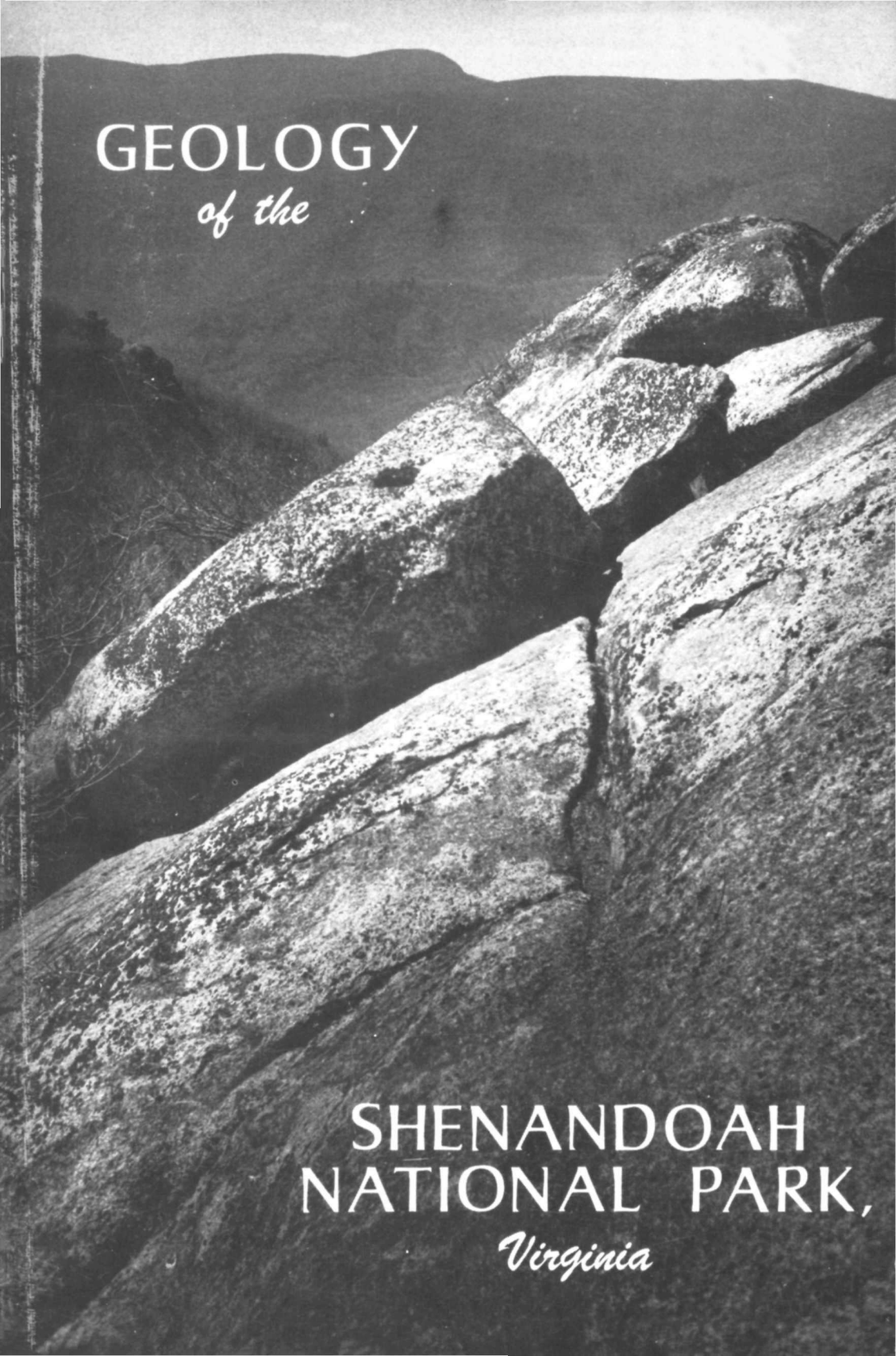
GEOLOGY
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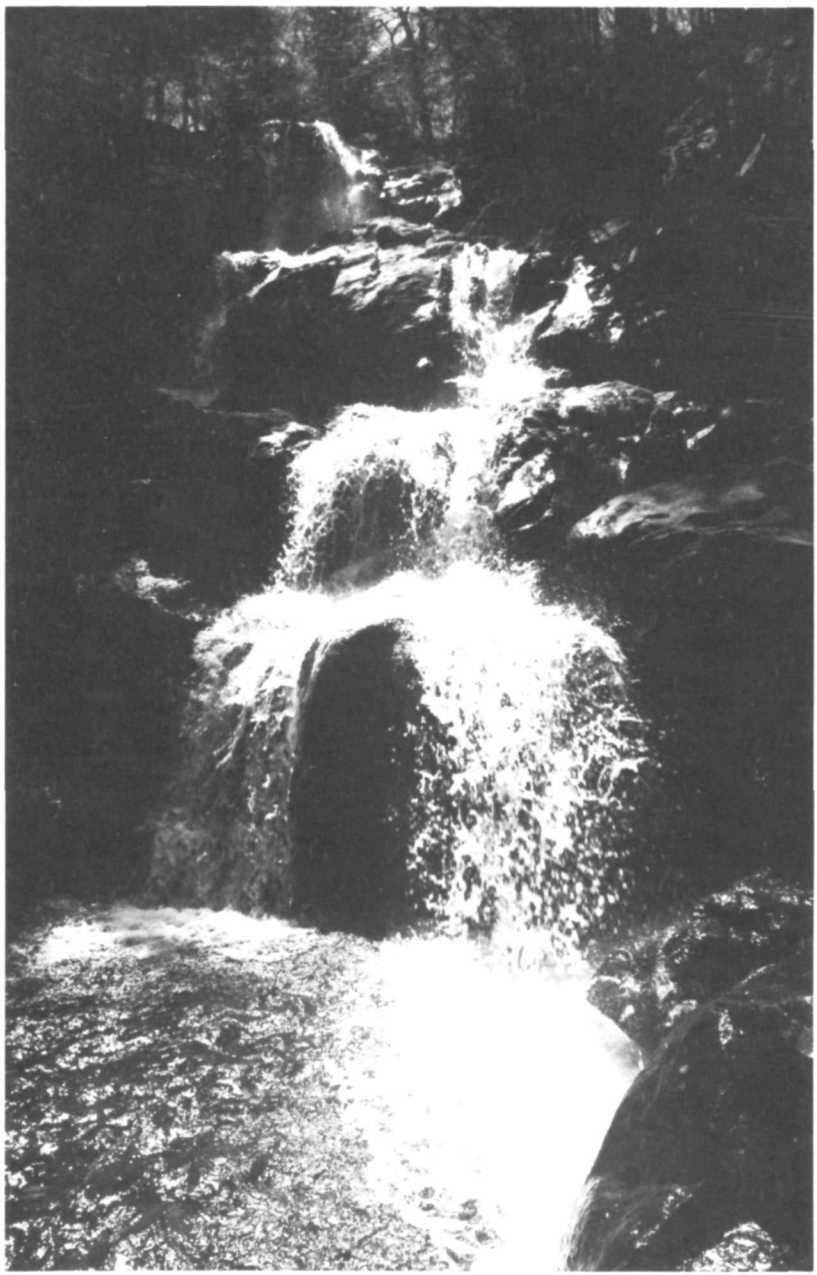
FRONT COVER: View from Old Rag Mountain toward Stony Man on the Blue Ridge crest.

BACK COVER: Columnar basalt ledge on the south side of Compton Mountain.



Dark Hollow Falls during a period of peak flow in early spring. The benches that form the cascades are developed on a resistant basalt flow of the Catoctin Formation where selective weathering along gently inclined fractures has caused differential removal of the rock material at several horizons.

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

GEOLOGY OF THE SHENANDOAH NATIONAL PARK, VIRGINIA

THOMAS M. GATHRIGHT II

BULLETIN 86

VIRGINIA DIVISION OF MINERAL RESOURCES
James L. Calver
Commissioner of Mineral Resources and State Geologist

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RICHMOND

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GEOLOGY OF THE SHENANDOAH NATIONAL PARK, VIRGINIA

By

Thomas M. Gathright II

INTRODUCTION

Shenandoah National Park lies astride a 70-mile segment of the Blue Ridge mountains in north-central Virginia between Front Royal at the park's north entrance and Rockfish Gap near Waynesboro at the south entrance. The park occupies more than 300 square miles in portions of eight counties (Figure 1).

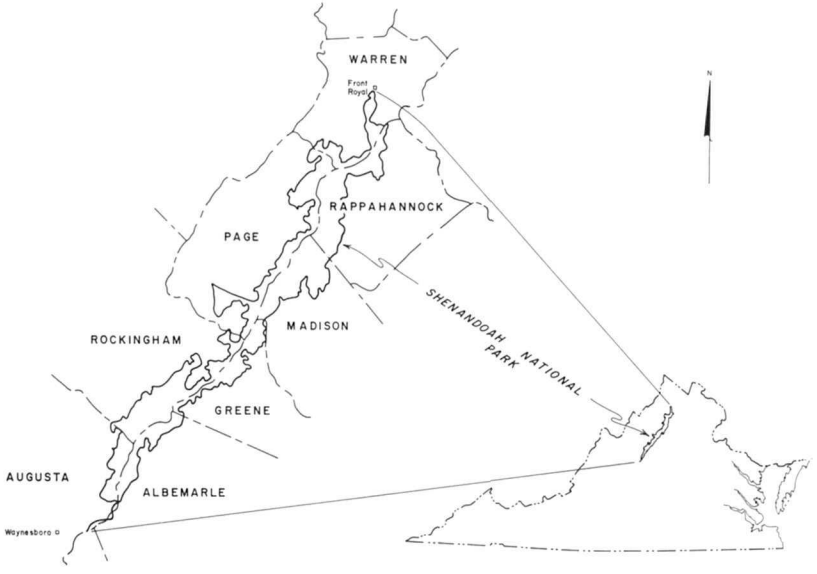

Figure 1. Location map of Shenandoah National Park, Virginia and surrounding counties.

The main body is 3- to 6-miles (5- to 10-km) wide with a very irregular boundary that encloses small portions of the Shenandoah Valley to the west and many of the lower Blue Ridge foothills to the east. Skyline Drive, the north-south highway along the crest through the park; the Appalachian Trail; and the numerous park-maintained footpaths provide access to the mountain wilderness and many scenic vistas of the Blue Ridge, the Shenandoah Valley, the Massanutten mountain range west of the park, and the rolling Piedmont to the east. The Blue Ridge

within the park area reaches 4,050 feet (1,234 m) in elevation on Hawksbill and consists of high, broad mountains, interconnected by high gaps and saddles with many peaks, and sinuous, sharp-crested ridges. Two of the more prominent gaps, Thornton and Swift Run, lend access to the central portion of the park via U. S. Highways 211 and 33, respectively, and divide the park into three sections—northern, central, and southern.

The quiet but rugged grandeur of the wilderness, the high meadows and rocky slopes, the arcuate escarpments, and plunging cataracts in the park area all compound a feeling of permanence that belies the action of onging geologic processes. Yet, it is these processes that through the past billion years, or more, have formed and shaped these mountains and the rocks from which they were carved. Much of the history of these processes and of the resultant mountains can be found in the Blue Ridge rocks. Some geologic processes and events can be documented with certainty, others are more obscure, and many we can only speculate about. Even those processes going on today such as weathering and erosion of the mountain surface are complex and not easily understood. What we see in the Blue Ridge today is a part of the geologic framework of the earth's crust altered and partially exposed by geologic events and the impact of climate and biological processes on the rock material that now forms the mountains.

Today, the park environment is undergoing rapid change. Indians were the first to leave their mark on the mountain forests, girdling the trees and burning the undergrowth to make small clearings for gardens or for hunting purposes. These changes were probably insignificant, as the small Indian population had only rudimentary hand tools and fire for clearing the forest. Early colonial settlers cleared more land and cut timber for their own use, but they had little more impact on the mountain wilderness than the Indians. Large tracts of virgin timber were still present in the park area in the late nineteenth century when rail access to the foot of the Blue Ridge and demand for construction materials in the northeastern United States brought the sawmills to the mountains. The timbering operations that followed and the devastating chestnut blight in the early twentieth century removed or killed many of the commercially valuable trees leaving only a few virgin stands, all devoid of the chestnut, in the less accessible areas.

In the nineteenth century the discovery of small deposits of iron, manganese, and copper brought mining and prospecting to the mountains and western foothills of the park. Iron and manganese deposits along the west foot of the Blue Ridge, generally just west of the park boundary, have been mined for more than 100 years. Iron was mined only until the early twentieth century, but manganese was mined intermittently until about 1960 with peak mining periods occurring around 1890 and during the two World Wars. Exploration trenches, opencut mines, and shafts mark the location of more than 40 abandoned mines in or just west of the park. Remnants of the largest and most productive opencut manganese mine can be seen from Crimora Lake Overlook on Skyline Drive. Copper mining was also attempted at several locations in or near the park during the late nineteenth and early twentieth centuries. Small amounts of copper oxides and sulphides and native copper occur in the ancient basalts that form much of the Blue Ridge crest. Only small mine operations were developed because the copper ore was neither extensive nor of high quality. Abandoned mines and spoil may be seen on Stony Man and near Dark Hollow Falls (Plate 2). However, the copper mining operations had few effects on the wilderness and these are rapidly fading away with the return of the forest.

During the establishment of Shenandoah National Park in the nineteen-twenties and -thirties at least several hundred families still lived in the park area, subsisting on small mountain farms and tending cattle or orchards on partially cleared mountain slopes or hollows (Figure 2). Small second-growth timber covered most uncleared portions of the Blue Ridge at that time. Logging and mining operations ceased within the park after its establishment and the families still living there gradually resettled in nearby areas. Since that time, most of the forest has been undergoing a rapid environmental change, which is the uninhibited process of returning to its natural state. Many of the old homesites are still evident in the park. Solitary rock chimneys, vine-covered foundations, broken-down rail fences, and overgrown apple orchards are only a few of the relics of the mountain farms. Young second-growth forest and thick underbrush are taking over the abandoned fields and yards—areas that will take the most time in reverting to the kind of wilderness present before human habitation.

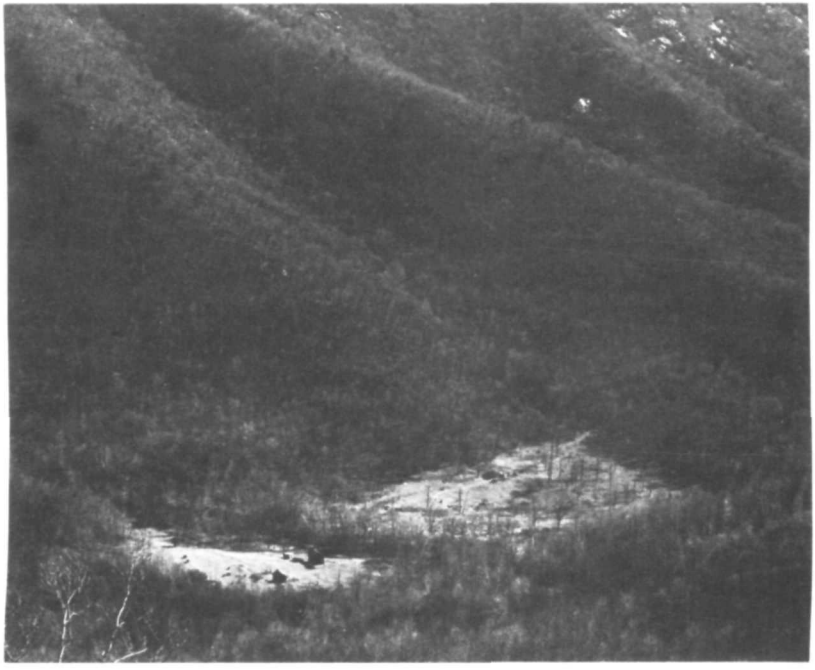

Figure 2. Small mountain farm in the upper reaches of Bacon Hollow as seen from Bacon Hollow Overlook. Many similar farms were present along the eastern slopes and crest of the Blue Ridge at the beginning of the twentieth century.

The geology of the Blue Ridge greatly influenced the location of the settlements and the life of the settlers. The early mountain people and probably the Indians before them selected homesites where water, gentle slopes, and fertile soils were present. This restricted almost all settlement to areas having bedrock of granite or basalt because only in these areas are springs abundant and soils and slopes adequate for small farms. This includes most of the northern half of the park and the eastern ridges in the southern half. The remaining southwestern quarter is largely underlain by metamorphosed sandstone and shale on which soils are very thin and rocky, slopes are steep, and springs intermittent (Figure 3), making the area much less hospitable than that portion underlain by basalt and granite.

The climate of the Blue Ridge is also influenced by the geology. The elevation of the mountains, directly related to the resistance of the rocks that form them, controls the local climate. In the Blue Ridge temperatures are lower by approxi-

mately 5-10° F (2-6° C), and precipitation and wind velocity is greater than in the adjacent lowlands. This more stringent climate probably limited settlement of the Blue Ridge as much as the ruggedness of the mountains. Its importance may be

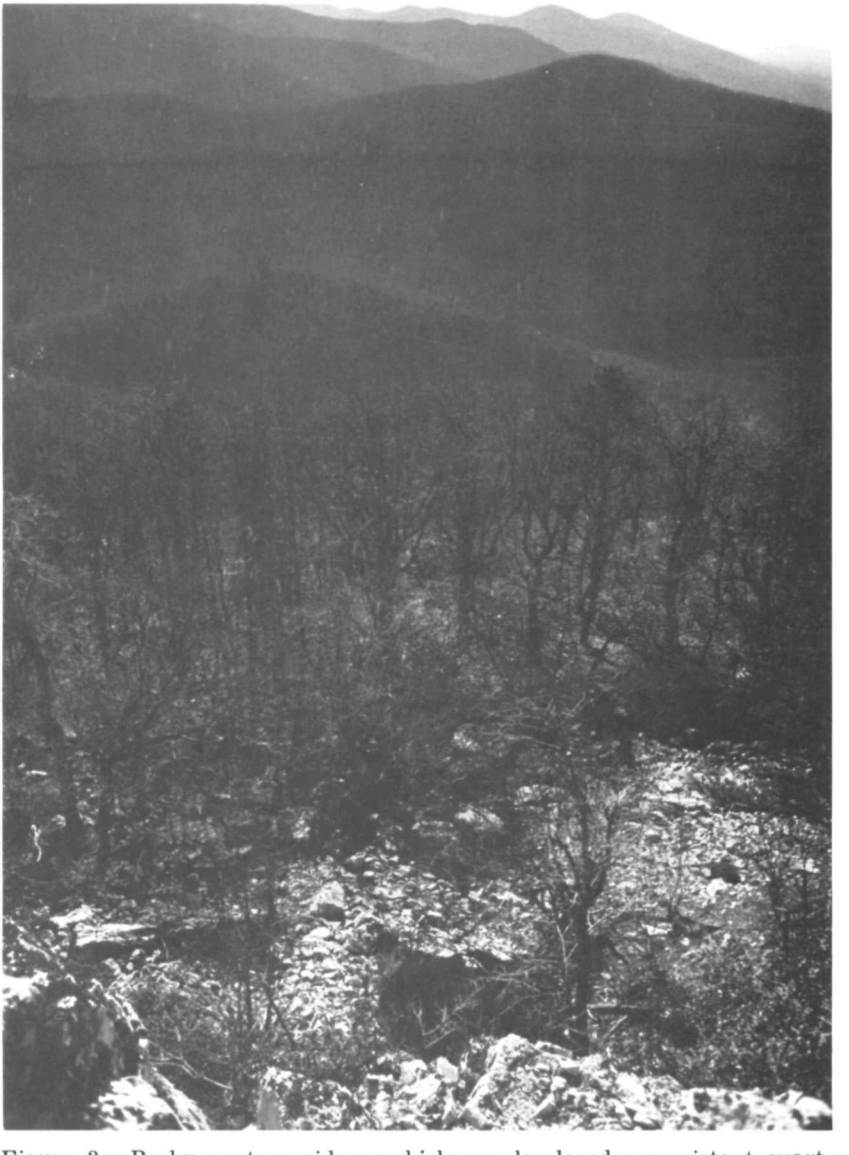

Figure 3. Rocky western ridges, which are developed on resistant quartzite beds and phyllite presented an inhospitable environment and were virtually unsettled when the park was established.

seen in the location of many of the former settlements which were so situated as to obtain some protection from the prevailing southwest or west winds and to receive as much sunlight as possible.

The park provides a look at a thick, mountain-forming sequence of volcanic rock that may be as much as 800 million years old. In the Blue Ridge rapid uplift may have taken place long ago while the rocks were being folded, but now the area is stable and uplift is not evident. The present forms of the mountains and ridges are smooth and rounded except where an occasional quartzite ledge or basalt cliff breaks through the forest cover (Figure 4). The valleys slope progressively more gently

Figure 4. Hawksbill from Crescent Rock. Rock ledges visible through the trees near the crest of the mountain are generally present on the steep, wooded slopes along the westward-facing Blue Ridge escarpments; they effectively restricted westward movement of the early settlers to the few low gaps in the mountain range.

away from the mountains into broad, gently rolling lowlands with meandering streams and rivers. This landscape is one of balance or equilibrium where none of the three environmental factors—climate, biology, and geology—that contribute to the formation of the landforms are dominant. The impact of the

geology on the origin and environment of the Blue Ridge mountains is subtle because the rocks are masked by soil and forest. Yet, through this cover the individual rock formations express themselves by the shapes and elevations of the mountains they form and by characteristic soils and vegetation.

The Blue Ridge mountains have been inspirational to man since his first encounter with them. They have been a barrier that had to be surmounted, a refuge from the changing world around them, and a place to replenish the spirit in an ever more rapidly paced world. For these and many more reasons the mountain wilderness of the park must be preserved, but to preserve it we must better know what the Blue Ridge is and why it is there. This, then is a part of the story of the Blue Ridge and of the rocks that form it.

REGIONAL GEOLOGIC SETTING

The Blue Ridge mountains in Shenandoah National Park lie entirely within the Blue Ridge physiographic province, the narrow mountainous area between the low-lying Piedmont province to the east and the Valley and Ridge physiographic province to the west. Geologically, the Blue Ridge is situated on the western flank of an extensive linear arch or upwarp extending from southern Pennsylvania into central Virginia or beyond and encompassing the Blue Ridge province and the western edge of the Piedmont. This complex upwarp, the Blue Ridge anticlinorium (Figures 5A, B), is an area of folding and faulting characterized by great uplift that is demonstrated by the presence of billion-year-old plutonic rocks that formed at great depth and which are now exposed along the axis of the anticlinorium. The flanks of the anticlinorium are delineated by a thick sequence of very resistant, metamorphosed volcanic and clastic sedimentary rocks of late Precambrian and early Cambrian age that form the Blue Ridge and a low parallel mountain range about 20 miles east of the Blue Ridge. This resistant layered rock sequence lies unconformably on the plutonic rocks and is the basal portion of the layered rock sequence that forms the Appalachian Mountains of which the Blue Ridge is only a small portion. Younger rocks, mostly of Paleozoic age, overlie the resistant sequence and are preserved in downfolded areas to the east and west of the anticlinorium. In the Piedmont to the east of the anticlinorium these rocks are a series of complexly

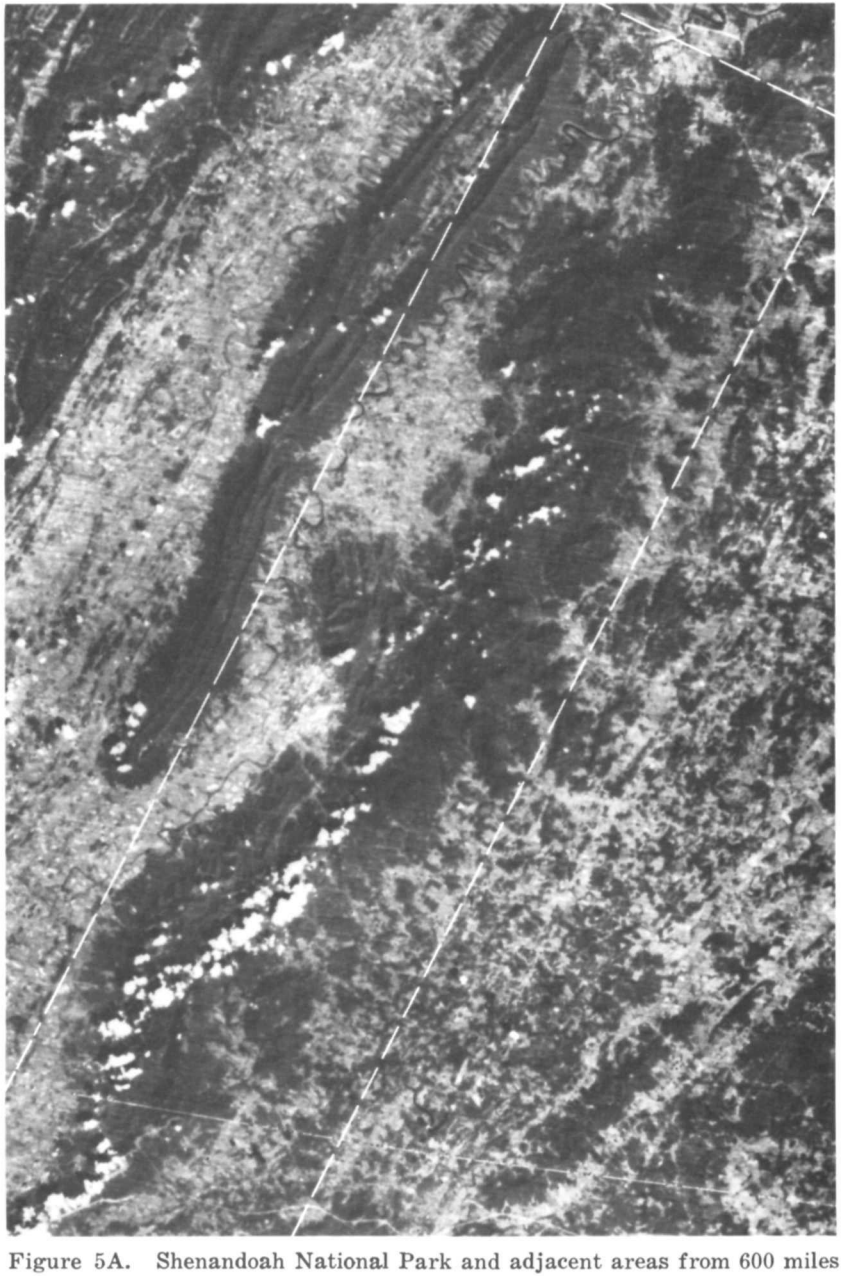

Figure 5A. Shenandoah National Park and adjacent areas from 600 miles above the earth (LANSAT imagery). The park lies in the dark (forested) mountainous area within the outline of Plates 1, 2, and 3.

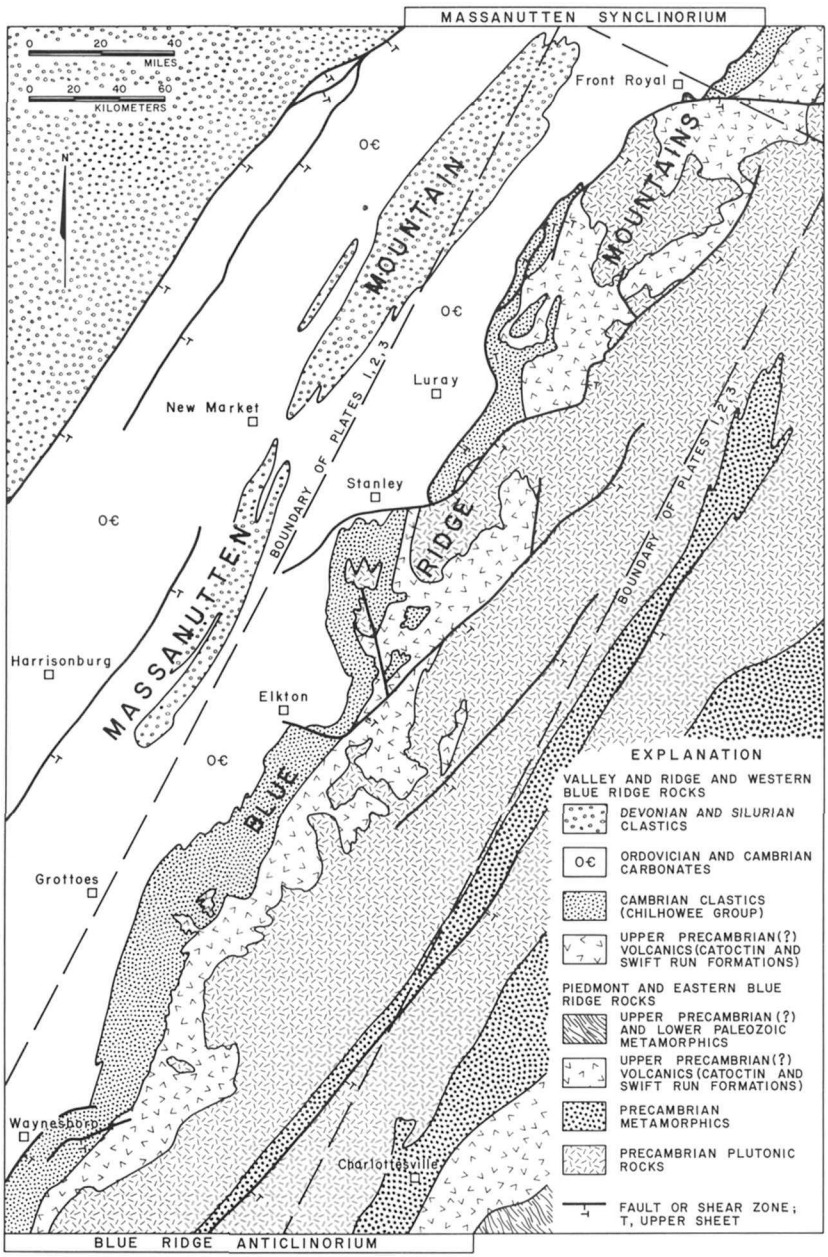

Figure 5B. Generalized geologic map of area shown in figure 5A. The Blue Ridge lies between the Valley and Ridge physiographic province to the west and the Piedmont physiographic province to the east.

folded and metamorphosed volcanic and sedimentary rocks intruded by granites and gabbros. To the west the younger rocks are mainly limestones, dolomites, shales, and sandstones of Cambrian through Devonian age and are only slightly metamorphosed and less complexly folded. Limestone and dolomite form the floor of the Shenandoah Valley and sandstone forms the crest of the Massanutten mountain range west of the park; shale underlies the lower slopes of the Massanuttens.

The trough or canoe-shaped downfold, now preserved as the Massanutten mountain range, is the Massanutten synclinorium (Figures 5A, B) that is the next regionally extensive fold system west of the Blue Ridge anticlinorium. The Blue Ridge anticlinorium and the Massanutten synclinorium are laterally continuous fold systems that share a common flank. Plutonic rocks in the Blue Ridge now occur at higher elevations than the Silurian rocks of the Massanutten mountain range due to vertical upwarping in the Blue Ridge of more than 4 miles (6 km) during Paleozoic time. The intensity of metamorphism and complexity of the folds decreases westward across the Blue Ridge from the Piedmont to the Valley and Ridge province. Faults and shear zones occur in and near the park and appear to be local features, but may be characteristic structures of the Blue Ridge anticlinorium and more extensive than shown on Plates 1-3 and Figures 5A and 5B.

Few areas in the Blue Ridge can match Shenandoah National Park for the variety of well-exposed geologic features in the several rock units that are present. Also in few areas are the relationships between the several Precambrian and early Cambrian rock units so well displayed as in much of the park.

STRATIGRAPHY

The bedrock of the Shenandoah National Park is Precambrian, Cambrian, Ordovician, and Triassic in age (Figure 6). However, formations in small areas of the western part of the park that are younger than the Cambrian Erwin Formation were not mapped (Plates 1, 2, 3). Also, for simplification of the geologic maps, Quaternary alluvium and other surficial deposits are not shown.

Numbers preceded by "R" in parentheses (R-4460) correspond to sample localities; those preceded by "F" (F-868) correspond to fossil localities (Plates 1, 2, 3). These samples are

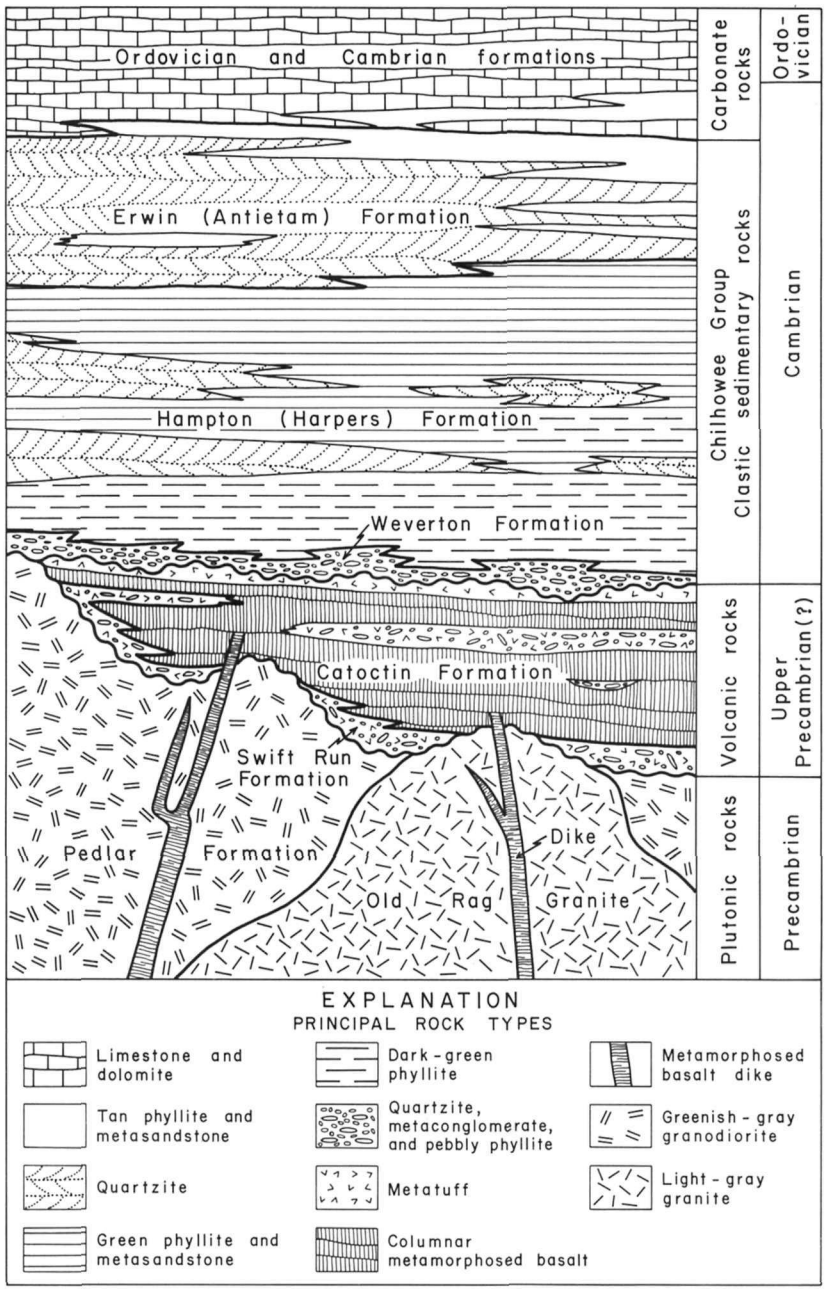

Figure 6. Generalized columnar section of rock formations in Shenandoah National Park, Virginia.

on file in the repository of the Virginia Division of Mineral Resources where they are available for examination.

PRECAMBRIAN ROCKS

The rocks in the core of the Blue Ridge anticlinorium that underlie portions of the Shenandoah National Park belong to extensive, metamorphosed plutonic bodies more than a billion years old (Tilton and others, 1958). These rocks are characterized by mineral compositions that range from granite to granodiorite and by granoblastic and cataclastic textures that indicate periods of intense metamorphism. Many of the higher peaks such as The Pinnacle, Oventop Mountain, and Old Rag Mountain are formed of these rocks as are most of the lower peaks and much of the lowlands on the eastern flank of the Blue Ridge.

Old Rag Granite

The Old Rag Granite, named and described from exposures on Old Rag Mountain (Plate 2) by Furcron (1934), is the most distinctive plutonic rock body in the park. The formation is unconformably overlain by the Catoctin and Swift Run formations west of Old Rag Mountain, and it is gradational into or in fault contact with the Pedlar Formation in other areas. It is a light-gray to nearly white, coarse-grained, porphyritic rock of granitic composition that is resistant to weathering and forms bold, extensive outcrops on several mountaintops. The granite is composed mainly of blue quartz and perthitic microcline. Many of the feldspar crystals exceed 1 inch (3 cm) in length (R-4459). The Old Rag Granite is almost devoid of dark minerals, containing only small amounts of chlorite, epidote, magnetite and/or ilmenite, and sphene (R-4456). A weak compositional layering of elongate patches and stringers of quartz forms a subtle foliation in the otherwise massive-appearing rock. Along the contact zone with the Pedlar Formation the Old Rag Granite tends to be a finer grained, well-foliated granite or granite gneiss with small amounts of fine-grained biotite.

The Old Rag Granite is well exposed on the crest of Old Rag Mountain (Plate 2), which is accessible to hikers by the Ridge Trail from a parking area at the end of State Road 600 in Madison County or by White Oak Canyon Trail and Old Rag Road from the Skyland area of the Park. Where the mountain

crest is locally devoid of vegetation and soil, large areas of unweathered, coarse-grained granite are exposed. The rock surface is notably abrasive due to microfracturing of the coarse quartz and feldspar grains that weather out in relief (R-4453). Large spheroidal boulders, some more than 10 feet in diameter (Figure 7), are clustered chaotically on the higher points of

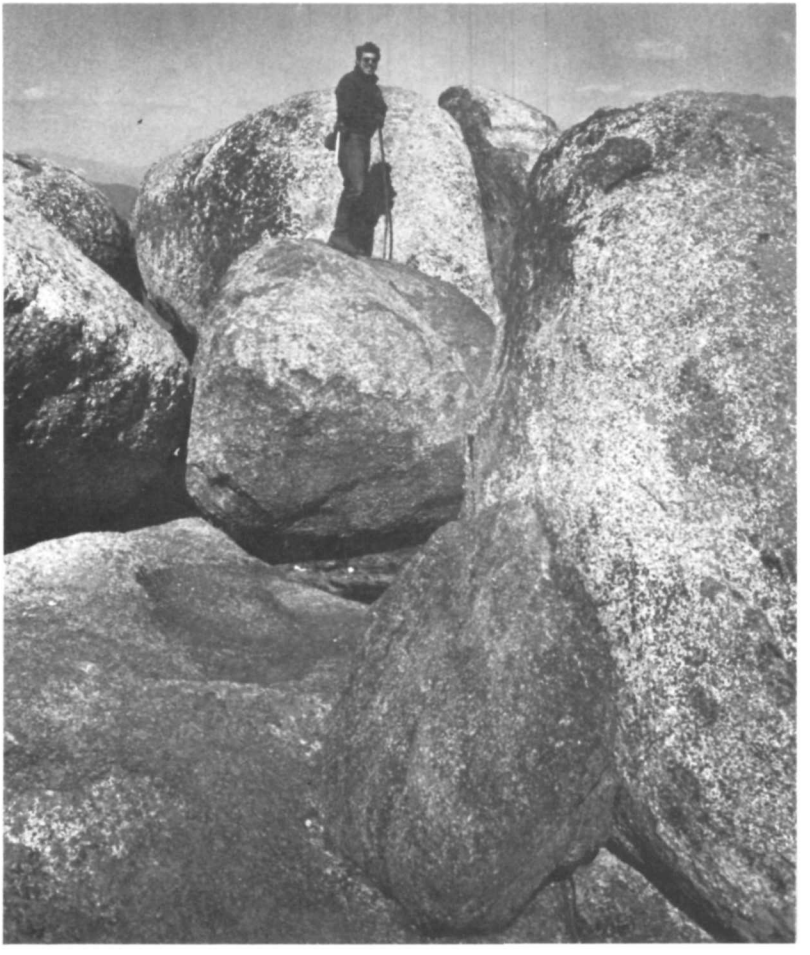

Figure 7. Boulders on the crest of Old Rag Mountain were formed by the direct action of wind and water on exposed blocks of granite.

the mountain and are evidence of the severe wind and water erosion that prevails on the crest of the Blue Ridge. These boulders have been formed essentially in place from originally

orthorhombic-shaped joint blocks of granite such as those exposed in the cliff faces on the north side of the crest. Many of these joint blocks have been partially rounded on their exposed edges (Figure 8), and a few of the smaller blocks have become

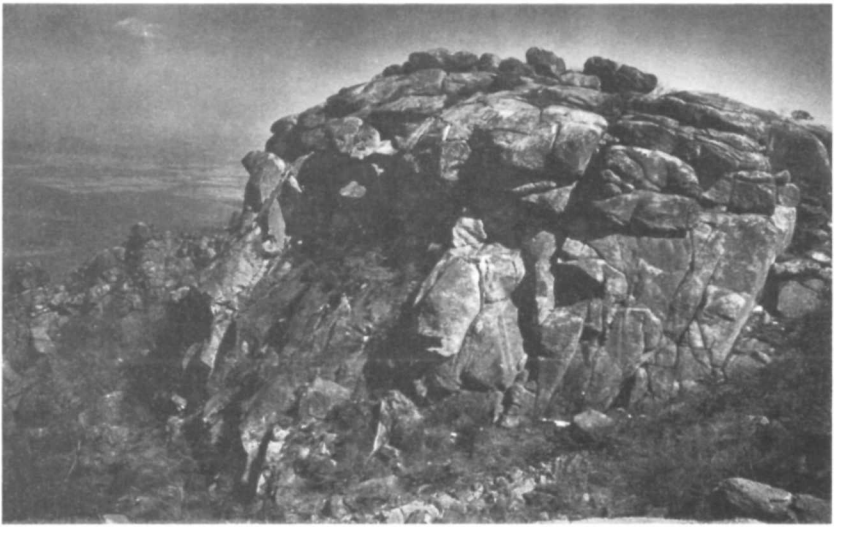

Figure 8. Vertical, subhorizontal, and moderately inclined joints exposed on the west face of the main crest of Old Rag Mountain. These joints form orthorhombic blocks that, when exposed to weathering, produce subspherical boulders as shown in Figure 7.

well rounded. Along the crest of the mountain the granite is cut by several northward-trending, diabasic greenstone dikes (altered basalt), which probably represent ancient conduits through which basalts of the Catoctin Formation were extruded (R-4460). Several of the smaller dikes are well exposed along Ridge Trail on the crest of the mountain (Figure 9), but the larger ones that may be several tens of feet in width are defined only by scattered blocks of diabase in linear depressions trending to the north across the mountain crest. Many exposures of Old Rag Granite may also be found on Oventop Mountain north of U. S. Highway 211 between Thornton Gap and Sperryville (Plates 1, 2). The crest of Oventop Mountain is also cut by many dikes similar to those on Old Rag Mountain.

Pedlar Formation

The name Pedlar Formation was first applied to rocks exposed in the Blue Ridge along the upper reaches of Pedlar River

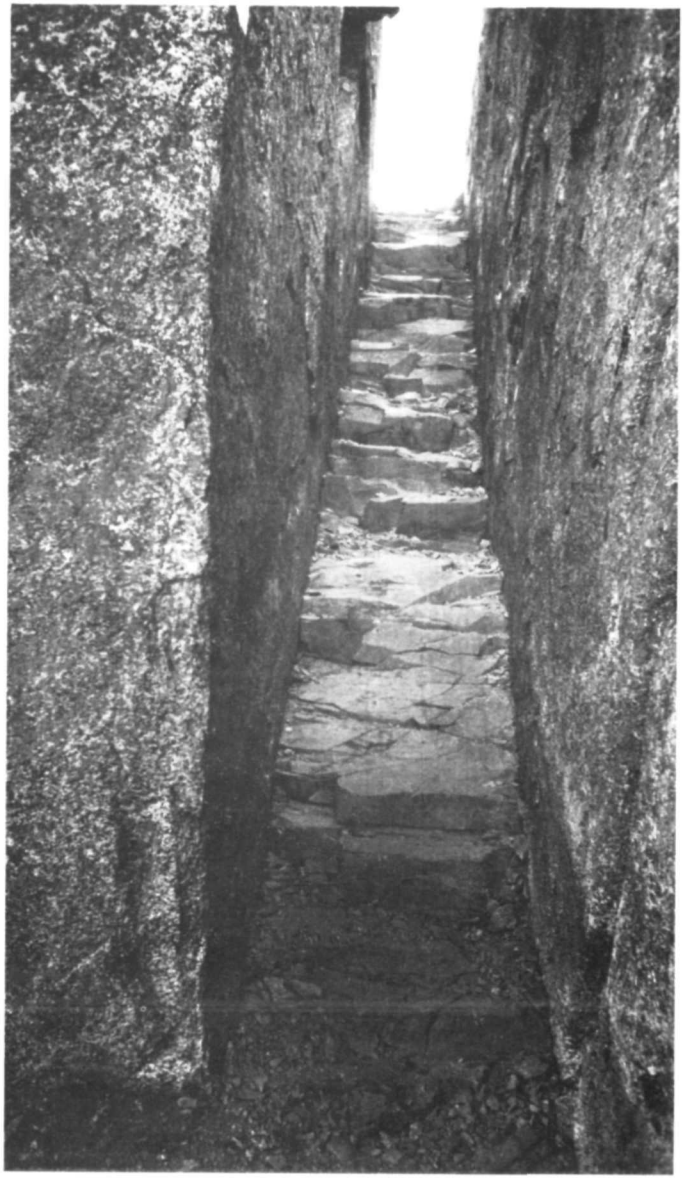

Figure 9. Greenstone dike that forms a flight of natural stairs between granite walls along the Ridge Trail on Old Rag Mountain. The stair-like surface on the dike is the result of selective weathering of columnar joint blocks that formed perpendicular to the granite walls during cooling of the basaltic magma.

in Amherst County, Virginia (Bloomer and Werner, 1955). Within Shenandoah National Park the Pedlar Formation was first used as a mapping unit (Allen, 1963) for the hypersthene granodiorites and related rocks in Madison and Greene counties. More recently the rocks mapped as the Pedlar have been referred to as hypersthene-bearing granulites (Reed, 1971) and as charnockites (Herz, 1969), which are probably more meaningful classifications as they give the connotation of originally high metamorphic-rank plutonic rocks.

The Pedlar Formation is unconformably overlain by the Swift Run and Catoctin formations along the flanks and crest of the Blue Ridge mountains, and by the Weverton Formation in one area near the westernmost extension of the park in the central section. On the east side of the Blue Ridge in the central and northern sections (Plates 1, 2), the Pedlar Formation is in fault contact with the Old Rag Granite along shear zones or grades laterally into it across a transition zone that ranges up to more than a mile in width. A dike or sill of granodioritic material similar in composition to the Pedlar is present on the crest of Old Rag Mountain (R-4461).

The unweathered rocks of the Pedlar Formation are medium to dark greenish or bluish gray, and commonly have a waxy or greasy luster on a broken, unweathered surface (R-4448, R-4398). They may have a generally massive appearance with only a faint linear or planar fabric, or a gneissic foliation of alternating dark and light mineral layers (Figure 10). More

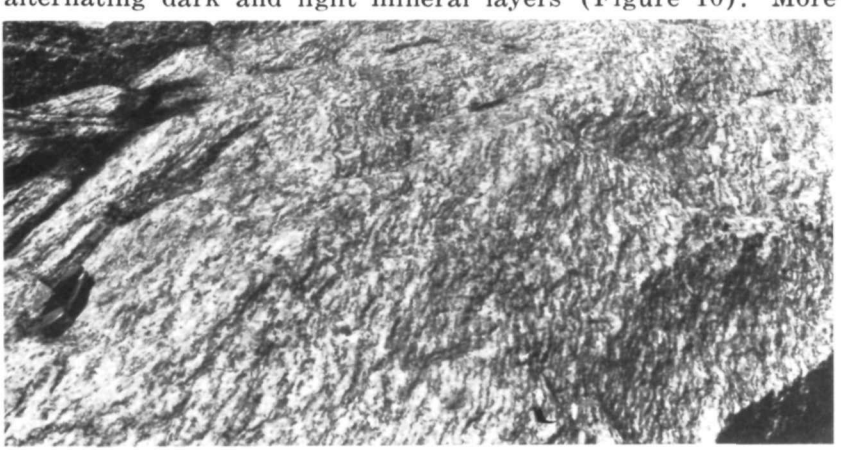

Figure 10. Gneissic hypersthene granodiorite of the Pedlar Formation at the south portal of Marys Rock Tunnel (Plate 2). One of the best exposures of the gneissic or layered phase of this rock unit in the park.

frequently elongate clots of dark minerals in a light-gray matrix give the rocks a diffuse, spotted, or lined appearance (R-4407). The rock is generally fine- to medium-grained granodiorite or quartz monzonite composed largely of plagioclase feldspars and quartz, with the dominant dark minerals being either hypersthene and augite or biotite, hornblende, and garnet. Microscopically, the mineral grains are of uniform size and have sutured, interlocking grain boundaries that define a well-developed granoblastic fabric probably indicative of complete recrystallization during a major metamorphic event. The granoblastic fabric has in itself been altered by shearing that has formed parallel slip planes, shear zones, and mylonites (zones of slaty, crushed rock) that locally transect all of the plutonic bodies. Within these shear features or fault zones the granoblastic fabric may be destroyed, and replaced by an aligned mineral assemblage of quartz, sericite, and chlorite (R-4422, R-4450, R-4452).

The layered variety of granodiorite is more prevalent in the northern half of the park (R-4389), although massive and spotted varieties occur locally. In the layered granodiorite small lenses and stringers of white granitic rock, similar to the Old Rag Granite, locally occur between dark hornblende or biotite-rich layers (Figure 11). Good exposures of layered granodiorite are at the Tunnel Parking Overlook at Marys Rock Tunnel on Skyline Drive (Plates 1 and 2) and along U. S. Highway 211 near the Piedmont Picnic Area. The more massive, lineated or spotted varieties are prevalent east of Skyline Drive in the central and southern sections (R-4407), and are well exposed along U. S. Highway 33 east of Swift Run Gap.

PRECAMBRIAN (?) ROCKS

Swift Run Formation

The Swift Run Formation is a discontinuous sequence of metaconglomerate, metasandstone, tuffaceous phyllite (R-4417), and coarse-grained volcano-clastic rocks that unconformably overlies the plutonic rocks. It was formed from debris that was eroded from the plutonic rocks and from volcanic ash and coarse volcanic debris which was ejected during the earlier phases of volcanism. The formation grades upward into the Catoctin Formation and is interbedded with it in many areas. The Swift Run ranges up to 200 feet (61 m) in thickness being absent in some portions of the park.

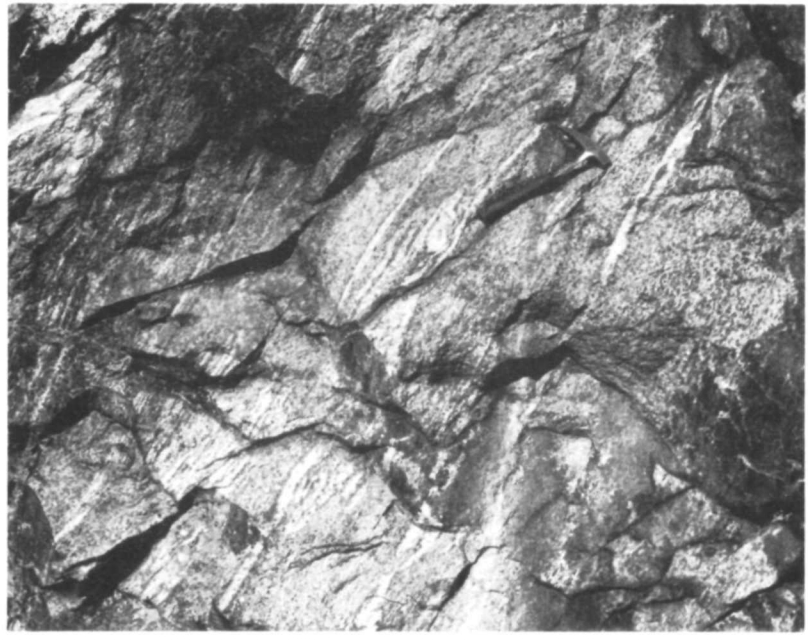

Figure 11. Granite gneiss on the north side of Skyline Drive, 0.3 mile (0.5 km) south of Land Run Gap (Plate 1). Although not typical of this formation, rocks of this type occur locally within the Pedlar granodiorite in the northern section of the park, and they are similar to gneissic rocks exposed in the core of the Blue Ridge anticlinorium east of the park. In this exposure the light-hued layers of quartzo-feldspathic material seem to outline tight, steeply plunging folds.

The heterogeneous nature of the Swift Run is its most dominant characteristic. Phyllites grade laterally into metasandstones or metaconglomerates within a few hundred feet. Coarse volcano-clastic rocks predominate in some areas and locally thin beds of metabasalt may be interbedded with any of the other rock types of the formation. Excellent exposures of the Swift Run can be seen on Skyline Drive at Hensley Hollow Overlook, in the northern part of Lewis Mountain Picnic Area, and on the trail east from Bear Fence Mountain Overlook (Plate 2). Characteristic exposures of interbedded conglomeratic phyllite and metasandstone are present in the first roadcut south of Powell Gap (Plate 3). The coarse volcano-clastic phase is exposed on the south side of Skyline Drive between Compton Gap and Indian Run Overlook (R-4391) (Plate 1). Very good exposures of the formation are present on the Mount Marshall

fire road about 1.0 mile (1.6 km) east of Hogwallow Flats (Plate 1). Coarse meta-arkose (R-4394), quartzite with cross laminations having steep dips, and brown, silver-gray, and purple tuffaceous phyllites are exposed along the fire road near Sprucepine Branch.

Catoctin Formation

The Catoctin Formation is a thick multilayered sequence of resistant volcanic and sedimentary rock that caps most of the higher mountains in the park. The formation contains many volcanic and a few sedimentary rock types but is characterized by a preponderence of metamorphosed basalt beds that were once ancient lava flows. Thin beds of metamorphosed sandstone, conglomerate, volcanic breccia, and tuff are interbedded with the metabasalt. In the park and nearby areas the formation ranges up to about 2,000 feet (610 m) in thickness; it is absent in at least one area near the western park boundary. The Catoctin overlies or is interbedded with the Swift Run Formation along its lower boundary except where the Swift Run is absent; in those areas the volcanic rocks lie directly on the plutonic rocks.

Figure 12. Metabasalt ledge of the Catoctin Formation above Big Bend fire road 0.5 mile (0.8 km) north of U. S. Highway 33 east of Swift Run Gap. The layering in the ledge may be an original layering of the lava flow.

The Catoctin volcanic rocks are best exposed along Skyline Drive in the northern and central sections of the park (Appendix; Plates 1, 2) where the rocks occur on the upright limbs of several large fold structures and are not greatly deformed. In these less deformed areas many of the original features of the volcanic rocks are still present as they survived metamorphism with little visible alteration (Figure 12).

Within the volcanic sequence the ancient lava flows are the most resistant beds and form topographic benches where the beds are upright. From 12 to 16 benches with intervening rock cliffs and debris slopes are present on Mount Marshall (Figure 13, Plate 1) and Spittler Hill (Plate 2). A series of these

Figure 13. Aerial photograph that delineates the series of Catoctin lava flows capping Mount Marshall (Plate 1). Browntown Valley Overlook and Skyline Drive have been constructed along the northwest side of the mountain on a bench formed on the top of one of the lava flows.

benches may be seen from the crest of Stony Man looking downslope toward Skyland Lodge (Plate 2). The metabasalt is very dense, tough, and generally dark-green, grayish-green, or purple. It is composed of fine-grained albite (feldspar) laths in a matrix of very fine-grained chlorite, actinolite, epidote, and pyroxene with varying amounts of magnetite and ilmenite. Where large amounts of epidote are present the metabasalt is pale green and very brittle. Columnar-joints—closely packed, near vertical, polygonal blocks many feet high—that formed while the lavas were cooling, are well displayed on Stony Man, Little Stony Man, and Compton Mountain (back cover; Plates 1, 2). The upper and lower portions of the basalt beds are commonly amygdaloidal. The amygdules are relic gas cavities now filled with coarsly crystalline minerals—quartz, epidote, chlorite, or calcite (Figure 14 and R-4457). They range from micro-

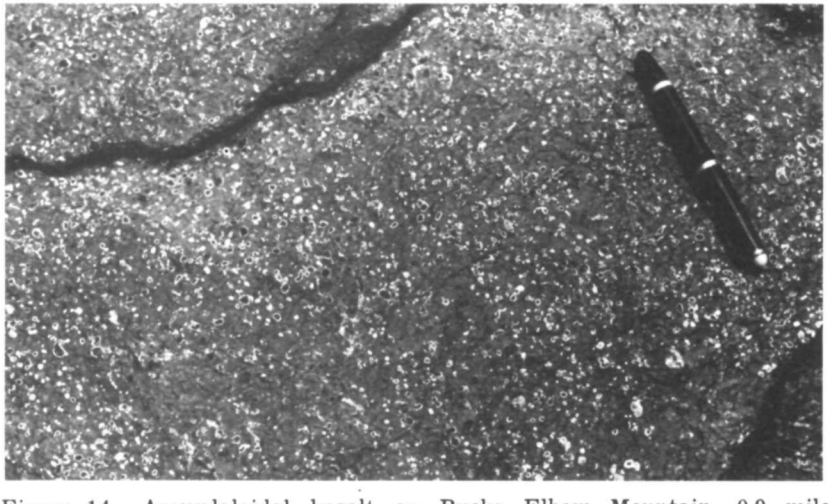

Figure 14. Amygdaloidal basalt on Bucks Elbow Mountain, 0.9 mile (1.4 km) east of Jarman Gap (Plate 3). This rock type occurs in the upper few feet of many basalt flows and consists of a dark-green, very fine-grained metabasalt with many small amygdules having epidote or jasperoid centers with quartz rims. In this flow the effusion of gases from the cooling lava virtually formed a froth before it solidified.

scopic in size near the center of the basalt beds to about 1.0 inch (2.5 cm) near the upper or lower surfaces.

A few metabasalt beds in the Big Meadows (Plate 2) and Loft Mountain areas (Figure 44, Plate 3) have coarse, white to pink crystals of plagioclase feldspar in the dark-green or purple

metabasalt matrix. The porphyritic beds were traced extensively by Reed (1969) in the Big Meadows area and their distribution suggests that these porphyritic lavas covered many square miles of the land surface when they were formed, and may be representative of the distribution of other less easily traceable lava beds.

Volcanic breccias mark the boundaries between the lava flows in many areas. The breccias consist of a chaotic zone of coarse, angular blocks and smaller fragments of the basaltic lavas with quartz, epidote, or jasper filling the void space between the clasts (Figure 15, R-4423). The coarse lava frag-

Figure 15. Epidotized flow breccia from the south of Skyline Drive at Beagle Gap in the southern section. Angular fragments of epidotized, medium greenish-gray, amygdaloidal basalt occur with quartz (white), epidote (light gray rims around quartz), and red jasper (dark gray) filling the voids.

ments are parts of an early crust formed on the lava that, during later movements of the still liquid inner portion of the flow, shattered and collapsed into the upper part of the flow or fell from the advancing lava front to be overridden and buried as the flow moved forward. The fragments of metabasalt tend

to be amygdaloidal as they were derived from the outer flow surfaces where gas bubbles were more likely to be abundant. Local, irregular masses of breccia several tens of feet thick may represent the zone of collision between flows where collapsing rubble on the lava fronts were brought together to form a breccia wall between the lavas. Breccia rubble covers much of the ground surface on the volcanic sequence as it tends to be more resistant to weathering than the other volcanic rocks.

Thin beds of metatuff in the form of dark-purple, yellow-spotted, mottled to laminated slate or phyllite (Figure 16) are present between many of the ancient lava flows and form the

Figure 16. Purple volcanic slate in the field on the southwest side of Skyline Drive at Beagle Gap in the southern section. The volcanic textures commonly found in this rock type have been destroyed by the intense deformation associated with recumbent folds in the southernmost extension of the park.

upper 10 to 200 feet (3 to 61 m) of the volcanic sequence through most of the park. The metatuffs have a fine-grained matrix of chlorite, ilmenite, and sericite with elongate blebs of yellow-weathered, dark-green chlorite. Most of the yellow-spotted slates appear to be devitrified volcanic ash, now highly deformed

and metamorphosed with little of the original texture preserved. Some samples of the upper, purple slate beds from the Jarman Gap and Rockfish Gap areas (Plate 3, R-4410) have well-preserved, microscopic, vitroclastic textures characterized by cresent-shaped masses of opaque minerals that outline deformed glass shards, pumice lapilli, and sericitized feldspar crystals. The curlicue pattern formed by the opaque minerals is characteristic of textures found in ash-flow tuffs (ignimbrites) formed during more violent eruptions. The uppermost purple slates, if truly ignimbrites, were deposited from a rapidly moving cloud of molten ash and effusing gases that swept across the area from some major volcanic center. This genesis would explain the widespread occurrence of the thin, but nearly continuous volcanic bed that marks the top of the Catoctin Formation and apparently the end of volcanic activity in the area. The laminated slates were probably formed from similar volcanic ash that had been reworked by streams and deposited in still water.

Thin, discontinuous beds, consisting principally of conglomeratic metasandstone and phyllite, are present between many of the lava flows, particularly in the southern section of the park (Figure 17). The most extensive sedimentary bed lies

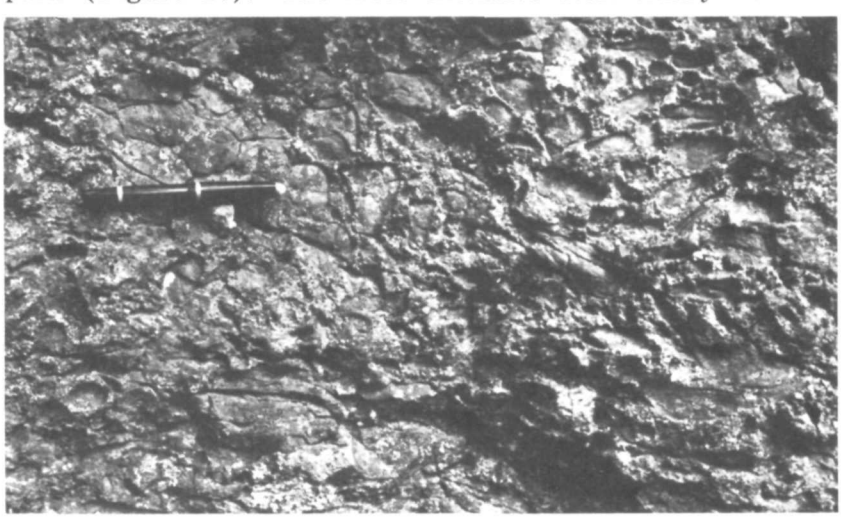

Figure 17. Conglomerate bed on Turk Mountain Trail about 1.0 mile (1.6 km) east of Skyline Drive in the southern section (Plate 3). The conglomerate, a part of the sedimentary unit in the upper part of the Catoctin Formation, contains pebbles and cobbles of metabasalt, metatuff, and granodiorite in a matrix of quartz sand and fine volcanic debris.

between the uppermost lava bed and the main body of the Catoctin Formation and ranges from 0 to at least 200 feet (61 m) in thickness. This rock unit, indistinguishable from rocks of the Swift Run Formation, has been separately mapped in the southern section of the park (Plate 3). The coarse-grained metasandstone contains a high percentage of feldspar and rock fragments and the conglomerate interbeds contain pebbles and cobbles of granite and basalt indicating a dual source for the sediment from which these rocks were derived. In many areas this metasedimentary rock unit lies on a few feet of purple laminated metatuff and the upper few feet of the unit may have a pervasive, pale-green epidote cement.

CAMBRIAN SYSTEM

Large areas of the western part of the Blue Ridge are underlain by metamorphosed, clastic sedimentary rocks including phyllite, quartzite, metasandstone, and metaconglomerate. These areas are characterized by steep, sharp-crested ridges, V-shaped hollows, ridge slopes that are commonly covered with coarse rock debris, and total forest cover except where rock cliffs jut from the ridge crests (Figure 3). The rocks in these areas overlie the Catoctin Formation and comprise the Chilhowee Group consisting of 3 formations—the Weverton, Hampton (Harpers), and Erwin (Antietam). Each formation is dominated by one or two rock types but each rock type also occurs sparsely in one or both of the other formations. The formations also intertongue with each other along their boundaries and vary greatly in thickness, although the total thickness of the three formations remains relatively constant in the park. The individual rock types in each formation represent a particular depositional environment and possibly a specific source of material for the sediments from which they were formed. The intertonguing of the dominant rock types demonstrates the coexistence of two or more depositional environments and shows the complexity of the stratigraphic relationships between the formations.

Weverton Formation

The Weverton Formation, 100- to 500-feet (30- to 150-m) thick, is a sequence of light-gray, locally iron oxide cemented, pebbly quartzite beds interlayered with tan, silvery-green, or purple phyllite and drab metasandstone. A scattering of well-

rounded quartz pebbles, characteristic of the unit, may be present in any of the rocks or may be concentrated in separate beds or lenses (R-4416). It is differentiated from similar rocks in the upper Catoctin Formation by the lack of epidote in the matrix. The formation appears to be of fluvial origin and represents the initial coarse-clastic phase of Chilhowee deposition. The stream sediments of the Weverton were deposited on an erosion surface that beveled the Catoctin, Swift Run, and Pedlar formations and appears to have had at least 100 feet of local topographic relief. The unconformable lower boundary of the Weverton Formation is placed at the base of the lowest unepidotized sedimentary rock strata above the older igneous rocks. The gradational upper boundary is placed at the uppermost occurrence of quartz pebbles below the lower, thick, bronze-weathering phyllite sequence of the Hampton (Harpers) Formation.

One to three pebbly quartzite ledges, individually ranging from 5 to 25 feet (2 to 8 m) in thickness, are generally present. Only the quartz pebbles persist to identify the formation in a few areas where quartzite is absent. The quartzite is light gray and composed of medium- to coarse-grained, moderately to poorly sorted, feldspathic, quartz sand held together with silica cement. It is banded or spotted by purple hematite cement that may outline cross-bedding or locally form the dominant cementing agent (R-4400). The conglomerate beds characteristic of the unit are composed of well-rounded quartz pebbles in a quartz, chlorite, and sericite matrix; a few purple slate or metabasalt pebbles may also be present. The phyllite interbeds that comprise the bulk of the Weverton Formation commonly contain small lenses and stringers of quartz pebbles and coarse sand (R-4412), and range from 5 to nearly 50 feet (2 to 15 m) in thickness.

The formation is well exposed in the valley of Overall Run (Figure 18), in Heiskell Hollow, and immediately west of the entrance to Shenandoah National Park Headquarters along U. S. Highway 211 in the northern section of the park (Plate 1). The boundary between the Weverton and Catoctin formations may be seen on Skyline Drive approximately 0.5 mile (0.8 km) west of Thornton Hollow Overlook. Along Honey Run near the western extension of the central section (Plate 2) quartz-pebble conglomerate of the formation lies directly on granodiorite of the Pedlar Formation. In the southern section (Plate 3)

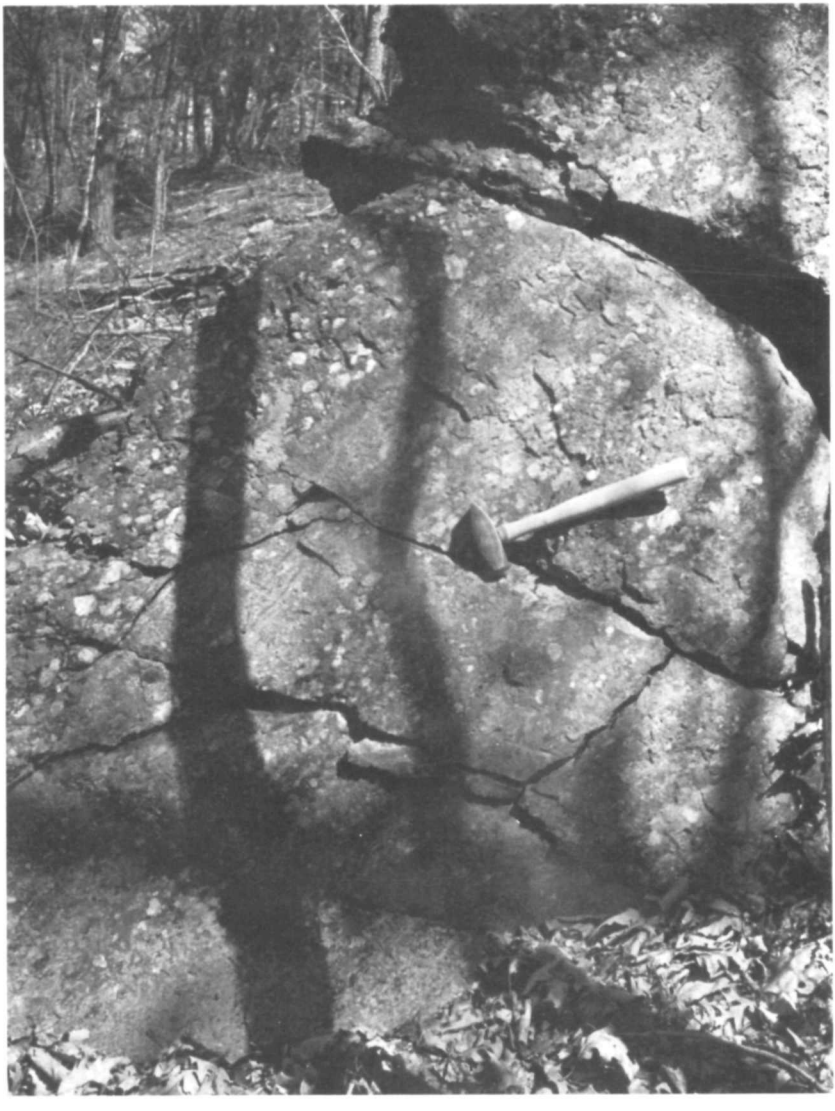

Figure 18. Quartz-pebble conglomerate lens at the base of the Weverton Formation on Overall Run, 2.4 miles (3.9 km) northwest of Matthews Arm Campground (Plate 1). Subangular to rounded quartz pebbles occur in a matrix of quartz sand and rock fragments and form a ledge approximately 300 feet (91 m) long.

Weverton quartzite is well exposed and accessible by trail along the east side of Ivy Creek and on Patterson Ridge in the Loft Mountain area. From Doyles River Overlook to Browns Gap

the formation is exposed along the Appalachian Trail (Figure 19) and Skyline Drive. These exposures, some of the best in the park, show the interbedding of the conglomeratic quartzite

Figure 19. Weverton quartzite ledge exposed on Appalachian Trail, 0.3 mile (0.5 km) south of Doyles River Overlook. The exposures along this trail are typical of the resistant rocks of the Weverton.

with the silvery-green sericitic phyllite and pebbly phyllite, and the lenticular nature of the beds. Farther south, Weverton quartzite is exposed in a fold at Sawmill Ridge Overlook (R-4413, Figure 46) and along the Appalachian Trail immediately to the east.

Hampton (Harpers) Formation

The Hampton (Harpers) Formation accounts for about two-thirds of the thickness of the clastic rocks in the park. The formation, 1,800 to 2,200 feet (549 to 671 m) thick, is a drab, monotonous sequence of dark greenish-gray to brown, fine-grained, medium- to thin-bedded, sericitic, metasandstone and metasiltstone and dark grayish-green, laminated phyllite. Its lower and upper contacts are conformable and intertongue with the Weverton and Erwin (Antietam) formations respectively. Trace fossils are present in many beds of the Hampton (Harpers) Formation and are the oldest fossil forms reported in this area. The most common is *Skolithos*, the vertical burrow

formed by an ancient, surface-feeding worm-like organism. The burrow is straight, cylindrical, between 2 and 5 mm in diameter, and extends through the bed, generally a quartzose metasandstone or quartzite, that encloses it. Slightly larger diameter U-shaped burrows (F-868, F-869) have been observed in a few localities in the green, fine-grained metasandstone as have tracks and trails of free-moving surface-feeding organisms. Many metasandstone beds exhibit bioturbation.

Phyllite (R-4409) dominates the lower third of the unit (Figure 20), and alternating interbeds of metasandstone and phyllite dominate the upper two-thirds. The monotony of the

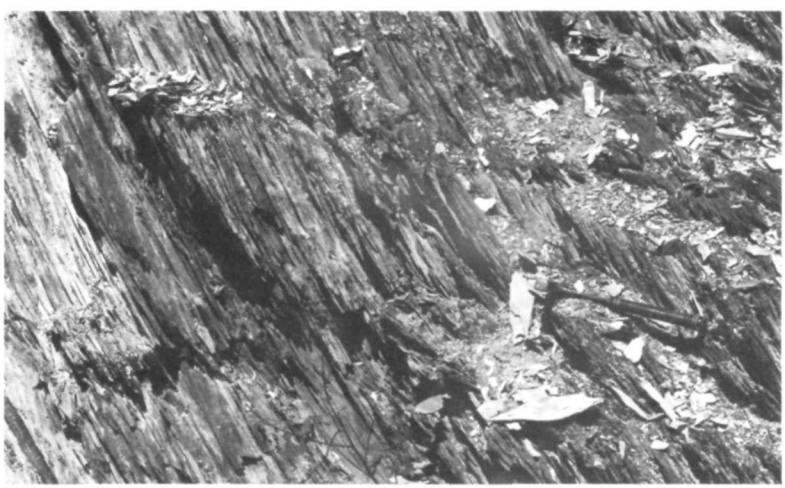

Figure 20. Hampton (Harpers) phyllite in the Chesapeake and Ohio Railway cut 1.5 miles (2.4 km) north of the south entrance to Shenandoah National Park. The well-developed cleavage displayed here is commonly found in the argillaceous beds of the Hampton Formation in the park. The cleavage planes have a steep dip to the right (southeast), and are spaced from less than 1 to 10 mm apart completely obscuring the bedding.

phyllite-metasandstone sequence is broken by the intermittent appearance of more resistant talus-forming quartzite beds in the upper two-thirds (R-4406, R-4418). These rocks are light tan, pale metallic blue, purple, or nearly black depending on the amount of hematite cement. They are medium-grained, cross-laminated or ripple-marked, and commonly contain *Skolithos* tubes (Figure 21). The more ferruginous quartzites are usually 10 to 30 feet (3 to 9 m) thick, but may reach 50 feet (15 m) locally. The thicker bodies tend to be relatively free of iron-

Figure 21. Quartzite beds at Blackrock in the southern section are the most resistant strata in the Hampton (Harpers) Formation and are responsible for extensive talus deposits on the eastern slopes of Trayfoot Mountain visible in the distance.

oxide cement, but as the units become thinner along the trend of the Blue Ridge the volume of iron-oxide cement increases, producing the pale metallic blue, purple, or nearly black coloration (R-4421, R-4403). *Skolithos* tubes (F-870) persist into the ferruginous quartzites but may be difficult to see due to this dark coloration.

Good exposures of the Hampton (Harpers) lithologies occur along Big Run and adjacent hollows (Plate 3, Figure 22). In the Big Run drainage basin the formation is about 1,800 feet (549 m) thick of which the upper 1,300 to 1,400 feet (396 to 427 m) is well exposed. Folding has affected this area less than most others in the park and though the beds are metamorphosed and have well-developed fracture cleavage, the fracturing has not obscured the bedding features. The drab, greenish-gray, very fine-grained metasandstones are evenly bedded with thicknesses that range up to about 3 feet (1 m). They are laterally extensive with little variation in thickness over several hundred feet of exposure, and are separated by very thin interbeds of drab, green phyllite (Figure 22). Bioturbation is readily visible in the smooth, water-worn exposures of silty sandstone in Big

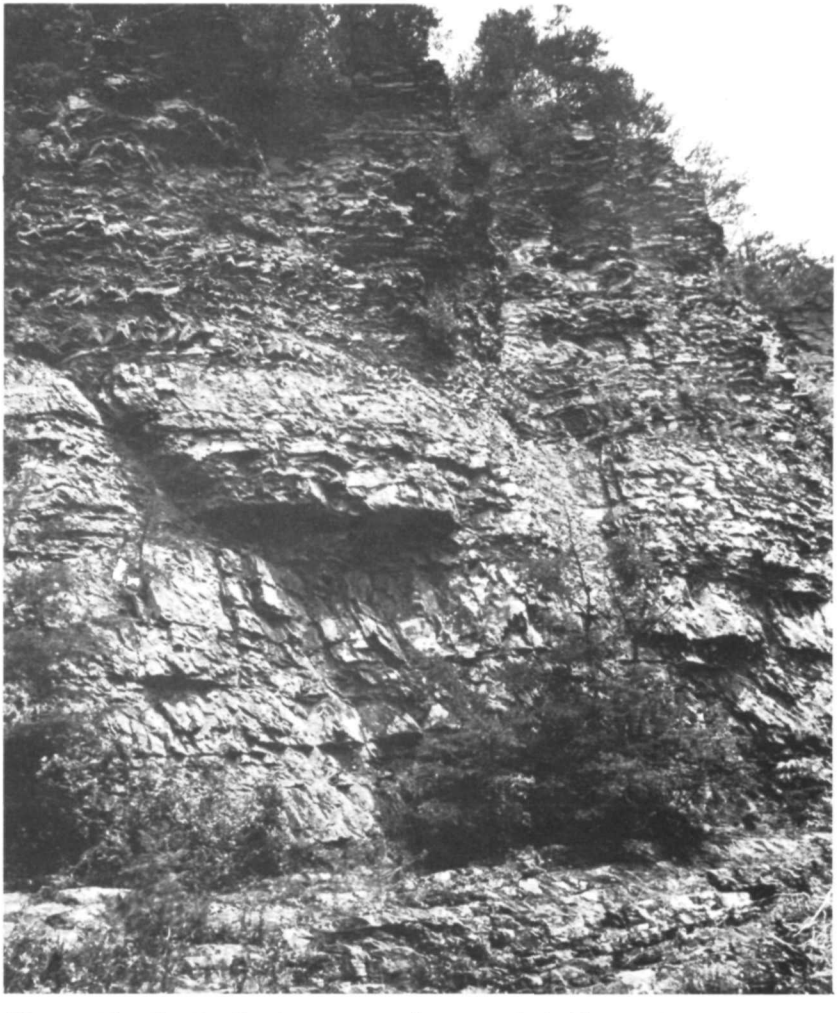

Figure 22. Gently dipping metasandstone and phyllite in the upper portion of the Hampton (Harpers) Formation on Big Run approximately 3 miles (5 km) north of Big Run Shelter (Plate 3).

Run upstream from the steel bridge near the mouth of Big Run hollow. Faint outlines of cylindrical burrows and disconnected or warped-bedding laminations are visible but are somewhat distorted by fracture cleavage. Sinuous trails, probably made by ancient surface-feeding organisms, occur sparsely on the upper surfaces of some sandstone beds exposed in the cliffs along Big Run (Figure 22). The drab, greenish-gray metasandstones locally contain short, vertical, poorly formed, cylindrical worm

burrows similar to the *Skolithos* tubes found in the lighter hued sandstones but are 0.2 to 0.6 inches (0.5 to 1.5 cm) in diameter.

The lower third of the formation is poorly exposed in the park, but appears to be mainly laminated phyllite with a few thin beds of ferruginous sandstone or siltstone. Weathered exposures can be seen along Skyline Drive at Milepost 79, and 0.5 mile (0.8 km) north of Sawmill Run Overlook (Plate 3).

Quartzite bodies in the Hampton attain maximum thickness and form widespread but thin, sheet-like bodies of talus downslope from the outcrops (Figure 26). The most extensive quartzite bed, essentially identical to the quartzites of the overlying Erwin Formation, is nearly 80 feet (24 m) thick and occurs within a sequence of drab, grayish-green, fine-grained sandstones about 800 feet (245 m) below the top of the Hampton. It is well-exposed at Black Rock (Figure 21), in Big Run, and on the trail to Calvary Rocks from Skyline Drive (Plate 3) but thins and is apparently absent to the northeast and southwest of these areas.

Figure 23. Erwin (Antietam) quartzite ledges and talus on the southwest side of Big Run. The pinnacle or column-like forms are produced by differential weathering along near-vertical fractures (joints) and subsequent collapse of the broken and weathered zones.

Erwin (Antietam) Formation

The Erwin (Antietam) Formation is characterized by thick-bedded, very resistant, light-gray to white quartzite beds that form sharp peaks, flatirons, and many of the higher ridges among the western foothills of the Blue Ridge. The formation is present almost continuously from Bentonville (Plate 1) to Waynesboro (Plate 3). The Erwin quartzite ledges may be seen from many points along Skyline Drive. On the west side of the Blue Ridge in the southern section, cliff-forming, white quartzite beds, some as much as 75 feet (23 m) thick, may be visually traced from ridge to ridge and through flextures or small folds on the ridge slopes. Below the ledges extensive boulder fields of white quartzite blocks cover the uppermost beds of the underlying Hampton Formation (Figure 23).

The Erwin Formation is almost 1,000 feet (305 m) thick along Big Run (Plate 3) and probably is not less than 700 feet (213 m) thick in other park areas. It has been divided into an upper and a lower member that are shown separately on Plates 1-3. The lower member consists of three to five very resistant quartzite ledges with an aggregate thickness of 400 to 850 feet (122 to 259 m) separated by intervals of less-resistant strata, generally friable metasandstone or interbedded phyllite similar to the phyllite in the Hampton Formation. The less-resistant strata are largely concealed beneath the talus of adjacent quartzite ledges but can be seen along Big Run (Plate 3), on Piney Mountain above Ugly Run (Plate 2), and along Overall Run northwest of Matthews Arm Campground (Plate 1). The quartzite is thick-bedded, cross-laminated, light bluish-gray to nearly white, vitreous, medium-grained, metamorphosed quartz sandstone (R-4419). *Skolithos* tubes are locally abundant in the lower ledges, with tube lengths approaching 3 feet (1 m) in the thicker beds. Where large populations of the longer tubes are present, the quartzites may exhibit a strong linear shear fabric along fracture surfaces paralleling the tubes (Figure 24). White quartzite beds with *Skolithos* tubes are well displayed along most of the Erwin outcrop belt, although exposures can be reached only by foot trail from Skyline Drive. The most accessible exposures are along fire trails that cross the lower ledges of the formation on Turk Mountain, Rocky Mount (Figure 25), and Calvary Rocks (Figure 24, Plate 3).

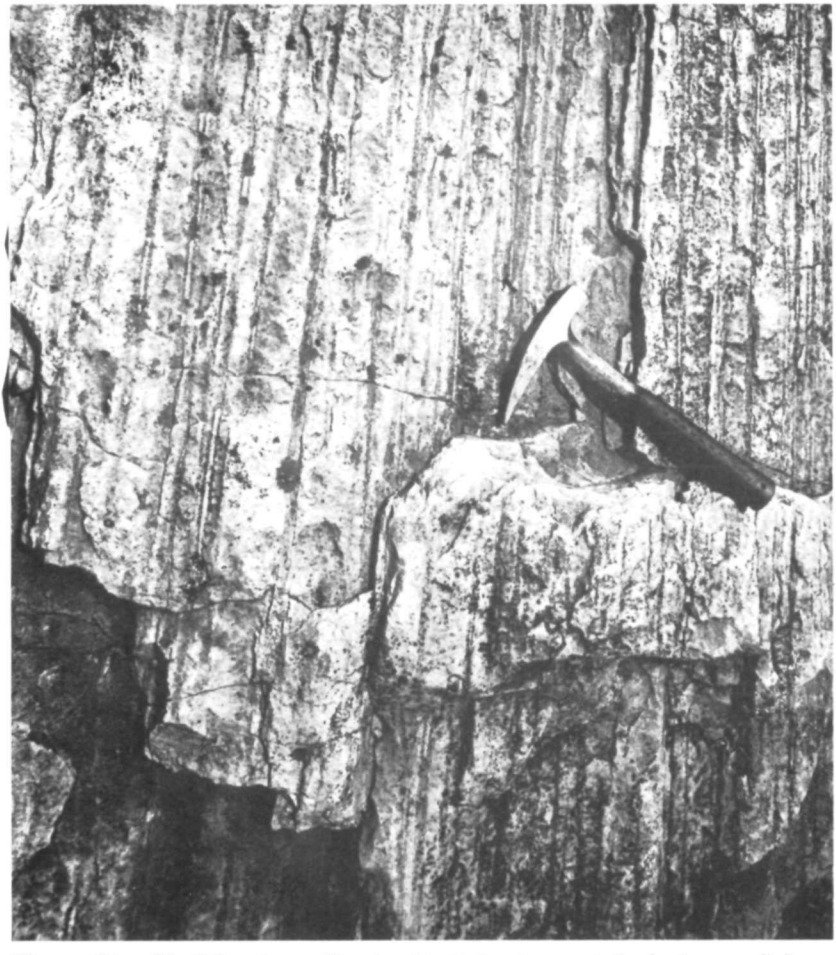

Figure 24. *Skolithos* in an Erwin (Antietam) quartzite bed near Calvary Rocks in the southern section. The fossil "tubes" or burrows are commonly exposed on a fracture surface, such as this, because they seem to provide a directional weakness along which the otherwise homogeneous quartzite beds tend to break.

The upper member of the Erwin Formation contains only a few thin quartzite beds and is very poorly exposed in the park. The lower boundary of this member is placed at the top of the series of ridge-forming quartzite ledges that form the lower member. The upper contact of the Erwin with the overlying Cambrian carbonate rocks is covered by talus or deeply weathered residual material and is not visible in or near the park.

Manganese and iron exporation pits and mines have been opened along the top of the upper member and have exposed light, varicolored, phyllitic clay (R-4401) and sandstone. These deeply weathered rocks are well exposed in the north end of the pits at the abandoned Crimora mine and may be part of the upper member or a transitional sequence between the upper member and overlying Cambrian carbonate rocks.

Figure 25. Erwin (Antietam) quartzite and extensive talus deposits along the trail crossing Rocky Mount.

TRIASSIC SYSTEM

Diabase Dikes

Dense, greenish-black, coarsly crystalline diabase dikes of Triassic age have intruded rocks of the Blue Ridge in the southern and central sections (Plates 2, 3). They trend a few degrees west of north, and are essentially vertical. Exposures are rare except in roadcuts, but the trace of the dikes is marked by spheroidal diabase boulders on the surface and in the soil or by sharp linear hollows and low gaps where they extend across the Blue Ridge crest. Sharp linear depressions are common throughout the park and many may mark the trace

of unseen diabase intrusions. These dikes are distinguished from the greenstone dikes of Precambrian age by their greater density and hardness, and by their lack of cleavage. One diabase dike only a few inches thick is exposed on Skyline Drive in the south end of the roadcut approximately 0.25 mile (0.40 km) south of Rocky Top Overlook (Plate 3).

SURFICIAL DEPOSITS

Although bedrock exposure in the Blue Ridge is locally extensive and sometimes spectacular, all except a very small percentage of the surface is covered by a mantle of soil; coarse, weathered, rock debris; boulder deposits; or alluvium. Most of the land surface is notably rocky. Boulder-strewn fields and woodlands are characteristic of the gently sloping upper mountain surfaces particularly where Catoctin basalt is present. Steeper slopes are commonly covered by talus, generally broad deposits of large angular quartzite, or basalt blocks that blanket the slopes for several hundred feet below cliffs or ledges of the resistant rock. These deposits are prevalent on slopes below the outcrop of Erwin or Hampton quartzites or Catoctin basalt and also have formed on very steep slopes underlain by the Pedlar or Old Rag formations. Much of the quartzite talus is devoid of vegetation or supports only a few small trees (Figure 23) and from a distance has the appearance of a white rockslide. The slopes covered by basalt talus are not as extensive or as apparent from a distance because they generally are well forested and have the beginning of a soil cover developing between the large, gray, basalt blocks. Granitic rock talus, such as seen on the north slope of Old Rag Mountain, differs from talus formed from the layered rocks mainly in the size range of the granitic boulders that form the deposit. Granite blocks range up to house size but are generally much smaller, the size range being governed by the spacing of fractures in the granite body (Figure 8). Talus formed from the layered rocks contains comparatively uniform size blocks as the rocks tend to break along bedding as well as across it (Figure 26). As the bedding surfaces are generally spaced a few inches to a few feet apart they limit the length of one dimension of the block. Closely spaced joints and cleavage present in all the layered rocks limit the other two dimensions of the block so that blocks more than a few feet square rarely occur (Figure 21).

Fertile and locally deep but stony soils have formed on

Figure 26. Upslope view of lichen-covered quartzite blocks in the talus deposit at Black Rock (Plate 3). The blocks are very regular in size and shape, being roughtly rectilinear and 2.0 to 4.0 feet (0.6 to 1.2 m) across, a condition controlled by the uniformity of thickness of the Hampton quartzite beds at this location.

the more soluble plutonic and volcanic rocks but only very thin sandy or shaly soils are present on the metasedimentary rocks. The difference in these soils is directly expressed in the

size and species of trees growing on them. The difference is most apparent along the boundary between the Catoctin and Weverton formations where the forest cover on both formations can be seen together. The forest on the soils of the Catoctin Formation has a diversity of tree types, sizes, and shapes with the trees being generally larger than those on the Weverton Formation which exhibit a uniformity of size, height, and shape broken only by a few scattered pines. The difference is most noticeable in October when the fall colors are at their peak brightness. Then, the entire forest area underlain by the metasedimentary rocks takes on a drab yellow-brown hue while the colors in the forest on the volcanic and plutonic rocks are bright reds, oranges, and yellows with many trees still partly or wholy green. The sharp color contrast probably reflects differences in soil moisture content as much or more than species differences between trees in the two rock types.

Narrow, discontinuous flood plains have developed along the lower reaches of many streams flowing from the Blue Ridge. They are covered with deposits of sand, cobbles, and boulders of resistant rock (granite, basalt, or quartzite) to depths as much as 5 feet (2 m) except in the stream channels where bedrock is commonly exposed. All along the west foot of the Blue Ridge and locally along the east foot, thick alluvial fans have been spread over the lowlands by these streams, covering bedrock for distances of up to 2 miles (3 km) from the mountains. Between Elkton and Waynesboro (Plate 3) the thick coalescing alluvial fans form an unbroken, westward-sloping plain between the Blue Ridge foot and the terraces along the Shenandoah River. North of Elkton the fans have been incised by crosscutting streams or removed by the encroachment of the Shenandoah River and are now absent or locally discontinuous. Quartzite, metabasalt, and granite boulders, cobbles, and pebbles in a sand and clay matrix make up the rock material in the fans. Stratification can be seen where roadcuts have exposed the poorly consolidated material. Although portions of the fan-covered areas can be seen from Skyline Drive they are best viewed from along U. S. Highway 340 between Elkton and Waynesboro.

STRUCTURE

Deformation of the rocks in the Blue Ridge may be seen as contorted strata where folds are present, as shattered masses

of quartzite (tectonic breccia) in zones of faulting, or as linear zones of dark, contorted, slaty mylonite formed by the crushing and milling of granitic rocks along faults or shear zones. The deformation is expressed microscopically by the parallel alignment of micas or stretched and flattened sand grains in the sedimentary rocks and by the shattered and crushed crystals in the plutonic rocks. The deformation is also expressed as a broad regional warping of rock units and fold systems too large in scale to be viewed directly.

The dominant structural feature, one that can be found in most rock exposures in the park, is the pervasive cleavage, a parallel, planar fracture or shear fabric that generally has a southeasterly dip and a northeasterly trend. It is best developed in the very fine-grained micaceous metasedimentary rocks (Figure 20), metatuffs, and mylonites. Even the normally massive granitic rocks and the hard quartzite strata of the Chilhowee Group have well-developed cleavage where the rocks have been subjected to intense deformation along fault zones or in attenuated fold limbs. The cleavage is genetically related to the folding and metamorphism that accompanied the tectonic uplift and northwesterly transport of the Blue Ridge mass in Paleozoic time. It is the remaining visible evidence of small, parallel zones of dislocation in the rock that was formed during this tectonism, and it was the mechanism that, through differential slip along innumerable shear planes, allowed folding to develop during periods of compression. Cleavage planes are not always planar but may be slightly kinked or crenulated locally by a younger, less well-developed cleavage.

Jointing, near-vertical or subhorizontal fracturing, is as pervasive as cleavage, with most rock outcrops displaying many fractures and several fracture-trend directions. Jointing is most visible in the resistant quartzite ledges of the Erwin Formation, or in the massive granites displayed on the crest and cliffs of Old Rag Mountain (Figure 8). Jointing may be related to the folding or may be a postfolding development related to deep vertical adjustments in the crust.

Large asymnetric folds are common and locally visible in the southern section of the park where the rocks of the Chilhowee Group are extensively exposed. Folds having amplitudes of several hundred to several thousand feet can best be seen where the Weverton or Erwin quartzites are involved. The resistant white ledges of the lower part of the Erwin Formation

Figure 27. Anticline and syncline outlined by quartzite ledges of the lower portion of the Erwin (Antietam) Formation west of Twomile Run Overlook (Plate 3). These large asymmetric folds are typical of those that are developed in the Chilhowee rocks along the west side of the Blue Ridge. In the distance the trend of the parallel limbs of the Massanutten synclinorium, defined by Silurian quartzites that form the ridge crests, differs greatly with the apparent trend and plunge of the folds in the Erwin quartzites.

outline an array of folds north of Big Run in the Brown Mountain-Rocky Mount area, some of which are visible even through heavy summer foliage from Twomile Run (Figure 27) and Big Run overlooks (Plate 3). Erwin ledges of a steep fold limb on Rocks Mountain can be seen from Skyline Drive between Riprap and Calvary Rocks overlooks. As one approaches the Erwin ledges along Calvary Rocks trail from Skyline Drive, moderately westward-dipping quartzite beds on the east limb of a syncline are encountered. Here, cleavage is nearly perpendicular to bedding and has been preferentially developed parallel to the once-vertical *Skolithos* tubes that now weather out in relief on the southeastward-dipping cleavage surfaces.

Small-scale folds with amplitudes and frequencies of less than 100 feet (31 m) are also common to rocks of the Chilhowee Group. There are few exposures in which both limbs of even the smaller folds can be viewed, and these occur only in the southern section (Plate 3). Small folds developed in the overturned west limb and axial portion of a larger anticline can be seen by the fire road along Paine Run north of Rocks Mountain. In the Loft Mountain area, where the Appalachian Trail leaves Ivy Creek and leads uphill to Ivy Creek Shelter, it extends across the hinge or axis of a small overturned syncline in the lower quartzite ledge of the Weverton Formation. The right-side-up base of the quartzite ledge is just above trail level where the trail parallels the creek. As the trail crosses the quartzite outcrop and leads uphill to the shelter the base reappears being overturned and inclined steeply to the southeast. If the base of the Weverton Formation is traced to the west, across Ivy Creek and along the south slope of Patterson Ridge, two additional small-scale folds can be seen. A sharply overturned anticline-syncline pair with a partly faulted-out or strongly attentuated overturned limb is present on the lower slope of Patterson Ridge in Eppert Hollow. These folds are typical of the small-scale folds found in the Chilhowee Group, and are mentioned here as they are very accessible.

Faults occur locally in all sections of the park and have had a strong influence on the location, shape, and development of the Blue Ridge. The presence of a fault is generally marked by linear low areas that are formed on the broken rocks or by the foot of an escarpment where resistant and nonresistant rocks are separated by the fault. Faults are commonly obscured by talus, alluvial gravel deposits, or deep soil and saprolite developed

on the intensely fractured rocks along the fault trace. Bedrock exposures of fault surfaces are rare, but generally contain evidence of intense deformation such as brecciated or mylonitized rock.

Linear zones of sheared rocks (mylonite and cataclastic gneiss) separate extensive areas of weakly foliated to massive

Figure 28. Strongely lineated protomylonite along State Road 600 approximately 2 miles (3 km) southwest of Sperryville (Plates 1 and 2) and 0.5 mile (0.8 km) east of the park boundary. North of Old Rag Mountain this mylonite zone lies between the Old Rag and Pedlar formations. Locally, within the zone the mylonites appear as coarse-grained layered rocks.

crystalline rock. The mylonites (layered slaty rocks) and the cataclastic gneisses (coarse-grained, layered crystalline rocks) are thought to have developed along faults or shear folds in the plutonic rocks (Figure 28). The zones of sheared rocks are slightly sinuous, generally trend northeastward and may be as much as 0.25 mile (0.40 km) wide. The intensity of deformation varies within the zones. Mylonite (R-4396, R-4397, R-4455, R-4458) is characteristic of the most intense deformation and is present locally within the zones; protomylonite or cataclastic gneiss (R-4395, R-4462, R-4465, R-4466) are characteristic of somewhat less intense deformation and occur near the boundaries of the zone with the relatively unsheared plutonic rocks. Masses of relatively undeformed plutonic rock may be present at places within the sheared rock zones (R-4454) and small folds in layered mylonite are present locally (Figure 29). The basalts

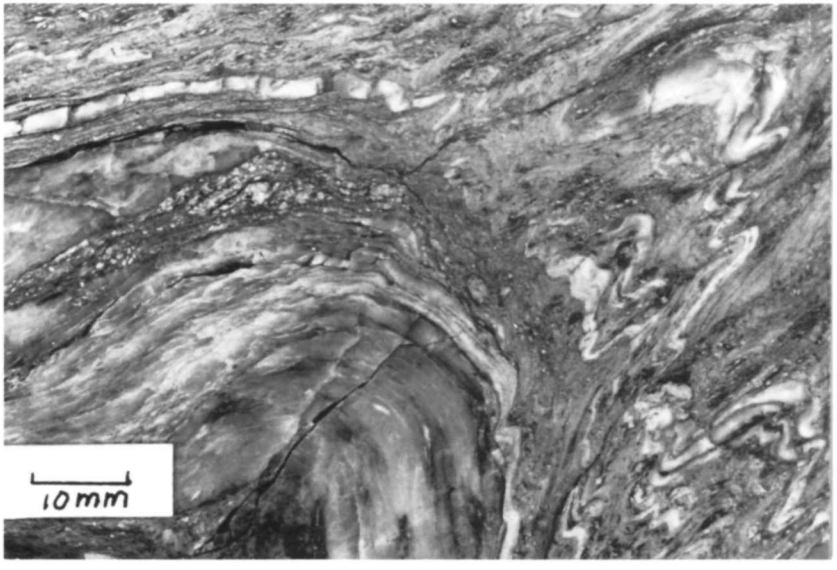

Figure 29. Sawed surface of refolded mylonite from near the locality shown in Figure 28. The layering developed during shearing of the granitic rocks and was folded during a later stage of deformation.

of the Catoctin Formation are less intensely deformed along faults, although some shearing and brecciation are present. Generally faults in the Catoctin Formation are characterized by a lack of bedrock exposure, extensive talus deposits, and a trace of vein quartz rubble in the soil. The quartzites of the Erwin Formation provide the most spectacular evidence for faulting.

Where faults cut through this formation, tectonic breccias consisting of large masses of coarse, white, sharply angular, quartzite fragments (R-4411) bound together by a dark-red iron-oxide cement mark the fault trace (Figure 30). Breccia masses

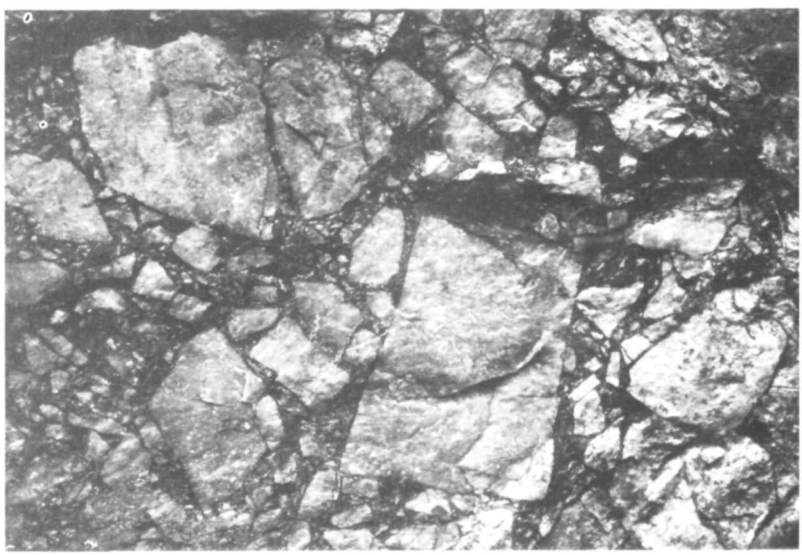

Figure 30. Brecciated Erwin (Antietam) quartzite formed along a transverse fault on Hershberger Hill approximately 3.5 miles (5.6 km) due west of Skyland. The angularity of the quartzite fragments shows that very little movement occurred along the fault. Red iron oxide cement fills the voids and forms a very resistant rock.

and layers occur locally along the west foot of the Blue Ridge between Front Royal and Stanley along the trace of a complex system of reverse or thrust faults, and in the Elkton and Waynesboro areas along similar faults or attenuated and collapsed fold limbs (Plates 1, 2, 3; Figure 5B).

Faults within the park fall into two general catagories. Of most importance are the high-angle reverse faults and thrust faults along which the upper block has moved up or out over the lower block. In and near the park these faults are inclined to the southeast at low to high angles and are laterally extensive. Displacement of the rocks is up to many thousands of feet (several kilometers) locally, resulting in large masses of the Precambrian and early Cambrian rocks being moved upward onto the younger Paleozoic carbonate rocks of the Shenandoah Valley (Plates 1, 2; Figure 5B).

Very high-angle, northwestward-trending transverse faults comprise the second category of faults. These trend to the northwest across the Blue Ridge, and have small vertical displacements, generally less than 500 feet (152 m). The transverse faults may have formed simultaneously with the reverse or thrust faults. Those portions of the reverse faults shown on Plates 1-3 which have a westerly trend may be in effect very steeply inclined transverse faults, the south side of which may have been upthrown and moved westward with the thrust- or reverse-fault movement.

Very large-scale structures of alternating upwarped and downwarped masses of Precambrian and Early Cambrian rock, each 10 to 20 miles (16 to 32 km) long, form a series of lobes and embayments with the Shenandoah Valley along the west side of the Blue Ridge (Figure 5B). These broad, fold-fault structures account for the unequal distribution of the Chilhowee rocks along the west side of the park. The northwesternmost exposures of Precambrian rocks occur in the central portion of these broad areas, and the northeastward-trending folds that cross the lobes (Plates 1-3) have a plunge away from the Precambrian exposures to the northeast and southwest. Each lobe is bounded on the north by westward-trending fault segments along which the rocks to the south of the faults appear to have been uplifted and moved west or northwest relative to rocks north or northeast of the faults.

ORIGIN OF THE BLUE RIDGE

The geologic history of the Shenandoah National Park area is essentially the history of the evolution of the Blue Ridge mountains in north-central Virginia. To begin deciphering the order of geologic events that shaped the Blue Ridge, we must look again to the geologic time scale now in general use (Figure 31). This time scale, orginally based on the order of occurrence of distinctive fossils in sedimentary rock sequences, was a relative time scale until the advent of radiometric age determinations. Radiometric dates have provided numerical ages for the various divisions of the time scale and have allowed age determinations to be made from many rocks that contain no fossils. In this time scale the last 570 million years have been divided into 12 periods of unequal duration beginning with the Cambrian (500 to 570 million years ago), the period in which the earliest

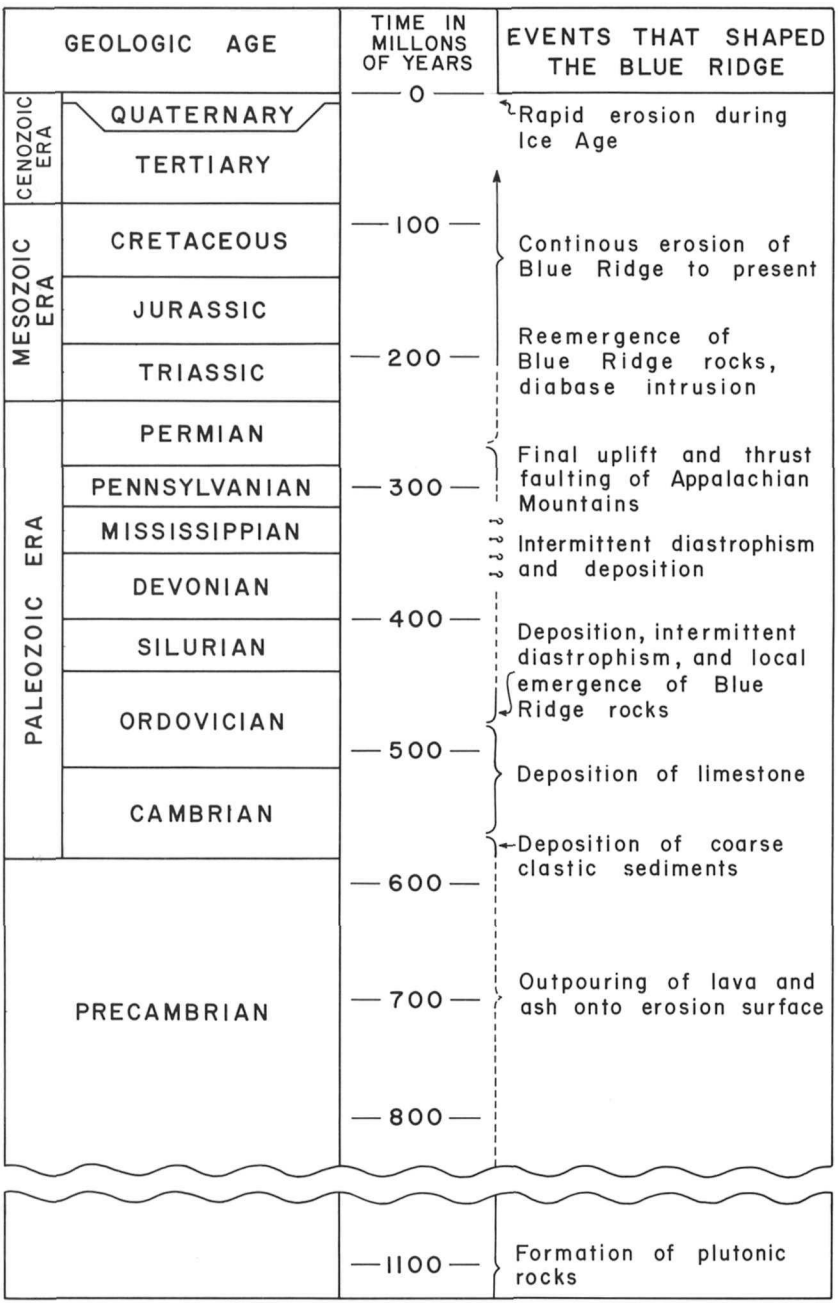

Figure 31. Geologic time scale showing estimated times of geologic events in the park area of the Blue Ridge.

known complex life forms developed and were preserved in the rocks as fossils. As the Precambrian rocks contain no known complex fossil forms, their age must be determined entirely by radiometric methods. It is during Precambrian and Cambrian time that most of the rocks in the Shenandoah National Park were formed.

PRECAMBRIAN PLUTONIC ROCKS

The geologic history of the Blue Ridge in the park begins in Precambrian time with the formation of the plutonic rocks which include the Old Rag Granite and the Pedlar Formation. These rock units are part of a complex series of ancient meta-igneous rock bodies now exposed in the core of the Blue Ridge anticlinorium. They are coarsely crystalline, homogeneous to layered, very feldspathic granodiorite and granite. The mineral grains that form these rocks are of about equal size and interlock to form a mosaic pattern. This pattern or texture is characteristic of rocks that crystallized at very high temperature and pressure, conditions that can only be obtained deep within the earth's crust. These rocks may have crystallized from molten rock originating deep within the crust or they may have been part of an older layered rock sequence that was melted and recrystallized during Precambrian metamorphism. Radiometric age determinations suggest an age of approximately 1.1 billion years for the time of crystallization, placing these rocks among the oldest exposed in the Appalachians. As there is little question that the Precambrian crystalline rocks were formed at great depth, a long period of time, possibly as much as 300 million years, was required for uplift and erosion to bring them to the surface in late Precambrian time.

LATE PRECAMBRIAN SURFACE

The late Precambrian landscape carved from the plutonic rocks may have looked much as the land surface to the east of the Blue Ridge would look today if the present vegetation and soil cover were removed. The highest mountains on the ancient surface probably reached little more than 2,000 feet (610 m) above the valleys. The crests and upper slopes were probably barren, exposed rock with weathered rock debris on the lower slopes and in the valleys. Accumulations of stream sediments, locally more than 200 feet (61 m) thick, were spread over the valley floors by the larger streams. This bleak and barren,

mountainous surface is now the surface preserved at the base of the layered rock sequence. This surface also became the floor of the Appalachian geosyncline, the broad trough in which sediments were intermittently deposited from the late Precambrian through Paleozoic time, a period of almost 600 million years. During this time these sediments became the rocks that now form the Appalachian Mountains.

LATE PRECAMBRIAN VOLCANISM

In late Precambrian time lavas breached the surface through an extensive series of fissures in the plutonic rocks. These fissures opened periodically in late Precambrian time and spread molten lava and volcanic ash laterally forming very broad, sheet-like bodies from 30 to more than 100 feet (9-30 m) thick (Figure 32). The resultant stack of lava flows and lesser

Figure 32. Late Precambrian time and the beginning of volcanism. Lavas spread across sediment-filled stream valleys from vents along fissures in the granitic crust.

amounts of ash probably exceeded 2,000 feet (610 m) in thickness as remnants of the flows range up to at least 1,800 feet (529 m) in thickness. The lava covered most of what is now the Blue Ridge anticlinorium north of the James River and probably was far more extensive than its present surface distribution suggests. The total volume of lava ejected from the fissures may have exceeded 1,000 cubic miles (4,170 cubic km) and possibly could have been several times greater.

The topography of the surface on the Precambrian plutonic rocks restricted the thickness and the regional distribution of the sedimentary and volcanic material that now forms the Swift Run and Catoctin formations. Buried hills of plutonic rocks exposed in the upper reaches of Rose River east of Big Meadows

and in White Oak Canyon have been described by Reed (1955, 1969) who estimates that as much as 1,000 feet (305 m) of topographic relief may be present locally on the erosion surface. Other large buried hills were found in the northern section of the park during this investigation, one at the head of Big Devil Stairs and the other at Hogback Mountain. Six or more lava flows terminate laterally against the flanks of these hills, the crests of which may have stood as much as 700 feet (213 m) above the local Precambrian valley floors.

When the Catoctin lavas flowed out onto this ancient Precambrian surface, they filled the valleys and covered successively higher hills until all but the highest peaks lay buried beneath a broad plain of solidified lava and volcanic ash (Figure 33).

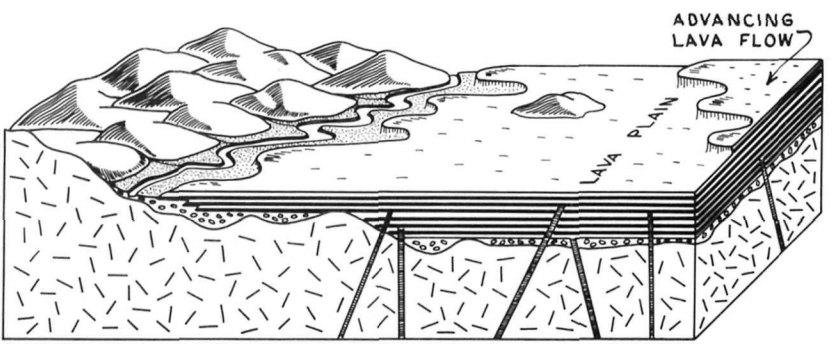

Figure 33. Late Precambrian time with continuing volcanism, erosion, and sedimentation. Subsidence of the land surface begins, marking the initial downwarping of the Appalachian geosyncline.

The lava flows did much more than bury the eroded surface; hot mineralizing fluids and gases from the advancing flows locally altered the exposed plutonic rocks. The alteration generally varied from place to place depending primarily on the degree of permeability of the rock material present at the surface. In the valleys and on the lower slopes, the sediments that are now the Swift Run Formation and much of the weathered plutonic rock debris was unconsolidated, permeable, and probably saturated with ground water when inundated by the lavas. Mineralizing fluids from the lavas altered the feldspars and other minerals, locally forming an epidote cement in the permeable weathered rock and sediments. Alteration is most evident in the material immediately beneath the flows, and it decreases downward; generally the upper 10 to 20 feet (3 to 6 m) of

permeable surface material is visibly altered. In the granodiorite the epidote formed a matrix around pink feldspar and smoky-gray quartz grains, producing unakite, an attractive green, pink, and gray mineral assemblage. However, plutonic rocks that were exposed as Precambrian mountaintops show relatively little alteration except in the upper few feet or inches of granitic rock or along ancient fractures in the 50 to 100 feet (15 to 31 m) of rock below the erosion surface.

VOLCANIC SEQUENCE

Within the volcanic-sedimentary rock sequence that forms the Swift Run and Catoctin formations are a variety of rock types that fall into three general categories. First, the greenstones, formed from very mobile basaltic lavas, comprise 80 percent or more of the volcanic sequence. These are the resistant rocks responsible for forming all of the higher ridges in the park. Interlayered with the greenstones are thin discontinuous beds of purple slate, the second rock category, that originally was tuff or pumice deposited from volcanic ash blown from the fissures during more violent eruptions. The ash falls appear to have alternated with the less violent lava outflows. Also interbedded with the basalt and slate beds are sedimentary rock units formed from the pebbles, sands, and clays of stream deposits. This third catgory is now a sequence of phyllites and metasandstones with or without pebbles of quartz, granite, basalt, or tuff.

The intricate interlayering of the three rock types show that the various volcanic and sedimentary processes were going on concurrently. Eruptions of pumice and ash, which probably heralded the coming of the lava flows, dumped large quantities of fine debris on the Precambrian landscape choking the streams and forming thick ash deposits in the lowlands. The first surge of lava from the fissures covered only the lowest areas, pushing the streams aside or damming them to form lakes that soon spilled across the still hot lava beds. The streams carved into the lava beds and deposited reworked volcanic ash in their channels with sand and pebbles from the granitic highlands and the lava flows. These deposits, a mixture of volcanic and granitic material, became the rocks of the Swift Run Formation and the sedimentary rocks within the Catoctin Formation. Continued ash falls and ejections of lava blocked streams from many areas for long periods of time resulting in a sequence of alter-

nating volcanic rock types almost devoid of sedimentary material. This sequence is characteristic of the northern and central sections (Plates 1, 2) where only thin discontinuous beds of sedimentary rocks are preserved. In the southern section (Plate 3) several stream systems were active intermittently during volcanism and have left a variety of clastic sedimentary rocks to mark their location. Sandstone, phyllite, and conglomerate beds are well exposed locally between Jarman Gap and the southern entrance to the park, each sedimentary unit commonly lying on volcanic ash beds (purple slates) and capped by greenstone lava flows. The presence of granitic pebbles in the uppermost sedimentary interbeds show that Precambrian granite peaks were still protruding through the lava beds near the end of volcanic activity.

The last volcanic event recorded in the rocks is a widespread ash fall that appears to have blanketed the entire Blue Ridge area in and near the park. This ash, now a purple, yellow-spotted slate bed as much as 200 feet (61 m) thick, is the uppermost layer of the volcanic sequence and marks the boundary between the Catoctin Formation and the overlying Cambrian rocks.

ADVANCE OF THE CAMBRIAN SEA

When volcanism ended, the streams reestablished their courses across the lava plains and deposited mud, sand, and quartz pebbles in their channels (Figure 34), which later became the rocks of the Weverton Formation. These sediments were largely derived from exposed portions of the Precambrian

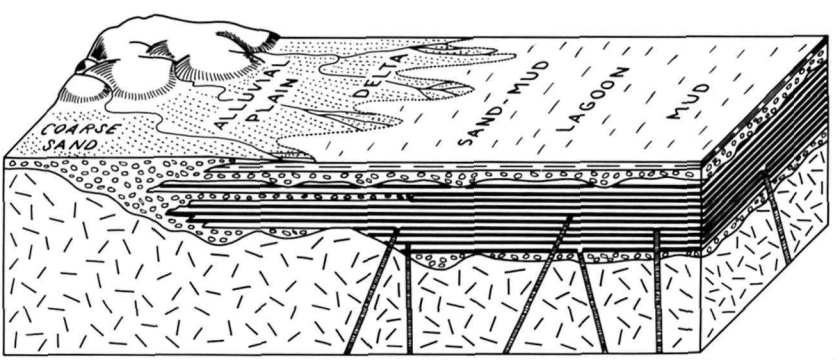

Figure 34. Earliest Cambrian time after the cessation of volcanism and at the beginning of the westward advance of the Cambrian sea. Stream deposits near the remnants of the granite mountains form contemporaneously with lagoonal deposits.

granitic surface that probably was a highland to the west, and which may have also blocked the westward movement of the lava flows. As the streams carried sediment into the area, subsidence in the form of a broad gentle downwarping of the land was underway and had probably been going on since the beginning of volcanism. As subsidence continued, the stream deposits were thickened until the stream systems were submerged and bogs and lagoons took their place, ever deepening as the early Cambrian sea approached from the east.

Early marine sediments of the Cambrian sea were fine-grained sandy muds and clays deposited in the quiet water of a lagoonal environment and protected from the turbulence of the open sea by offshore sandbars or barrier beaches along the seacoast (Figure 35). Soft-bodied marine worms living in the muddy

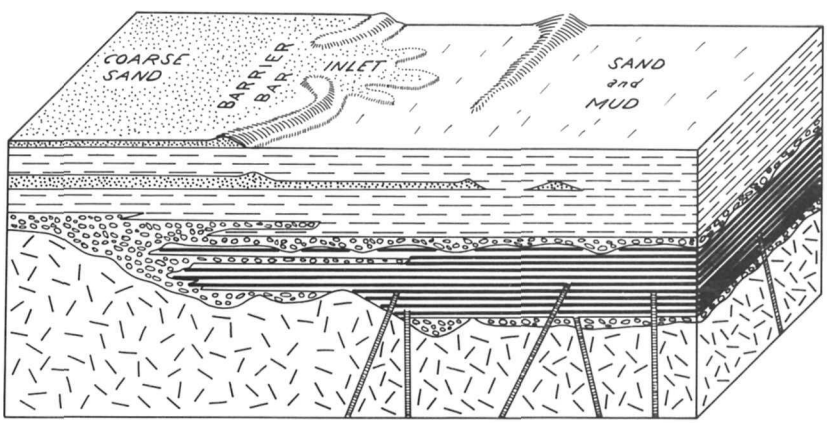

Figure 35. Early Cambrian time as the basin deepens. Sand and mud deposits form along the sea margin.

sands that now form the thick sequence of metasandstones and phyllites of the Hampton Formation left burrows and trails; these fossil forms are the earliest indicators of ancient life preserved in the Blue Ridge. As the basin continued to subside the seacoast extended westward positioning beach and offshore bar environments in what is now the park area. The clean, white beach and bar sands accumulated to depths of 600 to more than 1,000 feet (183 to 305 m). These sands, from which the Erwin quartzites were formed, contained a profusion of worm borings or *Skolithus,* which are preserved as straight, vertical, tube-like fossil forms 3 to 5 mm in diameter and up to 1 meter (3 feet) in length. Steeply inclined bedding (cross-

lamination), scour channels, and scattered quartz-pebble beds suggest that strong currents were present during the deposition of the sand beds. As the seacoast moved farther west the beach and bar environment followed, being replaced by a shallow offshore marine environment characterized by alternating mud and sand deposition that became increasingly calcareous as lime-precipitating organisms moved into the area. Eventually in Middle and Late Cambrian time most of the sediment being deposited in the basin was biologically or chemically precipitated calcium carbonate (Figure 36). Marine carbonate deposition

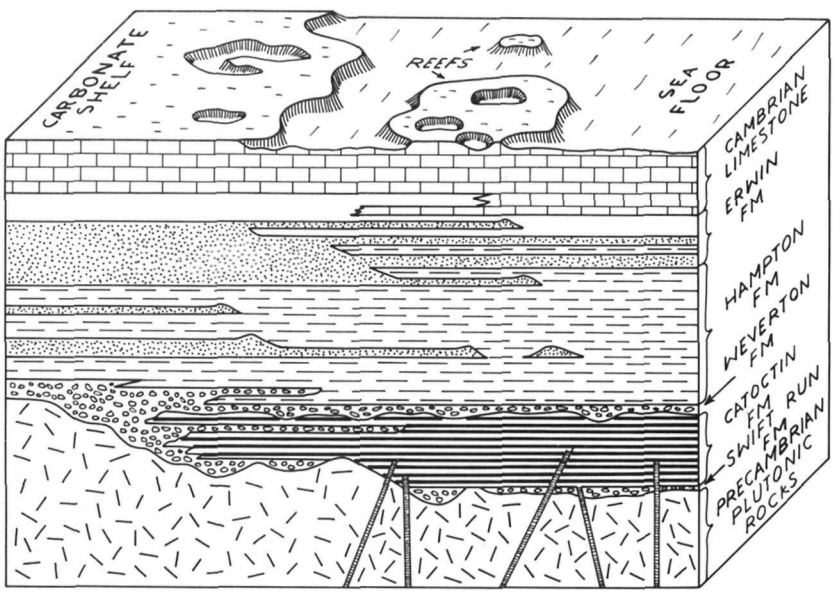

Figure 36. Middle and Late Cambrian time. The influx of coarse sediment into the basin diminishes and is replaced by organically precipitated lime muds that continue to fill the very shallow, slowly subsiding Cambrian basin.

continued through Cambrian and into Ordovician time forming the nearly 12,000-foot- (3,658 m-) thick limestone and dolomite rock sequence that underlies the Shenandoah Valley.

Geologic events in the park area after deposition of the Cambrian and Ordovician carbonates is largely inferred from late Paleozoic rocks west of the Blue Ridge. Sediments ranging in age from Middle Ordovician through most of the Paleozoic probably were deposited intermittently over part or all of the park area, but have since been removed by erosion.

PALEOZOIC DIASTROPHISM

From about Middle Ordovician through Permian time (450-225 million years ago) (Figure 31) the rocks in the Appalachian geosyncline were subjected to a series of diastrophic events. These stress-related events produced folding, faulting, and metamorphism that ultimately formed the structures of the Appalachian Mountains. In the Blue Ridge the rock strata, reacting to the intermittent pulses of diastrophic forces, were warped into a series of folds and broken along faults (Figure 37).

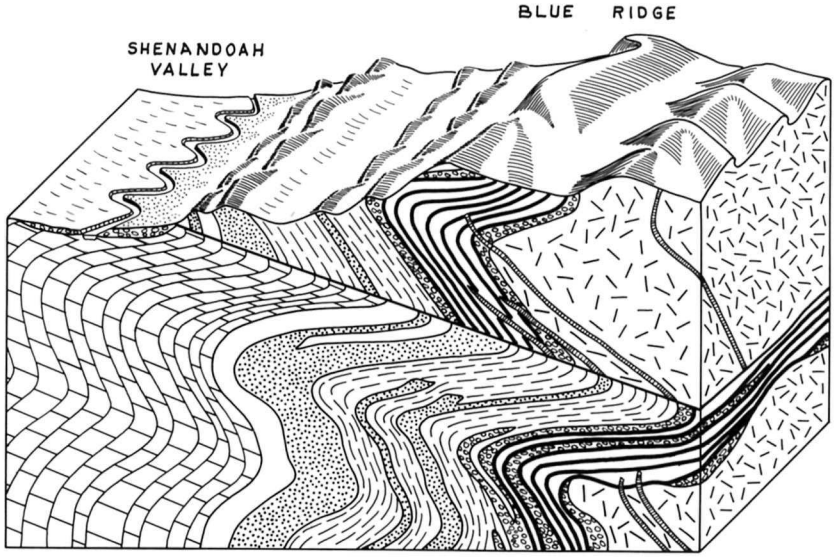

Figure 37. Present land surface and its relation to the rock formations and structures.

Stresses within the rocks were dissipated by mineral recrystallization and slippage along newly formed fracture surfaces that were generated during folding. Heat produced by this stress release and by the geothermal gradient (the rocks were at least 2.5 miles or 4.0 km below the surface and possibly much deeper) allowed new minerals, stable at the higher temperatures, to form during the recrystallization. The greatest alteration of mineral grains occurred in those areas where stresses were greatest, as within zones of intensly sheared and mylonitized plutonic rocks or in sharply overturned and attenuated fold limbs. Biotite, a common metamorphic mineral and indicator of relatively high temperatures and pressures, was found in many of the rocks

of these more intensely deformed areas. The visible results of metamorphism are pronounced in many of the rock types in the park. The quartzites of the Erwin Formation, originally well-sorted quartz sand beds, are now very hard and glassy rock with most of the original texture obliterated by the recrystallization of the quartz sand grains. The phyllites of the Hampton and the purple slates of the Catoctin, once sandy muds and volcanic ash beds, are now platy quartz-sericite rocks in which most of the original sedimentary or volcanic structures have been destroyed by dislocation and recrystallization. The greatest change occurred within the plutonic rocks where they were crushed and milled to form mylonite along several zones of intense dislocation or shear. The appearance of mylonite, a very fine-grained, drab, slaty rock, belies the granitic character of the parent rock. Other visible evidence of the diastrophic events is the universal fracturing of the rocks, most of which is related to stresses applied during diastrophism.

The assemblages of metamorphic minerals in the rocks of the Blue Ridge show that metamorphism during the Paleozoic took place at a relatively shallow depth, probably less than 6 miles (10 km). Also, the metamorphic minerals were formed concurrently with the cleavage development and folding, which suggests that the upward arching of the Blue Ridge anticlinorium, an event related to folding, was underway at the time of metamorphism. Southwest of the park in the Valley and Ridge province Ordovician sedimentary rocks contain a few pebbles and boulders of the sedimentary and volcanic rock of the Blue Ridge. This is positive evidence that the Blue Ridge rock sequence was at the surface and subjected to erosion during Ordovician time, a condition that would require a vertical uplift of several miles. The occurrence of these pebbles and boulders in the younger Ordovician rocks may be the only record of this early diastrophic event in the development of the Blue Ridge. Other and possibly stronger diastrophic events followed in later Paleozoic time and these may account for much or most of the folding, faulting, and metamorphism but direct evidence of Blue Ridge emergence and erosion in the post-Ordovician Paleozoic rocks is more difficult to substantiate.

MESOZOIC EVENTS

During the Triassic Period continental sediments accumulated in a number of basins east of the Blue Ridge and boulders and

cobbles derived from formations now exposed in the Blue Ridge made up a large part of the coarse material in these deposits. In addition, the presence of granitic boulders in the Triassic rocks is evidence that the plutonic rocks in the core of the Blue Ridge anticlinorium had been breached by erosion and that the Blue Ridge mountains were standing well above the surface of the Triassic basins. The Triassic and following Jurassic periods were also times of volcanism and mafic intrusion. Diabasic magma moved upward along fractures in the Blue Ridge and adjacent areas although only a few of the resultant diabase dikes have been found in the park. From Triassic time to the present the rocks of the Blue Ridge may have been at the surface continuously and if so were probably forming a mountain range.

CARVING OF THE MOUNTAINS

The present mountain landforms of the Blue Ridge have probably been evolving since Triassic time. Weathering and erosion impinging on the elevated rock masses have locally lowered the mountain surface at rates relative to the resistance of the various rocks on that surface, the resistance to weathering and erosion being governed by the chemical (mineral) composition and internal structure of the rocks. Common rock-forming minerals in the Blue Ridge consist of silica, very resistant to weathering and relatively insoluble in water; mica and feldspar, less resistant and more soluble; and calcium and magnesium carbonate minerals, the least resistant and among the most soluble. As all rocks of the Blue Ridge have been metamorphosed, the original open spaces (pores, vugs) have been destroyed by recrystallization, so that the only open spaces through which water has been able to enter and induce mineral solution is through fractures (joints, cleavage, faults) formed during diastrophism. These controlling factors, mineral composition and fracture frequency, are variable from place to place and react accordingly to weathering and erosion. The differential removal of rock material from the variably deformed heterogeneous rock sequence of the Blue Ridge has resulted in a great variety of landforms and elevations (Figure 37). Quartzite beds, composed of nearly pure silica make higher ridges than phyllite, which is rich in mica. Limestone and dolomite (calcium and magnesium carbonates) form the lowlands of the Shenandoah Valley with only a few low ridges where sandstone or chert beds

within the limestone provide some resistant silica. The thicker remnants of volcanic rocks form the highest ridges. Also where the normally resistant ridge-forming rocks, quartzite or basalt, are present in overturned fold limbs or along faults or shear zones only lower ridges or small valleys are present. Faults or shear zones commonly appear as linear topographic lows between the less deformed mountain-forming rocks.

The distribution of the landforms (mountains, valleys, ridges) and the location of the drainage network is best explained by natural differences in erosional rates and does not require recent tectonic uplift or subsidence as a mechanism for forming specific topographic features. Uplift of the Blue Ridge and surrounding areas has certainly occurred in the geologic past, as evidenced by the presence of the rocks in the Blue Ridge that could only have formed deep within the crust. Uplift may still be going on, but at such a low rate that weathering and erosion have maintained a mountain and valley topography that expresses only the distribution of resistant and nonresistant rock.

In the past million years during the Pleistocene Epoch, four periods of continental glaciation brought significant changes in the climate of North America. Although the glacial ice approached from the north and northwest to within 200 miles of the park as recently as 7,000 years ago, no evidence for glaciation in the Blue Ridge has been found. The glaciation to the north was accompanied by a major decrease in temperature and an increase in rainfall in the Blue Ridge which together accelerated weathering and erosional processes. Some effects of the climatic changes are still visible in the park (Hack, 1966). The extensive talus deposits formed of Erwin quartzites or other resistant rock units are the result of the Pleistocene weather. These deposits appear to be weathering and disintegrating more rapidly than they are being formed. Also, much of the sand and boulder material in the wide alluvial fans sloping gently westward into the Shenandoah Valley must have been deposited during periods of heavy rainfall in the past million years. These deposits are now being actively eroded by streams issuing from the Blue Ridge, probably the same streams that formed the deposits initially.

Thus we reach the present hoping to have explained in some part the origin of the Blue Ridge rocks and structures and the development of the topographic forms that we see.

PREVIOUS STUDIES AND ACKNOWLEDGEMENTS

This report on the geology of Shenandoah National Park has been compiled from data collected during detailed and reconnaissance geologic mapping by the author and several other members of the staff of the Virginia Division of Mineral Resources and from published geologic reports and maps that included portions of the park. It is an outgrowth of ground-water studies conducted in the park by the Virginia Division of Mineral Resources between 1961 and 1971 (DeKay, 1972). This report, it is hoped, will contribute to a better understanding of the rocks of the Blue Ridge by tying together for the first time the geology of a large area of the mountains in northern Virginia.

The first efforts to explore and describe the geology of the Blue Ridge were undertaken by William Barton Rogers between 1835 and 1841 during his extensive study of the geology of Virginia and West Virginia. Rogers' (1884) reports provided the first generalized picture of the distribution, structures, and mineral deposits of the rocks in the two states and were the first to depict, in a general sense, the geology of the Blue Ridge. During the next 100 years geologic studies of the Blue Ridge in the area that has become Shenandoah National Park were largely restricted to the evaluation of economic mineral deposits (manganese, iron, and copper) and to regional geologic studies. Reports by Arthur Keith (1894a,b) are of particular interest as they were the first to describe many of the rock formations in the park.

The manganese shortage that developed during World Wars I and II activated interest in the manganese deposits along the west foot of the Blue Ridge and initiated a number of studies of these deposits and of the geology of the Blue Ridge and adjacent Shenandoah Valley. One such study (King, 1950) became the first detailed geologic report to include a portion of the park. Within this report, geologic relationships and stratigraphic terminology were established which formed the basis for subsequent geologic studies of the Blue Ridge in this area. Beginning with King's report, papers dealing with portions of the park appeared more frequently. Of the more recent geologic studies the following have been most useful in preparing this manuscript and Plates 1, 2 and 3: Allen (1963, 1967), Bloomer and Werner (1955), Brent (1960), Hack (1965), King (1950), Nelson (1962), and Reed (1955, 1969). The geologic maps ac-

companying the above reports cover approximately three-quarters of the park area, including some or all of those portions in Albemarle, Augusta, Greene, Madison, Nelson, Page, and Rockingham counties. Other portions of the park, largely in Augusta, Rappahannock, and Warren counties, and those areas of the park for which these maps were inadequate were mapped by the writer under the supervision of R. H. DeKay and with the assistance of Donald Fulkerson, M. T. Lukert, E. B. Nuckols III, E. W. Nunan, and P. G. Nystrom, Jr., staff members of the Virginia Division of Mineral Resources. Geologic data acquired during this study suggested that some minor alterations to the geology shown on existing maps should be made, and these alterations are incorporated on Plates 1, 2, and 3.

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GLOSSARY

alluvium—Unconsolidated stream-deposited material laid down during comparatively recent time.

amygdule—A mineral-filled vesicle in an igneous rock, such as in basalt.

anticlinorium—An anticlinal structure of regional extent composed of lesser folds.

anticline—A fold generally in the form of a linear arch with the older strata in the center of the arch; an upfold.

argillaceous—Said of a sediment or rock containing abundant clay.

asymmetric fold—A fold, the limbs of which are not equally inclined and which does not have a vertical axial plane.

bedrock—The continuous solid rock that is exposed at the surface or is directly beneath soil or other unconsolidated deposits.

bioturbation—The churning and stirring of sediment by organisms.

breccia—A coarse-grained clastic rock composed of large, angular, and broken rock fragments that are cemented together in a finer-grained matrix.

cataclastic texture—A rock texture characterized by the flattening, fragmentation, and granulation of rock-forming minerals in zones of intense deformation.

charnockite—A hypersthene-bearing granite thought to have formed at high temperature and pressure.

clastic—Pertaining to a rock or sediment composed of fragmental material.

cleavage—The property of a rock to split along secondary, aligned fractures or other closely spaced, planar structures or textures, produced by deformation or metamorphism.

colluvium—A general term for a heterogeneous mass of unconsolidated rock or soil material that has moved downslope under the influence of gravity.

diastrophism—A general term for all movement of the crust produced by Earth forces, including the formation of ocean basins, continents, and mountain ranges.

dike—A tabular igneous intrusive mass that transects the bedding or foliation of the rocks adjacent to it.

dip—The angle between the horizontal and a described plane.

fabric—The sum of the structural and textural features of a rock.

fan—A gently sloping, fan-shaped mass of outwashed rock material commonly formed where mountain streams exit onto a valley floor.

fault—A surface or zone of rock fracture along which there has been displacement, from a few inches to a few miles.

fault-shear zones—Zones of intensely deformed and mylonitized rock along which significant displacement has occurred.

flatiron—One of a series of short, triangular-shaped hogbacks terminating a spur or ridge on the flank of a mountain, having a narrow apex and broad base, and formed on steeply dipping, resistant strata.

fluvial—Produced by the action of streams or rivers.

foliation—The laminar or layered structure of a metamorphic or igneous rock that reflects a segregation or preferred orientation of platy or rod-like constituent minerals. Compositional layering and cleavage are common forms.

formation—The basic or fundamental rock-stratigraphic unit used in the classification of rock bodies.

granoblastic texture—A crystalline rock texture characterized by interlocking grain boundaries between equidimensionable grains, caused by complete recrystallization of the rock at high temperature and pressure.

granulite—A relatively coarse granular rock formed at high pressure and temperature that exhibits a crude layering and granoblastic texture.

group—A major classification of rock units next higher in rank than a formation and containing two or more formations.

joint—A surface or parting in a rock, without displacement; generally planar and in parallel sets.

lithology—The physical character of rock.

metamorphism—The process by which rock is transformed in response to changes in temperature and/or pressure, and sometimes accompanied by changes in chemical environment.

mylonite—A granular or slaty rock with a banded or streaky layering that was produced by extreme crushing and shearing.

phenocryst—A relatively large crystal surrounded by a finer matrix in an igneous rock.

plunge—The inclination of a fold axis, measured by its departure from horizontal.

plutonic—Pertaining to rocks of igneous or metamorphic origin that were formed at great depth.

pyroclastic—Pertaining to fragmental rock material formed by volcanic explosion or expulsion.

recumbent fold—An overturned fold, the axial plane of which is nearly horizontal.

relic—Pertaining to a mineral, structure, or feature of a rock or ancient land surface that has survived processes such as metamorphism or erosion that have tended to destroy it.

relief—Difference between elevations on a land surface in a given area.

reverse fault—An inclined rock fracture along which the upper block has moved up the inclined fracture surface relative to the lower block.

saprolite—Soft, clay-rich, thoroughly decomposed rock formed in place by chemical weathering of igneous or metamorphic rocks, and commonly retaining visible relic structures.

siliceous—Said of a rock containing abundant silica.

strike—The compass direction of a horizontal line in the plane of a stratum; the trend of an inclined planar feature.

syncline—A fold, generally in the form of a linear trough, with the younger strata in the center of the trough; a downfold.

synclinorium—A complex syncline that consists of subordinate folds, the whole having a trough-like form.

talus—Coarse rock waste which has accumulated at the bottom of a cliff or on a steep slope chiefly as the result of physical weathering and gravity.

tectonic breccia—A breccia formed as a result of crustal movements and produced by pressure or by tension.

terrace—A large bench or step-like planar surface interrupting the continuity of a slope, formed by stream erosion.

trace fossil—A sedimentary structure consisting of a fossilized boring, burrow, track, trail, tube, or tunnel resulting from the activities of an animal.

transverse fault—A fault the strike of which is oblique or perpendicular to the regional structural trend.

unconformity—A substantial time break or gap in the geologic record where rock units are absent due to erosion or nondeposition. It may be an ancient erosion surface, and a marked angularity between the surface and strata below the surface may occur.

vesicle—A cavity of variable shape in lava formed by the entrapment of a gas bubble during solidification of the lava.

vitreous—Having the luster resembling broken glass.

APPENDIX

ROAD LOG ALONG SKYLINE DRIVE

The following road log is a guide to important geologic features that can be seen from Skyline Drive in the Shenandoah National Park. The log is keyed to the numbered mileposts along Skyline Drive. It begins at the north entrance to the park, at the intersection of U. S. Highway 340 and Skyline Drive (mile 0.0) near the southern corporate limit of Front Royal, and continues to the south for 105.2 miles (169.3 km). Places of special interest geologically are marked with an asterisk.

Most of the geologic features can be seen from or near overlooks that provide room for safe parking, or are located in areas where Skyline Drive has wide shoulders on which parking is safe in dry weather. When parking along Skyline Drive, be sure to pull completely off the pavement and do not block fire roads or the entrance to overlooks or other facilities. *Rock samples may not be collected or removed from Shenandoah National Park in accordance with National Park Service regulations.*

Cumulative miles	*(km)*	*Explanation*
0.0	(0.0)	Enter Skyline Drive from U. S. Highway 340 near southern corporate limit of Front Royal. At this location the drive is on Ordovician limestone and dolomite of the Rockdale Run Formation of the Beekmantown Group, which is obscured by rock debris from the Catoctin Formation.
0.5	(0.8)	Park Entrance Station. Skyline Drive crosses the Front Royal fault that separates the Rockdale Run and Catoctin formations.
1.4	(2.3)	Massive, purplish brown weathering, locally vesicular, northwestward-dipping basalt flow of the Catoctin Formation exposed along northbound lane. Brecciated basalt with epidote cement visible at north end of exposure.
2.0	(3.2)	Shenandoah Valley Overlook at milepost 2. View of the Front Royal area and the north end of Massanutten Mountain.
3.9	(6.3)	Basalt of the Catoctin Formation exposed by the northbound lane from this point to mileage 4.3 (km 6.9).
4.7	(7.6)	Entrance to Dickey Ridge Visitor Center and Picnic Grounds.

Cumulative miles	*(km)*	*Explanation*
5.2	(8.4)	Parking overlook by southbound lane opposite locally epidotized basalt in roadcut. Zone of weathered-out vesicles visible near top of exposure.
*5.7	(9.2)	Signal Knob Overlook. To the west, meander loops of the South Fork of the Shenandoah River are visible near the west side of the valley. In the background is Massanutten Mountain on which several talus deposits have been formed from blocks of Silurian Massanutten Sandstone that have moved downslope from the mountain crest. In the roadcut to the east is one of the best exposures along Skyline Drive of a boundary between basalt flows and the sedimentary rocks commonly found in the Catoctin Formation (Figure 38).

Figure 38. Catoctin Formation at Signal Knob Overlook consisting of a thin, dark-red arkosic sandstone overlying a dark, dense, partially epidotized, vesicular basalt and underlying a lighter-hued basalt flow with columnar jointing. The dark iron-red coloration of the sedimentary layer is probably due to mineralization and "baking" by the overlying lava flow.

*6.9	(11.1)	Gooney Run Overlook. The boundary between the Catoctin and Pedlar formations, a profound unconformity between the late Precambrian volcanics and the porphyritic granodiorite of an earlier Precambrian pluton, passes beneath the parking area (not to the west of the overlook as is incorrectly shown on Plate 1). Purple pyroclastic phyllite and pale-green rhyolitic(?) tuffs of the basal Catoctin Formation are exposed between weathered basalt beds in the roadcut. A good exposure of the Pedlar granodiorite

Cumulative miles	*(km)*	*Explanation*
		occurs 200 feet (61 m) west of the overlook at the end of the footpath.
7.3	(11.7)	Gooney Manor Overlook. Browntown Valley to the southwest and the low hills to the west are underlain entirely by rocks of the Pedlar Formation. The main body of the Blue Ridge encircles the valley to the north, east, and south, with most of the visible crest capped by Catoctin basalt.
9.2	(14.8)	Lands Run Gap. Here the road crosses a small concealed linear fault or flexure that separates the Catoctin Formation from granodiorite of the Pedlar Formation. Traces of rocks similar to those found in the Swift Run Formation and of epidotized granodiorite that commonly occur below the Catoctin Formation at the Precambrian unconformity are present along this linear depression. This association suggests that this boundary is an exposure of the unconformity along a vertical fold limb and probably not a fault as shown on Plate 1.
*9.5	(15.3)	Pull off on shoulder by southbound lane. Exposures 300 feet (91 m) upgrade to south are migmatitic, granitic gneiss of the Pedlar Formation (Figure 11). Light and dark layers in the gneiss define plunging folds. Massive hypersthene granodiorite is present on the crest of the ridge above the exposures, and it may have been intruded into the gneiss exposed here.
*10.1	(16.3)	For several hundred feet south and north of the sharp bend in Skyline Drive a series of near vertical diabasic dikes, each several tens of feet thick, extend across the road and are exposed in the roadcuts. These and similar dikes in the plutonic rocks of the Blue Ridge represent conduits through which the basaltic magmas of the Catoctin Formation were extruded. The dikes are very dark green, fine-grained and porphyritic, and contain fragments and a few large blocks of epidotized granodiorite. Where contacts of dikes with the wall rock are visible, the Pedlar granodiorite is moderately epidotized or unakitic.
10.5	(16.9)	Pyroclastic mud flows at the base of the Catoctin Formation are exposed for several hundred feet up the slope above the southbound lane. These rocks are shown as the Swift Run Formation on Plate 1, but are not typical of that unit and possibly should be placed within the Catoctin Formation.
*10.7	(17.2)	Indian Run Overlook. The basal basalt flow of the Catoctin Formation is exposed in the roadcut by the overlook. The best display of columnar jointing along Skyline Drive can be seen at the north end of this exposure (Figure 39).

Cumulative miles	*(km)*	*Explanation*
		The terrane to the east and north is underlain by rocks of the Pedlar Formation capped, at the higher elevations, by thin remnants of the basal Catoctin basalt flows, possibly the same flows that are exposed in the roadcut.

Figure 39. Columnar basalt of the Catoctin Formation in the roadcut at the north end of Indian Run Overlook. Locally, the subparallel columns fan upward from high-temperature areas that existed in the flow during solidification.

11.2	(18.0)	Small exposures of the Swift Run Formation occur along the southbound lane of Skyline Drive. The road continues to the south on the Pedlar Formation for the next 3.1 miles (5.0 km).
12.4	(20.0)	Jenkins Gap Overlook. A view of the terrane developed on crystalline igneous rocks east of the Blue Ridge crest.
*13.8	(22.2)	Hogwallow Flats Overlook. This overlook provides a good view of the foothills formed by the plutonic rocks along the east side of the Blue Ridge mountains. Visible on very clear days, about 20 miles (32 km) to the east, are low ridges formed by rocks of the Catoctin Formation and the Chilhowee Group along the east flank of the Blue Ridge anticlinorium in Fauquier County.
14.3	(23.0)	The contact between the Pedlar and Catoctin formations extends across Skyline Drive just south of the Appalachian Trail crossing. The drive is on the Catoctin Formation for the next 6.7 miles (10.8 km).
14.9	(24.0)	Browntown Valley Overlook. At this overlook, and for nearly a mile to the south, Skyline Drive is constructed on

Cumulative miles	*(km)*	*Explanation*
		a natural bench developed on the upper part of a Catoctin basalt flow, one of the 13 flow benches that can be seen along the west face of Mount Marshall (Figure 13). Across Browntown Valley and the low hills that separate it from the Shenandoah Valley, both crests of Massanutten Mountain are visible on clear days, as well as part of Great North Mountain, the next major ridge west of the Massanutten mountain range. These ridge crests mark the outcrop of steeply dipping quartzite beds of Silurian age.
*17.2	(27.7)	Range View Overlook. This overlook provides a rare, panoramic view of the Blue Ridge to the south and of the mountains and ridges to the east and west of it. From this location it can be seen that the shape, elevation, and linear extent of the ridges of the Piedmont province east of the Blue Ridge contrast strongly with those of the Valley and Ridge province to the west. The eastern ridges and hills of the Piedmont, formed on the massive plutonic rocks in the core of the Blue Ridge anticlinorium, vary in shape and elevation from ridge to ridge. These hills are of limited linear extent although they are generally aligned with their long axes parallel to the prevailing northeastward trend of the Blue Ridge mountains. The Massanutten mountain range and other ridges to the west in the Valley and Ridge are linear, and have relatively uniform shape and crestal elevations for long distances along their northeasterly trend. The differing morphology of the mountains in the Piedmont and Valley and Ridge is a reflection of the bedrock and structure. The hills to the east are formed by homogeneous intrusive and metamorphic rocks that are fractured and sheared along lines parallel to the Blue Ridge, and randomly crisscrossed by faults, joints, and dikes. In this area weathering and mass wasting is more rapid along the zones of fracture and the linear intrusive bodies, and has produced discontinuous linear lows that bound the irregularly shaped hills and ridges formed on the less intensely fractured plutonic rock. To the west the rocks of the Valley and Ridge are stratified, heterogeneous, and tilted with the thicker, inclined, resistant rocks forming the long, parallel, even-crested ridges typified by Massanutten Mountain. Fault and joint systems also modify the rates of weathering and mass wasting of the stratified rocks producing gaps and saddles, but do not mask the dominating influence of the stratified sequence in controlling the characteristic shape and extent of the resistant ridges.

Cumulative miles	*(km)*	*Explanation*
18.4	(29.6)	Gimlet Ridge Overlook. Another good view of Browntown Valley and the ridges to the northwest. Distant rock exposures on the steep slopes to the west are of the Pedlar Formation. The steep, narrow, closely spaced hollows along the escarpment are characteristically formed on the plutonic rocks on steep slopes below the contact with the Catoctin Formation.
19.0	(30.6)	Mount Marshall Overlook at milepost 19. A series of low gaps between the main Blue Ridge mass and the several southeastward-trending subsidiary ridges mark the location of a fault zone that separates the Catoctin Formation from the Pedlar Formation to the east. Massive basalts exposed north of the overlook have coarse columnar jointing.
19.3	(31.1)	Skyline Drive crosses a small vertical fault within the Catoctin Formation. Near the road the fault is not exposed, but a zone of angular basalt rubble appears to define its trace across the mountain crest.
19.7	(31.7)	Little Hog Back Overlook. To the west the very steep slope is underlain by the Pedlar Formation and is typical of slopes developed on this unit at higher elevations where the Catoctin Formation overlies it or has overlain it in the recent geologic past. The unconformity between the Catoctin and Pedlar formations passes beneath the eastern part of this overlook, with no evidence for the presence of the Swift Run Formation.
*20.1	(32.3)	Little Devil Stairs Overlook. The deep, steeply inclined gorge (Little Devil Stairs) to the south is formed in the Catoctin Formation along a northward-trending zone of fractures. Several northward-trending Catoctin feeder dikes at the head of the gorge are exposed in the roadcut at milepost 20 just north of the overlook, and may have influenced the development of Little Devil Stairs, if they penetrated the lower Catoctin basalt flows. Dark, coarse-grained granodiorite of the Pedlar Formation, much of which is unweathered, is well exposed adjacent to the overlook and to the north. Penetrating, dark-red iron stains, thought to be paleoweathering features preserved from late Precambrian time, are well displayed in both the fresh and weathered rock (see description for Hogback Overlook, milepost 21).
*21.0	(33.8)	Hogback Overlook at milepost 21. Due to the removal of the Catoctin Formation by erosion in the recent geologic past, the crest of Hog Back Mountain is now underlain by the Pedlar Formation. The contact between the two rock

Cumulative miles (km) *Explanation*

units was little more than 100 foot (30 m) above the present crest, indicating that the rocks now exposed at the overlook were probably subjected to weathering prior to the extrusion of the Catoctin basalt flows in late Precambrian time. Dark-red iron stains that penetrate the granodiorite along incipient fractures are suggestive of ancient weathering features, as other generally open fractures in the same rock exhibit the typical brown iron-oxide-staining characteristics of recent weathering. These features can be seen in the rock exposures at the overlook near road level (Figure 40).

Figure 40. Granodiorite of the Pedlar Formation on the south side of Skyline Drive at Hogback Overlook, 0.2 mile (0.3 km) south of milepost 21 (Plate 1). The granodiorite is a light-gray, porphyritic, moderately foliated crystalline rock. The rocks exposed here were probably less than 100 feet (30 m) below the Precambrian erosion surface. The intersecting arm-like forms in the rock are purple, penetrative, iron-oxide stains along ancient healed fractures. The stains probably relate to mineralization during Catoctin volcanism or to weathering before the lavas covered the Precambrian surface.

Cumulative miles	*(km)*	*Explanation*
		The view to the north from Hogback Overlook is the best in the northern section of the park. It encompasses much of the northernmost protuberance of the Blue Ridge into Shenandoah Valley. This area, underlain by Cambrian and Precambrian rocks, has been thrust several miles westward over the younger Cambrian and Ordovician carbonates. Browntown Valley, a portion of the protuberance is in the foreground with the Blue Ridge escarpment and Mount Marshall to the northeast.
21.3	(34.3)	The contact between the Catoctin and Pedlar formations extends across Skyline Drive at this point, but no evidence of the Swift Run Formation is visible.
21.8	(35.1)	Rattlesnake Point Overlook. A view of the eastern Blue Ridge mountains and the southeast foothills. Fine vesicular basalts are exposed in the roadcut at the north end of the overlook.
22.2	(35.7)	Entrance to Matthews Arm Campground.
24.0	(38.6)	Entrance to Elkwallow Wayside at milepost 24.
24.2	(39.0)	Entrance to Elkwallow Picnic Grounds.
25.0	(40.2)	The base of the Weverton Formation between mileposts 25 and 26 parallels Skyline Drive just above road level, and basalts or purple slate are exposed locally in the roadcut.
26.4	(42.5)	Jeremys Run Overlook. Jeremys Run drains a large, steep area underlain largely by the Catoctin Formation with caps of the Weverton and Hampton formations on the higher surrounding ridges. To the west, parts of Shenandoah Valley can be seen, with New Market Gap in the Massanutten Mountain area visible in the distance.
26.9	(43.3)	Jointed sandstone beds of the lower part of the Weverton Formation with well-developed spheriodal weathering are exposed by the southbound lane.
*27.1	(43.6)	Contact between the Catoctin and Weverton formations exposed above the southbound lane. Vesicular basalt of the Catoctin Formation is directly overlain by a conglomerate of angular basalt fragments and rounded quartz pebbles that comprise the base of the Weverton Formation at this location.
27.6	(44.4)	Thornton Hollow Overlook. A view to the east and north of the Blue Ridge foothills and the Elkwallow area, respectively. Massive basalts of the Catoctin Formation in

Cumulative miles	*(km)*	*Explanation*
33.1	(53.3)	Hazel Mountain Overlook. Additional exposures of the Pedlar granodiorite.
35.1	(56.5)	Pinnacles Overlook. View to the south of the north face of Old Rag Mountain with Corbin and Robertson mountains to the south and west, respectively, all areas underlain by the Old Rag Granite. Several exposures of the Pedlar Formation are present at the overlook.
36.4	(58.6)	Jewell Hollow Overlook. View to the northwest of sharp-crested ridges formed on rocks of the Chilhowee Group near Shenandoah National Park Headquarters.
36.7	(59.1)	Entrance to Pinnacle Picnic Grounds.
38.6	(62.1)	Stony Man Overlook (Hughes River Gap). Exposures in roadcut of light-hued, fine-grained Pedlar granodiorite. The view to the west is of Luray and of Page Valley, that segment of Shenandoah Valley between Stanley and Luray which is underlain by Cambrain and Ordovician carbonates and shales. To the south, the profile of Stony Man is outlined in outcrops of columnar basalts of the Catoctin Formation.
39.1	(63.0)	Trail Parking Area. The concealed contact between the Pedlar and Catoctin formations is less than 100 feet (30 m) to the north. Excellent exposures of the Catoctin Formation along Stony Man Trail and for the next 0.7 mile (1.1 km) along Skyline Drive. Differentially epidotized columnar basalts are best displayed near the parking area along this section. To the north the Pedlar Formation exhibits the rectilinear, red iron stain patterns characteristically present in the plutonic rocks just below the Catoctin contact, and are thought to be the result of Precambrian weathering or the introduction of mineralizing fluids during Catoctin volcanism.
39.8	(64.0)	Hemlock Springs Overlook. A view to the north of the plutonic-rock terrane in the Pinnacles area. The hollow at the south end of the overlook is typical of the debris-filled hollows formed on the Catoctin Formation.
*40.6	(65.3)	Thorofare Mountain Overlook. The best view of Old Rag Mountain from Skyline Drive. Late afternoon lighting accentuates the northward-trending joint system visible on the north face of the mountain (Figure 41).
41.1	(66.1)	Along the north side of Skyline Drive boulder fields and talus deposits of basalt debris lie on gently southeastward-dipping, differentially epidotized basalt flows of the Catoctin Formation for the next 0.4 mile (0.6 km).

Figure 41. North face of Old Rag Mountain, with late afternoon light accentuating the north-trending fracture system in the granitic rocks. These joints roughly parallel the trend of the Catoctin feeder dikes exposed along the crest and may have formed during Catoctin volcanism.

Cumulative miles	*(km)*	*Explanation*
41.7	(67.1)	North entrance to Skyland (highest elevation on Skyline Drive). In the Skyland area to the west more than 200 feet (61 m) of Swift Run sedimentary rocks separate Pedlar granodiorite from the lower basalt flows of the Catoctin Formation. The Swift Run Formation is exposed downslope (west) from Skyland restaurant and in a small quarry north of the stables. It is a stratified sequence of phyllite and coarse, pebbly sandstone of both pyroclastic and detrital origin. The restaurant and upper cabin area is on strongly cleaved basalts, and the lower cabin area mostly on very dark-gray, gneissic granodiorite. All of Page Valley and most of Massanutten Mountain are visible from the Skyland area on clear days.
42.5	(68.4)	South entrance to Skyland. The contact between the Catoctin and Swift Run formations extends across Skyland Drive at this entrance and passes through the White Oak Canyon parking area to the east.
42.7	(68.7)	Approximate location of contact between the Swift Run and Pedlar formations.
*43.3	(69.7)	Timber Hollow Overlook. View to the west of Page Valley and of Hershberger Ridge beyond the small community of Ida at the west foot of the Blue Ridge. Hershberger Ridge is formed by rocks of the Erwin Formation and appears to be bounded by faults on the southeast and northwest. Just west of the overlook are exposures of Pedlar granodiorite cut by veins of epidote that may be the result of

Cumulative miles	*(km)*	*Explanation*
		mineralization associated with the early Catoctin basalt flows.
43.8	(70.5)	Approximate location of the concealed Swift Run Formation. Skyline Drive passes onto the Catoctin Formation to the southeast.
44.3	(71.3)	Crescent Rock Overlook. View of Hawksbill Mountain to the southwest, the highest peak in the park, with several cliffs of columnar basalt visible on the northwest face (Figures 4, 42).

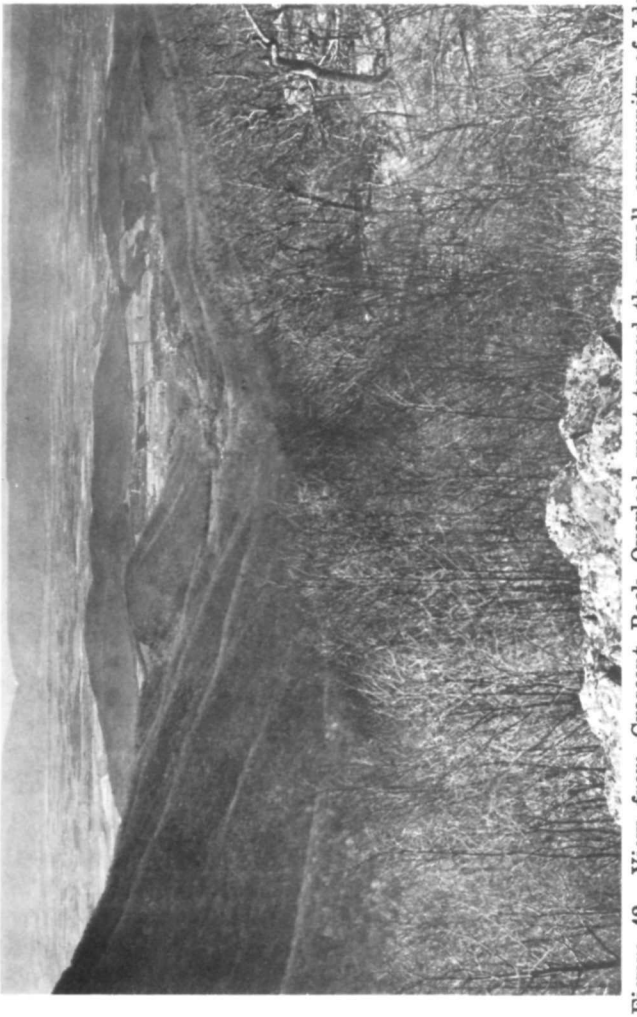

Figure 42. View from Crescent Rock Overlook west toward the small community of Ida at the mouth of Timber Hollow. The ridges just beyond the community mark the location of a narrow, folded belt of Catoctin and Chilhowee rocks that are apparently bounded by faults along the east and west foot of the ridges. Beyond these ridges is Page Valley, a segment of Shenandoah Valley that is floored by Cambrian and Ordovician carbonate rocks. Beyond the valley is the Massanutten mountain range and New Market Gap (upper left) that provides access between Page Valley and the northwestern part of Shenandoah Valley.

Cumulative miles	*(km)*	*Explanation*
45.3	(72.9)	Exposures by southbound lane of gently southeastward-dipping, amygduloidal basalt with veins of epidote and jasper. These rocks are characteristic of the upper few feet of many Catoctin basalt flows.
45.7	(73.5)	Hawksbill Trail parking area.
46.5	(74.8)	Old Rag View Overlook. Profile of the steep north face of Old Rag Mountain.
46.6	(75.0)	Upper Hawksbill parking area.
47.2	(76.0)	In curve on northeast side of Skyline Drive are exposures of Catoctin basalt in which small sedimentary dikes formed while the flow was cooling and possibly still mobile. The sediments are very fine-grained, yellow to purple, exhibit pseudo-bedding features, and were probably injected as a fluid mass into fractures at the base of the flow as it advanced across unconsolidated sediments.
47.8	(77.0)	Approximate location of the contact between the Catoctin and Pedlar formations; no evidence of the Swift Run Formation was found in this area.
*48.1	(77.4)	Spitler Knoll Overlook on rocks of the Pedlar Formation. A view to the northwest of Page Valley, the town of Stanley, and New Market Gap in Massanutten Mountain. The sharp-crested peaks and ridges to the west comprise the northern part of an uplifted mass of Precambrian and Early Cambrian clastic rocks that extends lobe-like out into the valley. It is separated from later Cambrian and Ordovician carbonate rocks of Page Valley by the Stanley fault that passes between Stanley and the northern line of ridges.
48.3	(77.8)	Approximate location of the contact between the Pedlar and Catoctin formations, with the Catoctin present to the south.
49.0	(78.8)	Franklin Cliff Overlook at milepost 49. Several thick epidotized basalt flows form Franklin Cliffs, and remnants of an epidotized basalt breccia that marks the top of the upper flow are preserved in the wooded area between the cliffs and Skyline Drive at the north end of the overlook. To the west the low farmlands along the base of the Blue Ridge are covered by alluvial fans and terraces formed from resistant rock debris derived from the Blue Ridge and transported into the valley. These clay, sand, and boulder deposits conceal bedrock along a belt 1 to 3 miles (2 to 5 km) wide at the west foot of the Blue Ridge for many miles.

Cumulative miles	*(km)*	*Explanation*
49.4	(79.5)	Fishers Gap Overlook.
50.6	(81.4)	Dark Hollow Falls parking area. The trail leads downhill for several thousand feet to Dark Hollow Falls (Frontispiece) where the surface drainage from much of the Big Meadows area tumbles over a series of small benches formed on a resistant basalt flow. Amygdaloidal and porphyritic basalts are well exposed along the stream above the falls (Figure 43).

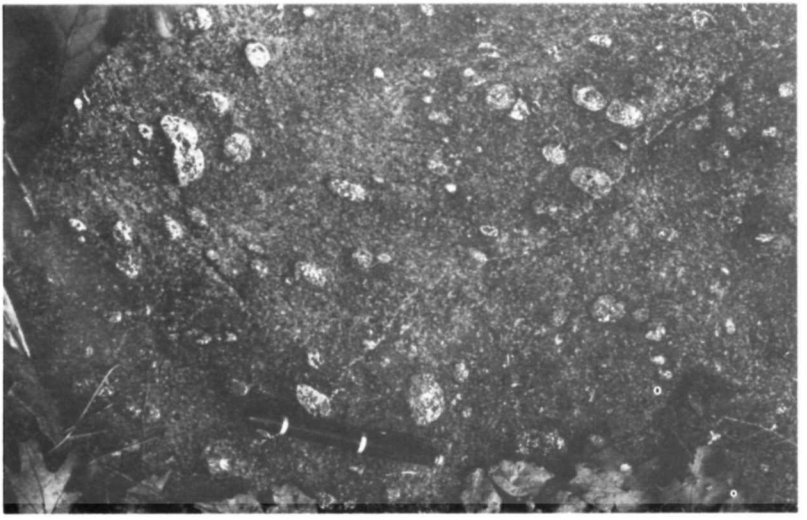

Figure 43. Amygdaloidal metabasalt with the amygdules weathered out in relief along the trail to Dark Hollow Falls from Dark Hollow Falls parking area.

50.8	(81.7)	Entrance to Byrd Visitor Center.
51.0	(82.1)	Big Meadows marshy grassland at milepost 51 on south side of Skyline Drive.
*51.2	(82.4)	Entrance to Big Meadows lodge, restaurant, and campgrounds. The view from Blackrock on the trail west of Big Meadows Lodge is a panorama of Page Valley and the Blue Ridge escarpment north of Big Meadows. This is one of the few points from which many of the major structural elements of this area may be seen. The approximate trace of the Stanley fault can be followed to the east where it turns northeast through the valley at the foot of the Blue Ridge escarpment. Beyond the escarpment it turns to the east again, and extends across the Blue Ridge at Thornton Gap.

Cumulative miles	*(km)*	*Explanation*
		To the west and north the straight, even crests of the paralleling ridges of Massanutten Mountain contrast sharply with the irregular, lobate front of the Blue Ridge, and attest to the greater structural complexity of the rock strata in the Blue Ridge.
*51.5	(82.9)	Tanners Ridge Overlook. The ridges bounding the westward bulge of the Blue Ridge on the northwest and southwest are formed by steeply tilted, resistant quartzites of the Erwin (Antietam) Formation.
53.4	(86.0)	Naked Creek Overlook. A westward view across Long Ridge capped by the Weverton Formation. Much of the mountainous area to the west is underlain by the Catoctin, Swift Run, and Pedlar formations except at the base of the western (Erwin) ridges where the Chilhowee Group lies directly on the Pedlar Formation.
*54.8	(88.2)	Hazeltop Ridge Overlook. A broad extension of Shenandoah National Park protrudes westward almost to the South Fork of the Shenandoah River. At milepost 55, just south of the overlook on the east side of Skyline Drive, are exposures of Catoctin basalts with epidosite lenses, wavy cleavage surfaces, and slickensides with chatter-marked surfaces.
55.6	(89.5)	The Point Overlook. Panorama from the western ridges to the southwest to Tanners Ridge and Blackrock to the north. Intensely sheared Catoctin basalt flows and volcanic tuff beds can be seen in the roadcut on the east side of Skyline Drive.
56.4	(90.8)	Bearfence Mountain Parking Area. Less than 200 feet (61 m) east along the trail to Bearfence Mountain, ledges of coarse-grained, very quartzose, cross-laminated sandstones of the Swift Run Formation are exposed in the nose of a northeastward-plunging, overturned anticline. These sandstones exhibit better sorting and rounding of the sand grains than most exposures of Swift Run clastics. Skyline Drive crisscrosses the thin, poorly exposed Swift Run Formation several times in the next 2 miles (3 km) to the south.
57.5	(92.5)	Entrance to Lewis Mountain Campground. Vertical sandstones of the Swift Run Formation are exposed in the northern part of the campground and to the north.
59.1	(95.1)	Oaks Overlook.
61.3	(98.6)	Baldface Mountain Overlook. The town in the distance is Shenandoah, built mostly on terrace-gravel deposits that cover Ordovician limestones and dolomites.

Cumulative miles (km)	*Explanation*
62.7 (100.9)	South River Overlook and entrance to South River picnic grounds. View down South River gorge between two mountains of Catoctin basalt.
*64.4 (103.6)	Hensley Hollow Overlook. Good exposures of the Swift Run Formation in the roadcut. The formation as exposed here is mostly phyllite with some beds containing dispersed pebbles and cobbles of granitic rock, vein quartz, and phyllite clasts. Skyline Drive crosses the contact between the Swift Run and Pedlar formations several times to the south between here and Swift Run Gap. Beyond Hensley Ridge to the northwest, Elkton is visible at the west end of a linear fault segment that separates quartzites and phyllites of the Chilhowee Group to the south from the Cambrian carbonates of the Shenandoah Valley to the north (Plate 2).
65.5 (105.4)	Swift Run Gap and junction of Skyline Drive with U. S. Highway 33. The Swift Run Formation was named and described from exposures about a mile east of Skyline Drive along an abandoned road above U. S. Highway 33. The gap is underlain by granodiorite of the Pedlar Formation, which is exposed intermittently along the drive for the next 4.5 miles (7.2 km).
67.2 (108.1)	Swift Run Overlook. Pedlar granodiorite exposed in the roadcut and overlook is porphyritic, coarse-grained, locally epidotized, and jointing is well developed. Exposures of Catoctin basalts can be seen high on the ridge to the east.
*67.8 (109.1)	Sandy Bottom Overlook. Massive exposures of Pedlar granodiorite in the roadcut to the east. The panoramic view to the west includes sharp-crested phyllite and quartzite ridges of the western part of the Blue Ridge and the south peak of Massanutten Mountain in the distance. South of the overlook the park terrane west of Skyline Drive is dominated by ridges formed by rocks of the Chilhowee Group.
68.5 (110.2)	Smith Roach Gap. The Catoctin Formation caps the Pedlar granodiorite in the gap and on adjacent ridges.
*69.3 (111.5)	Bacon Hollow Overlook. The strongly foliated Pedlar granodiorite exposed in and near the overlook is typical of the rocks that underlie Bacon Hollow to the east. This spectacularly deep U-shaped hollow exemplifies the rapid weathering and disintegration of the Pedlar Formation that takes place after the removal of the protecting cap of resistant Catoctin basalt flows. Basalt cliffs rim the northern escarpment above cliffs developed in the granodiorite (Figure

Cumulative miles	*(km)*	*Explanation*
		2). The mountain to the south is capped by a much thicker remnant of the basalts, and the escarpment below them is not as well developed. Several small copper mines were opened in the lowest Catoctin basalt flow along the northern escarpment in the early twentieth century. Small quantities of native copper, malachite, cuprite, bornite, and chalcopyrite have been found in epidotized portions of the lower basalt flows.
*70.1	(112.8)	The Swift Run Formation, comprised of pebbly and sandy phyllites, is well exposed in the deep roadcut. The well-formed cleavage surfaces transverse to bedding have been flexed by a second cleavage parallel to the bedding, possibly indicating two periods of deformation.
70.6	(113.6)	Eaton Hollow Overlook. Good view 10 miles (16 km) to the north, where the lower Cambrian clastic rocks and Precambrian volcanic and plutonic rocks form a westward protuberence of ridges into the Shenandoah Valley.
71.2	(114.6)	Rocky Mount Overlook. A closer view of Rocky Mount, a ridge and talus deposit formed by the quartzites of the Erwin Formation (Figure 25). The low ridge and hollow east of Rocky Mount are underlain by phyllites and non-resistant metasandstones of the Harpers and Weverton formations. Strongly jointed basalt is exposed in the roadcut opposite the overlook.
72.3	(116.3)	Beldore Hollow Overlook. View to the west of a broad expanse underlain by the Hampton Formation, the phyllitic middle portion of the Chilhowee Group. Massive epidotized basalts of the Catoctin Formation are exposed in the roadcut.
74.5	(119.9)	Loft Mountain Overlook. Dense, purple, slightly vesicular Catoctin basalts are exposed in the roadcut and on the overlook. Basalt-capped mountains to the east (Flat Top Mountain) and southwest (Loft Mountain) flank a boulder-filled valley cut by Ivy Creek down into the Pedlar granodiorite.
75.3	(121.2)	Pinefield Gap. Approximate location of the contact between the Catoctin and Weverton formations, with the Weverton poorly exposed on the west.
75.4	(121.3)	Approximate location of the concealed contact between the Weverton and Hampton formations. Phyllites and metasandstones of the Hampton Formation are exposed intermittently from here to Twomile Run Overlook.
*76.2	(122.6)	Twomile Run Overlook. View to the west between Rocky Mountain and Rocky Mount, aptly named ridges capped by

Cumulative miles (km)	*Explanation*
	folded white Erwin quartzite strata and sheathed in quartzite talus. The sinuous, sharp-crested ridges and steep V-shaped hollows leading out from Skyline Drive to the north are typical landforms developed on incompetent metasandstone and phyllite of the Hampton Formation. To the northwest the resistant Erwin quartzite strata outline a syncline-anitcline fold-pair in the ridge top silhouetted against Shenandoah Valley and Massanutten Mountain (Figure 27).
76.9 (123.7)	Brown Mountain Overlook. View to the west into the Big Run drainage basin and southeast slope of Rocky Mountain. Folded, westward-dipping fine-grained metasandstone, phyllite, and coarse-grained quartzite of the Hampton Formation is exposed in the roadcut.
77.6 (124.9)	Ivy Creek Overlook. A view of Loft Mountain and the upper reaches of Ivy Creek gorge. In winter and early spring, quartzite ledges in the Weverton Formation are discernable along the low ridge east of Ivy Creek.
77.8 (125.2)	Good exposures of Hampton metasandstone and phyllite in the roadcut with well-defined bedding and cleavage. Cliffs of Weverton quartzite, in an overturned fold limb adjacent to its contact with the Catoctin Formation, are visible to the south in the upper (south) end of Ivy Creek gorge.
*78.1 (125.7)	Rocky Top Overlook. View to the west into the Big Run drainage basin, one of the largest drainage basins within the park. It is rimmed to the west and north by ridges capped by generally westward-dipping, but folded Erwin quartzite beds, and to the south and east by high Hampton and Catoctin ridges in the Loft Mountain area. Exposures of thick-bedded, phyllitic metasandstones and thin, interbedded shales of the Hampton Formation are exposed in a westward-dipping sequence in the roadcut by the overlook.
78.4 (126.1)	Cross-laminated, cross-grained quartzite of the Hampton Formation is exposed by the northbound lane adjacent to talus formed from the more common phyllites and metasandstones of that unit.
79.0 (127.1)	Exposure at milepost 79 of the lower phyllite member of the Hampton Formation along the southbound lane.
*79.4 (127.8)	Typical exposure of the lower Weverton Formation in the roadcut. Coarse, arkosic metasandstone, quartzites, and interbedded phyllite, all containing minor amounts of small quartz pebbles, are present in a westward-dipping sequence immediately above the purple slates that comprise the

Cumulative miles (km)	*Explanation*
	uppermost Catoctin Formation (not visible here). Park in the wayside to the south.
79.5 (128.0)	Entrance to Loft Mountain Campground on the east, and wayside (service station and restaurant) on the west.
*80.9 (130.2)	Purple, porphyritic basalts of the Catoctin Formation crop out along the northbound lane in one of the best exposures of this rock type in the park (Figure 44). Park at Big Run Overlook to the south.

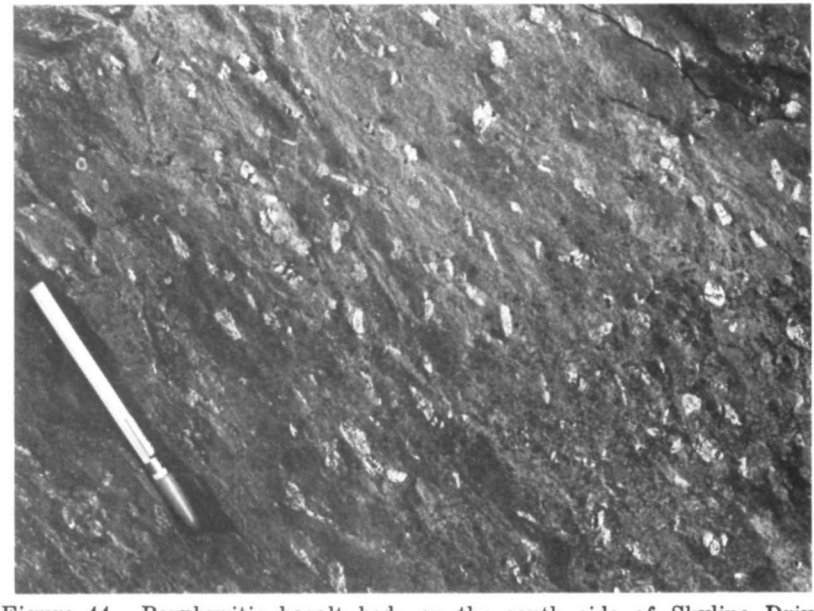

Figure 44. Porphyritic basalt beds on the south side of Skyline Drive. The dark, purplish-red metabasalts contain large crystals (phenocrysts) of red-stained feldspar and locally provide recognizable horizons in the metabasalt sequence.

81.0 (130.3)	Exposures at milepost 81 along the northbound lane of purple slate and arkosic metasandstone of the Catoctin and Weverton formations, respectively, at the overturned contact between the units.
*81.2 (130.7)	Big Run Overlook. Northwest view of the Big Run drainage area and the gap between the Erwin quartzite ridges through which Big Run exits into Shenandoah Valley. Many of the better exposures of the Erwin and Hampton formations in Shenandoah National Park are present in this gap and upstream along Big Run. Pebbly, metasandstones of the Weverton Formation are exposed in the roadcuts to the east.

Cumulative miles (km)	*Explanation*
81.9 (131.8)	Doyles River Overlook. Eastward view of the Browns Cove drainage area formed on the Catoctin Formation and drained by Doyles River and Jones Run, along which several waterfalls may be seen from Falls Trail.
*82.3 (132.4)	Appalachian Trail crossing. From here to Browns Gap exposures along the southbound lane and along the Appalachian Trail to north (Figure 19) are representative of most lithologies in the Weverton Formation. Lenses of coarse-grained, pebbly quartzite and laminated, silvery-green phyllite represent the range of clastic sedimentary strata exposed along Skyline Drive in this area. The lateral variation in bedding thickness and rock type is indicative of the probable fluvial origin of these sedimentary rocks. The Catoctin-Weverton contact, although not exposed, is at road level in Browns Gap.
83.7 (134.7)	Dundo Overlook and entrance to Dundo Campground. A broad expanse of gravel fans and terraces underlie the surface of the Shenandoah Valley visible to the west through the gap at the mouth of Dundo Hollow.
84.1 (135.3)	Falls Trail parking area on east.
*84.8 (136.4)	Gated fire road on west side of Skyline Drive provides hiking access to Blackrock, less than 0.5 mile (0.8 km) to the southwest. A large outcrop of bluish-gray, cross-laminated quartzite (Figure 21) within the Hampton Formation with an extensive talus deposit (Figure 26) forms Blackrock. The view to the west of Trayfoot Mountain includes several large but discontinuous talus deposits that were formed from equally discontinuous lenses of quartzite that appear to be lateral recurrences of the ledge-forming beds at Blackrock.
*86.8 (139.7)	Trayfoot Mountain Overlook. A broad view to the south of the crest of the Blue Ridge, with Trayfoot Mountain to the west and Pasture Fence Mountain to the east. From Dundo south to Jarman Gap, Skyline Drive follows the crest formed by rocks of the Hampton Formation. The paralleling ridge to the east is underlain by the Catoctin Formation that commonly forms higher crests than rocks of the Hampton Formation. In this area, however, the Hampton strata are gently inclined and only slightly folded, and include quartzite strata that make the unit more resistant to erosion and therefore capable of forming higher ridges. On and near Trayfoot Mountain the Hampton quartzites reach their maximum thickness and account for the still higher elevation of that ridge.

Cumulative miles (km)	*Explanation*
87.1 (140.1)	Appalachian Trail crosses Skyline Drive near exposure of ferruginous metasandstones of the Hampton Formation in the roadcut along the southbound lane.
87.6 (141.0)	Good view to northwest of the talus deposits formed by erosion of the Hampton quartzites on Trayfoot Mountain.
*88.7 (142.7)	Horsehead Overlook. View of Rocks Mountain to the southwest, an Erwin quartzite-capped ridge, and talus deposits of Hampton quartzite on the south end of Trayfoot Mountain. Exposures of interbedded metastandstone and phyllite of the Hampton Formation in the parking area have well-defined bedding and cleavage relationships that indicate these strata are overturned to the northwest (Figure 45).

Figure 45. Phyllite and thin interbedded metasandstone of the Hampton (Harpers) Formation in the overturned limb of a fold at Horsehead Mountain Overlook.

90.0 (144.8)	Calvary Rocks parking area. The trail west from Skyline Drive leads to Calvary Rocks, the nearest exposures of Erwin quartzites to Skyline Drive (Figure 24).
*91.4 (147.1)	Riprap Overlook. Turk Mountain, the high peak to the southwest, is capped by Erwin quartzite that has been preserved in the northeastern end of a southwestward-plunging syncline. To the west a broad expanse of farmland in the Shenandoah Valley may be seen. Low, forest-covered conical hills and linear, northeastward-trending ridges in the valley are formed where concentrations of

Cumulative miles (km)	*Explanation*
	chert or sandstone provide resistant zones in the Cambrian and Ordovician limestone and dolomite sequence.
*92.0 (148.0)	Moormans River Overlook. A view to the southeast through a major gap in the ridges formed by basalt flows of the Catoctin Formation. The lake, Moormans River Reservoir, a part of the Charlottesville water supply system, is impounded on granitic rocks of the Pedlar Formation where the Catoctin and Swift Run formations have been breached by Moormans River. The northeastward-trending segment of Moormans River occupies an extensive linear low within the Catoctin Formation, and may follow the trace of a reverse fault extending from the Loft Mountain area southwest through Jarman Gap. Additional evidence for such a fault may be the intensely sheared basalts locally exposed along this lineament.
92.1 (148.2)	Wildcat Ridge Overlook on west side of Skyline Drive.
92.7 (149.2)	Crimora Lake Overlook. Westward view of an abandoned manganese-mining operation. The ore was concentrated in the sandy-clay residual material formed along the contact between the Erwin and overlying Shady formations.
93.7 (150.8)	Turk Mountain Overlook on west side of Skyline Drive.
94.6 (152.2)	Roadcut exposures of phyllite in the lower portion of the Hampton Formation for next 0.3 miles (0.5 km).
95.4 (153.5)	Sawmill Run Overlook. View to the south of the Blue Ridge crest formed by a folded sequence of basalts and interbedded sedimentary and tuffaceous rocks of the Catoctin Formation. Good exposures of folded quartzite beds in the Weverton Formation may be seen along the Appalachian Trail near the crest of the pine-covered ridge to the southeast.
95.6 (153.8)	Approximate contact between the Weverton and Hampton formations; Weverton to the southeast.
*95.9 (154.3)	Sawmill Ridge Overlook. Large lenses and discontinuous beds of Weverton metastandstone and quartzite interbedded with sericitic phyllite are displayed in roadcut. The upper part of an overturned anticline is visible at road level adjacent to the overlook (Figure 46).
96.1 (154.6)	Sandy phyllite in the base of the Weverton Formation exposed along northbound lane.
96.2 (154.8)	Contact of the Weverton and Catoctin formations just north of gas pipeline in gap. In this area discordant attitudes of beds across the contact suggest the presence of a small

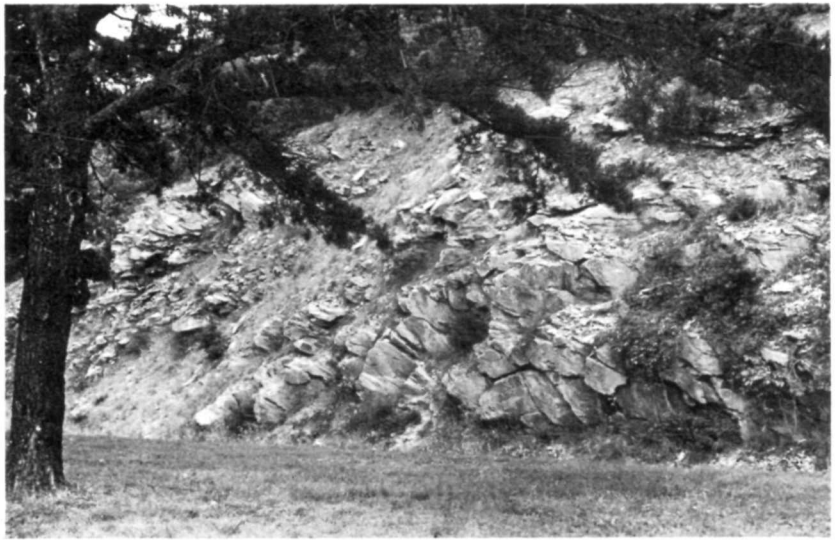

Figure 46. Crestal portion of an overturned anticline in the Weverton Formation at Sawmill Ridge Overlook. Well-developed cleavage inclined to the right (southeast) tends to obscure bedding features even in the quartzites and competent metasandstones that are exposed here.

Cumulative miles (km)	*Explanation*
	fault, an angular unconformity, or fluvial channels cut in the surface of the Catoctin Formation and subsequently filled with cross-laminated sediments that now comprise the base of the Weverton Formation.
96.3 (154.9)	Epidotized metasandstones of Catoctin Formation along the northbound lane trend obliquely into the contact with sediments of the lower part of the Weverton Formation to the west.
96.9 (155.9)	Jarman Gap.
97.4 (156.8)	Massive basalts of the Catoctin Formation are exposed in roadcut below the power-transmission line.
97.6 (157.0)	Conglomerate, meta-arkose, and phyllite of the Catoctin Formation in roadcut by northbound lane. This sedimentary member is in contact with purple amygdaloidal slates below (exposed below road level to the north) and with epidotized basalt breccia above (exposed a few hundred feet along Skyline Drive to the south, at the intersection with an abandoned logging road). Traces of epidotized conglomerate rubble, characteristic of the top of sedimentary units over-

Cumulative miles (km)	*Explanation*
	lain by basalts, are found near this contact. Interbedded basalt, arkosic metasandstone, and phyllite are intermittently exposed along the Skyline Drive from here south to Calf Mountain Overlook, approximately 1.3 miles (2.1 km).
98.2 (158.0)	Sedimentary member of the Catoctin Formation offset by high-angle fault (not exposed on Skyline Drive).
*98.9 (159.1)	Calf Mountain Overlook. View of the Waynesboro area to the west across a structurally complex terrane developed on rocks of the Chilhowee Group. South of Jarman Gap the trend of the rocks in the Blue Ridge shifts abruptly westward nearly 35 degrees. This shift in trend is accompanied by an increased number of overturned fold limbs and the appearance of thrust faults only rarely present northeast of Jarman Gap in the southern section of the park. To the north and west of the overlook are the crests of Turk and Ramsey mountains, formed by steeply dipping quartzite strata in the lower Erwin Formation. This rock unit is exposed here along the east limb of a plunging syncline that is overturned southwest of the gap separating the two mountains. The western escarpment of the Blue Ridge south of Jarman Gap has developed on basalts of the Catoctin Formation along its overturned contact with the Weverton Formation. Approximately 50 feet (15 m) west of the overlook are exposures of conglomeratic, arkosic metasandstone of the Catoctin Formation which contain clasts of volcanic rocks.
99.6 (160.3)	Beagle Gap. Typical mountain pasture land on the Catoctin Formation. Vesicular basalts and flow-top breccias are exposed to the south along the Appalachian Trail on private land.
*99.9 (160.7)	Beagle Gap Overlook. View to the east of the Ragged Mountains, a series of peaks and sharp-crested ridges developed on older Precambrian gneisses within the core of the Blue Ridge anticlinorium. The long, low mountain range on the horizon (Brown Mountain and Southwestern Mountain) marks the east flank of the Blue Ridge anticlinorium and the outcrop belt of the Catoctin Formation along it.
102.1 (164.3)	McCormick Gap. This gap, and the hollows leading into it from the north and south, are developed along the trace of an extensive Triassic diabase dike. The dike, which has weathered more rapidly than the Catoctin basalts, is well exposed where it traverses the Pedlar Formation south of the Blue Ridge and the Chilhowee rocks to the north, but is buried beneath Catoctin debris on the Blue Ridge proper.

Cumulative miles (km)	*Explanation*
102.4 (164.8)	McCormick Gap Overlook. View to the west of the Waynesboro area and the Shenandoah Valley. The low, linear, wooded ridges to the west and northwest are formed by resistant quartzites of the Erwin, Hampton, and Weverton formations.
104.7 (168.5)	South entrance station to Shenandoah National Park. In roadcut to the east is exposure of southeastward-dipping, overturned beds of conglomeratic, sandy phyllite within the upper Catoctin Formation. Granite pebbles in this portion of the formation attest to the presence of a mountainous granitic terrane protruding through the older basalt flows and acting as a local source for the clastic sediments after most of the Catoctin basalts had been deposited.
105.2 (169.3)	Leave Shenandoah National Park and Skyline Drive, begin Blue Ridge Parkway. Interchange immediately to the south with U. S. Highway 250 and Interstate Highway 64 at Rockfish Gap, between Waynesboro and Charlottesville.

END OF ROAD LOG

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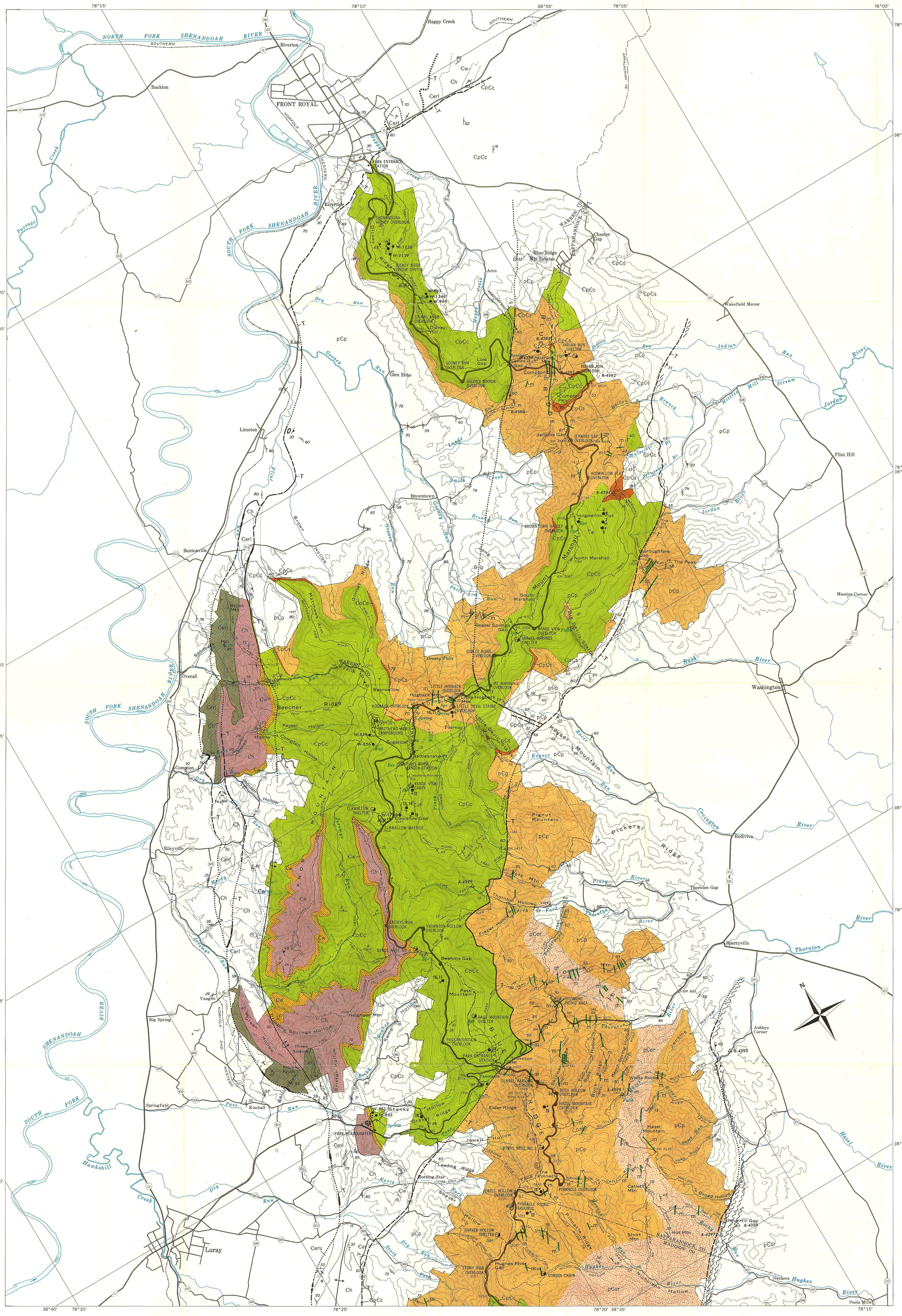
COMMONWEALTH OF VIRGINIA
DEPARTMENT OF CONSERVATION AND ECONOMIC DEVELOPMENT
DIVISION OF MINERAL RESOURCES
James L. Calver
Commissioner of Mineral Resources and State Geologist



EXPLANATION

CAMBRIAN

Ꞓeru / Ꞓerl — Erwin (Antietam) Formation
Ꞓeru, upper member: light-gray to white quartzose and arkosic sandstone with interbedded, yellowish-red to white clay and sandy clay. Ꞓerl, lower member: light-gray to white, very resistant, thick-bedded quartzite with interbedded brown shale and siltstone; quartzite contains abundant Scolithus linearis.

Ꞓh — Hampton (Harpers) Formation
Brown to greenish-gray shale and siltstone with interbedded greenish-brown to black, resistant, ferruginous quartzite.

Ꞓw — Weverton Formation
Light-gray, ferruginous, locally resistant, conglomeratic quartzite with interbedded brown and green, locally conglomeratic shale and silvery-green sericitic shale.

ꞒpꞒc — Catoctin Formation
Dark-green metamorphosed basalt with interbedded purple phyllite.

m — Metamorphosed basalt
Dikes that intrude lower Catoctin and older rock units.

ꞒpꞒs — Swift Run Formation
Dark-gray to purple sericitic shale, gray to brown quartzite, and brown argillaceous pebble-conglomerate.

PRECAMBRIAN

pꞒp — Pedlar Formation
Greenish-gray, coarse-grained, massive to banded granodiorite.

pꞒor — Old Rag Granite
Light-gray, coarse-grained, quartz-potash feldspar granite.

CONTACTS

- exposed
- approximate
- covered or inferred

FOLDS

- Anticline—trace of axial plane
- Overturned anticline—trace of axial plane

FAULTS

Thrust: T—overthrust side

- exposed; heavier line represents breccia
- approximate
- covered or inferred

Normal: U—upthrown side; D—downthrown side

- exposed
- approximate
- covered or inferred
- Shear Zone

ATTITUDE OF ROCKS

- 60 Strike and dip of inclined beds
- 40 Strike and dip of overturned beds
- Strike of vertical beds

FOLIATION AND CLEAVAGE

- 50 Strike and dip of inclined compositional banding
- Strike and dip of vertical compositional banding
- 29 Strike and dip of cleavage

STRATIGRAPHIC CONTROL

- R-4399 Location and repository number of representative sample collected
- W-1203 Location of test hole

WEIR LOCATIONS

- Location and reference number of weir and spring

MINES AND QUARRIES

- Fe Abandoned mines: iron (Fe), manganese (Mn); abandoned quarries: aggregate from weathered quartzite (q).

Base map by U.S.G.S. Geology after King (1950) and Reed (1955 & 1969) and modified from Nelson (1962) and Allen (1963 & 1967); see text for other credit.

GEOLOGIC MAP OF THE SHENANDOAH NATIONAL PARK, VIRGINIA
NORTHERN SECTION

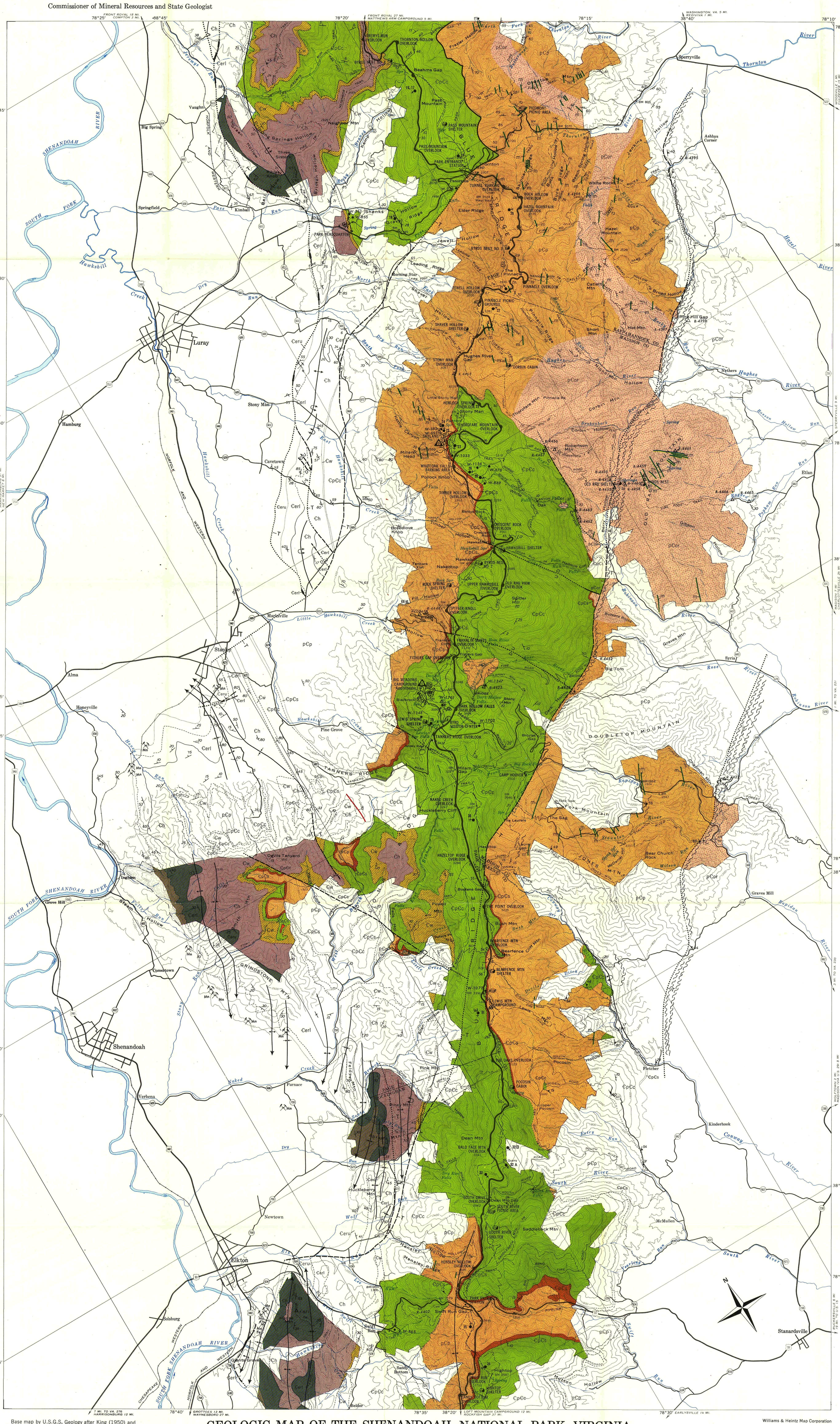
Geology by Thomas M. Gathright, II

SCALE 1:62500
1 ½ 0 1 2 3 4 MILES
3000 0 3000 6000 9000 12000 15000 18000 21000 FEET
1 .5 0 1 2 3 4 5 KILOMETERS
CONTOUR INTERVAL 200 FEET WITH 40-FOOT CONTOURS IN THE PARK AREA
DATUM IS MEAN SEA LEVEL

1972

Williams & Heintz Map Corporation
Copyright 1972
Commonwealth of Virginia

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



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GEOLOGIC MAP OF THE SHENANDOAH NATIONAL PARK, VIRGINIA
CENTRAL SECTION

Geology by Thomas M. Gathright, II

SCALE 1:62 500

CONTOUR INTERVAL 200 FEET WITH 40-FOOT CONTOURS IN THE PARK AREA
DATUM IS MEAN SEA LEVEL

1972

Williams & Heintz Map Corporation

Copyright 1972
Commonwealth of Virginia

EXPLANATION

TRIASSIC

d

Intrusive igneous rocks
Dikes of mafic composition

CAMBRIAN

Ꞓeru, Ꞓerl

Erwin (Antietam) Formation
Ꞓeru, *upper member: light-gray to white quartzose and arkosic sandstone with interbedded, yellowish-red to white clay and sandy clay.* Ꞓerl, *lower member: light-gray to white, very resistant, thick-bedded quartzite with interbedded brown shale and siltstone; quartzite contains abundant Scolithus linearis.*

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Brown to greenish-gray shale and siltstone with interbedded greenish-brown to black, resistant, ferruginous quartzite.

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Light-gray, ferruginous, locally resistant, conglomeratic quartzite with interbedded brown and green, locally conglomeratic shale and silvery-green sericitic shale.

PRECAMBRIAN

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Catoctin Formation
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m

Metamorphosed basalt
Dikes that intrude lower Catoctin and older rock units.

ꞒpꞒs

Swift Run Formation
Dark-gray to purple sericitic shale, gray to brown quartzite, and brown argillaceous pebble-conglomerate.

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Pedlar Formation
Greenish-gray, coarse-grained, massive to banded granodiorite.

pꞒor

Old Rag Granite
Light-gray, coarse-grained, quartz-potash feldspar granite.

CONTACTS

exposed
approximate
covered or inferred

FOLDS

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

FAULTS

Thrust: T—overthrust side
exposed; heavier line represents breccia
approximate
covered or inferred

Normal: U — upthrown side; D — downthrown side
approximate
covered or inferred

Transverse: relative movement indicated
approximate
covered or inferred
Shear Zone

ATTITUDE OF ROCKS

40 — Strike and dip of inclined beds
40 — Strike and dip of overturned beds
Strike of vertical beds

FOLIATION AND CLEAVAGE

50 — Strike and dip of inclined compositional banding
Strike and dip of vertical compositional banding
30 — Strike and dip of cleavage

STRATIGRAPHIC CONTROL

R-4013 — Location and repository number of representative sample collected
F-871 — Location and repository number of fossil(s) collected
W-1033 — Location of test hole

WEIR LOCATIONS

Location and reference number of weir and spring

MINES AND QUARRIES

Active quarry: aggregate and fill from weathered quartzite
Fe — Abandoned mines: iron (Fe), manganese (Mn), and copper (Cu); abandoned quarries: aggregate from weathered quartzite (q).

COMMONWEALTH OF VIRGINIA
DEPARTMENT OF CONSERVATION AND ECONOMIC DEVELOPMENT
DIVISION OF MINERAL RESOURCES
James L. Calver
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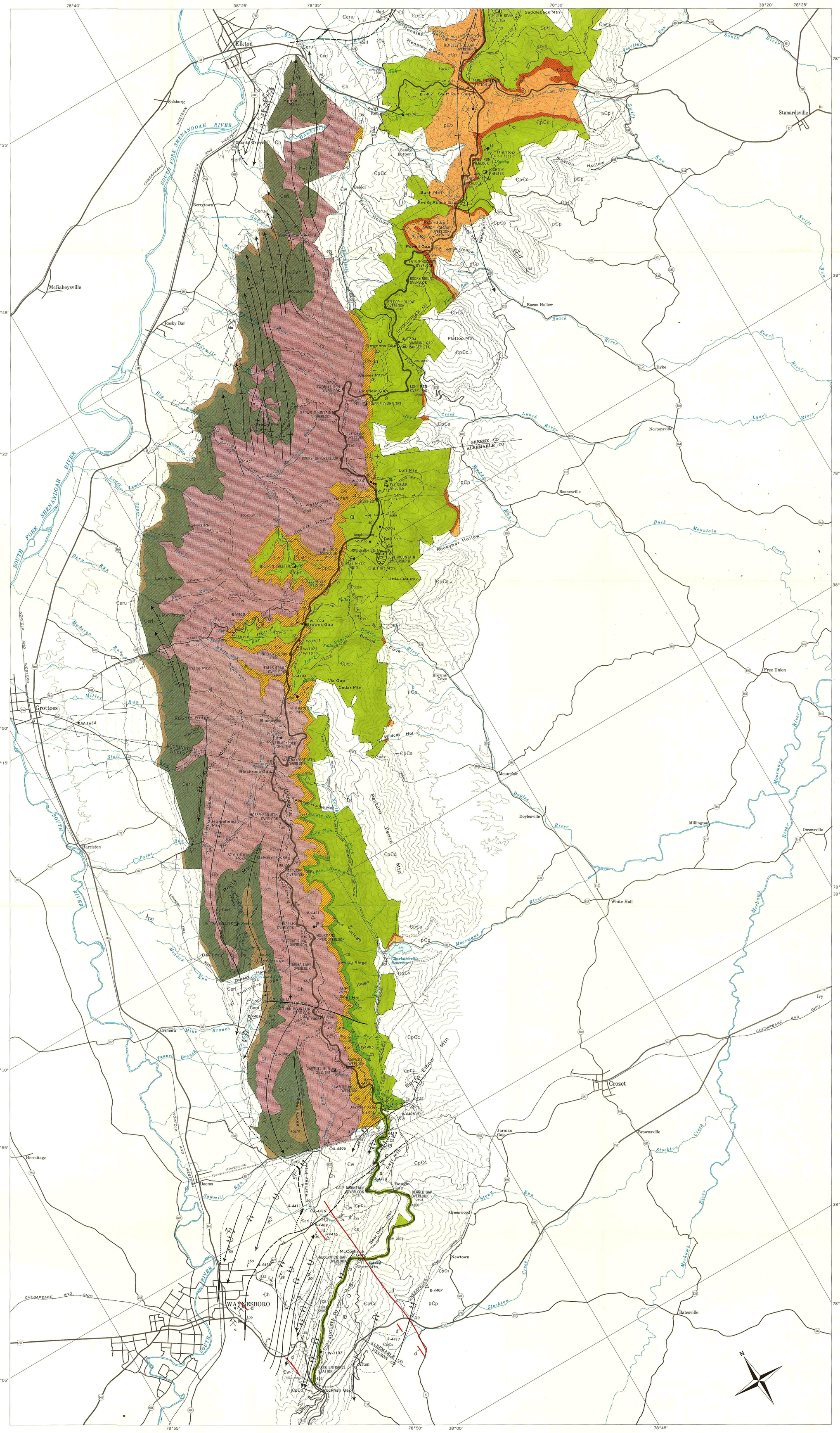

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GEOLOGIC MAP OF THE SHENANDOAH NATIONAL PARK, VIRGINIA SOUTHERN SECTION

Geology by Thomas M. Gathright, II

SCALE 1:62 500

CONTOUR INTERVAL 200 FEET WITH 40-FOOT CONTOURS IN THE PARK AREA
DATUM IS MEAN SEA LEVEL

1972

EXPLANATION

TRIASSIC

d — Intrusive igneous rocks
Dikes of mafic composition

CAMBRIAN

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Light-gray, ferruginous, locally resistant, conglomeratic quartzite with interbedded brown and green, locally conglomeratic shale and silvery-green sericitic shale.

cs, ꞒpꞒc — Catoctin Formation
Dark-green metamorphosed basalt with interbedded purple phyllite. cs, *arkosic sandstone, sandy siltstone, purple phyllite, quartzite, and metamorphosed basalt; abundant epidote cement.*

PRECAMBRIAN

ꞒpꞒs — Swift Run Formation
Dark-gray to purple sericitic shale, gray to brown quartzite, and brown argillaceous pebble-conglomerate.

pꞒp — Pedlar Formation
Greenish-gray, coarse-grained, massive to banded granodiorite.

CONTACTS

exposed
approximate
covered or inferred

FOLDS

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

FAULTS

Thrust: T—overthrust side
exposed; heavier line represents breccia
approximate
covered or inferred

Normal: U—upthrown side; D—downthrown side
exposed
approximate

ATTITUDE OF ROCKS

Strike and dip of inclined beds
Strike and dip of overturned beds
Strike of vertical beds

STRATIGRAPHIC CONTROL

R-4403 — Location and repository number of representative sample collected
F-868 — Location and repository number of fossil(s) collected
W-1137 — Location of test hole

WEIR LOCATIONS

Location and reference number of weir and spring

MINES AND QUARRIES

Active quarry: aggregate and fill from weathered quartzite

Abandoned mines: iron (Fe), manganese (Mn), and copper (Cu); abandoned quarries: aggregate from weathered quartzite (q).