. 19, 20, 21) that the writer has designated the Honey Run mine. King (1950, p. 67) described a mine of this name as located on the west side of Honey Run, and remnants of two open cuts can still be seen although the area is now covered with heavy brush. East of Honey Run, along the contact of the gravels and the Erwin (Antietam) are a series of old pits and trenches that indicate some extensive prospecting in the past. The area is easily accessible as it is immediately adjacent to the grade of the Norfolk and Western Railway. The workings are located in residuum overlying the Shady, and small quantities of iron oxides and scattered pieces of manganese oxides can be found. No records seem to be available concerning production, but information from local residents indicates that the cuts were worked for iron ore between 1890 and 1900.

Ingham Mine

The Ingham mine (Plate 1, No. 24) was operated between 1880 and 1890 (King 1950, p. 67-68), and the workings may be the same as the old property known as the Beverley bank. The workings are in residuum overlying the lower part of the Shady Formation and are near outcrops of the Erwin (Antietam). Small amounts of iron and manganese oxide can be found in the area. South of the Ingham mine, and along the contact between Quaternary gravel and the Erwin (Antietam), there are several indications of old prospect pits, and the small mounds of clay from the workings contain scattered pieces of iron and manganese oxide.

Little Ore Bank

The Little Ore bank (Plate 1, No. 25) is the site of old workings on a branch of Fultz Run. It has also been known as "Fultz Run Prospect" and was described by King (1950, p. 68), who indicated that manganese concentrates were shipped from the operation in 1915. This property, as those previously described, is located in residuum overlying the Shady Formation.

Shenandoah Iron Works Operations

During the period 1836 and 1905 a number of mines were opened for iron ore in the region east of the town of Shenandoah, and the operations are generally known as the Shenandoah Iron Works. King

(1950, p. 68-72) has given a rather complete history of the operations, mining, milling, and smelting, and has described the more productive mine workings. The operations described by King (1950) and shown on Plate 1 of this report are: Smith bank (No. 26), Boyer mine (No. 27), Atwood workings of Kimball bank (No. 28), Bolan workings of Kimball bank (No. 29), Garrison bank (No. 30), and Baker bank (No. 31).

The workings known as Smith bank, the Atwood and Bolan workings of Kimball bank, and the Baker bank are in clayey residuum over the lower part of the Shady Formation, whereas the Boyer mine and Garrison bank are located farther from the mountain front of the Shenandoah salient and are in the outcrop belt of the Rome Formation. Iron ore was the principal product of Smith bank (later some white kaolinitic clay was mined), Boyer mine, and the Baker bank, and both iron ore and manganiferous iron ore were mined from the Kimball bank (particularly the Atwood workings) and the Garrison bank. In 1941 there was active prospecting for manganese ores at the Kimball bank and the Garrison bank, and some hand-picked ore was shipped from the latter.

Some detail concerning the extent of the workings and the quantity and quality of ore mined at the several operations in the Page County part of the Shenandoah Iron Works area was presented by King (1950). Evidently most of the ore was recovered from open pits, although the Boyer mine was operated entirely from deep workings; some of the ore from the Smith bank was mined underground, and deep (100 feet or more) shafts were sunk on the Baker and Garrison banks. Analyses given by King (1950) indicate that the iron ore varied from 40.87 to 55.8 percent iron, and the reported analysis of manganese ore from the Garrison bank indicates about 53 percent manganese. Such reports of ore analyses are not to be taken as representative of an entire pit however, nor is the method of sampling stated. Production figures for the individual mines or for the entire Shenandoah Iron Works system do not seem to be available, but it is evident that for a period of about 70 years a flourishing industry was based on the production of these mines.

Watson Tract

The Watson tract operation, located along Mudhole Run on the southwest side of Grindstone Mountain (Plate 1, No. 32), apparently was not a part of the Shenandoah Iron Works system. King (1950, p. 72-73) noted that the area was prospected for manganese ore in 1908, and some mining involving open cuts, pits, inclines, and shafts was done prior to 1915. In 1941 the tract was explored by the U. S. Bureau of Mines; prospecting consisted of 15 test holes, a 540-foot incline and a 70-foot-deep shaft. Manganese oxides consisting of psilomelane nodules, layers of wad and wad-impregnated clay, and some iron oxides are contained in the residuum of the Shady Formation.

King (1950, p. 78) reported an occurrence of magnetite in the valley of Hawksbill Creek above Marksville. As magnetite grains are quite common in the Catoctin Formation, in many places occurring in sufficient quantity to deflect a compass needle, the sands in the beds of many of the streams that drain the west slope of the Blue Ridge contain discernible amounts of magnetite.

QUARTZOSE ROCKS

Both the Erwin (Antietam) and Massanutten sandstones have been used in construction work in the Page County area and especially for newer construction in the Shenandoah National Park. A small quarry (Plate 1, No. 4) on Massanutten Mountain about 1.5 miles northeast of Burners Gap was operated in the Massanutten Sandstone for building stone and for wall and coping stone. Material was being quarried from this locality intermittently during the course of the field investigation. Much of the stone used in the construction of new National Park facilities at Panorama (Thornton Gap) is Erwin (Antietam) sandstone or "orthoquartzite" that was quarried from several locations within the park area. Rock of this type, from the Trayfoot Mountain area of Augusta County, was used in construction of buildings and patios at Skyland.

Two localities (Plate 1, Nos. 9, 10) on Piney Hill, about 3 miles southeast of Luray, have been worked intermittently for stone. One locality (No. 9) has been a source of sand and stone for crushing, and the other (No. 10) was a site for dimension stone. The occurrence of Erwin (Antietam) along the western foothill belt of the Blue Ridge provides a source of quartzose dimension stone that could well be exploited when the market demand exists. The Erwin and Massanutten sandstones are potential sources of silica sand for foundry use and glass manufacture, and as aggregate for the plaster and concrete industry.

SAND AND GRAVEL

Supplies of sand and gravel are plentiful in Page County. The lower reaches of many streams that flow westward from the Blue Ridge, especially Hawksbill Creek, Stony Run, Dry Run, Pass Run, and Jeremys Run, contain large quantities of sand and gravel. Cub Run and Big Run, flowing eastward from Massanutten Mountain, also are sources of this material. The extensive blanket of gravel that covers much of the bedrock in Page County to thicknesses as great as 150 feet (King, 1950, p. 58-60) affords an abundant source of gravel material.

Sand is not as plentiful along the tributaries of the South Fork of the Shenandoah River as in the alluvial flood plain of the river. Shenandoah Sand and Gravel, Inc., is extracting material from a site (Plate 1, No. 23) along the South Fork of the Shenandoah River near Shenandoah. From time to time sand in quantity has been taken from the alluvial material along the river between Alma and Leaksville. The Dry Run Sand and Gravel Company has taken sand and gravel from Dry Run about 3 miles east of Luray, and at the time of the field investigation operated a crushing and screening plant at the site (Plate 1, No. 8). The same company has operated a large pit (Figure 18) on the west slope of Piney Hill (Plate 1, No. 9) in the Erwin (Antietam); at this site sand and rock fragments were lifted by diesel shovel and trucked to the crushing and screening plant located along Dry Run. Gravel, in reality highly fractured and broken rock, from the Erwin (Antietam) has been recovered from an outcrop along State Road 629, 1 mile east of Cavetown; from an outcrop adjacent to Mt. Calvary Church; and

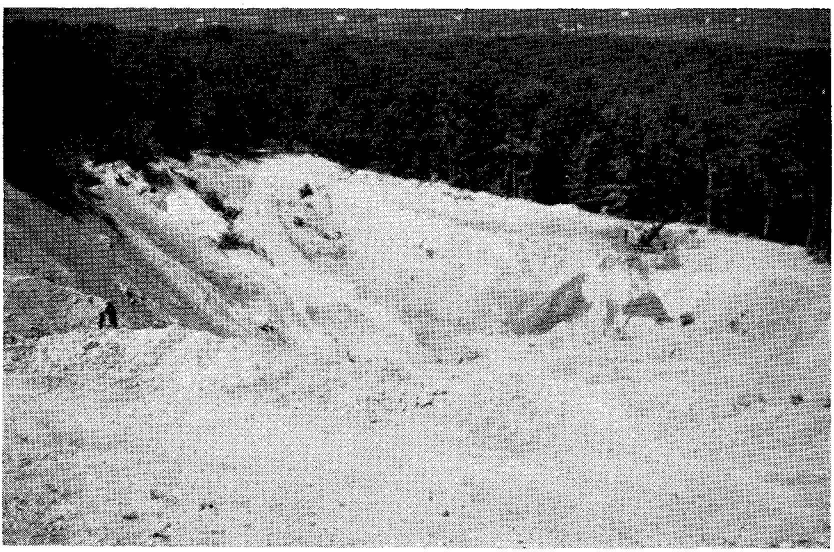

Figure 18. Extraction site of the Dry Run Sand and Gravel Company located on the west slope of Piney Hill. Material is removed from the Erwin (Antietam) Formation and trucked to a crushing and screening plant along Dry Run.

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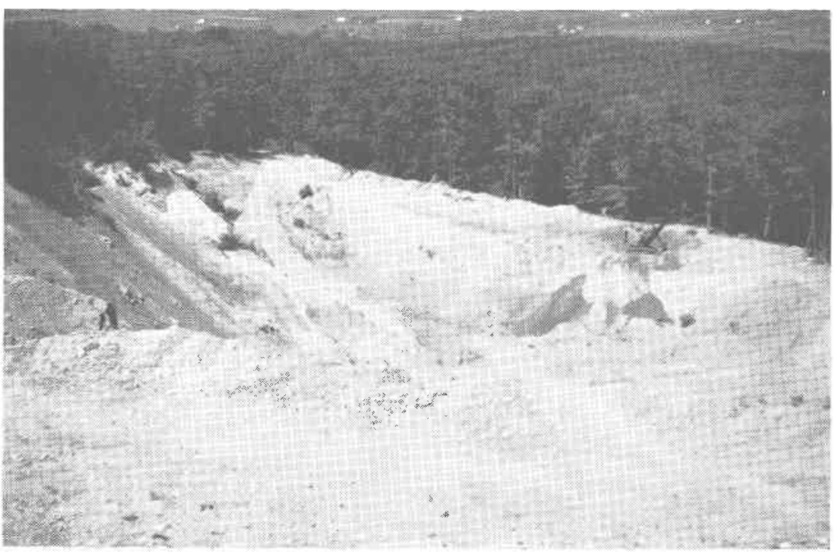

Figure 18. Extraction site of the Dry Run Sand and Gravel Company located on the west slope of Piney Hill. Material is removed from the Erwin (Antietam) Formation and trucked to a crushing and screening plant along Dry Run.

from an outcrop along State Road 611 east of Vaughn Station at the mouth of Green Hollow.

MISCELLANEOUS MINERALS

A considerable quantity of calcareous tufa ($CaCO_3$), or travertine, is present along Mill Creek west of Hamburg, and small amounts are present along the lower reaches of Hawksbill Creek and along Cub Run. The material may be used as a source of lime and as fertilizer.

Small quantities of hematite (Fe_2O_3) were found in thin veinlets in the Catoctin outcrops west of Lewis Spring and also in outcrops in the extreme headwater valley of Naked Creek. Small fluorite crystals occur in vugs in the Edinburg Formation in a quarry (often referred to as the Woodward quarry, Figure 11) adjacent to State Road 646. A list of mineral occurrences in Page County has been compiled by Dietrich (1967, p. 49).

WATER RESOURCES

The economic development and the population of a region are influenced by the quantity and quality of water available. Water is a renewable or replenishable natural resource, and an understanding of the occurrence of both surface and ground water is desirable so that an efficient search for, and utilization of, this valuable resource can be achieved. Page County has an average annual rainfall of about 40 inches and an average annual runoff of about 13 inches; an amount of available water that with good conservation practices may be sufficient for industrial, agricultural, and domestic demands.

Surface Water

The South Fork of the Shenandoah River is the principal stream in Page County. No large tributary stream enters the South Fork within the limits of the county, but several small streams such as Naked Creek, Cub Run, Hawksbill Creek, and Jeremys Run drain the county. In the Blue Ridge and Massanutten Mountain areas stream gradients are steep; and where the streams cross outcrops of the Catoctin, waterfalls are common. Hawksbill Creek, from its headwaters near St. Luke Mission to Baileys Store, has a gradient of 670 feet per mile; from Baileys Store to Luray, a gradient of 45 feet per mile; and from Luray to the point of discharge into the South Fork of the Shenandoah River, a gradient of 17 feet per mile. The average gradient of the South Fork within Page County is approximately 6 feet per mile. Where the small streams emerge from the mountainous region to the valley of the South Fork, they cross thick accumulations of gravel; and much if not all the water moves underground. A further loss of surface water occurs in many places where the streams flow across areas of carbonate rock.

Records of the quantity of water discharged by the South Fork of the Shenandoah River indicate the extreme fluctuation of that stream. The following data are from the U. S. Geological Survey (1964, p. 496).

South Fork Shenandoah River near Luray, Virginia (upstream side of bridge on U. S. Highway 221, 4.1 miles west of Luray, Page County).

Drainage area: 1377 square miles.
Record for period: April 1925 to September 1930, and October 1938 to September 1951.
Average discharge for 18 years: 1264 cfs.
Maximum discharge of 100,000 cfs on October 16, 1942.
Minimum discharge of 70 cfs on September 27, 1941.
Minimum daily discharge of 135 cfs on September 16, 1925 and on September 28, 1930.

Surface-water data for the South Fork of the Shenandoah River at Front Royal, Virginia, is as follows:

Drainage area: 1638 square miles.
Average discharge for 37 years: 1621 cfs.
Maximum discharge of 130,000 cfs on October 16, 1942.
Minimum discharge of 59 cfs on January 30, 1934.

Ground Water

Of the average annual precipitation of 40 inches in the Page County area, about 13 inches is involved in runoff, and it has been estimated that about 6 or 7 inches infiltrates into the ground. For the 316 square miles of the county, the amount of ground water infiltration is approximately 101,000 acre feet of water, or 33 billion gallons per year. Penetration of water from rain, snow, sleet, and hail into the ground is, in general, favored by a slow rate of precipitation, a gently sloping to flat ground surface, a large amount of vegetation, a high atmospheric humidity, and, especially, high porosity and permeability of the soil and rock. Water percolates downward by gravity through the pore spaces between mineral grains and through secondary openings such as joints, rock cleavage, faults, and other fractures. Water moves downward through the vadose zone, or zone of aeration near the ground surface. Beneath this is the phreatic zone, or zone of saturation, where the rock openings become completely saturated with water. Locally, however, the openings may be saturated in the zone of aeration. The surface marking the top of the saturated zone is referred to as the water table. The water table condition has its optimum development in rock of high porosity and permeability but is poorly defined in dense impermeable rock. The water table roughly parallels the topographic surface, but is at a shallower depth beneath the ground surface in areas of low elevation. Ground water moves downslope and may intersect the ground surface at a lower elevation in the form of a spring or at the level of a stream, contributing water to the stream discharge. The fluctuation, or rise and fall, of the water table is related to the quantity of precipitation; usually the water table rises after heavy rains and falls during and after times of drought. Below the water table, the movement of water depends on the topography of the area and on the quantity, spacing, continuity, and size of the rock openings. Generally, the flow of water in the saturated zone is much slower than in the zone of aeration.

The movement of ground water is dependent on a number of factors, the two most important being porosity and permeability. Porosity, the percentage of open spaces or voids in a rock, can be visualized by noting that if 1 cubic foot of sand holds 0.25 cubic foot of water, the porosity of the sand is said to be 25 percent. Permeability is the capacity of the rock to transmit a fluid (in this case, water). In rocks with relatively high permeability water may move several feet an hour; if the water moves at the rate of several feet per year, the permeability is relatively low.

In Page County, coarse surface gravels and sands have high porosity and permeability. The stratified sedimentary rocks vary in their water-storage and -transmitting characteristics. Fractured massive carbonate rocks that contain solution channels may provide high yields; medium to high yields may be obtained from fractured quartzites. Sufficient quantities of water for domestic and farm use are available in the thin-bedded carbonate rocks and shales at most places in the county. Granites, gneisses, and extrusive igneous rocks, such as the altered basalts of the Catoctin, generally have low porosity and permeability unless characterized by numerous joints, fractures, or other secondary openings. Most wells have been drilled to obtain only the small quantities of water needed for domestic or farm use, and reported yields do not reflect aquifer capacity because too few adequate pump tests have been conducted. Additional ground-water data are on file at the Virginia Division of Mineral Resources in Charlottesville.

Because the igneous and most metamorphic rocks along the crest and west slope of the Blue Ridge are relatively impermeable, wells drilled in this area generally have low yields, usually less than 10 gallons per minute. In the Skyland area, wells that penetrate the Swift Run Formation between the Pedlar and the Catoctin generally have good yields. There are several flowing springs at or near the contact of the Swift Run and Catoctin formations such as Lewis Spring near Big Meadows and Furnace Spring at Skyland. Wells drilled in the Cambrian rocks along the western foothills of the Blue Ridge are generally shallow but produce sufficient water for domestic use; the water is generally relatively soft and may contain some iron.

Most of the wells drilled along the crest and west slope of the Blue Ridge are from 50 to 300 feet deep; the deepest well, located along the eastern boundary of the county in the Shenandoah National Park just north of Lewis Spring, reached a depth of 500 feet. About half of the wells in this area have yields that range from 0 to 10 gallons per minute; and about one-third, from 10 to 35 gpm. A few of the wells exceed 35 gpm; the largest recorded yield, from a well located about 0.5 mile east of Marksville, is greater than 100 gpm.

There are a number of springs along the foot of the Blue Ridge, and those springs that emerge from the gravel fans at the base of the mountains generally have sustained flows. The town of Luray operates a reservoir to catch and retain water from springs near the Blue Ridge.

The central part of Page County is underlain mostly by carbonate rock, with much of the area covered by a veneer of gravel. Wells range from 60 feet to nearly 600 feet in depth, and yield from 1 to 400 gallons per minute. Of the 76 wells in this area for which records are available, 37 are less than 200 feet deep, 28 are 200 to 400 feet, and 11 are deeper than 400 feet. Most of the yields are less than 10 gpm; 22 wells have yields ranging from 10 to 20 gpm, and 5 have yields greater than 100 gpm. Shallow wells in the gravels are erratic producers although some penetrate subsurface water channels and give sustained yields. Wells producing from carbonate rock may provide sufficient yields if they are in fractured zones or solution channels, although mud may initially affect the clarity of the water. Surface contamination may be a problem with these wells and casing should be extended well into bedrock to prevent the entry of near-surface water. The water from carbonate rocks is usually hard. The town of Stanley obtains water from two wells that yield more than 120 gallons per minute during dry months of the year.

An example of a well in the Valley area is the one completed in July 1962 on Cave farm near State Road 611, 0.5 mile south of

U. S. Highway 211. The well penetrated 135 feet of sand, clay, and gravel, 19 feet of soft ocherous limestone and clay, and 19 feet of carbonate rock, for a total depth of 173 feet. The well initially produced 75 gallons of muddy water per minute, and after 4 weeks of pumping, it stabilized at 70 gallons per minute of clear water.

There are a number of large springs in the central part of the county, and north of Luray the Yagers spring is reputed to have a flow of approximately 6 million gallons per day. There are other perennial springs in the vicinity of Luray which flow from 500 to 2000 gallons per minute. Hites Spring, about 1 mile east of Luray, flows 1.5 million gallons per day. The ground water in this part of the county generally has a total hardness of 60 to 120 ppm, and the average temperature of ground water at depths of 30 to 60 feet is about 55° F.

West of the South Fork of the Shenandoah River much of the county is underlain by the Martinsburg Formation, essentially a shale and siltstone unit, and by Silurian and Devonian sandstones and shales. Wells in the Martinsburg are generally shallow, from 25 to 75 feet deep, and generally yield from 1 to 5 gallons per minute. Of 9 wells in the Martinsburg, 4 are less than 100 feet deep, 2 are from 100 to 200 feet, and 3 are deeper than 200 feet; 2 of the wells have yields less than 10 gpm, 3 range from 10 to 20 gpm, and 4 range from 20 to 35 gpm. The wells in gravel fans or terrace deposits along the east front of Massanutten Mountain usually yield from 10 to 20 gallons per minute if in deep gravel, and the water is generally soft. Wells in the folded sandstones and shales in Massanutten Mountain are generally less than 75 feet deep and furnish enough water (3 to 5 gallons per minute) for domestic use.

There are a number of springs along the east slope of Massanutten Mountain but the larger, perennial springs are within the major synclinal structure of the mountains. Pitt Spring, about 2 miles west of Catherine Furnace near the Rockingham County line, is on the west limb of an anticlinal fold at the contact of the Massanutten Sandstone and rocks of the Cayuga Group and is reported to have a steady year-round flow.

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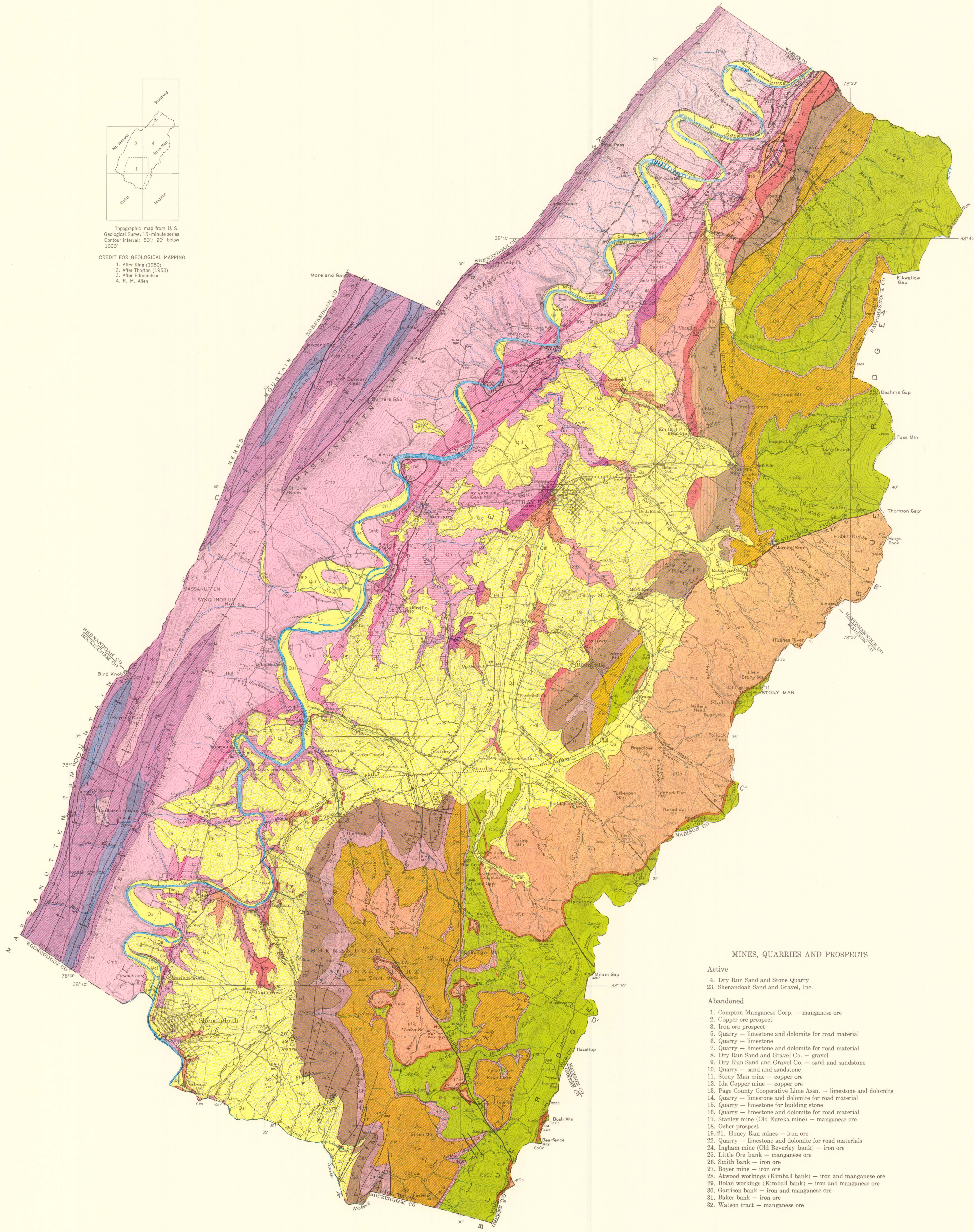
COMMONWEALTH OF VIRGINIA
DEPARTMENT OF CONSERVATION AND ECONOMIC DEVELOPMENT
DIVISION OF MINERAL RESOURCES
James L. Calver
Commissioner of Mineral Resources and State Geologist

Geologic Map
PAGE COUNTY VIRGINIA

Geology by Rhesa M. Allen, Jr.

SCALE 1:62500

1966



Topographic map from U. S. Geological Survey 15-minute series
Contour interval: 50′; 20′ below 1000′

CREDIT FOR GEOLOGICAL MAPPING
1. After King (1950)
2. After Thorton (1953)
3. After Edmundson
4. R. M. Allen

EXPLANATION

QUATERNARY

Qal — River flood-plain deposits
Gravel, sand, and clay

Qg — Terrace gravel

TRIASSIC

Ѣd — Dikes of mafic igneous rocks

DEVONIAN

Du — Devonian undivided
Post-Tonoloway Formation: limestone, light- to dark-gray, fine- to coarse-grained, with minor amounts of claystone and shale (may be Silurian in part); Needmore Formation; Millboro Shale.

SILURIAN

Scy — Cayuga Group
Bloomsburg sandstone, siltstone, and shale, red; Tonoloway Formation: shaly limestone, gray fine-grained, with mud cracks.

Sm — Massanutten Sandstone
Quartzite, white; sandstone, white, fine-grained.

ORDOVICIAN

Omb — Martinsburg Formation
Shale, silty shale; arkosic sandstone and calcareous layers at base.

Oe — Edinburg Formation
Limestone, dark-gray, dense; shale, gray and black, graptolites.

Oln — New Market Limestone and Lincolnshire Formation
Limestone, light-gray, dense, generally conglomeratic at base; cherty limestone, dark-gray, medium- to coarse-grained.

Ob — Beekmantown Formation
Dolomite, gray, medium-grained, thick-bedded; limestone, light-gray, fine-grained; chert. Beekmantown and Chepultepec formations mapped as one unit south of Alma.

Och — Chepultepec Formation
Limestone, blue and gray, dense; dolomite.

CAMBRIAN

Ꞓco — Conococheague Formation
Dolomite, gray, fine-grained; limestone, blue; sandstone, white.

Ꞓe — Elbrook Formation
Dolomite and limestone, thin- to thick-bedded; chert.

Ꞓr — Rome Formation
Shale, red and brown; limestone at top.

Ꞓs — Shady Formation
Dolomite and limestone, deeply weathered.

Ꞓer — Erwin (Antietam) Formation
Quartzite, white, thick-bedded at base; quartzose and arkosic sandstone at top.

Ꞓh — Hampton Formation
Sandstone and siltstone, green; shale at base.

Ꞓw — Weverton Formation
Conglomerate and quartzose and arkosic sandstone at base; sandstone and shale at top.

Ꞓl — Loudoun Formation
Tuffaceous slate, red and purple.

pꞒꞒc — Catoctin Formation
Altered basalt and tuffaceous sediment.

pꞒꞒs — Swift Run Formation
Conglomerate, arkosic quartzite, phyllite, and slate.

PRE-CAMBRIAN

pꞒp — Pedlar Formation
Granodiorite, gneiss, and unakite.

CONTACTS
exposed
approximate
covered

FOLDS
Anticline—trace of axial plane and direction of plunge of axis
Syncline—trace of axial plane and direction of plunge of axis
Overturned anticline—trace of axial plane
Overturned syncline—trace of axial plane

FAULTS
NORMAL AND REVERSE
exposed
approximate
covered
U- upthrown side
D- downthrown side

THRUST
exposed
approximate
covered
T- overthrust side

TRANSVERSE
exposed
approximate
covered
Arrows indicate relative movement

ATTITUDE OF ROCKS
Strike and dip of beds
Strike of vertical beds
Strike and dip of overturned beds
Horizontal beds

FOLIATION
Strike and dip of foliation

MINES, QUARRIES, PROSPECTS, AND SAMPLE LOCATIONS
Mine or quarry
Abandoned mine or quarry
Prospect
R-650 Location of sample for ceramic and lightweight aggregate tests

MINES, QUARRIES AND PROSPECTS

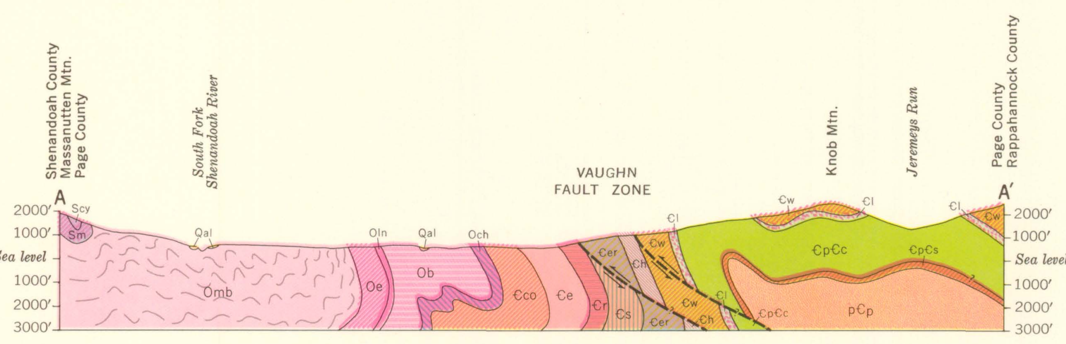
Active

4. Dry Run Sand and Stone Quarry
23. Shenandoah Sand and Gravel, Inc.

Abandoned

1. Compton Manganese Corp. — manganese ore
2. Copper ore prospect
3. Iron ore prospect
5. Quarry — limestone and dolomite for road material
6. Quarry — limestone
7. Quarry — limestone and dolomite for road material
8. Dry Run Sand and Gravel Co. — gravel
9. Dry Run Sand and Gravel Co. — sand and sandstone
10. Quarry — sand and sandstone
11. Stony Man mine — copper ore
12. Ida Copper mine — copper ore
13. Page County Cooperative Lime Assn. — limestone and dolomite
14. Quarry — limestone and dolomite for road material
15. Quarry — limestone for building stone
16. Quarry — limestone and dolomite for road material
17. Stanley mine (Old Eureka mine) — manganese ore
18. Ocher prospect
19.-21. Honey Run mines — iron ore
22. Quarry — limestone and dolomite for road materials
24. Ingham mine (Old Beverley bank) — iron ore
25. Little Ore bank — manganese ore
26. Smith bank — iron ore
27. Boyer mine — iron ore
28. Atwood workings (Kimball bank) — iron and manganese ore
29. Bolan workings (Kimball bank) — iron and manganese ore
30. Garrison bank — iron and manganese ore
31. Baker bank — iron ore
32. Watson tract — manganese ore

Williams & Heintz Map Corporation, Wash., D.C. 20027



No Vertical Exaggeration