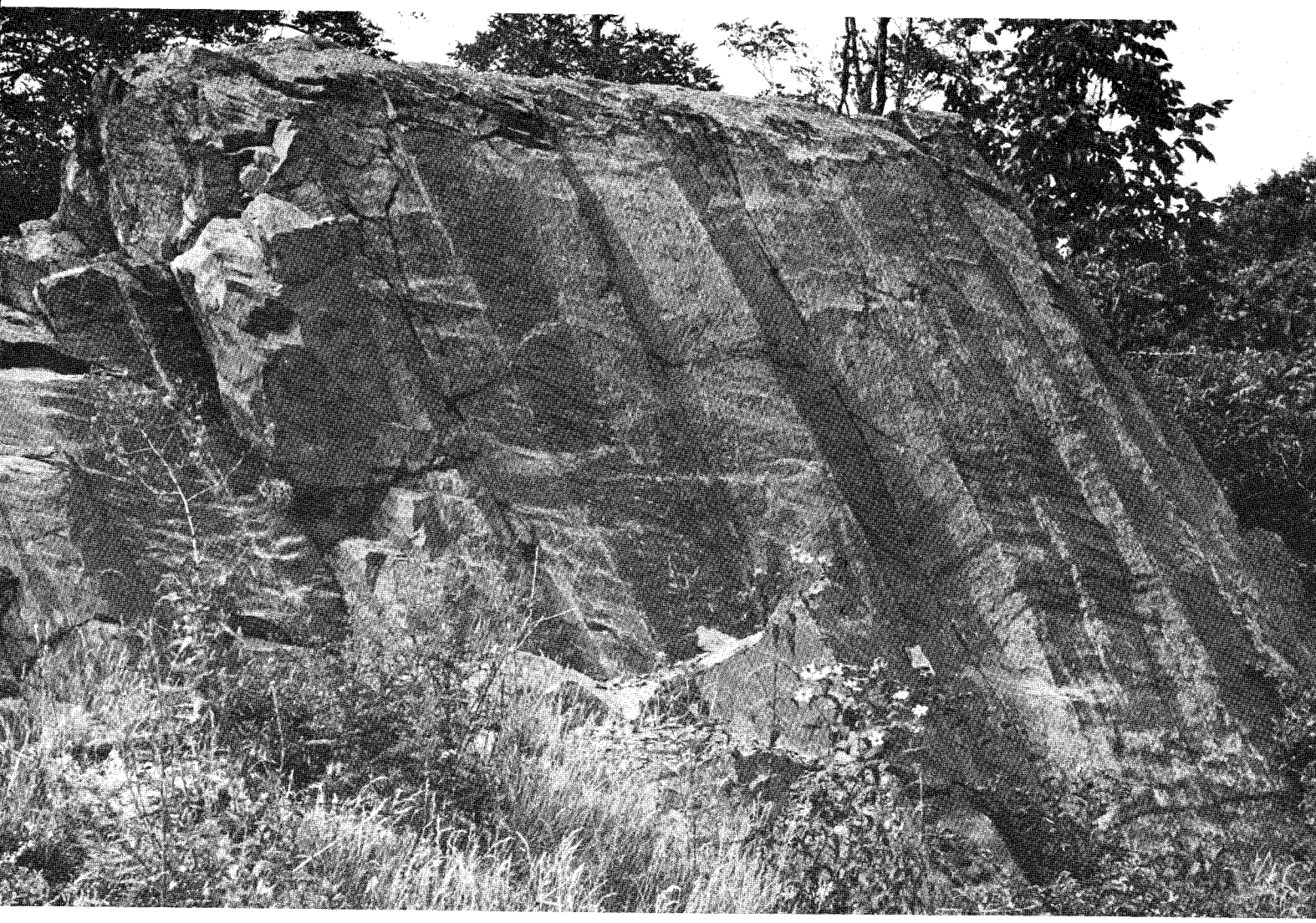
VIRGINIA DIVISION OF MINERAL RESOURCES PUBLICATION 4

GEOLOGY OF THE GREENFIELD AND SHERANDO QUADRANGLES, VIRGINIA

MERVIN J. BARTHOLOMEW



COMMONWEALTH OF VIRGINIA

DEPARTMENT OF CONSERVATION AND ECONOMIC DEVELOPMENT
DIVISION OF MINERAL RESOURCES

James L. Calver, Commissioner of Mineral Resources and State Geologist

CHARLOTTESVILLE, VIRGINIA

1977

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FRONT COVER: Columnar joints in metabasalt of the Catoctin Formation at Greenstone Overlook on the Blue Ridge Parkway. (Photograph by T. M. Gathright II.)

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DEPARTMENT OF PURCHASES AND SUPPLY

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Bartholomew, M. J., 1977, Geology of the Greenfield and Sherando quadrangles, Virginia: Virginia Division of Mineral Resources Publication 4, 43 p.

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GEOLOGY OF THE GREENFIELD AND SHERANDO QUADRANGLES, VIRGINIA

By
Mervin J. Bartholomew

ABSTRACT

The Greenfield and Sherando 7.5-minute quadrangles, encompassing an area of about 118 square miles (306 sq km), are located in the Blue Ridge, Piedmont, and Valley and Ridge physiographic provinces in Albemarle, Augusta, and Nelson counties, Virginia. A 1- to 3-mile- (2- to 5-km-) wide zone of cataclastic rocks bisects approximately the area from the north-central part of the Greenfield quadrangle southwestward to the southeastern part of the Sherando quadrangle. East of this zone, layered gneiss with northwestward-trending segregation layering was metamorphosed to granulite facies and partially melted during emplacement of massive Lovingston granitic gneiss; both rock units were intruded by massive charnockite during Grenville metamorphism. West of the cataclastic zone, layered gneiss with eastward-trending segregation layering was metamorphosed to granulite facies and intruded by Grenville-age massive charnockite of the Pedlar Formation. The late Precambrian(?) Swift Run and Catoctin volcanic sequence overlies the latter rocks. This volcanic sequence is overlain by the Cambrian clastic and carbonate sequence of the Weverton, Harpers, Antietam, Shady, and Waynesboro formations. These Cambrian rocks occur beneath and adjacent to extensive Quaternary sediments to the northwest of the Blue Ridge in the northwest corner of the Sherando quadrangle. Mafic dikes intruded the area prior to Paleozoic metamorphism and during the Triassic Period.

Thrusting along the Rockfish Valley fault and cataclasis in the zone of cataclastic rocks east of the fault occurred concurrent with regional Paleozoic greenschist-facies metamorphism that produced prominent, overturned to recumbent folds and associated axial-plane foliation. These structures were truncated by younger Paleozoic thrust faults that predate late Paleozoic(?), northeastward-trending, high-angle faults and broad, open, northwestward-trending fold axes. The youngest structures are northwestward-trending, high-angle faults mostly covered by Quaternary sediments.

Currently, there is no mining of mineral deposits in the Greenfield and Sherando quadrangles. Iron and manganese, manganese, and copper were mined sporadically within the Sherando quadrangle from the early 1800's to the middle part of the 1900's at the Mount Torry tract, the Lyndhurst mine, and the Allen mines, respectively.

INTRODUCTION

The Greenfield (Plate 1) and Sherando (Plate 2) 7.5-minute quadrangles are located in Nelson, Albemarle, and Augusta counties in central Virginia (Figure 1).

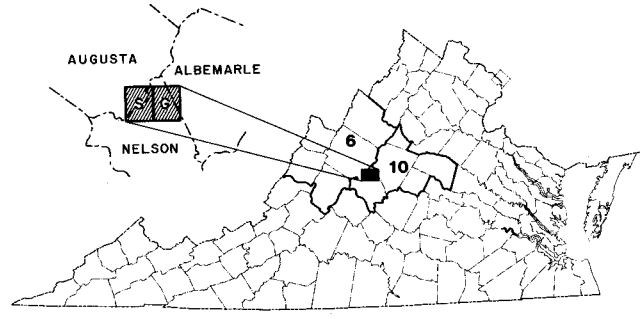


Figure 1. Index map showing location of the Greenfield (G) and Sherando (S) quadrangles in Planning Districts 6 and 10, Virginia.

They encompass an area of about 118 square miles (306 sq km) and are bounded by 37° 52′30″ and 38° 00′ north latitudes and 78° 45′ and 79° 00′ west longitudes. Approximately two-thirds of the Sherando quadrangle is in the Blue Ridge province, and the northwestern one-third is in the Valley and Ridge province; the southeastern corner of the quadrangle is in the Piedmont province. The western margin of the Greenfield quadrangle is in the Blue Ridge province, and the remainder is in the Piedmont province. Elevations range from less than 540 feet (165 m) along Rockfish River at the south edge of the Greenfield quadrangle to 3,851 feet (1,174 m) on the top of Devils Knob near the Blue Ridge in the Sherando quadrangle. The northeastward-trending Blue Ridge, extending across the Sherando quadrangle, is the most prominent topographic feature. The Blue Ridge Parkway and Appalachian Trail extend along or near its crest. Northwest of the Blue Ridge is a large, hummocky plain of the Valley and Ridge province drained by northward-flowing Back Creek and its tributaries. Sherando is located on this plain along Back Creek. State Roads 610 and 664 plus numerous public and private dirt roads provide good access to this part of the Sherando quadrangle. Southeast of the ridges the scenic, southeastward-drained Stony Creek gorge extends about 2 miles (3 km) before merging with the larger, northeastward-drained South Fork of the Rockfish River. State Roads 151, 627, 664, and 751 provide good access to the valleys in this portion of the Sherando quadrangle. Most of the field work in the Sherando quadrangle was done from November 1969 to March 1970, November 1970 to March 1971, and July to November 1971.

The Greenfield quadrangle is characterized by numerous knobs and short ridges, 1,500 to 2,000 feet (457 to 610 m) in elevation. It is primarily drained by the Rockfish River, its North and South forks, and their tributaries. State Highways 6 and 151 provide the major access to the Rockfish Valley; access to the mountainous terrain east and west of it is provided by state roads. Most of the field work in the Greenfield quadrangle was done during March 1971, from July to November 1971, and from March to July 1976.

The Sherando quadrangle and the western quarter of the Greenfield quadrangle were mapped by the writer (Bartholomew, 1971) in partial fulfillment of requirements for the Doctor of Philosophy degree at Virginia Polytechnic Institute and State University. The earlier mapping was funded partially by Virginia Landmark Corporation of Richmond, Virginia. The Virginia Division of Mineral Resources funded the mapping of the Greenfield quadrangle. Funds for some thin section and chemical analyses were provided through North Carolina State University Faculty Research and Professional Development Award, project number 00575.

Special thanks and acknowledgement of the academic contributions to this report are given to B. N. Cooper and M. C. Gilbert, Virginia Polytechnic Institute and State University. In addition, discussions with the following faculty members were helpful: E. S. Robinson, C. E. Sears, G. C. Grender, W. D. Lowry, A. K. Sinha, and Lynn Glover III, Virginia Polytechnic Institute and State University; Ernst Cloos, Johns Hopkins University; and R. V. Dietrich, Central Michigan University. Special thanks is also due T. M. Gathright, Virginia Division of Mineral Resources, who freely spent his own time in the field with the writer and who contributed many of the photographs. E. S. Robinson and J. J. Gryta contributed photographs. T. C. Windisch, S. P. Brown, and R. J. Moye, former students at North Carolina State University, helped map detailed geology along the west slope of the Blue Ridge in the Sherando quadrangle, and J. J. Gryta assisted with mapping of the Massies and Archer mountains and Rockfish River areas in the Greenfield quadrangle. C. B. Fogg assisted in preparing the blueline mylars.

Numbers preceded by "R" in parentheses (R-6778) correspond to sample localities. These samples and thin sections from them are on file in the repository of the Virginia Division of Mineral Resources where they are available for examination.

STRATIGRAPHY

PRECAMBRIAN ROCKS

Grenville-age igneous and metamorphic rocks are found in two distinctive massifs separated by a 1- to 3-mile- (2- to 5-km-) wide zone of cataclastic rocks (Bartholomew, 1976). East of the herein-named Rockfish Valley fault (which is the western border fault of the cataclastic zone), the Lovingston massif consists of layered granulite gneiss (Table 1) first intruded by the Lovingston Formation and subsequently by small bodies of massive charnockite. Cataclastic rocks, which were derived from these rocks during Paleozoic metamorphism, are considered part of this massif. West of the fault the Pedlar massif consists of layered granulite gneiss associated with massive charnockite of the Pedlar Formation.

Layered Granulite Gneiss

Layered granulite gneiss is subdivided into three types: strongly layered granulite gneiss, poorly layered granulite gneiss, and migmatitic granulite gneiss. The strongly layered granulite gneiss occurs west of the cataclastic rocks in close association with the Pedlar Formation (Plates 1, 2). The other two gneisses are present within and east of the cataclastic rocks in close association with the Lovingston Formation and the massive charnockite unit (Plate 1).

In addition to the obvious layering, the gneiss is distinguished from massive charnockite by granoblastic texture, finer grain size, and different relative proportions of the major granulite-facies minerals: perthitic feldspar, plagioclase (about An_{30}), quartz, hypersthene, hornblende, and garnet. Accessory minerals common to the gneiss and charnockite include magnetite, apatite, and zircon.

Strongly layered granulite gneiss: This type of gneiss is well exposed in the west-central part of the Greenfield quadrangle (Plate 1) west of State Highway 151, and in the east-central part of the Sherando quadrangle (Plate 2) along Stony and Pauls creeks as well as in a large roof pendant in the Bee Mountain area. Easily accessible outcrops occur along State Road 627. The unit (R-6494; R-6495; R-6778) is a dark greenish gray to dark-green quartzo-feldspathic gneiss with well-developed compositional layering (Figure 2) and granoblastic texture (Figure 3). It typically has the mineral assemblage of perthitic feldspar, plagioclase, quartz, garnet, and pyroxene. The pyroxenes are commonly uralitized (R-6779) and other minerals such as biotite, chlorite, sericite, epidote, and quartz, all products of Paleozoic retrograde metamophism, are also generally present (Figure 4). Well-developed segregation layering typically has steep to vertical dips and east-west trends. Layers commonly range in thickness from about 5 mm to 5 cm and consist of laterally discontinuous, 1- to 2-cm-thick layers of coarse-grained quartz-feldspar gneiss alternating with finer grained layers of gneiss containing pyroxene and garnet. Where the granulite gneiss-Pedlar contact was observed, segregation layering is cut by Pedlar charnockite (Figure 5). The

Table 1.–Geologic formations in the Greenfield and Sherando quadrangles.

Age	Name		Character	Thickness in feet (meters)
Quaternary	Alluvium		Light- to medium-brown, unconsolidated gravel, sand, silt, and clay; boulder and cobble deposits in steep-gradient stream beds.	0-20± (0-6±)
	Terrace deposits		Brown to reddish-brown, unconsolidated cobbles in sand, silt, and clay matrix.	0-150± (0-46±)
Triassic	Diabase dikes		Black, medium- to coarse-grained diabase composed of plagioclase, pyroxene, olivine, and magnetite.	0-100± (0-30±)
Cambrian	Waynesboro Formation		In subsurface only.	
	Shady Formation		In subsurface only.	
	Chilhowee Group	Antietam Formation	Gray, tan, and pink quartzite interbedded with gray to light-tan, fine-grained quartzose sandstone; quartz-pebble conglomerate occurs locally; medium-brown to tan and green interbeds of fine-grained siltstone and mudstone near the top; *Scolithus* tubes locally.	600± (183±)
		Harpers Formation	*Upper member:* dark greenish-gray to medium-brown interbedded metasiltstone and fine-grained metasandstone; quartzite and reddish-brown ferruginous metasandstone interbeds near top. *Middle member:* dark grayish green mudstone phyllite. *Lower member:* dark greenish gray, fine-grained metasiltstone interbedded with dark greenish gray to medium-brown and light-tan, fine-grained metasandstone and coarse-grained metasiltstone.	3,500± (1,067±)
		Weverton Formation	Dark greenish brown to brown, fine- to coarse-grained quartzose metasandstone, quartzite, and graywacke; lithic pebble metaconglomerate and metasiltstone locally.	500± (152±)
Precambrian(?)	Catoctin Formation		Dark-green, massive metabasalt flows with irregular light-green epidosite and light-green to reddish-brown metavolcanic breccia interlayered with thin beds of gray tuff-phyllite, gray siltstone phyllite (rhythmite), green to pink arkosic metasandstone and coarse-grained meta-arkose. Feeder dikes of dark-green metabasalt occur in older Precambrian rocks.	2,500± (762±)
	Swift Run Formation		Medium greenish gray, medium- to coarse-grained lithic and quartzose sandstone, conglomerate, and phyllite; light-gray, felsic tuff and phyllite, and boulder and cobble metaconglomerate containing metatuff and purple quartz fragments locally.	0-1,000± (0-305±)
	Mafic dikes		Dark-gray to black amphibolite.	0-50± (0-15±)
	Pyroxenite dike		Black ultramafic dike composed chiefly of orthopyroxene and clinopyroxene with minor spinel.	
Precambrian	Pedlar Formation		Dark-gray to greenish-gray, coarse-grained, massive, garnet-and hypersthene-bearing charnockite; locally lenses of gravity-stratified charnockitic gneiss and roof-pendants of layered granulite gneiss; greenish unakite locally.	
	Massive charnockite		Medium- to dark-gray, coarse-grained, massive charnockite with abundant white feldspar porphyroblasts.	
	Lovingston Formation		Medium- to dark-gray, massive, coarse-grained, biotite-bearing granitic gneiss, in part altered during cataclasis to medium- to dark-gray, medium- to coarse-grained biotite-bearing mylonitic gneiss.	
	Layered granulite gneiss		Dark greenish-gray to dark-green or medium-gray, quartzo-feldspathic gneiss with poorly to well-developed segregation layering.	
	Cataclastic rocks		Interlayered, dark grayish-black to greenish-gray to light-gray quartzo-feldspathic gneiss and light-gray blastomylonite.	

chemical composition of two samples of gneiss are shown in Table 2.

Poorly layered granulite gneiss: This type of gneiss is exposed in the mountainous terrain in the southeastern and east-central portions of the Greenfield quadrangle, east of State Highway 6 and south of State Road 635. Easily accessible outcrops occur along State Roads 633 and 634 near Heards. The gneiss (R-6780; R-6781) is a medium- to dark-gray, poorly layered (Figure 6) quartzo-feldspathic gneiss originally having a granoblastic texture (Figure 7). The steeply dipping segregation layering generally has a northwesterly trend and a northeasterly dip.

The original mineral assemblage of the granulite facies typically consists of either perthitic feldspar, plagioclase and hypersthene or perthitic feldspar, plagioclase, hypersthene, hornblende, and quartz. Paleozoic metamorphism has produced a lower-

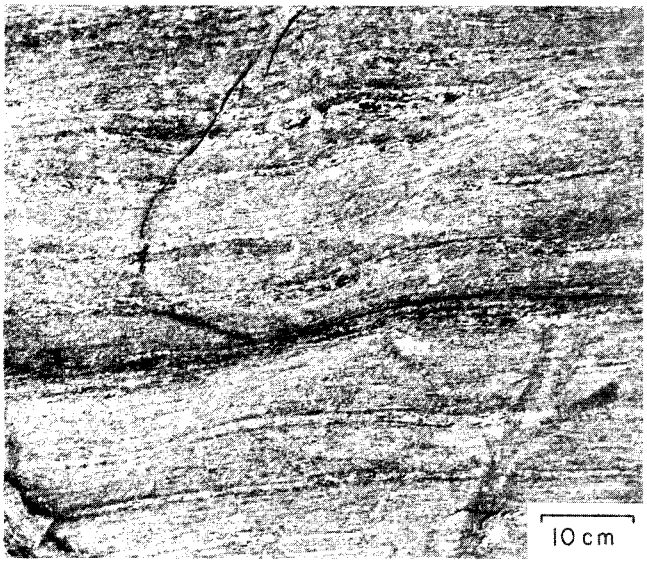


Figure 2. Strongly layered quanulite gneiss (R-6494) exposed in bed of Stony Creek; nearly vertical segregation layering has a strike to the northeast. (Photograph by J. J. Gryta.)

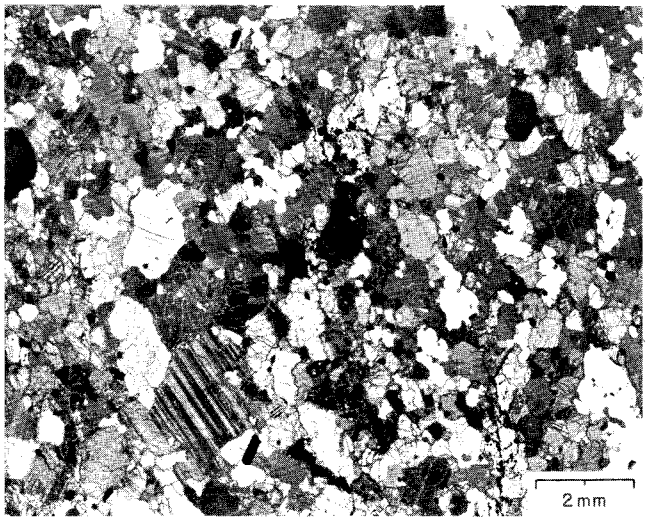


Figure 3. Photomicrograph of strongly layered granulite gneiss (R-6494) showing uralitized pyroxenes intergrown with other typical granulite facies minerals—perthitic feldspars, plagioclase, quartz, and magnetite.

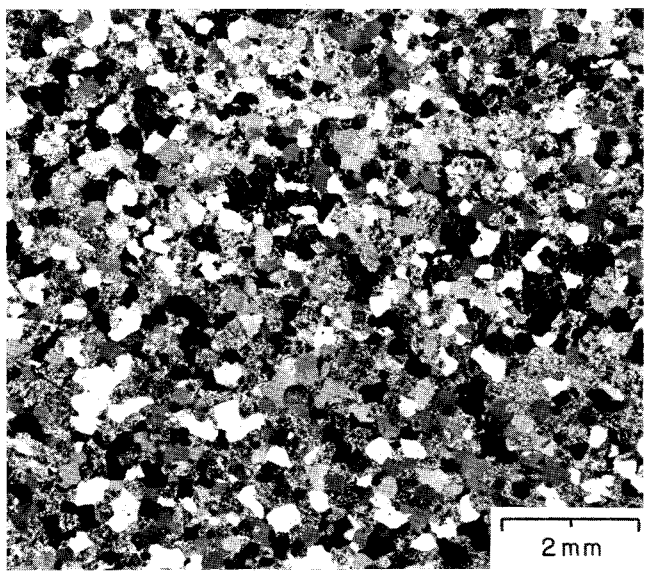


Figure 4. Photomicrograph of strongly layered granulite gneiss showing mineral assemblage (R-6779) retrograded to greenschist facies during Paleozoic metamorphism; quartz makes up about half the rock and is intergrown with sericite and actinolite.

Table 2.—Whole-rock chemical analyses of the strongly layered granulite gneiss (in percentage).[1]

	R-6494	R-6495
SiO_2	64.2	70.6
Al_2O_3	14.5	12.6
Fe_2O_3	2.6	2.8
FeO	3.9	1.9
MgO	2.1	0.40
CaO	3.3	1.4
Na_2O	2.9	2.1
K_2O	3.4	6.4
CO_2	<0.2	<0.2
TiO_2	1.1	0.68
P_2O_5	0.17	0.17
MnO	0.077	0.045
H_2O	—	—
L.O.I. (1,000°F)	1.1	0.8
Total	99.5	100.1

[1]Analyses by Skyline Labs, Inc., Wheat Ridge, Colorado.

amphibolite facies assemblage (R-6781) of quartz, clinozoisite, biotite, and a strongly pleochroic (blue-green-brown) hornblende (Figure 8).

The gneiss is frequently cut by narrow, nearly vertical, northward- to northeastward-trending zones of mylonitic biotite gneiss derived from intrusive Lovingston granitic gneiss. These cataclastic zones, laterally discontinuous over distances up to about 0.5 mile (0.8 km), are not mapped separately (Plate 1), but are identified by steeply dipping, northeastward-trending foliation symbols.

The contacts of the poorly layered granulite gneiss with the intrusive Lovingston Formation are generally gradational over distances of about 500 feet (152 m). The contacts between this gneiss and the spacially and genetically associated migmatite found in roof pendants on Pilot and Ennis mountains, however, are gradational over distances of about 1,000 feet (305 m); these latter contacts are marked by gradually increasing amounts of coarse-grained, granitic-looking gneiss at the expense of the slightly finer-grained, poorly layered gneiss. The granulite gneiss-migmatite contact is particularly well-exposed in the stream valley northeast of sample location R-6797 south of Pilot Mountain where the debris avalanches generated by Hurricane

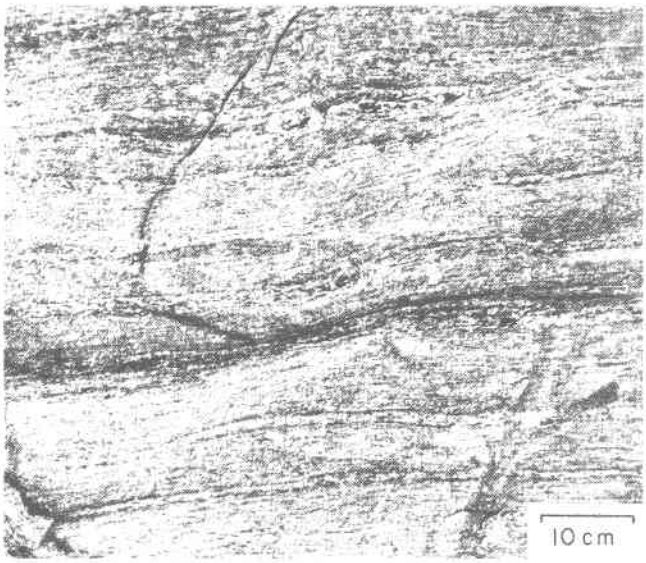
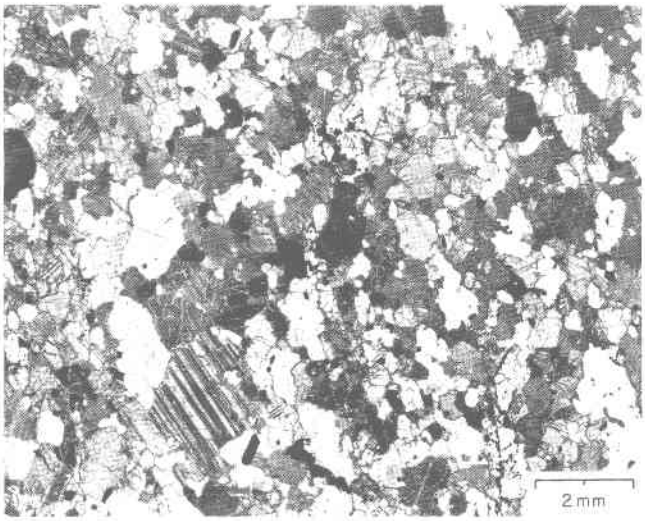


Figure 2. Strongly layered quanulite gneiss (R-6494) exposed in bed of Stony Creek; nearly vertical segregation layering has a strike to the northeast. (Photograph by J. J. Gryta.)



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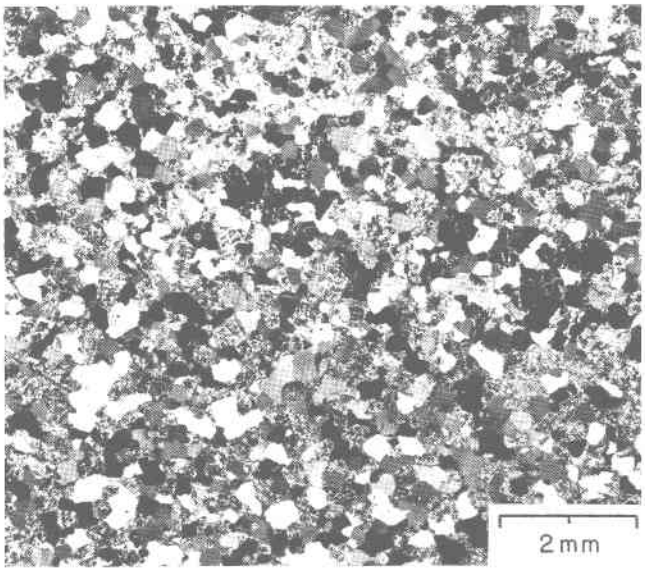

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	R-6494	R-6495
SiO_2	64.2	70.6
Al_2O_3	14.5	12.6
Fe_2O_3	2.6	2.8
FeO	3.9	1.9
MgO	2.1	0.40
CaO	3.3	1.4
Na_2O	2.9	2.1
K_2O	3.4	6.4
CO_2	$<$ 0.2	$<$ 0.2
TiO_2	1.1	0.68
P_2O_5	0.17	0.17
MnO	0.077	0.045
H_2O	——	——
L.O.I. (1,000°F)	1.1	0.8
Total	99.5	100.1

[1]Analyses by Skyline Labs, Inc., Wheat Ridge, Colorado.

amphibolite facies assemblage (R-6781) of quartz, clinozoisite, biotite, and a strongly pleochroic (blue-green-brown) hornblende (Figure 8).

The gneiss is frequently cut by narrow, nearly vertical, northward- to northeastward-trending zones of mylonitic biotite gneiss derived from intrusive Lovingston granitic gneiss. These cataclastic zones, laterally discontinuous over distances up to about 0.5 mile (0.8 km), are not mapped separately (Plate 1), but are identified by steeply dipping, northeastward-trending foliation symbols.

The contacts of the poorly layered granulite gneiss with the intrusive Lovingston Formation are generally gradational over distances of about 500 feet (152 m). The contacts between this gneiss and the spacially and genetically associated migmatite found in roof pendants on Pilot and Ennis mountains, however, are gradational over distances of about 1,000 feet (305 m); these latter contacts are marked by gradually increasing amounts of coarse-grained, granitic-looking gneiss at the expense of the slightly finer-grained, poorly layered gneiss. The granulite gneiss-migmatite contact is particularly well-exposed in the stream valley northeast of sample location R-6797 south of Pilot Mountain where the debris avalanches generated by Hurricane

Figure 5. Xenolith of strongly layered granulite gneiss (R-6495) in massive Pedlar charnockite exposed in the bed of Little Stony Creek; shows discordant contact. (Photograph by T. M. Gathright II.)

Figure 6. Poorly layered granulite gneiss (R-6780) exposed in debris-avalanche-scoured stream valley east of State Road 810 at stop 10, road log cumulative miles 33.05(Appendix); steeply dipping segregation layering has a strike to the northwest. (Photograph by T. M. Gathright II.)

Camille in 1969 scoured a considerable portion of the stream channel down to bedrock. The criteria used to map this contact is based on the disappearance of poorly layered granulite gneiss (Figure 6) as discrete, laterally continuous zones (Figure 9) and the appearance of thin, discontinuous, aligned, gneissic xenoliths within a coarse-grained granitic-looking gneiss (Figure 10).

Migmatitic granulite gneiss: This type of gneiss (Figure 10) is closely associated with the poorly layered granulite gneiss on Ennis and Pilot mountains. It is well exposed in the debris-avalanche chutes in the Pilot Mountain roof pendant. The migmatite is a coarse-grained, medium to dark greenish gray to dark-gray, granitic-appearing gneiss (R-6782, R-6783) with large, white feldspar porphyroblasts and numerous gneissic xenoliths aligned subparallel to the northwestward-trending segregation layering in the poorly layered granulite gneiss.

The migmatitic granulite gneiss consists of both large, perthitic, poikiloblastic feldspar porphyroblasts (Figure 11) and smaller poikiloblastic perthitic feldspars. The remaining major Grenville-age minerals are plagioclase, quartz, and hypersthene. The hypersthene is typically altered to light-green actinolite (Figure 11), which is also altered around the margins to dark bluish-green hornblende.

This gneiss resembles massive charnockite, but the former has abundant aligned xenoliths and numerous large, white feldspar prophyroblasts, many of which have indistinct boundaries with the host rock. These two distinctive and characteristic features suggest an

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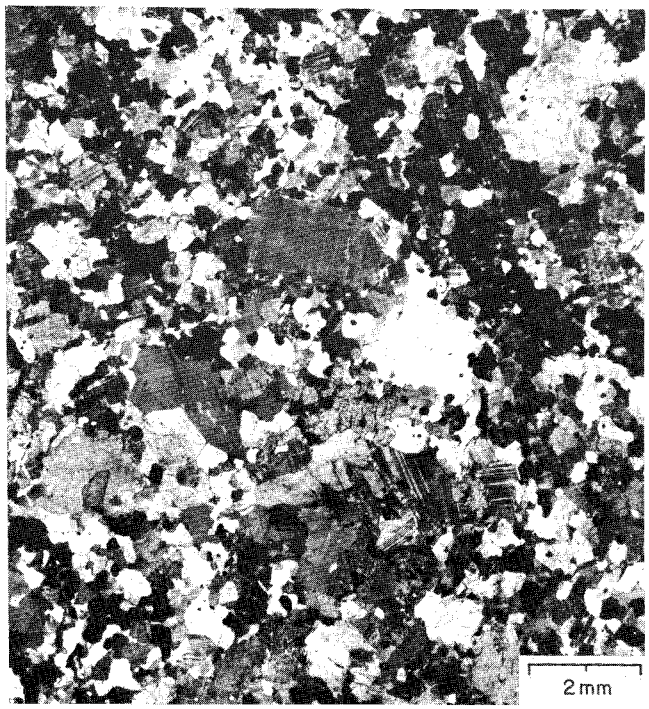

Figure 7. Photomicrograph of poorly layered granulite gneiss (R-6780) showing hypersthene intergrown with perthitic feldspar, plagioclase, and magnetite.

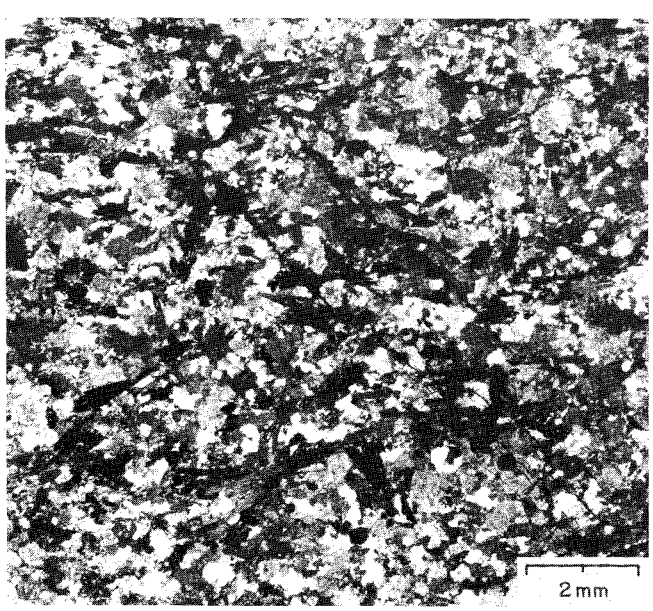

Figure 8. Photomicrograph of poorly layered granulite gneiss showing mineral assemblage (R-6781) retrograded to upper-greenschist/lower-amphibolite facies during Paleozoic metamorphism; relict minerals of Grenville metamorphism are replaced by the mineral assemblage of strongly pleochroic (blue-green-brown) hornblende, biotite, clinozoisite, and quartz.

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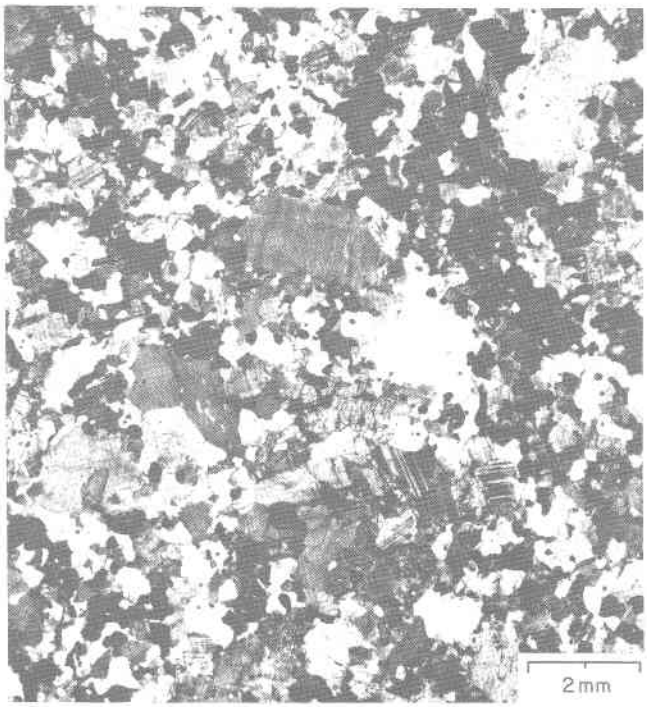
Figure 9. Contact zone of poorly layered granulite gneiss with migmatitic granulite gneiss exposed near sample location R-6797; zone consists of alternating layers of coarse-grained, poorly layered, granitic-looking migmatitic gneiss and finer-grained, poorly layered granulite gneiss; layering has a strike to the northwest, subparallel to nearly vertical segregation layering in poorly layered granulite gneiss. (Photograph by T. M. Gathright II.)

Figure 10. Migmatitic granulite gneiss exposed in debris-avalanche chute about 1,000 feet (305 m) east of sample location R-6797; aligned xenoliths have a strike to the northwest, subparallel to segregation layering in the adjacent poorly layered granulite gneiss; many of the white perthitic feldspar porphyroblasts have indistinct boundaries with the host rock. (Photograph by T. M. Gathright II.)

the migmatite may represent the partially melted contact zone of the poorly layered granulite gneiss adjacent to the pluton of massive, biotite-bearing Lovingston granitic gneiss.

The Cooks Hollow area in the northwestern part of the Greenfield quadrangle is underlain by what may be the higher grade equivalent to the migmatite zone in



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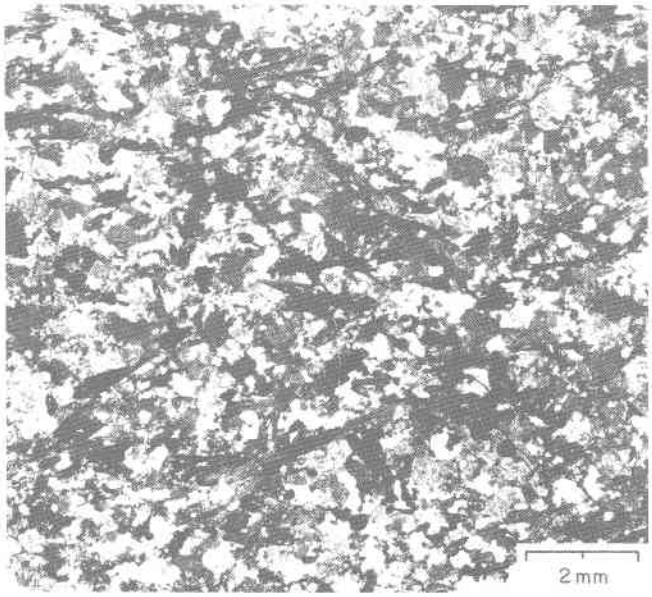

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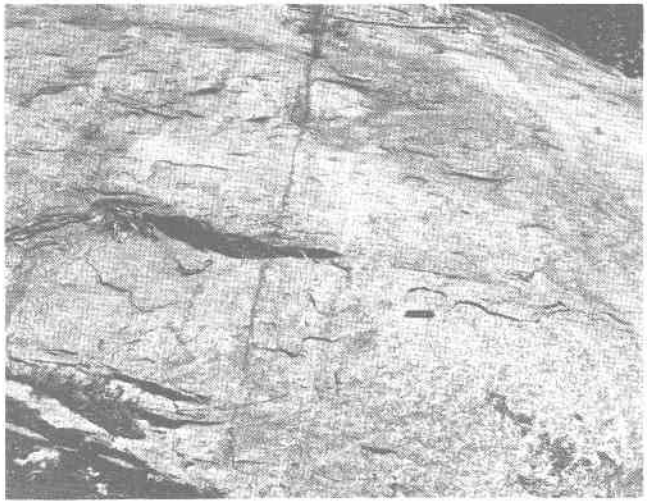

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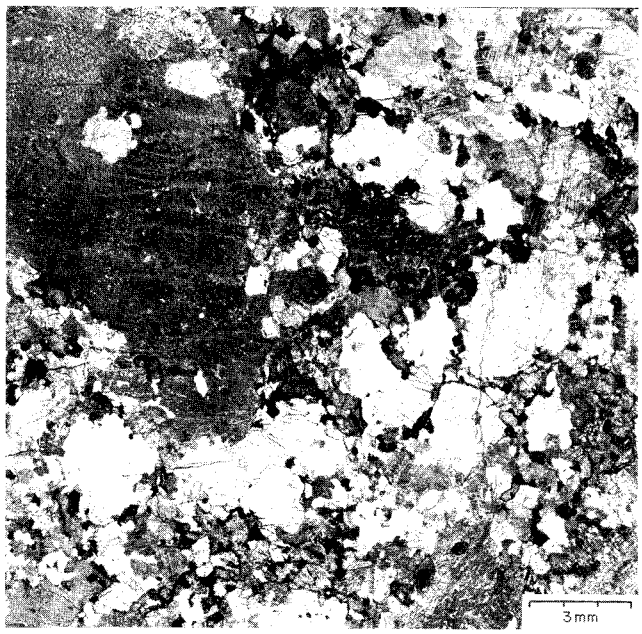


Figure 11. Photomicrograph of migmatitic granulite gneiss (R-6782) with large, perthitic feldspar porphyroblast in finer grained rock consisting of perthitic feldspar, plagioclase, quartz, uralitized pyroxene, and magnetite.

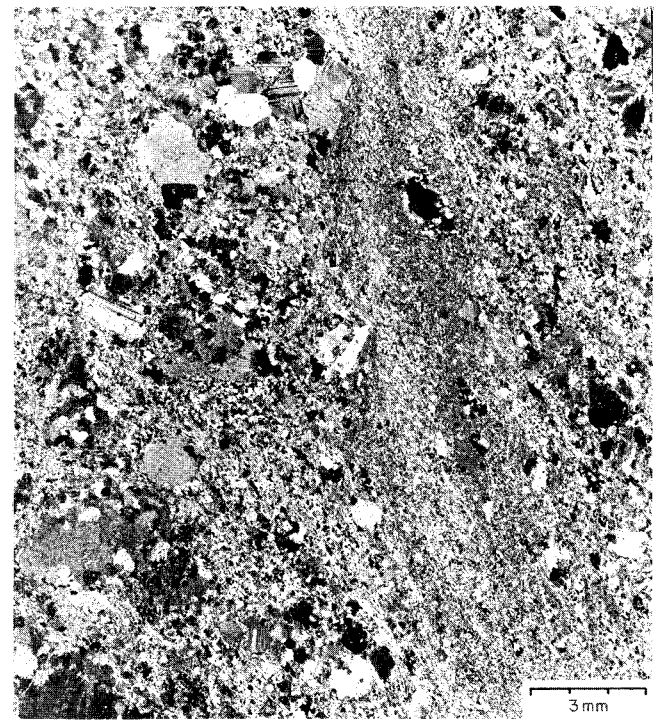


Figure 12. Photomicrograph of massive granitic gneiss in the Lovingston Formation (R-6789) exposed at stop 9, road log cumulative miles 31.65 (Appendix); gneiss is cut by nonpenetrative biotite s surface (vertical zone); poorly developed biotite foliation (diagonal) and sphene, clinozoisite, and microcrystalline quartz were formed during Paleozoic metamorphism; feldspars are the dominant relicts of Grenville metamorphism.

the Pilot Mountain roof pendant. At the former location, massive Pedlar charnockite (R-6784) crops out in the core of a large westward-trending antiformal dome, about 2 miles (3 km) across, which contains wide zones of strongly layered granulite gneiss more or less concordantly wrapped around its margins. Additionally, the massive charnockite in the interior contains abundant, essentially concordant, elongated xenoliths of layered gneiss (R-6779). Although usually highly retrograded (Figure 4) and folded, the elongated xenoliths somewhat resemble the elongated zones of xenoliths in the Pilot Mountain roof pendant (Figure 10).

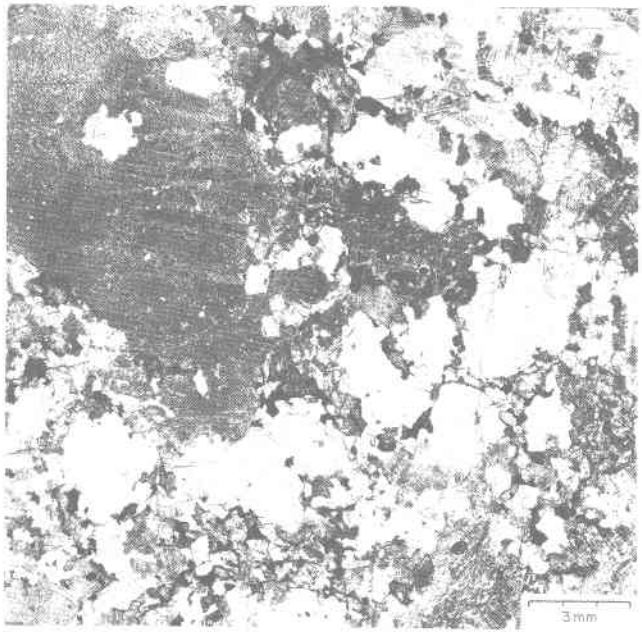
Lovingston Formation

Within the Greenfield quadrangle the Lovingston Formation is divided into two mappable rock units: (1) a massive to slightly foliated, granitic to quartz monzonitic gneiss (R-6789) and (2) mylonitic gneiss (R-6493; R-6791) and mylonitic schist (R-6790).

Massive granitic gneiss: This gneiss (R-6789) is widespread east of State Highway 151 (Plate 1) where it forms the main rock type of the Lovingston massif. It is particularly well exposed along State Highway 6 and the Rockfish River. The unit typically consists of medium- to dark-gray, massive to slightly foliated, biotite-bearing granitic to quartz monzonitic gneiss. Biotite is present both as clumps of relict grains inherited from Grenville progenesis and as aligned grains formed during Paleozoic metamorphism. Within the folded rocks in the southeastern corner of the Greenfield quadrangle the gneiss was slightly more altered during Paleozoic metamorphism to a coarse-grained biotite-bearing augen gneiss. It frequently contains several types of xenoliths that are similar to those within the migmatitic granulite gneiss but which generally occur as isolated xenoliths lacking the well-defined northwestward trend of those in the migmatite.

In thin section (Figure 12), Lovingston gneiss (R-6789) commonly contains relict fragments of perthitic feldspars, plagioclase, microcline, quartz, and myrmekite as well as small grains of apatite and zircon. The Paleozoic metamorphic mineral assemblage typically consists of biotite, sphene, clinozoisite, and microcrystalline quartz.

Mylonitic gneiss: This gneiss is found in a northeastward-trending belt along the South Fork of the Rockfish River, and extends northeastward along State Road 635 across the Greenfield quadrangle. Representative exposures are found along State Road 634 south of Nellysford and east of the intersection of State Highways 6 and 151 in the southern part of the Greenfield quadrangle. The rock consists of medium- to dark-gray, biotite-bearing, mylonitic (augen) gneiss (R-6493; R-6791) and dark-gray to black, biotite-bearing,



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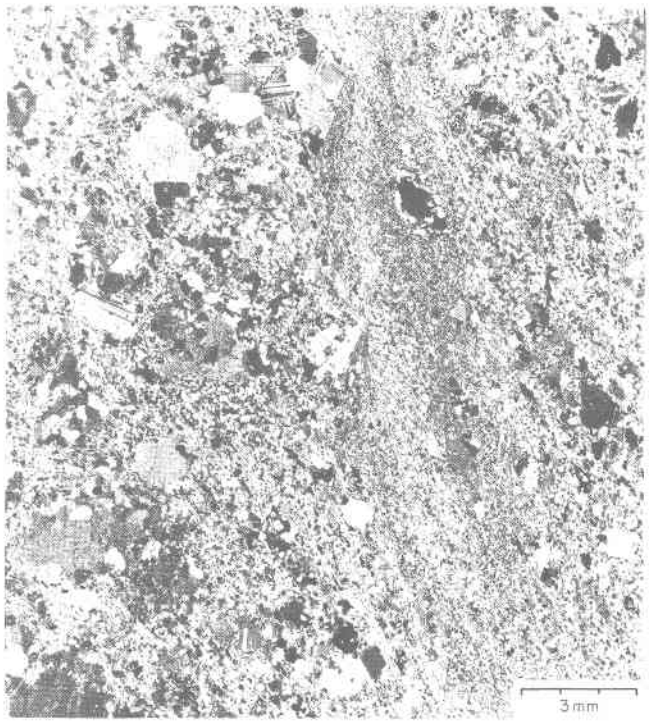

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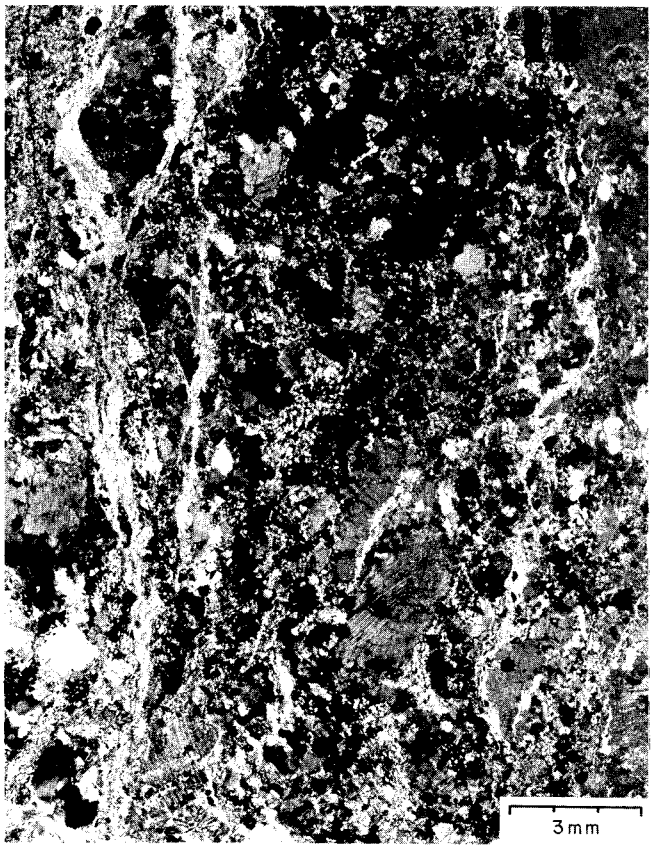


Figure 13. Photomicrograph of mylonitic (augen) gneiss in the Lovingston Formation (R-6493) exposed in the southeast corner of the Sherando quadrangle; mica foliations are near vertical and diagonal; feldspars form the principal type of porphyroclast (augen).

Massive Charnockite

The charnockite occurs typically as both irregular masses (Plate 1) and as smaller elongated bodies (R-6786) intruded into the granulite gneiss and Lovingston Formation. The rock (R-6785) is a coarse-grained, medium- to dark-gray, massive charnockite with abundant white, perthitic feldspar porphyroblasts. It is similar to massive Pedlar charnockite except that it lacks the distinctive green feldspar that characterizes the Pedlar charnockite and contains white feldspar porphyroblasts similar to those in the migmatitic granulite gneiss. It differs from the latter in that it lacks the abundant, aligned xenoliths and the porphyroblasts have sharp, well-defined boundaries.

The Grenville mineral assemblage (Figure 14) consists of both large, perthitic feldspar porphyroblasts

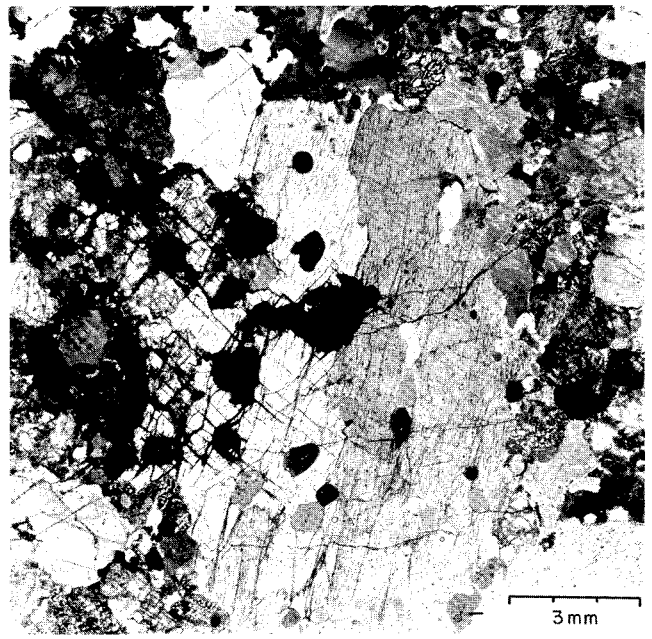


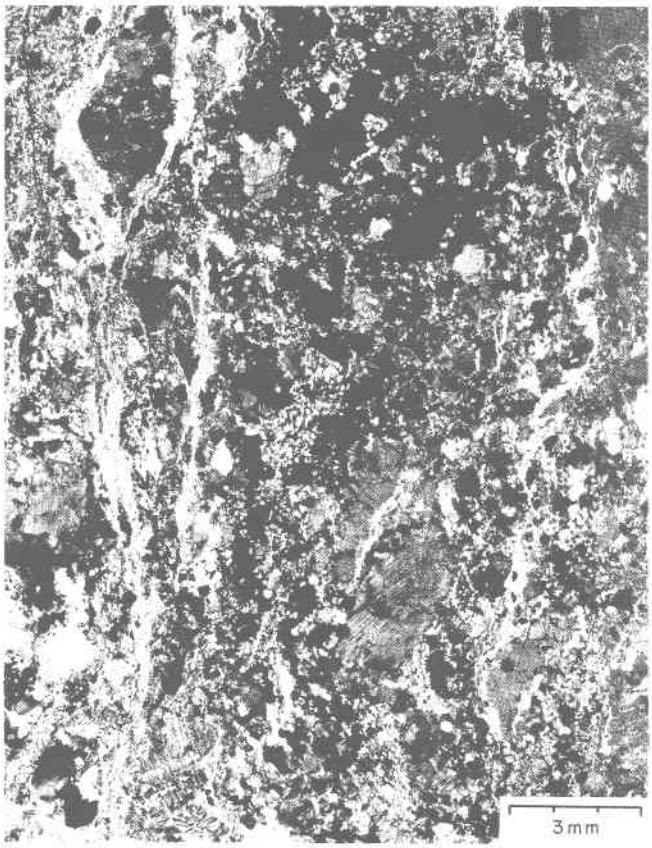
Figure 14. Photomicrograph of the massive charnockite unit of the Lovingston massif (R-6785) exposed about 1,000 feet (305 m) southeast of road log cumulative miles 16.25 (Appendix); note textural and mineralogical similarities with massive Pedlar charnockite (Figure 15) and migmatitic granulite gneiss (Figure 11); rock contains large, white, perthitic feldspar surrounded by smaller perthitic feldspars, quartz, plagioclase, uralitized pyroxene, and magnetite; myrmekite commonly occurs near margins of perthitic feldspar, and plagioclase is relatively rare compared with perthitic feldspar.

and smaller perthitic feldspar, plagioclase, microcline, quartz, and pyroxene. Myrmekite is common adjacent to the perthitic feldspars, and the pyroxenes are typically uralitized. Actinolite, formed at the expense of pyroxene, is commonly altered to dark bluish green hornblende along its margins. The texture is typically hypidiomorphic-granular.

Pedlar Formation

The Pedlar Formation underlies most of the southwestern portion of the Sherando quadrangle and occurs as an apparently discordant intrusion into granulite gneiss north of Crawford Knob; it also underlies a small area along the northeast margin of the quadrangle (Plate 2). In the Greenfield quadrangle the Pedlar is limited to the Cooks Hollow area. The formation is primarily a uniform-appearing, massive charnockite (R-6497) locally altered to unakite (R-6499). Adjacent to high-angle faults the formation is locally sheared and mineralized (R-6498) whereas adjacent to thrust faults it is locally characterized by mylonitic gneiss (R-6500) with a well-developed fluxion structure and downdip lineation. In thin section (Figure 15) the typical massive charnockite of the Pedlar has a hypidiomorphic-

mylonitic schist (R-6790). In thin section (Figure 13), the gneiss commonly contains augen of white perthitic feldspar, plagioclase, and blue quartz in a Paleozoic mineral assemblage of biotite, sphene, clinozoisite, and microcrystalline quartz with or without muscovite.



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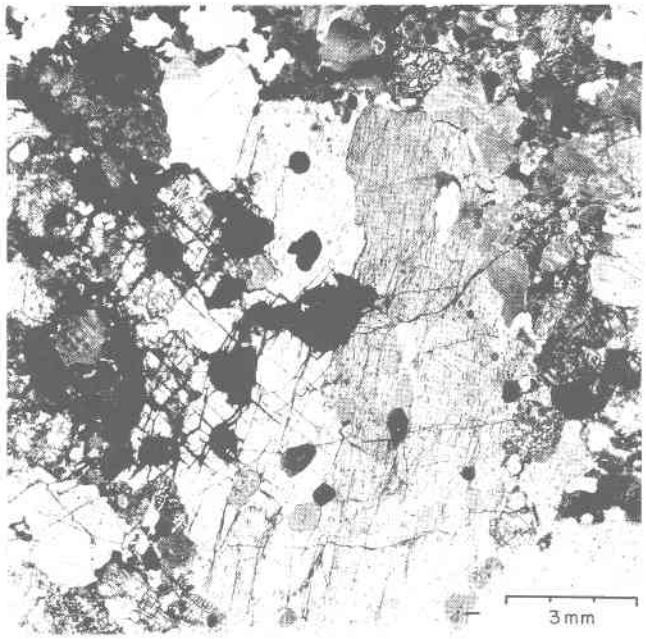

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Figure 15. Photomicrograph of massive Pedlar charnockite (R-6497) exposed on Black Rock Mountain; small, uralitized pyroxene grains are intergrown with perthitic feldspar and quartz; myrmekite commonly occurs near the margin of perthitic feldspars; chlorite, biotite, sericite, and epidote are found in the altered groundmass.

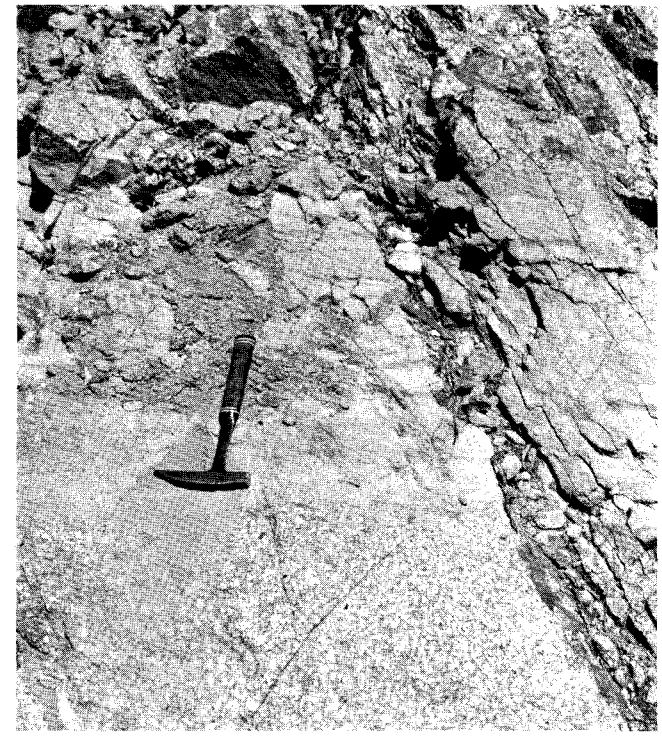

Figure 16. Concordantly layered granulite gneiss within massive Pedlar charnockite; exposed near center of debris-avalanche chute shown in Figure 17. (Photograph by E. S. Robinson.)

Figure 17. Small debris-avalanche chute developed in saprolite of massive Pedlar charnockite near the head of Spruce Creek during Hurricane Camille on August 20, 1969. (Photograph by E. S. Robinson.)

granular texture and consists mainly of quartz, perthitic feldspar, and uralitized hypersthene with lesser amounts of plagioclase, brown hornblende, garnet, and myrmekite. Sericite, biotite, actinolite, chlorite, and epidote are the main products of Paleozoic greenschist-facies metamorphism.

The unakite (R-6499), a local product of this later retrograde metamorphism, consists of epidote, quartz, and pink feldspar. The sheared rocks (R-6498) along high-angle faults contain relict grains indicative of massive charnockite, but they also contain large amounts of calcite and/or sericite, chlorite, and epidote. Along the thrust faults sericite and microcrystalline quartz are the dominant alteration products (R-6500) formed from the massive charnockite.

Within the massive charnockite of the Pedlar several small lenses of concordantly layered granulite gneiss ("gg", Plate 2), 20 feet (6 m) thick, are present in the Grassy Ridge area, and one other (Figure 16) is located in a debris-avalanche chute along one of the tributaries at the head of Spruce Creek (Figure 17). These zones of layered gneiss strongly resemble rhythmic layering in the lujavrites, Ilimaussaq intrusion, South Greenland (Wager and Brown, 1967, p. 494, *their* figure 272) and hence, may be relicts of gravity-stratified igneous rhythmites. The layered gneiss at the chute (Figure 16) consists of a 24-inch- (61-cm-) thick sequence of eight layers of alternating light and dark gneiss. All eight layers are laterally traceable for about 20 feet (6 m) to the edges of the exposure, and all in-

Figure 15. Photomicrograph of massive Pedlar charnockite (R-6497) exposed on Black Rock Mountain; small, uralitized pyroxene grains are intergrown with perthitic feldspar and quartz; myrmekite commonly occurs near the margin of perthitic feldspars; chlorite, biotite, sericite, and epidote are found in the altered groundmass.

Figure 16. Concordantly layered granulite gneiss within massive Pedlar charnockite; exposed near center of debris-avalanche chute shown in Figure 17. (Photograph by E. S. Robinson.)

Figure 17. Small debris-avalanche chute developed in saprolite of massive Pedlar charnockite near the head of Spruce Creek during Hurricane Camille on August 20, 1969. (Photograph by E. S. Robinson.)

granular texture and consists mainly of quartz, perthitic feldspar, and uralitized hypersthene with lesser amounts of plagioclase, brown hornblende, garnet, and myrmekite. Sericite, biotite, actinolite, chlorite, and epidote are the main products of Paleozoic greenschist-facies metamorphism.

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ternal contacts are subparallel to the marginal contacts. The lighter-colored layers range in thickness from 7 to 18 cm (3 to 7 inches) and consist of medium greenish brown, fine-grained (1 to 2 mm), pyroxene-bearing quartzo-feldspathic (perthitic feldspar and plagioclase) gneiss. The darker-colored gneiss layers range in thickness from 2 to 5 cm (1 to 2 inches) and consist of medium grayish green to dark greenish black, finer grained (less than 1 mm) gneiss containing little plagioclase, more pyroxene, and in some layers large (1 to 3 mm) flakes of mica (stilpnomelane?). Some chlorite, sericite, and epidote are also present as retrograde minerals.

PRECAMBRIAN(?) ROCKS

Pyroxenite Dike

At the head of Cooks Hollow in the northwestern part of the Greenfield quadrangle is the singular occurrence of what is either a pyroxenite or a pyroxene-granulite dike. The interior rock (R-6787) is coarse-grained (1 to 5 mm) and has a xenomorphic-granular texture. It consists essentially of clinopyroxene (pigeonite?) and orthopyroxene with a small amount of intergrown green spinel and magnetite (Figure 18). The margins of the orthopyroxenes are commonly altered to actinolite.

Near its contact with massive Pedlar charnockite, the marginal rock (R-6788) is fine-grained (about 1 mm), but also has a xenomorphic-granular texture. It consists principally of zoned plagioclase (An_{37} to An_{26}) and orthopyroxene with minor clinopyroxene and magnetite. Quartz occurs as inclusions within plagioclase, and the margins of clinopyroxenes are altered to chlorite and actinolite.

Because of the lack of alteration and the texture it is suggested that the dike could be as young as post-Paleozoic metamorphism. The An-content of the plagioclase, however, is evidence that it could be a Grenville-age dike that was "dry" at the time of Paleozoic metamorphism and hence was only slightly altered. This rock (Figure 18) contrasts sharply with the metamorphosed mafic dikes of the region (Figure 19).

Mafic Dikes

Numerous metamorphosed mafic dikes (R-6795; R-6796) are present in the Greenfield quadrangle and are most abundant in the southeast corner. These northeastward-trending dikes range in size from a few inches to about 50 feet (15 m) in width and can be traced laterally for as much as 0.5 mile (0.8 km). The dikes are mineralogically similar and probably genetically related to a large mafic intrusion along the Rockfish River in the adjacent Lovingston 7.5-minute quadrangle

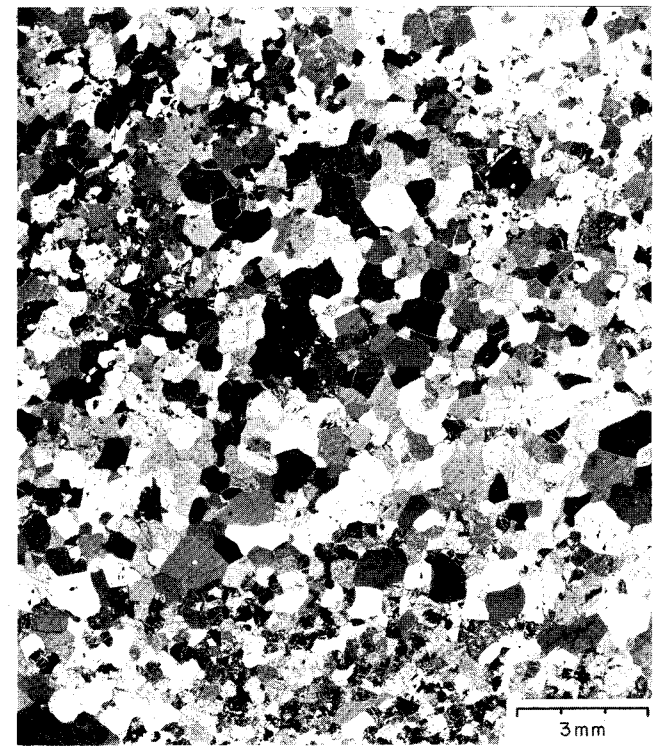

Figure 18. Photomicrograph of interior rock from pyroxenite or pyroxene granulite(?) dike (R-6787) exposed at stop 6, road log cumulative miles 23.75 (Appendix); larger grains of clinopyroxene (pigeonite?) are intergrown with smaller, partially uralitized grains of orthopyroxene; a few grains of magnetite are intergrown with spinel in the lower left- and upper right-hand corners; spinel occurs mainly as very small, scattered grains in the lower half.

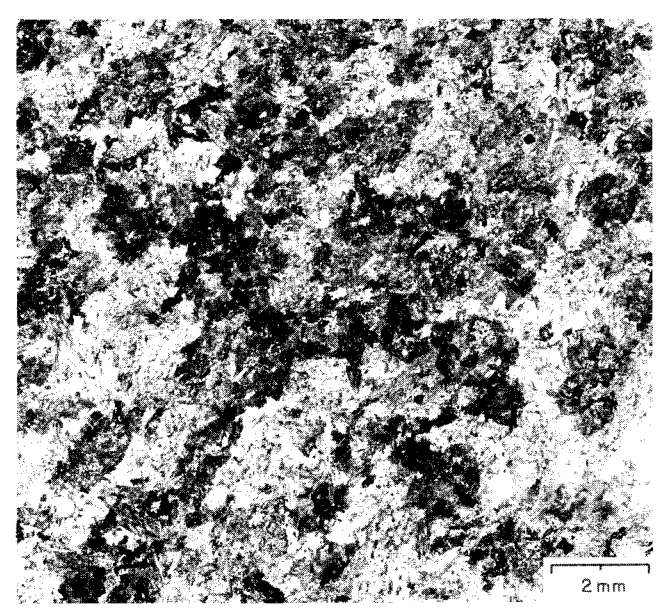

Figure 19. Mafic dike (R-6795) exposed about 0.5 mile (0.8 km) east of State Road 810 (Plate 1); rock consists primarily of relict plagioclase in a metamorphic mineral assemblage of strongly pleochroic (blue-green-brown) hornblende, biotite, clinozoisite, quartz, and magnetite.

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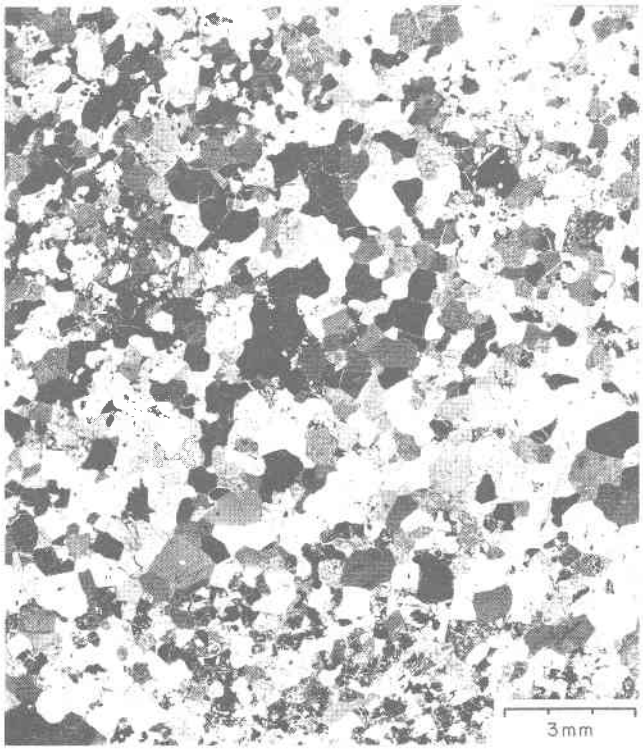

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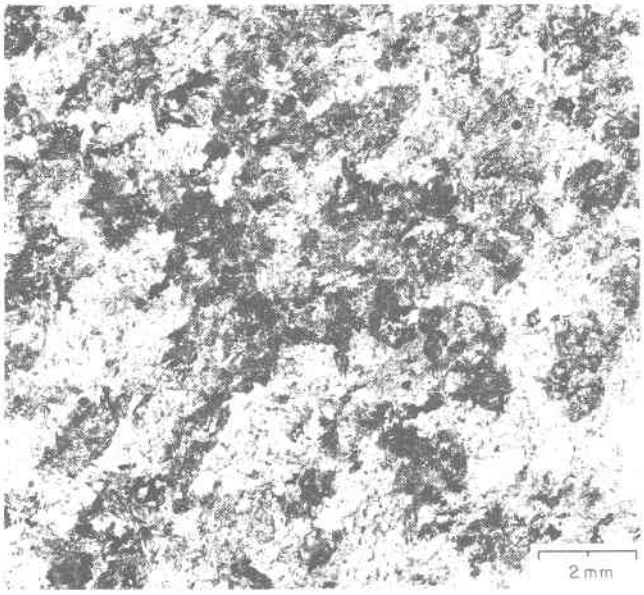

Figure 19. Mafic dike (R-6795) exposed about 0.5 mile (0.8 km) east of State Road 810 (Plate 1); rock consists primarily of relict plagioclase in a metamorphic mineral assemblage of strongly pleochroic (blue-green-brown) hornblende, biotite, clinozoisite, quartz, and magnetite.

(Bloomer and Werner, 1955, their Plate 1; Davis, 1974). Dike rocks are typically massive to foliated, medium- to coarse-grained, dark-gray or black amphibolite (R-6795; R-6796). In thin section (Figure 19) relict plagioclase and apatite are common and in the dike on the hill south of Meriwether Creek relict pyroxenes are also present. At the latter location the Paleozoic metamorphic assemblage (actinolite, chlorite, epidote, quartz) is indicative of the greenschist facies. To the southeast (R-6795) the metamorphic assemblage (strongly pleochroic blue-green hornblende, biotite, clinozoisite, quartz) is characteristic of upper-greenschist or lower-amphibolite facies.

Swift Run Formation

The Swift Run Formation is well-exposed around the margin of Stony Creek gorge, around a series of folds just east of the gorge, and near the heads of both Pond Hollow and Pauls Creek. Except on Crawford Knob and Black Rock Mountain, Swift Run metasediments underlie Catoctin volcanics and rest unconformably on older charnockite and gneiss. On Black Rock Mountain the metasediments gradually pinch-out and Catoctin volcanics rest directly on the Pedlar Formation. Along the northwestern edge of Crawford Knob, Swift Run metasediments conformably overlie one or more Catoctin metabasalt flows. In addition, light-gray tuff-phyllite (R-6501), also characteristic of Catoctin volcanism, occurs near the middle of the formation west of the falls at the head of Stony Creek gorge. The thickness of the Swift Run metasediments ranges from less than 1 to nearly 1,000 feet (less than 0.3 to nearly 305 m). Bedding, and commonly cross-bedding, are discernable in most exposures.

Dominant lithologies in the Swift Run Formation are slightly foliated, coarse-grained, conglomeratic quartzose metasandstone (R-6502) and sandy, lithic quartz-pebble metaconglomerate. Thinly bedded siltstone-phyllite is present near the middle of the formation south of Spruce Creek and west of the falls at the head of Stony Creek gorge. Very coarse, lithic, quartz-cobble and -boulder metaconglomerate is the dominant lithology in exposures along the lower part of Little Stony Creek (Figure 20) and due east of the mouth of the same creek. At both localities, randomly oriented, medium-gray to medium-purple tuff-phyllite fragments are common; at the latter locality, where boulders reach their maximum observed diameter of 17 inches (43 cm), both milky and purple-quartz cobbles and boulders are abundant. Many purple-quartz cobbles have milky-quartz overgrowths developed during Paleozoic metamorphism. At the easternmost part of the exposures on the upper part of Pauls Creek both quartz-cobble and lithic metaconglomerate beds are also present. However, here the lithic fragments are rounded cobbles of granulite-facies gneiss. Adjacent to the lower reaches of Stony Creek, the general character of the Swift Run Formation changes to grayish-green, quartz-pebble mica-schist (R-6503) due to a slight increase in the grade of metamorphism to the southeast.

Figure 20. Metaconglomerate in the Swift Run Formation containing flattened quartz cobbles and tuff-phyllite fragments exposed in the north bank of Little Stony Creek near the contact with the Pedlar Formation at elevation 1,180 feet (360 m). (Photograph by E. S. Robinson.)

In thin sections of conglomeratic metasandstone (Figure 21), detrital grains are primarily quartz with substantially lesser amounts of rock fragments and feldspar grains. All detrital grains appear to have been originally rounded or subrounded. The matrix is commonly altered to a greenschist-facies assemblage of sericite and microcrystalline quartz with lesser amounts of epidote and chlorite. Detrital heavy minerals include magnetite, garnet, and zircon.

Catoctin Formation

The Catoctin Formation is the most resistant rock unit in the Sherando quadrangle and as such it underlies almost all of the higher ridges and peaks in this portion of the Blue Ridge. The formation is principally composed of metabasalt (greenstone and epidosite), but it also contains numerous thin beds of arkosic metasandstone, meta-arkose, siltstone-phyllite (rhythmite), and tuff-phyllite. Portions of some of these units are shown on Plates 1 and 2 at an exaggerated scale where they could be laterally traced. Most of the interbedded units consist of more than one rock type; however, only the dominant lithology is shown on

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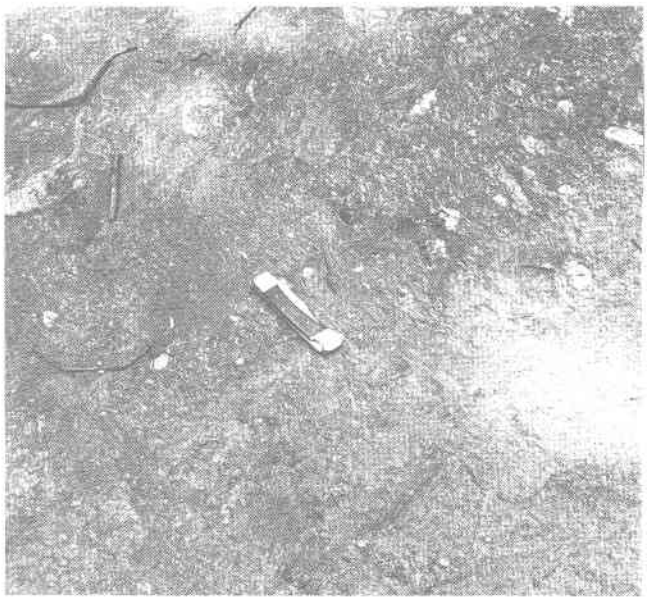

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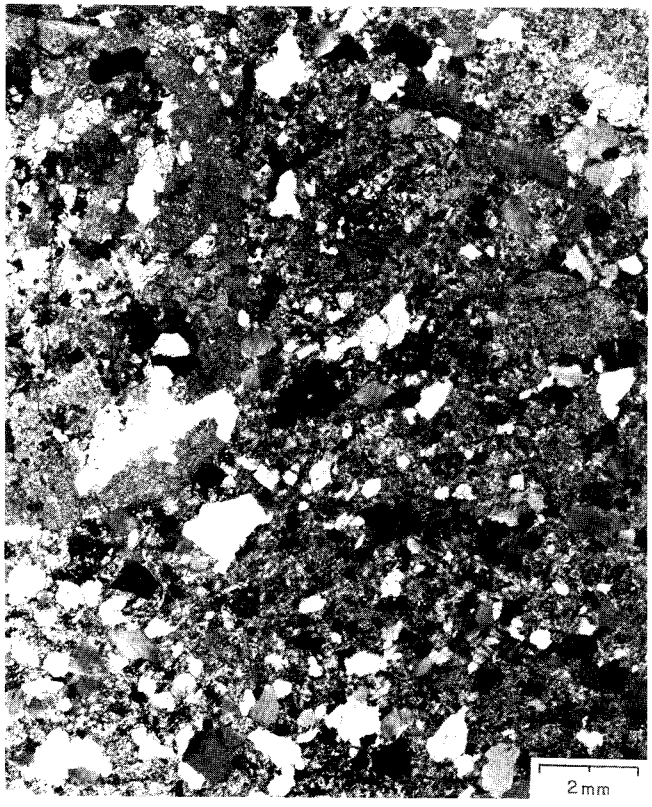


Figure 21. Photomicrograph of conglomeratic metasandstone in the Swift Run Formation (R-6502); note large, rounded, highly altered rock fragment in upper left-hand corner.

Plates 1 and 2. Because of complex folding, as well as the laterally discontinuous nature of these units, no attempt was made to correlate specific strata from one part of the area to another; only the portion of each unit that was traced by walking is shown on the maps. The thickness of the Catoctin Formation in this area appears to exceed 2,500 feet (762 m), but is probably less than 4,000 feet (1,219 m); no complete, unfolded, stratigraphic section is known to exist here.

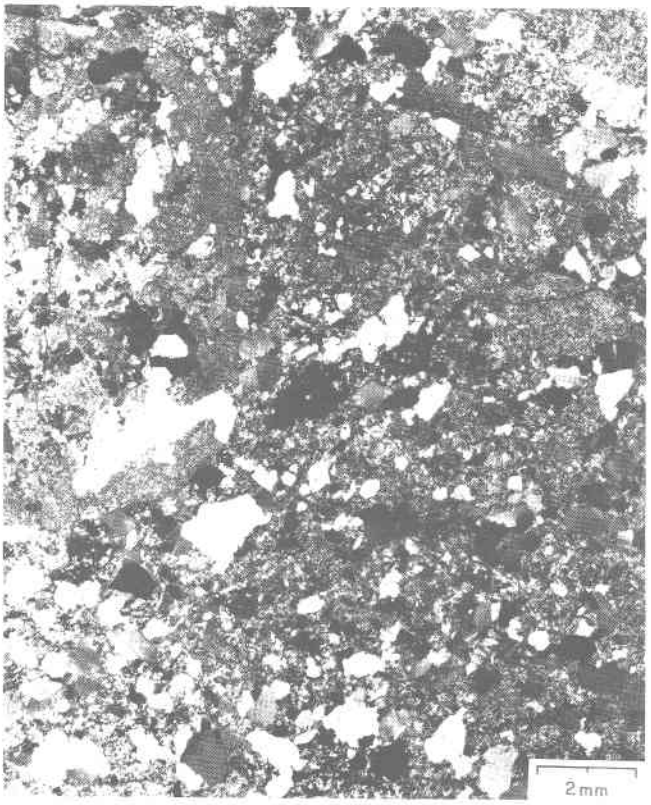
Earlier papers pertaining to the formation in this area (Bloomer and Bloomer, 1947; Bloomer, 1950; Bloomer and Werner, 1955) generally described the greenstone as having a spilitic character. More recent work (Reed, 1955; Reed, 1964; Reed and Morgan, 1971) has indicated that the spilitic nature of the greenstone is probably of metamorphic origin and that, when the bulk chemistry (greenstone plus epidosite) is considered, the Catoctin metabasalt originally had a tholeiitic composition.

Metabasalt flows: In general, flow-on-flow contacts are poorly exposed and are not easily recognized. Where the rocks are nearly flat-lying on steep slopes, such contacts may be discerned on aerial photographs and in the field by the stair-step or ledgy outcrop pattern; good examples of this occur along the western flank of Stony Creek gorge. One excellent exposure of a flow-on-flow contact can be seen at the base of a cliff on the west end of Potatopatch Mountain (Figure 22). Individual flows appear to range in thickness up to a maximum of about 100 feet (31 m) and internally consist of a mixture of both epidosite and greenstone, generally in irregular pods and masses. Metavolcanic breccia is common near the base of flows (Figure 23) and locally is abundant along the crest of Potatopatch

Figure 22. Flow-on-flow contact in the Catoctin Formation exposed at the base of a prominent westward-facing cliff at elevation 3,200 feet (975 m) on the west end of Potatopatch Mountain. The upper flow is primarily epidosite with steeply dipping, widely spaced cleavage; the lower flow is greenstone with a gently inclined chlorite foliation. (Photograph by E. S. Robinson.)

Mountain. Near the head of Pauls Creek, at the base of the Catoctin Formation, cobbles of unakite were engulfed as exotic blocks by basalt flows. Columnar joints (Figure 24) are found in metabasalt saprolite along State Road 664.

The greenstone (R-6504) is typically a dark-green, fine-grained, massive to thinly foliated, dense, amygdulodial rock that contains no megascopic relict volcanic textures. In thin section (Figure 25) greenstone commonly contains a few relict pyroxene and/or plagioclase (An_{28} to An_{33}) grains, but consists mostly of metamorphic minerals. Bloomer and Werner (1955) re-



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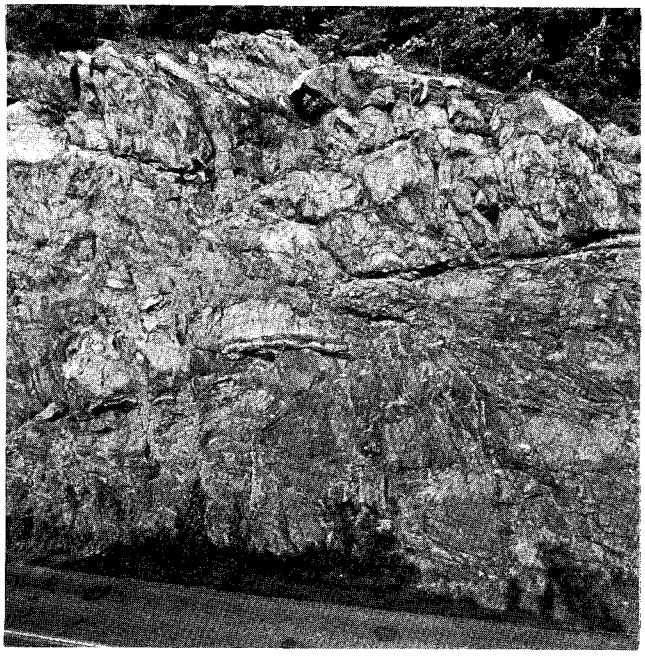

Figure 23. Recumbent folds with axial-plane chlorite foliation in the Catoctin Formation in southeast wall of roadcut at stop 24, road log cumulative miles 68.6 along the Blue Ridge Parkway; nappe and folds are outlined by 1- to 4-inch- (2- to 10-cm-) thick layer of metasandstone overlain by 6 to 12 inches (15 to 30 cm) of metavolcanic breccia overlain by epidosite pods; lower metabasalt flow contains large, irregularly shaped amygdules filled with quartz and epidote. (Photograph by T. M. Gathright II.)

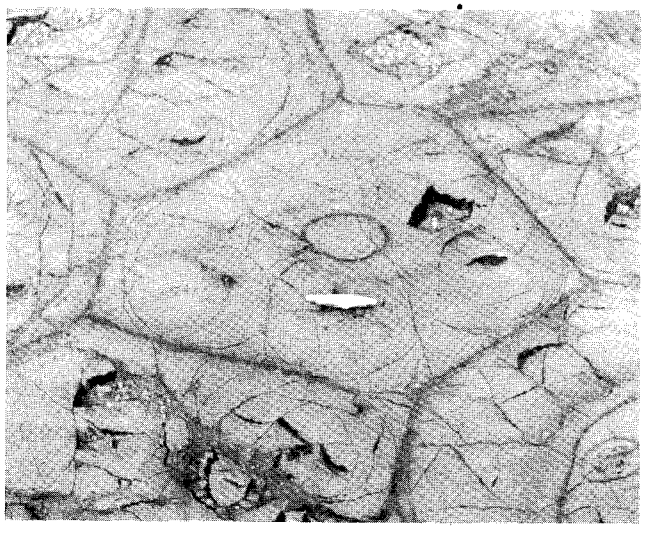

Figure 24. Columnar joints exposed in metabasalt saprolite of the Catoctin Formation along the southeast side of State Road 664 at an elevation of 1,880 feet (573 m) at road log cumulative miles 56.70; this exposure was uncovered during road repairs in 1970 and 1975. (Photograph by E. S. Robinson.)

ported relict plagioclase of composition An_{40} from greenstone in this general region. The major metamorphic minerals are quartz, albite, epidote (or calcite as in R-6516), penninite (or fibrous actinolite) and

Figure 25. Photomicrograph of Catoctin greenstone (R-6504); penninite-filled amygdules are aligned parallel to foliation; matrix consists of albite, penninite, epidote, and microcrystalline quartz.

magnetite ($\pm$ hematite). In general, the amount of fibrous actinolite increases to the southeast at the expense of relict pyroxene, penninite, and magnetite. Amygdules in the greenstone consist of two basic types, the most common of which is 0.3- to 2.0-inch (0.6- to 5.1-cm), elongated, penninite-filled amygdules (Figure 25) that are typically flattened parallel to the plane of foliation. The other type of amygdules consist of coarse-grained crystals of mainly epidote, quartz, and penninite with minor amounts of calcite or fibrous actinolite in larger, 1- to 8-inch (3- to 20-cm), more irregularly shaped masses (Figure 23).

The typical epidosite (R-6505) is light- to medium-green, fine- to coarse-grained rock that contains no relict volcanic textures or mineral grains. It essentially consists of epidote and quartz with minor amounts of albite, penninite, actinolite, magnetite, and hematite. Amygdules consist of irregular masses of coarse-grained epidote and quartz. Metavolcanic breccias (R-6506) have a mineralogy similar to epidosite, but differ from it in that the original volcanic-breccia texture is still preserved (Figure 23).

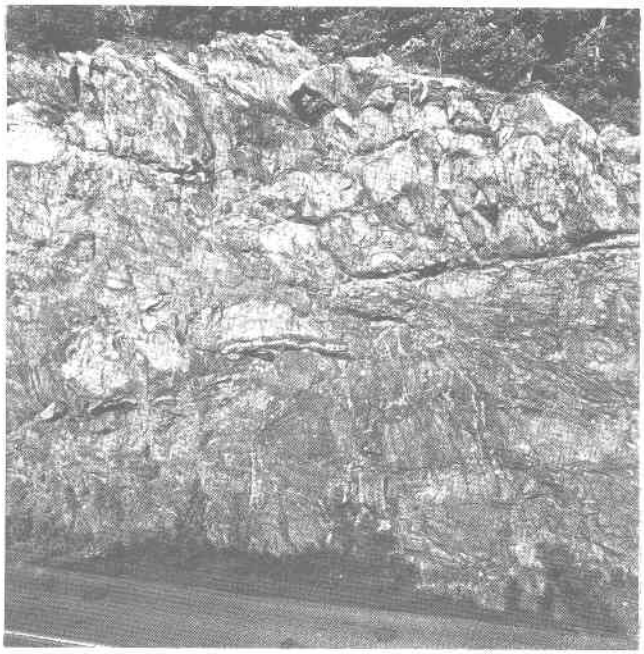

Figure 23. Recumbent folds with axial-plane chlorite foliation in the Catoctin Formation in southeast wall of roadcut at stop 24, road log cumulative miles 68.6 along the Blue Ridge Parkway; nappe and folds are outlined by 1- to 4-inch- (2- to 10-cm-) thick layer of metasandstone overlain by 6 to 12 inches (15 to 30 cm) of metavolcanic breccia overlain by epidosite pods; lower metabasalt flow contains large, irregularly shaped amygdules filled with quartz and epidote. (Photograph by T. M. Gathright II.)

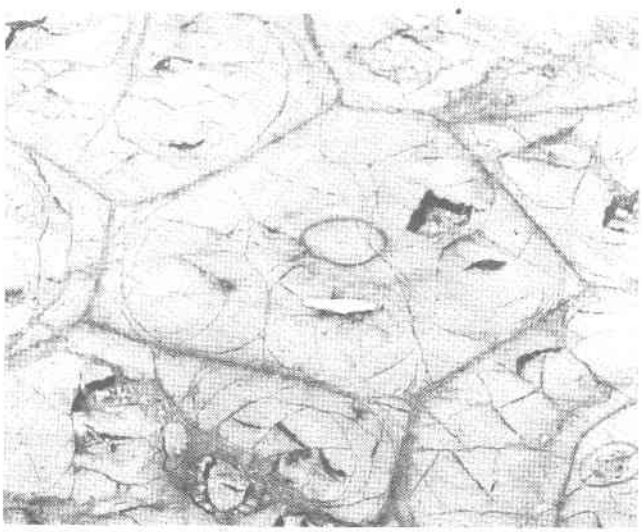

Figure 24. Columnar joints exposed in metabasalt saprolite of the Catoctin Formation along the southeast side of State Road 664 at an elevation of 1,880 feet (573 m) at road log cumulative miles 56.70; this exposure was uncovered during road repairs in 1970 and 1975. (Photograph by E. S. Robinson.)

ported relict plagioclase of composition An_{40} from greenstone in this general region. The major metamorphic minerals are quartz, albite, epidote (or calcite as in R-6516), penninite (or fibrous actinolite) and

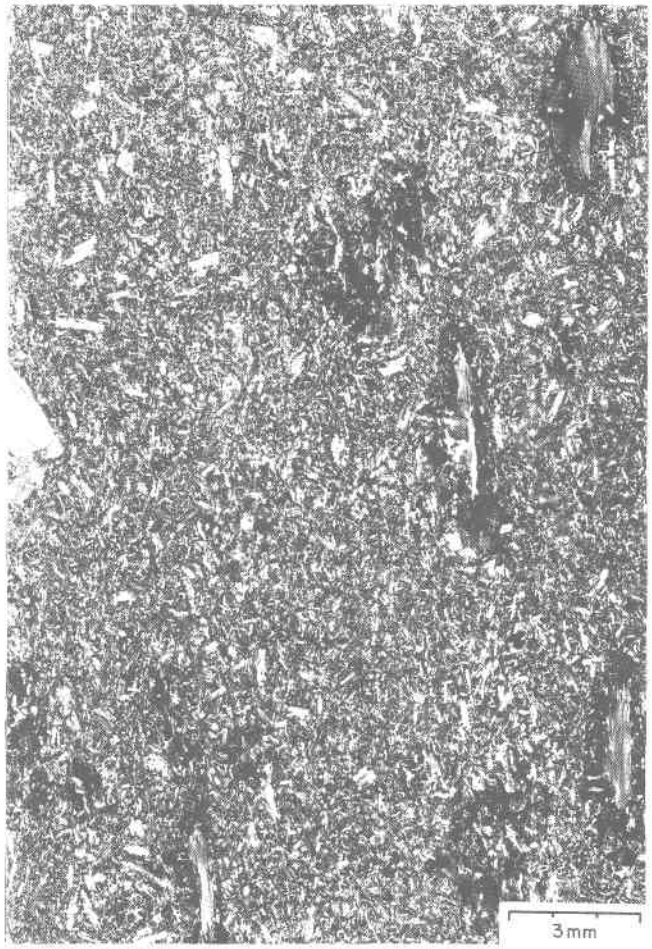

Figure 25. Photomicrograph of Catoctin greenstone (R-6504); penninite-filled amygdules are aligned parallel to foliation; matrix consists of albite, penninite, epidote, and microcrystalline quartz.

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Metabasalt dikes: Scattered metabasalt dikes up to about 50 feet (15 m) wide are shown at an exaggerated scale on Plates 1 and 2. At the Little Stony Creek locality (Plate 2) numerous small dikes also occur for at least several hundred yards upstream and downstream from the larger dike, suggesting that this was a locus of fissure eruptions. The metabasalt dikes (Figure 27) are dark greenish gray, fine-grained rocks, which resemble greenstone. In thin section (Figure 26) dike rock (R-6507; R-6797) consists of quartz, albite, penninite, and actinolite with minor amounts of epidote, magnetite, and relict pyroxene. Contact zones (Figure 26, 27) between the metabasalt dikes and Pedlar charnockite

Figure 26. Photomicrograph of Catoctin metabasalt dike (R-6507) showing contact zone with older, massive Pedlar charnockite; note well-developed foliation in dike.

are seldom more than 1 cm thick but may appear wider because of brecciation in the massive charnockite. The contact zone (figure 26) consists of fibrous actinolite adjacent to metabasalt and fine-grained epidote adjacent to country rock.

Tuff-phyllite: These rocks (including those of the Swift Run Formation) consist of medium- to dark-gray or medium-purple, fine-grained, soft, thinly foliated phyllite with flattened, muscovite amygdules (R-6501; R-6517), 2 to 10 mm long. They have a characteristic,

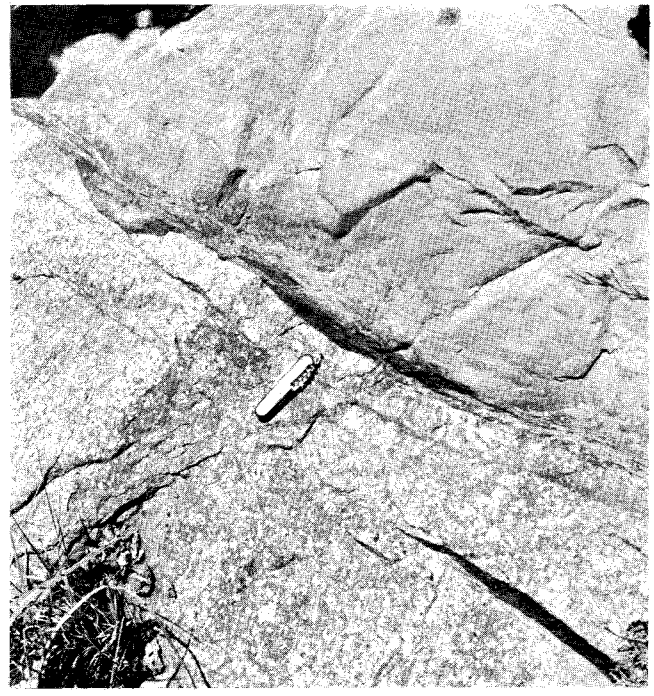

Figure 27. Contact zone of Catoctin metabasalt dike (R-6797) that intruded poorly layered granulite gneiss; near-vertical contacts on this 50-foot (15-m) Catoctin dike have an approximate easterly strike. (Photograph by T. M. Gathright II.)

megascopic relict texture in which outlines of former lithic fragments are preserved (R-6517). No relict minerals are preserved, and metamorphic minerals are uniformly distributed throughout the relict fragments suggesting that these rocks were probably felsic-tuff deposits consisting of volcanic glass(?) and glass(?) shards. Both the bulk chemistry (Furcron, 1969, p. 78, his table 2; Reed, 1955, p. 892, his table 3) and mineralogy suggest that these tuff deposits underwent extensive chemical alteration after deposition. The rocks were relatively depleted in SiO_2 and relatively enriched in Al_2O_3, Fe_2O_3, and K_2O, among others. Once these tuff deposits were covered by metabasalt flows it is unlikely that such extensive chemical alteration could have affected them without affecting the adjacent metabasalts. Inasmuch as the bulk chemistry of the metabasalts has not been significantly altered (Reed, 1964; Reed and Morgan, 1971), the chemical alteration of the numerous interlayered tuff deposits probably occurred before later flows covered them.

Tuff-phyllite is interlayered throughout the entire Swift Run and Catoctin formations as 2- to 50-foot- (1- to 15 m-) thick deposits parallel to bedding in adjacent sedimentary layers. The contacts between the phyllite beds and overlying and underlying metabasalt flows and metasediments are sharp and well defined. The phyllite occurs between metabasalt flows, between flows and metasediments, and interlayered with metasediments, some of which are of probable

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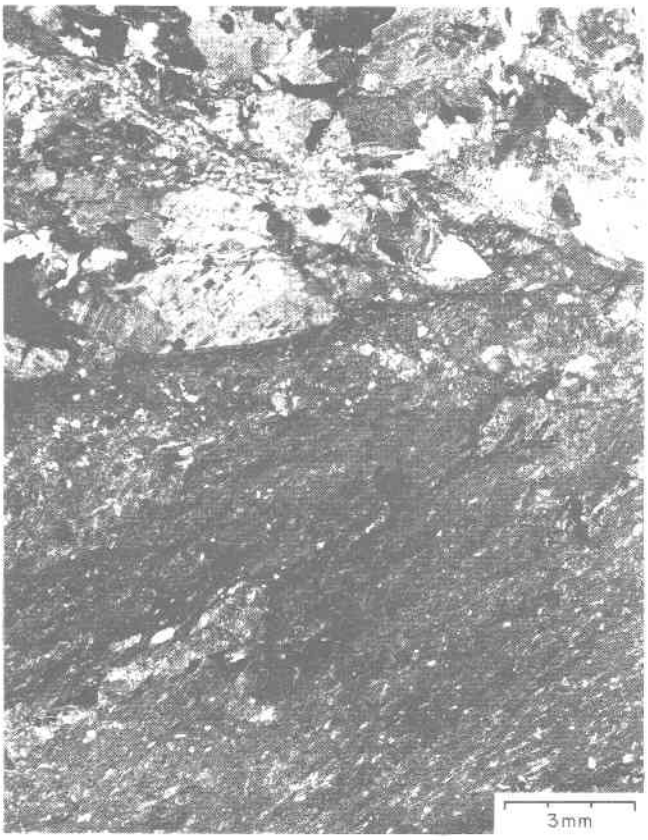

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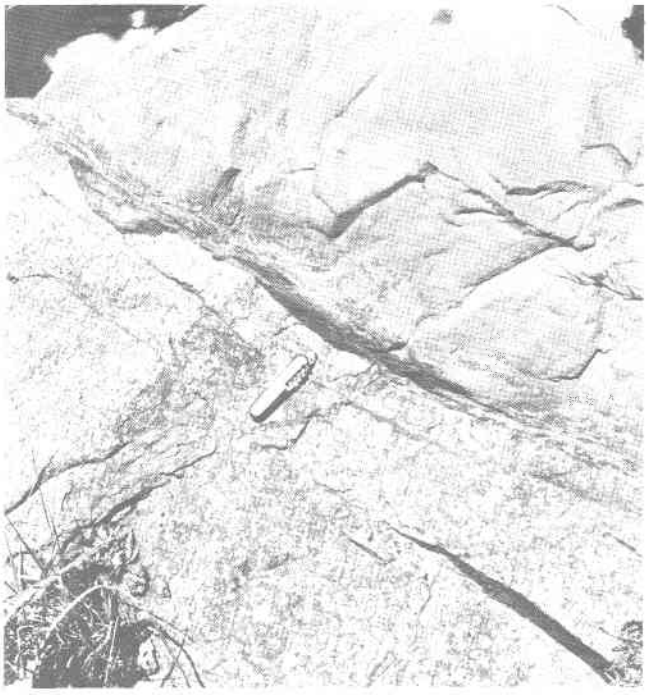

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lacustrine or marine origin (rhythmites). The tuff-phyllite mineralogy remains essentially unchanged regardless of their geologic associations, which suggests that they are not subaerially weathered metabasalt saprolite as suggested by Reed (1955, p. 893).

In thin section (Figure 28), the tuff-phyllite consists of uniformly distributed, fine-grained sericite (± penninite), microcrystalline quartz, and magnetite. The sericite has a preferred orientation parallel to the visible foliation in the rock. By comparison, siltstone-phyllite (rhythmite) (Figure 29) and mudstone-phyllite of the same grain-size typically have well-developed

Figure 28. Photomicrograph of Swift Run tuff-phyllite (R-6501) showing uniformly random distribution of sericite, magnetite, and microcrystalline quartz; foliation subhorizontal.

bedding preserved with magnetite and other heavy minerals concentrated along bedding planes. Thus, it is unlikely that the tuff-phyllite has a sedimentary origin. The interpretation most consistent with bulk chemistry, mineralogy, and geologic occurrence is that the phyllite is a metamorphic product of tuff deposits chemically altered at the time of deposition, probably by weathering, and once altered became "closed systems" when covered by later metabasalt flows.

Siltstone-phyllite (rhythmite): Most of the siltstone-phyllite (R-6508) occurs in the upper part of the volcanic sequence. Geographically, it is most abundant

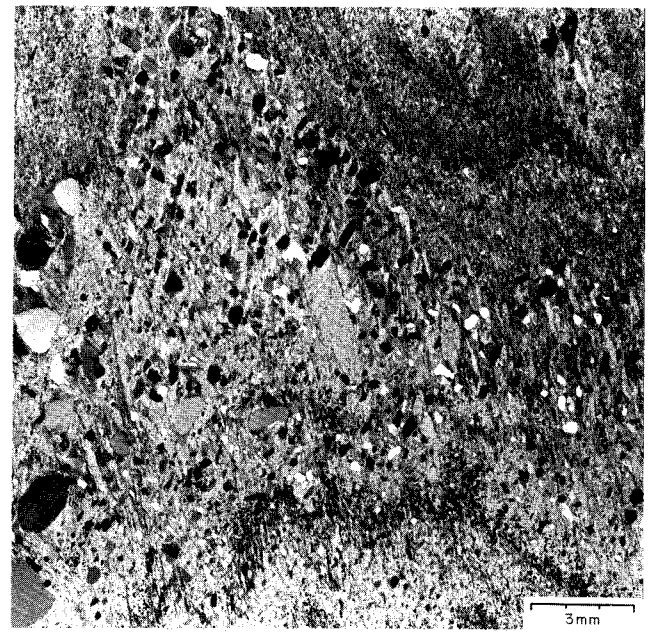

Figure 29. Photomicrograph of Catoctin siltstone-phyllite (rhythmite) (R-6508) showing axial-plane foliation (parallel to elongated rock fragments) cut by younger muscovite foliation (near vertical); note magnetite at base of graded sequence (subhorizontal).

in the north-central part of the Sherando quadrangle where it forms an outcrop belt 500 to 700 feet (152 to 213 m) wide. This belt can be traced southwestward for about 2 miles (3 km) to where the rhythmite gradually becomes interbedded with meta-arkose. This belt also can be traced northward into the Waynesboro West quadrangle for a short distance where it likewise grades into arkosic metasandstone. This purple-spotted, silvery-gray or greenish-gray, fine-grained phyllite consists of a very thick (folded?) sequence of graded beds, each of which range from 1.0 to 10.0 cm (0.4 to 4.0 inches) in thickness. The laminae within the graded sequence range from 1 to 5 mm in thickness and in thin section (Figure 29) are defined by layers alternatingly rich then poor in detrital heavy minerals. Each sequence of laminae becomes gradually finer grained upward in the section. Quartz and orthoclase pebble-conglomeratic lenses with pebble ellipsoids up to 1.0 cm (0.4 inch) long locally form the basal layer of an individual graded sequence. Only one possible ice-rafted pebble was found in rhythmite in and near the Sherando quadrangle and no tillite was found. The absence of tillite and ice-rafted pebbles suggests that the rhythmite is not of glacial origin, and thus it is unlike similar-appearing rhythmite in the Mount Rogers Formation that does contain ice-rafted pebbles, cobbles, and boulders and is associated with tillite in southwestern Virginia (Rankin, 1967, p. 12). The rhythmite in the Sherando quadrangle probably is of either lacustrine or marine origin, which suggests that

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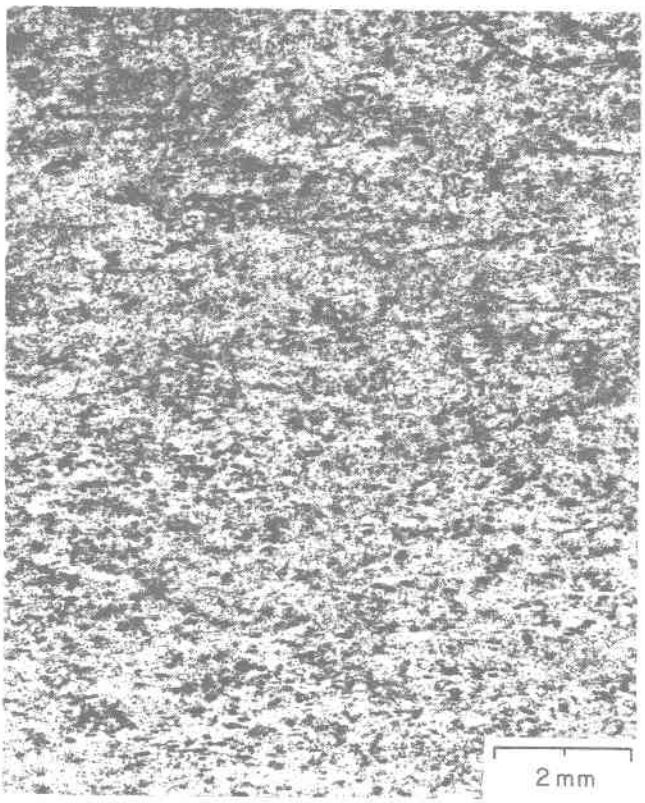

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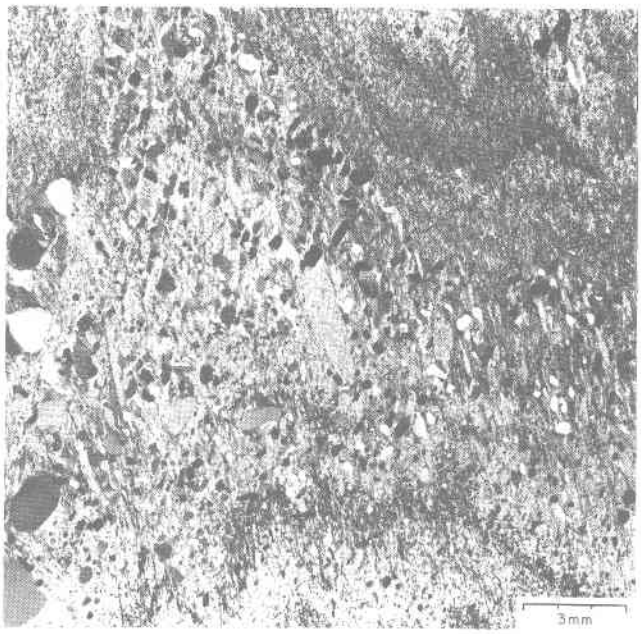

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the basal portion of some Catoctin flows in this area occurred as subaqueous flows. This is consistent with the lack of metabasalt detritus in interlayered metasediments.

Meta-arkose and arkosic metasandstone: Numerous arkosic metasandstone beds (R-6509) and in the upper part of the volcanic sequence meta-arkose (R-6510) beds are interlayered with metabasalt flows and tuff-phyllite. Thickness of most beds ranges from about 25 to 100 feet (8 to 31 m). Bedding within the finer-grained, light-tan to pinkish-brown, somewhat conglomeratic, arkosic metasandstones ranges from 2 inches (5 cm) to about 3 feet (1 m). Internally, individual beds are either massive or cross-bedded. Cross-bedding suggests that major directions of sediment transport in early Catoctin time were from the southeast and to a lesser extent the northwest; in late Catoctin time transport was mainly northeast-southwest. Grain size of detrital material is 1 to 5 mm with some quartz pebbles up to 2.5 cm. Quartz and feldspar form the bulk of the clastic detritus. Heavy minerals include zircon, garnet, and magnetite. Most matrix material is altered to epidote, sericite, and microcrystalline quartz.

Very coarse, conglomeratic meta-arkose is present along the western foothills of the Blue Ridge from Toms Branch (Plate 2) southwestward to where State Road 814 intersects the quadrangle boundary. These meta-arkoses are pinkish-tan to greenish-pink, poorly sorted conglomerate in massive beds generally 1.0 to 3.0 feet (0.3 to 0.9 m) thick. Coarse detrital grains that range in size from 5 to 20 mm consist almost exclusively of subangular to rounded, pink grains of feldspar, which were identified by X-ray analysis as maximum microcline. The finer grained detrital part of the matrix consists of poorly sorted, angular to rounded grains of feldspar and quartz.

CAMBRIAN SYSTEM

Weverton Formation

The basal rock unit of the Chilhowee Group, the Weverton Formation, underlies Pine Ridge in the north-central part of the Sherando quadrangle where it is in probable thrust contact with the underlying Catoctin Formation. Here, it is estimated to be about 500 feet (152 m) thick. Along Pine Ridge the medium- to greenish-brown quartzite and quartzose metasandstone can be traced southwestward for about 3 miles (5 km) to where they terminate in a possible fold nose. Beds of metasiltstone and pebble metaconglomerate are locally interlayered within the Weverton. Quartzite and metasandstone beds range from about 15 to 30 cm (6 to 12 inches) in thickness with a few beds up to 6 feet (2 m) thick. Foreset bedding is common.

The finer-grained detrital quartz is typically 2 to 3 mm in diameter. Pebbles in the metaconglomerate range from 5 to 20 mm long and are mainly subrounded grains of quartz with some subrounded rock fragments up to 25 mm in length. The metaconglomerate (R-6511) is poorly sorted and consists of massive beds less than 5.0 feet (1.5 m) thick. Sand-size material consists of poorly sorted, subangular grains of quartz, quartzite, and quartz-sericite-chlorite schist. Matrix material consists of sericite and fine-grained epidote and has a preferred orientation parallel to the visible foliation. In many places secondary hematite has replaced part of the matrix. Magnetite and zircon are the principal heavy minerals.

Harpers Formation

The Harpers Formation has been subdivided into lower, middle, and upper members. The middle member is substantially finer-grained than the upper and lower members, and the upper member contains white quartzite beds near its gradational contact with the overlying Antietam Formation. The contact with the underlying Weverton Formation is both laterally and vertically gradational. Contacts between the three members are gradational over distances of a few feet.

Lower member: This member consists primarily of dark greenish gray metasiltstone beds and interbedded ferruginous metasandstone and quartzite. Its thickness is estimated to be about 1,000 feet (305 m) in the Pine Ridge area and about 2,000 feet (610 m) along State Road 814 where the Weverton is absent and the lower member rests (disconformably?) directly on top of the Catoctin Formation. The metasiltstone typically consists of larger (3 to 5 mm), floating, detrital quartz grains in a finer grained (less than 2 mm) matrix of detrital quartz, sericite, and heavy minerals. The latter are mostly ilmenite, magnetite, apatite, zircon, and tourmaline. The metasandstone and quartzite are mostly coarser grained (2 to 3 mm), poorly sorted, subangular to subrounded detrital quartz and quartzite rock fragments. In the ferruginous beds most or all of the former metamorphic matrix minerals have been replaced by secondary hematite (R-6512).

Middle member: This member occurs in a generally overturned southwestward-trending belt that narrows to the southwest in the north-central part of the Sherando quadrangle and in the core of a syncline located near the junction of the North and South forks of Back Creek. It is typically poorly exposed except along roads and some stream beds. The thickness is estimated at about 1,500 feet (457 m). Its variable outcrop belt is inferred to be indicative of extensive internal folding and faulting. The member consists of interbedded mudstone and siltstone-phyllite with a well-

developed southeastward-dipping cleavage. Bedding is 3 to 15 mm thick, although a few thin siltstone-phyllite beds up to about 15 cm in thickness occur locally. Fresh samples are bluish-gray, whereas weathered specimens are usually greenish-gray or tan.

In thin section the middle member mudstone-phyllite (R-6513) is a very fine-grained laminated rock in which the laminae are about 2 mm thick and consist of alternating bands of two slightly different rocks: coarser grained siltstone layers consisting mainly of quartz with lesser sericite and finer-grained layers of about equal amounts of quartz and sericite. A well-developed orientation parallel to the visible foliation is displayed in the sericite, whereas the quartz grains are randomly oriented and are typically subrounded. An X-ray pattern showed the mudstone-phyllite to consist of quartz, muscovite, and penninite.

Upper member: Exposed only in a series of folds in the north-central part of the Sherando quadrangle, this member is very similar to the lower member and consists mainly of interbedded metasiltstone and ferruginous metasandstone. The upper member differs from the lower member in that it is less metamorphosed and typically does not have a visible foliation developed. In addition, white quartzite beds occur in the upper part of the member similar in appearance to and near its gradational contact with the overlying Antietam Formation. The thickness of this member is estimated to be 1,000 feet (305 m).

Antietam Formation

The formation is exposed in and east of Back Creek in the north-central part of the Sherando quadrangle and also underlies Torry Ridge and the two hills north of the ridge in the west-central part. In addition, it has been reported to occur in the subsurface near Lyndhurst mine and the Mount Torry tract (Knechtel, 1943). No complete stratigraphic section of Antietam was observed in the Sherando quadrangle, but in the adjacent Vesuvius 15-minute quadrangle Werner (1966, p. 25) estimates its thickness at about 600 feet (183 m).

The formation is typically light-gray, tan, pink, or rust-colored, weathered quartzite (R-6514) and quartzose sandstone. On a fresh surface the rock is light-gray. Bedding ranges from 1 to 5 feet (30 to 152 cm) in thickness, and within the beds the rock appears massive. Grain size is less than 2 mm in diameter. Variations from the typical quartzite include conglomeratic beds on the top of Torry Ridge which contain quartz-pebble ellipsoids with axes 5 x 5 x 15 mm. Interbedded mudstone and siltstone are present in beds up to 15 cm (6 inches) thick north of Mill Creek. In thin section the quartzite is almost entirely detrital quartz and quartzite clasts in a silica cement. Minor to trace amounts of feldspar, muscovite, and heavy minerals are also present.

Tectonic or collapse breccia of Antietam quartzite is present in the bed of Back Creek at Sherando (Plate 2). It is also reported by Knechtel (1943) to occur in the subsurface near Lyndhurst mine and the Mount Torry tract. In exposures along Back Creek, bedding is somewhat preserved by crude alignment of bedded breccia fragments in zones interlayered with chaotic breccia fragments. Breccia fragments range in size up to several feet (meters).

Skolithos tubes are common in Antietam quartzites exposed along State Road 664 just north of Mount Torry furnace. They also are found in exposures along the North Fork of Back Creek approximately 1,000 feet (305 m) east of the Sherando quadrangle boundary. An examination of *Skolithos* tubes in thin section revealed that they differ from the surrounding quartzite in that hematite forms part of the cementing material, and that they commonly are filled with a slightly coarser size of quartz grain.

Shady Formation

The Shady Formation is not exposed in the Greenfield or Sherando quadrangles, but previous workers (Stose and others, 1919; Knechtel, 1943) note its presence in the subsurface near Sherando (Plate 2). Stose and others (1919, p. 101) state that a dolomite (their Tomstown) was found in the bottom of a shaft of unknown depth in Orebank Hollow. They describe the rock as dense, light-gray dolomite containing small pyrite cubes. Knechtel (1943, p. 184) in a reference believed to be to the same shaft, reports the depth to be less than 15 feet (5 m), and he also states that dolomite was encountered in 3 out of 10 deeper exploratory holes drilled in the same general area in 1941-42. He (1943, his plates 29 and 30) identifies this dolomite, which was encountered at depths greater than 45 feet (14 m), as Shady (his Tomstown). Knechtel (1943, p. 183) also reports that 1 of the 12 exploratory holes drilled near the abandoned Lyndhurst mine in 1942 bottomed in fresh dolomite that he (his plate 29) identified as Shady (his Tomstown). The writer found some massive, light-gray, oolitic dolomite float in the Mount Torry tract that is probably Shady dolomite.

Waynesboro Formation

The Waynesboro Formation is known only from subsurface data in the Sherando quadrangle; Knechtel (1943) reports the only known occurrence of the formation within the quadrangle. He (p. 183) states that near the old Lyndhurst mine, 11 out of 12 exploratory drill holes bottomed in Waynesboro shale at depths as much as 167 feet (51 m) (see his Figure 16, p. 182 and his Plate

29 for drill-hole locations). Exposures of the Waynesboro Formation are found along streams in the Waynesboro West 7.5-minute quadrangle adjacent to the northwestern corner of the Sherando quadrangle, suggesting that the formation probably occurs extensively in the subsurface beneath the unconsolidated Quaternary deposits.

CATACLASTIC ROCKS

A zone of cataclastic rocks (Bartholomew, 1976) underlies the 1- to 2-mile- (2- to 3-km-) wide valley along State Highway 151 and the South Fork of the Rockfish River. The zone extends from the southern part of the Sherando quadrangle northeastward to the center of the Greenfield quadrangle, thence northward along State Highway 151 and the North Fork of Rockfish River to Onan, where it abruptly widens to about 6 miles (10 km). The interlayered mylonitic gneiss and schist within this zone are mapped as a single unit because the poor exposure, amount of weathering, and degree of mylonitization generally prevents subdividing these rocks into separate units based on the parent material. Near Onan, a mile-long mass of fairly recognizable Lovingston granitic gneiss has been mapped within the zone. In general, most of the cataclastic rocks appear to have been derived from gneiss of the Lovingston massif to the east rather than from that of the Pedlar massif to the west. The western edge of the zone is marked by the Rockfish Valley fault along which the Lovingston massif has been thrust westward over the Pedlar massif.

These cataclastic rocks are in scattered saprolitic outcrops beneath Quaternary terrace deposits along streams and in roadcuts, and they usually consist of highly weathered muscovite-biotite schist. In fresher, more extensive exposures of saprolite in roadcuts along State Highway 151, the rock consists of alternating layers of micaceous, quartzo-feldspathic mylonitic gneiss and micaceous mylonitic schist, which are 12 to 60 inches (30 to 152 cm) thick. Near the western, leading edge of the thrust zone, ductile deformation produced a dark greenish gray gneiss (R-6792) consisting of quartz and feldspar porphyroclasts in a matrix of microcrystalline quartz, muscovite, and sericite (Figure 30). Farther eastward narrow zones of light-gray blastomylonite (R-6793) are interlayered with the dominant rock type that consists of less intensely sheared, medium- to dark-gray mylonitic gneiss and schist (R-6794). The blastomylonite consists of microcrystalline quartz with a small amount of biotite and muscovite forming a prominent foliation (Figure 31). The Paleozoic metamorphic mineral assemblage of the mylonitic gneiss and schist is epidote, muscovite, chlorite, and biotite.

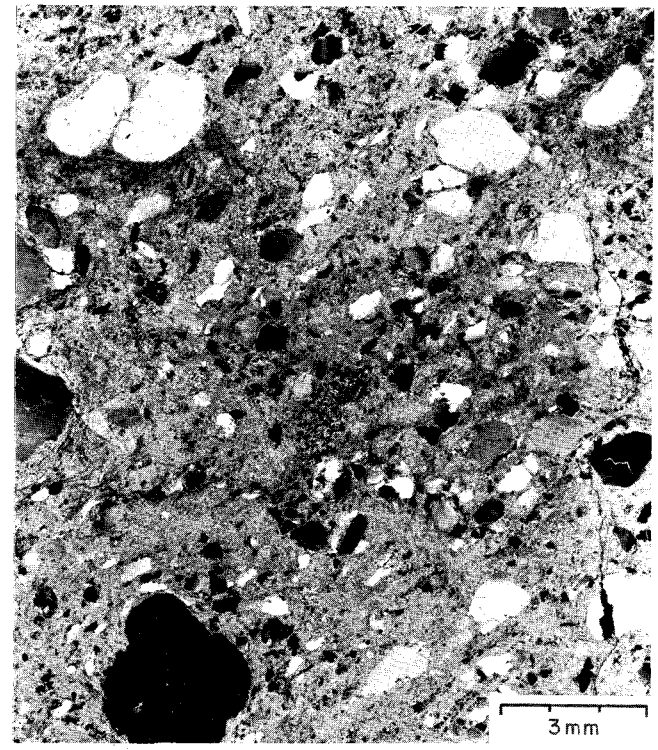

Figure 30. Photomicrograph of mylonitic schist (R-6792) from the cataclastic rocks that are exposed along the eastern flank of the Blue Ridge near Goodwin Creek in the northwestern part of the Greenfield quadrangle; quartz is the dominant type of porphyroclast floating in a matrix of chlorite, sericite, and microcrystalline quartz.

TRIASSIC SYSTEM

Diabase Dikes

A series of northward- and northwestward-trending diabase dikes occur in a 3- to 4-mile (5- to 6-km) wide zone that longitudinally crosses the center of the Greenfield quadrangle. In addition, one diabase intrusion (R-6515) was found near Wintergreen in the Sherando quadrangle and another near the Blue Ridge Parkway (Road Log mile 73.05); the latter was observed during a field check subsequent to preparation of the geologic map, and therefore is not shown on Plate 2. Most of the dikes are mapped on the basis of float, hence the thickness is probably exaggerated; however, in at least four localities (Plate 1) float and outcrops show that dikes may locally be as much as 100 to 400 feet (30 to 122 m) wide. Attitudes of dike contacts generally have a strike due north to N. 15°W. and are vertical or have a steep easterly dip. The dike near Wintergreen (Plate 2) has a strike about N. 30°W. and is nearly vertical. Dikes (R-6515), commonly medium- to coarse-grained, black diabase, weather into orangish-brown blocks. The rock is typically composed of zoned plagioclase (An_{64} to An_{33}), olivine, pyroxene (pigeonite), and magnetite.

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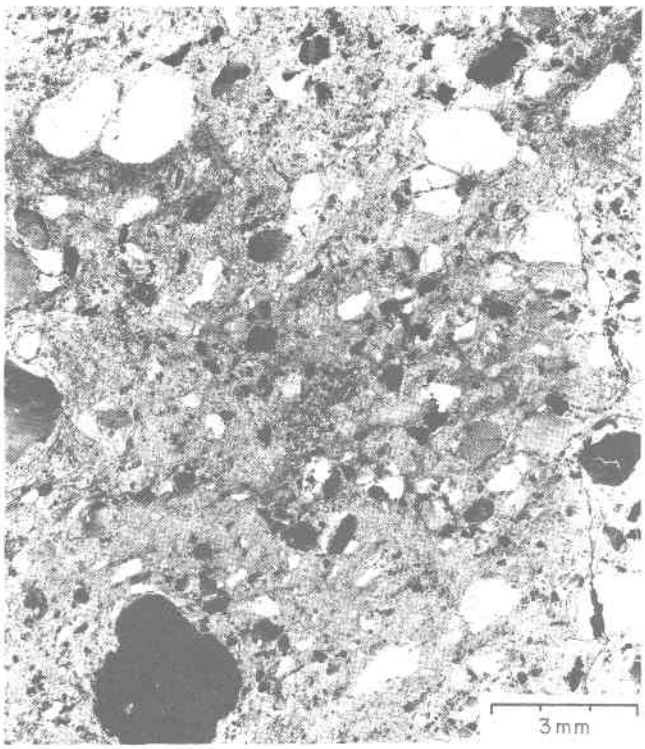

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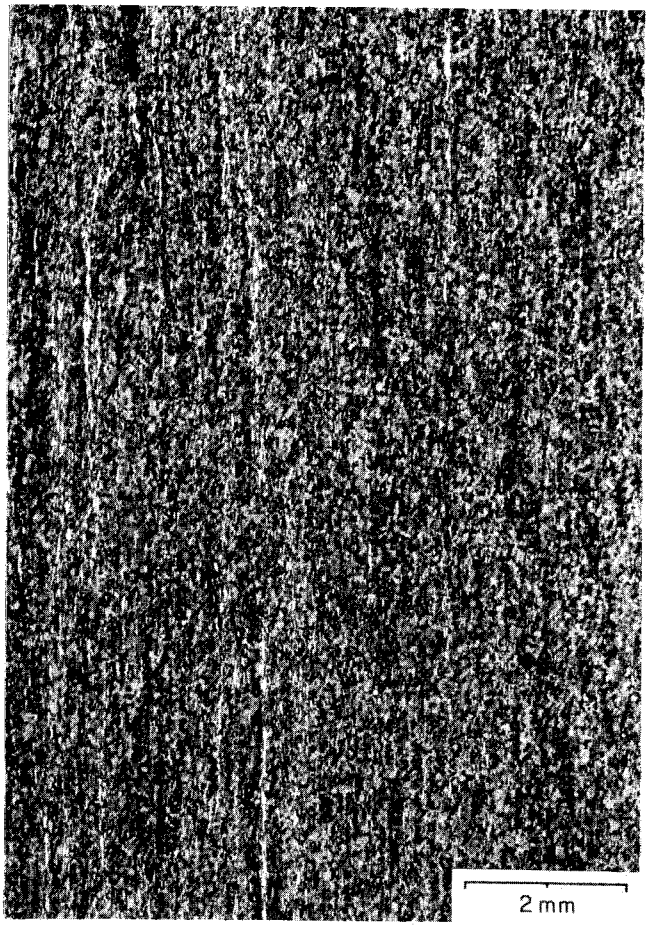


Figure 31. Photomicrograph of a blastomylonite layer (R-6793) within interlayered mylonitic gneiss and schist from the cataclastic rocks; subparallel biotite and muscovite foliations are vertical.

QUATERNARY SYSTEM

Terrace Deposits

Extensive terrace deposits are found in Rockfish Valley (Plates 1, 2) and in Sherando valley west of Back Creek (Plate 2). In Sherando valley the younger alluvium was not differentiated from terrace deposits; the valley is covered by poorly sorted quartzite cobbles and boulders in a brown to reddish-brown, poorly sorted, loosely compacted matrix of sand, silt, and clay. Knechtel (1943) shows that the depth of unconsolidated material ranges from 15 to 150 feet (5 to 46 m) near the abandoned Lyndhurst and Mount Torry tract mines. This broad plain, covered with terrace material, is part of a bajada that extends west-southwestward from Sherando for about 15 miles (24 km) along the foot of the Blue Ridge to the vicinity of Vesuvius (Werner, 1966, his Plate 1). In the vicinity of the Lyndhurst mine east of Back Creek several small dissected terrace deposits are also present. These deposits probably developed contemporaneously with the bajada and differ only in that a large portion of the detritus was of local origin derived from the mountains to the west.

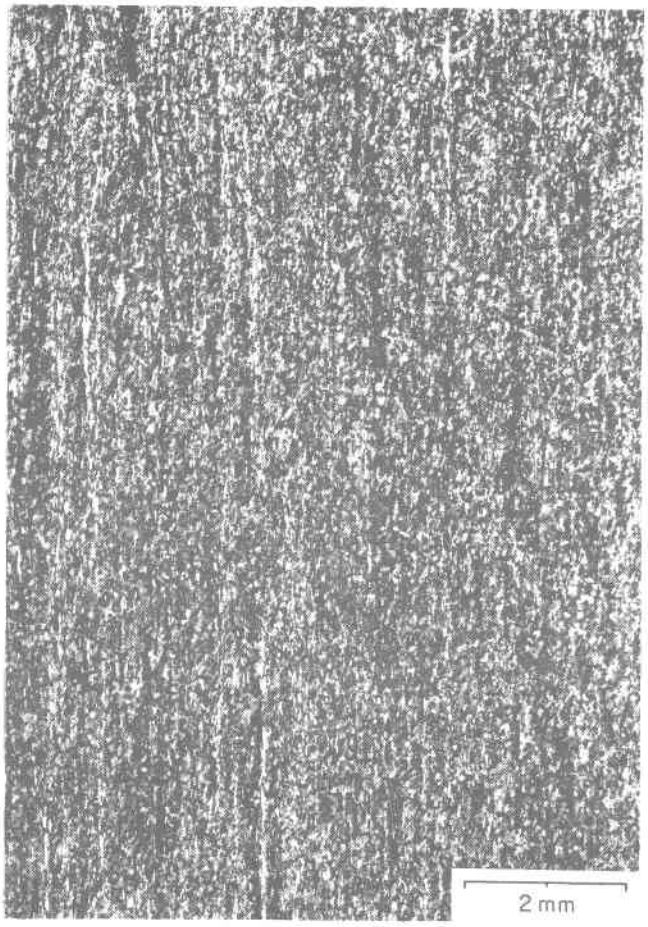
In Rockfish Valley a well-dissected bajada is also present at elevations from 10 to 40 feet (3 to 12 m) above the present drainage. This feature consists mainly of confluent alluvial fans that were formed by the formerly eastward-draining Stony, Little Stony, and Spruce creeks. Allen Creek and other nearby small creeks are abandoned channels cut into the bajada by Stony and Little Stony creeks when they formerly drained eastward. The bajada extends as far north as Meriwether Creek, and a similar dissected *alluvial* slope is found along and north of Goodwin Creek. Detrital material on the bajada reflects the local derivation of detritus. Pebbles, cobbles, and boulders of quartz, granite, gneiss, and greenstone dominate the clasts in a brown to reddish-brown matrix of sand, silt, and clay. Except locally the thickness of these terrace deposits seldom exceeds 10 feet (3 m).

Alluvium

Alluvium includes flood-plain and mountain-stream deposits. Flood-plain deposits are present along Rockfish River, Back Creek, and the lower parts of most of their tributaries. They generally consists of light- to medium-brown, pebbly or gravelly sand and silt and locally contain cobbles and boulders. Flood-plain detritus similar to terrace deposits reflects the local origin of the material. Mountain-stream deposits are present along all high-gradient perennial and intermittent streams in both quadrangles. These deposits consist of loosely piled boulders and cobbles with lesser amounts of pebbles, sand, silt, and clay of local origin. Debris-avalanches are believed to be the principal transporting mechanism for much of the material in mountain stream deposits.

Landslide Areas

In 1969 extensive debris-avalanches, landslides, and flooding in the Tye and Rockfish river basins caused extensive material damage and loss of human life. In the 1969 catastrophe most damage was attributed to a torrential rainfall (numerous accounts report more than 27 inches in less than 8 hours during the night of August 19-20) that accompanied Hurricane Camille during its east-northeastward movement across Virginia. The Sherando and Greenfield quardangles are on the northern fringe of the severely devastated region (Virginia Division of Mineral Resources, 1969; Webb, Nunan, and Penley, 1970), and as such they were not as seriously affected as regions to the south. Within the Sherando quadrangle, numerous small landslides occurred, primarily along roadcuts and other steep



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slopes in the Rockfish Valley, along the Blue Ridge Parkway, and along many jeep trails and stream valleys in the mountains in the southern half of the quadrangle. Within the more devastated region to the east debris-avalanche chutes were developed in the southeastern part of the Greenfield quadrangle in soil and saprolite of the Lovingston Formation and layered granulite gneiss in about 100 steep ravines (Plate 1). By contrast, only 13 debris-avalanche chutes were formed in the southern part of the Sherando quadrangle (Plate 2). Seven of these chutes were developed in soil and saprolite of Pedlar charnockite (Figure 17 and road log cumulative miles 61.4). Five chutes (road log cumulative miles 54.70) and one landslide were formed in saprolite of the Catoctin and Swift Run metasediments, and one in saprolite of granulite gneiss. Unique chutes developed on the Swift Run and Catoctin metasediments. In all six chutes in these rocks the slide material detached along southeastward-dipping foliation surfaces, which in three instances were subparallel to dip-slope bedding. In most cases, the metasedimentary saprolite transmitted ground water beneath unweathered or slightly weathered greenstone causing the detachment of a large mass of material consisting mainly of greenstone blocks with or without blocks of fresher metasedimentary material. The potential for this kind of detachment is great on all steep, southeastward-dipping slopes underlain by the Catoctin and Swift Run formations.

METAMORPHISM

Two distinct, contrasting periods of metamorphism are easily recognizable in the Precambrian rocks of the Blue Ridge core whereas only one period of metamorphism affected the upper Precambrian(?) and overlying lower Paleozoic rocks. The earlier period is generally correlated with metamorphism of the Grenville province of Canada, and it is therefore commonly referred to as "Grenville metamorphism" (Espenshade, 1970; King, 1970; Rodgers, 1972). In the Blue Ridge of Virginia, Grenville metamorphism is characterized by widespread massive charnockite associated with layered granulite gneiss. The younger period of polyphase Paleozoic metamorphism, however, only reached lower-greenschist to lower-amphibolite facies in this region.

PRECAMBRIAN (GRENVILLE) METAMORPHISM

Grenville metamorphism in this part of Virginia was characterized by prograde metamorphism of quartzo-feldspathic rocks to the granulite facies, more or less coincident with emplacement of extensive biotite-bearing granitic and charnockitic plutons. As a result of Paleozoic thrusting, rocks of the eastern (Lovingston) massif were thrust over rocks of the western (Pedlar) massif. Thus, within the confines of the Sherando and Greenfield quadrangles some differences in metamorphism exist between rocks on opposing sides of the zone of cataclastic rocks that now separates the two massifs. The massive, biotite-bearing granitic gneiss (Lovingston Formation) of the Lovingston massif is cut by only a few small intrusions of massive charnockite, whereas the Pedlar massif is primarily massive charnockite with no biotite granitic gneiss. Thus, the Lovingston massif probably represents a higher crustal level than the Pedlar massif.

In general, the layered granulite-gneiss of the Pedlar massif is evidence for a slightly deeper crustal level (higher grade) of metamorphism than that of the Lovingston massif for the following reasons: (1) segregation layering is better developed in gneiss of the Pedlar massif (Figures 2, 6); (2) contacts between individual layers and rock types are much sharper and better defined (Figures 2, 5, 16); (3) anatexis of the Cooks Hollow dome appears to have progressed farther than that of the Pilot Mountain and Ennis Mountain roof pendants, and (4) garnet, indicative of higher pressure (Saxena, 1968), is widespread throughout the western massif (Plates 1, 2), but it is generally lacking in the eastern massif except for a few scattered outcrops in rocks within and near the cataclastic zone (R-6496). Grenville mineral assemblages are shown in Table 3.

PALEOZOIC METAMORPHISM

All rocks southeast of the Back Creek fault were regionally metamorphosed progressively from lower-greenschist facies on the west (Sherando quadrangle) to upper-greenschist and lower-amphibolite facies on the east (Greenfield quadrangle). Extensive cataclasis and thrusting of the Lovingston massif over the Pedlar massif along the Rockfish Valley fault took place more or less concurrent with polyphase Paleozoic metamorphism that produced the prominent northeastward-trending axial-plane foliation in the folded Catoctin and younger rocks (Figure 23) and the northeastward-trending blastomylonitic fluxion structure in the cataclastic rocks and Lovingston mylonitic gneiss. Fullagar and Dietrich (1976, p. 358-359) place a Rb-Sr age of 520-583 million years on this period of metamorphism.

Continued metamorphism produced lower oxidation state assemblages, indicative of a slight increase in metamorphic grade, more or less coincident with the formation of a secondary crinkle foliation in the Catoctin metavolcanics. The various metamorphic mineral assemblages are shown in Tables 4 and 5. The

Table 3.—Grenville mineral assemblages recognized in rocks of the Lovingston and Pedlar massifs.

Massif	Rock Type		Perthitic feldspar	Plagioclase	Quartz	Clinopyroxene	Orthopyroxene	Garnet	Hornblende	Spinel	Biotite
Pedlar	Strongly layered granulite gneiss	(1)	X	X	X		X				
		(2)	X	X	X		X	X			
	Massive Pedlar charnockite	(1)	X	X	X		X	X			
		(2)	X		X		X		X		
	Concordantly layered granulite gneiss	(1)	X		X		X	X			
		(2)	X	X	X		X				
	Pyroxenite or mafic granulite(?) dike+	(1)				X	X			X	
		(2)		X		X	X				
Lovingston	Poorly layered granulite gneiss	(1)	X	X			X				
		(2)	X	X	X		X		X		
	Migmatitic granulite gneiss	(1)	X	X	X		X				
	Lovingston Formation and cataclastic rocks	(1)	X	X	X		X	X			X
		(2)		X	X			X			X
	Massive charnockite	(1)	X	X	X		X				

X Present in samples.

(1) Numbers indicate the number of stable mineral assemblages recognized within a rock type.

+ This rock is probably a Grenville-age mafic-granulite dike.

Table 4.—Paleozoic metamorphic mineral assemblages recognized in the Lovingston and Pedlar massifs.

Massif	Rock Type		Quartz	Biotite	Muscovite	Stilphomelane(?)	Sphene	Chlorite	Actinolite	Hornblende	Epidote	Clinozoisite
Pedlar	Strongly layered granulite gneiss		X		X				X			
	Concordantly layered granulite gneiss		X			X			X		X	
	Pedlar charnockite		X	X	X	X		X	X		X	
	Mafic dikes		X					X	X		X	
Lovingston	Poorly layered granulite gneiss		X	X	X					X		X
	Migmatitic granulite gneiss		X		X				X		X	
	Massive charnockite		X		X				X		X	
	Lovingston massive gneiss		X	X			X					X
	Lovingston mylonitic gneiss		X	X	X		X					X
	Cataclastic rocks	*(1)	X		X			X			X	
		(2)	X	X	X							
		(3)	X	X	X		X					X
	Mafic dikes		X	X						X		X
	Catoctin metabasalt dikes		X						X		X	

X Present in samples.

* This assemblage is restricted to the area west of State Highway 151 in the northwest corner of the Greenfield quadrangle.

(1) Numbers indicate the number of stable mineral assemblages within a rock type.

Table 5.—Paleozoic metamorphic mineral assemblages recognized in the Swift Run, Catoctin, Weverton, Harpers, and Antietam formations.

Formation	Rock Type	Original Mineralogy		Quartz	Albite	Sericite	Epidote	Penninite	Magnetite	Hematite	Calcite	Fibrous actinolite	Biotite
Antietam	Quartzite	Quartz, minor matrix		X		X							
Harpers	Siltstone-phyllite	Quartz, clay matrix		X		X	X						
	Claystone-phyllite	Clay, minor quartz	(1)	X		X		X					
			(2)	X		X							X
Weverton	Metasandstone	Quartz, feldspar, clay matrix	(1)	X	X	X	X						
	Greenstone	Ca-feldspar, pyroxene, ± olivine	(1)	X	X		X	X	X				
			(2)	X	X			X	X		X		
			*(3)	X	X		X					X	
	Epidosite	Ca-feldspar, pyroxene, ± olivine		X	X		X			X			
Catoctin	Tuff-phyllite	Glass(?)		X		X			X				
	Arkosic metasandstone	Quartz, orthoclase, microcline, clay matrix	(1)	X		X	X	X					
			*(2)	X		X						X	
	Siltstone-phyllite	Orthoclase, ± quartz, clay matrix		X		X							
Swift Run	Metasandstone	Quartz, feldspars, silt/clay matrix	(1)	X		X	X	X					
			(2)	X		X	X						X

X Present in samples.

* Denotes higher grade assemblages.

(1) Numbers indicate the different stable mineral assemblages recognized within a rock type.

massive charnockite and granulite gneiss of the Pedlar massif typically have few megascopically observable effects of Paleozoic metamorphism; thus, they were probably "dry", whereas the overlying Catoctin volcanics and younger clastics were "wet" when metamorphosed. The megascopic effects in the charnockite rocks are generally limited to localized unakite, poorly defined chlorite-epidote foliations and veins, uralitization of pyroxene, and sericitization of feldspars. Within the Lovingston massif where the grade of Paleozoic metamorphism was higher retrograde alteration of the Grenville mineral assemblages is substantially more extensive.

STRUCTURE

Structures in the Sherando and Greenfield quadrangles can be grouped into three genetically and temporally distinct types: Precambrian structures associated with Grenville-age metamorphism and deformation, structures related to Paleozoic cataclasis and metamorphism, and postmetamorphic structures that generally trend obliquely to the structural trend of the Appalachian orogenic belt.

PRECAMBRIAN (GRENVILLE) STRUCTURES

Precambrian structures are limited to steeply dipping segregation layering in layered granulite gneiss (Figures 2, 5, 6, 9) and associated isoclinal flow folds with axial surfaces parallel to segregation layering (Figure 32). Larger scale folds with axial surfaces parallel to segregation layering are indicated by the outcrop patterns of rocks in the Pilot Mountain and Ennis Mountain roof pendants and the Cooks Hollow dome. Where Paleozoic folds are superimposed on the older Grenville-age folds interference patterns are common, such as the Ramsay type-3 (Ramsay, 1967, p.

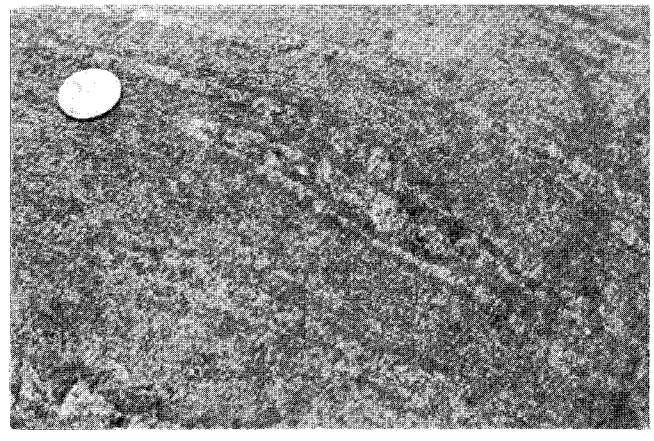

Figure 32. Isoclinal fold in strongly layered granulite gneiss (R-6494); near-vertical segregation layering has a strike to the northeast; fold axes at this exposure have a steep plunge to the southwest. (Photograph by J. J. Gryta.)

Table 5.—Paleozoic metamorphic mineral assemblages recognized in the Swift Run, Catoctin, Weverton, Harpers, and Antietam formations.

Formation	Rock Type	Original Mineralogy		Quartz	Albite	Sericite	Epidote	Penninite	Magnetite	Hematite	Calcite	Fibrous actinolite	Biotite
Antietam	Quartzite	Quartz, minor matrix		X		X							
Harpers	Siltstone-phyllite	Quartz, clay matrix		X		X	X						
	Claystone-phyllite	Clay, minor quartz	(1)	X		X		X					
			(2)	X		X							X
Weverton	Metasandstone	Quartz, feldspar, clay matrix	(1)	X	X	X	X						
	Greenstone	Ca-feldspar, pyroxene, ± olivine	(1)	X	X		X	X	X				
			(2)	X	X			X	X		X		
			*(3)	X	X		X					X	
	Epidosite	Ca-feldspar, pyroxene, ± olivine		X	X		X			X			
Catoctin	Tuff-phyllite	Glass(?)		X		X			X				
	Arkosic metasandstone	Quartz, orthoclase, microcline, clay matrix	(1)	X		X	X	X					
			*(2)	X		X						X	
	Siltstone-phyllite	Orthoclase, ± quartz, clay matrix		X		X							
Swift Run	Metasandstone	Quartz, feldspars, silt/clay matrix	(1)	X		X	X	X					
			(2)	X		X	X						X

X Present in samples.

* Denotes higher grade assemblages.

(1) Numbers indicate the different stable mineral assemblages recognized within a rock type.

massive charnockite and granulite gneiss of the Pedlar massif typically have few megascopically observable effects of Paleozoic metamorphism; thus, they were probably "dry", whereas the overlying Catoctin volcanics and younger clastics were "wet" when metamorphosed. The megascopic effects in the charnockite rocks are generally limited to localized unakite, poorly defined chlorite-epidote foliations and veins, uralitization of pyroxene, and sericitization of feldspars. Within the Lovingston massif where the grade of Paleozoic metamorphism was higher retrograde alteration of the Grenville mineral assemblages is substantially more extensive.

STRUCTURE

Structures in the Sherando and Greenfield quadrangles can be grouped into three genetically and temporally distinct types: Precambrian structures associated with Grenville-age metamorphism and deformation, structures related to Paleozoic cataclasis and metamorphism, and postmetamorphic structures that generally trend obliquely to the structural trend of the Appalachian orogenic belt.

PRECAMBRIAN (GRENVILLE) STRUCTURES

Precambrian structures are limited to steeply dipping segregation layering in layered granulite gneiss (Figures 2, 5, 6, 9) and associated isoclinal flow folds with axial surfaces parallel to segregation layering (Figure 32). Larger scale folds with axial surfaces parallel to segregation layering are indicated by the outcrop patterns of rocks in the Pilot Mountain and Ennis Mountain roof pendants and the Cooks Hollow dome. Where Paleozoic folds are superimposed on the older Grenville-age folds interference patterns are common, such as the Ramsay type-3 (Ramsay, 1967, p.

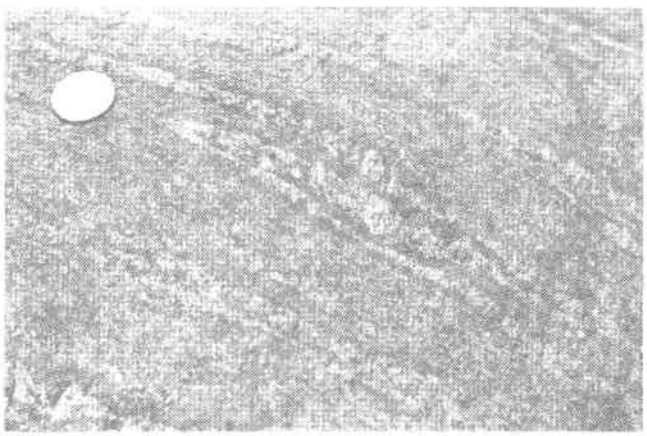

Figure 32. Isoclinal fold in strongly layered granulite gneiss (R-6494); near-vertical segregation layering has a strike to the northeast; fold axes at this exposure have a steep plunge to the southwest. (Photograph by J. J. Gryta.)

Figure 33. Paleozoic folding superimposed on segregation layering in strongly layered granulite gneiss (R-6778) at stop 8, road log cumulative miles 27.6; segregation layering has a strike to the east and younger southwestward-plunging chevron folds have refolded a few older isoclinal folds (Figure 32) to form Ramsay type 3 interference patterns. (Photograph by T. M. Gathright II.)

531, figures 10-13, form I) in granulite gneiss in Blundell Hollow (Figure 33).

PALEOZOIC STRUCTURES

Polyphase Paleozoic tectonism is divided into several periods. The first is characterized by cataclasis, thrusting along the Rockfish Valley fault, and the formation of axial-plane foliation. Later episodes are characterized by less intense folding followed by younger Paleozoic thrusting. South and east of the Back Creek thrust fault in the Sherando quadrangle the earlier phase of folding produced overturned to recumbent folds (Figure 23) whose axial surfaces have a dip of 10° to 45° SE. These are the dominant fold types in the Blue Ridge (Plate 2). The axial-plane foliation typically has a trend about N. 40° to 50° E. In two areas within the Sherando quadrangle such folds are well outlined by marker beds in the Catoctin Formation as well as by other formational contacts: (1) north of State Road 664 between the Back Creek thrust fault and the thrust fault adjacent to the Blue Ridge Parkway and (2) northward from the thrust fault in Rockfish Valley to Little Stony Creek and Crawford Knob. North and west of the Back Creek thrust fault in the Torry Mountain region this first phase of deformation may be represented by northeastward-trending, broad, open fold forms in the Antietam Formation, which have vertical to steeply southeastward-dipping axial surfaces.

In the Greenfield quadrangle (Plate 1) bent first-phase folds are exposed in rocks along Pauls and Goodwin creeks where they are outlined by Catoctin marker beds. These folds formed essentially contemporaneously with lower-greenschist facies metamorphism of the Catoctin volcanics and extensive cataclasis associated with the thrusting of the Lovingston massif over the Pedlar massif. Large- and small-scale northeastward-trending folds in the southeast corner of the Greenfield quadrangle also may have formed during this first phase. These folds are characterized, however, by nearly vertical axial-plane foliation, which may denote a later period of deformation.

Additional evidence of a second phase of Paleozoic folding is shown by isoclinal folds that fold fluxion-structure developed in cataclastic rocks during the first phase (Figure 34). Likewise, in the Spruce Creek (Plate 2) and Ennis Mountain (Plate 1) areas a second foliation extends across the older foliation (R-6798). This younger foliation is characterized by a northeasterly trend and development of greenschist-facies minerals (Figure 35). A few scattered, small-scale, northward-trending folds, perhaps related to this younger foliation, are also found in the Greenfield quadrangle.

All thrust faults except the older Rockfish Valley fault generally have trends about N. 40° to 60° E. and probably at all places have dips to the southeast at angles of less than 45°. These thrust faults are younger than the main phase of Paleozoic thrusting (Rockfish Valley fault) and concomitant metamorphism and folding.

The anomalous, gently dipping to flat-lying nature of the strata from Humpback Mountain to Devils Knob is probably due to this area being part of the right-side-up limb of an anticlinal nappe. This limb is inferred to have been detached and to have overridden the inverted synclinal limb during the younger period of thrusting (Plate 2, cross sections A-A' and B-B'). The truncation of the nappe limb is marked by a 2-mile-(3-km-) wide zone containing five thrust faults. As this zone splays northeastward, several of the smaller thrust faults appear to die out and the nappe forms become better developed northward into the Waynesboro area. The western boundary of the zone is the Back Creek thrust fault which marks the tectonic margin of the Blue Ridge as far north as Sherando. Northward from Sherando this margin is marked by collapse breccia along the western edge of a collapsed antiformal nappe. The eastern boundary of the zone is marked by a northeastward-trending thrust fault adjacent and subparallel to the Blue Ridge Parkway from Meadow Mountain to Humpback Gap where the fault changes to an eastward trend. At the extreme eastern edge of the Sherando

Figure 33. Paleozoic folding superimposed on segregation layering in strongly layered granulite gneiss (R-6778) at stop 8, road log cumulative miles 27.6; segregation layering has a strike to the east and younger southwestward-plunging chevron folds have refolded a few older isoclinal folds (Figure 32) to form Ramsay type 3 interference patterns. (Photograph by T. M. Gathright II.)

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Figure 34. Fluxion structure folded about refolded recumbent fold exposed at stop 5, road log cumulative miles 19.5; fold axis has a moderate southeasterly plunge and the axial surface is folded about near-vertical, northwestward-striking axial surfaces at right edge of photograph (see also Figure 36). (Photograph by T. M. Gathright II.)

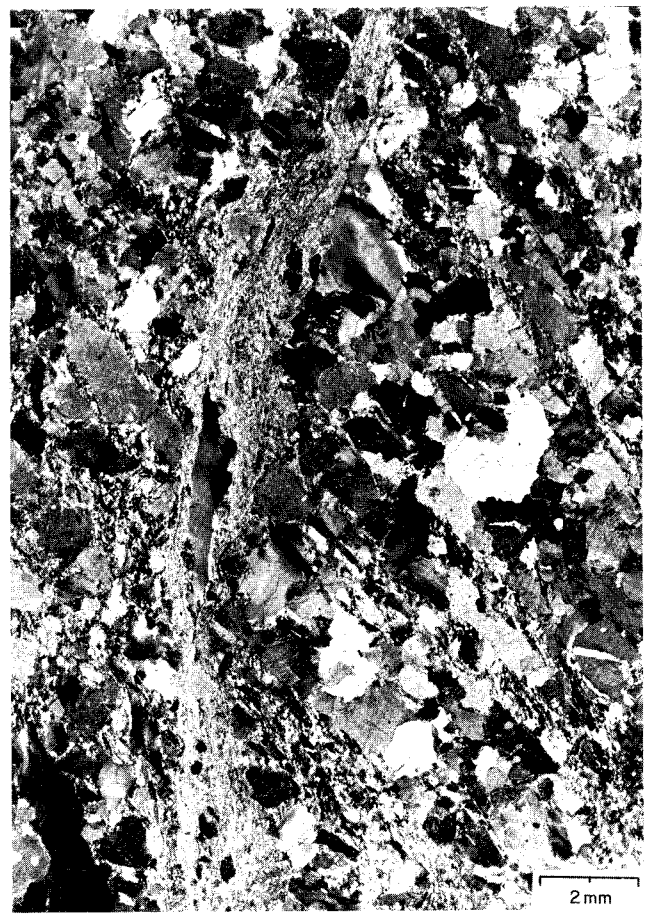

Figure 35. Photomicrograph of younger foliation extending across older fluxion structure in mylonitic gneiss (R-6798) exposed at road log cumulative miles 3.4; northeastward-trending chlorite foliation is vertical, and older northeastward-trending fluxion structure is diagonal.

quadrangle, this thrust fault appears to be terminated by a high-angle fault. The thrust fault could not be traced beyond the high-angle fault, but probably continues northeastward beneath the alluvium along Goodwin Creek into the subsurface within the cataclastic rocks (Plate 1, cross section A-A′).

Both boundary thrust faults of this multiple fault zone can be traced beyond the Sherando quadrangle into the Vesuvius 15-minute quadrangle to the southwest (Werner, 1966), and the Back Creek thrust fault may extend into the Waynesboro West quadrangle to the north. Minimum displacement on the zone within the Greenfield and Sherando quadrangles appears to be on the order of several miles. Two other major thrust faults are located in Rockfish Valley (near the older Rockfish Valley fault) beneath alluvium and terrace deposits in the southeastern part of the Sherando quadrangle. One extends northeastward across the Greenfield quadrangle into the Crozet 7.5-minute quadrangle and is bordered on the southeast by a 2-mile- (3-km-) wide zone of Lovingston mylonitic gneiss. The other is traceable only into the western part of the Greenfield quadrangle. The amount of displacement is unknown.

POSTMETAMORPHIC STRUCTURES

A postmetamorphic period of folding is shown by northwestward-trending fold axes that typically have a gentle plunge to the southeast. These folds are generally broader, open-type folds (Plate 1, cross section B-B′). In the Sherando quadrangle small folds of this type are found in the Harpers Formation in roadcuts along State Road 814. Also, between State Roads 814 and 664 an overturned, first-phase fold has been bent or warped about a northwesterly axis (Plate 2).

In the Greenfield quadrangle along State Road 636 near Onan northwestward-trending, southeastward-plunging folds (Figure 36) have refolded earlier isoclinal folds (Figure 34). Similarly, steeply dipping zones of cataclastic rocks (Figure 37) in the Pilot Mountain area have been folded about northwestward-trending axes. These folds in conjunction with the

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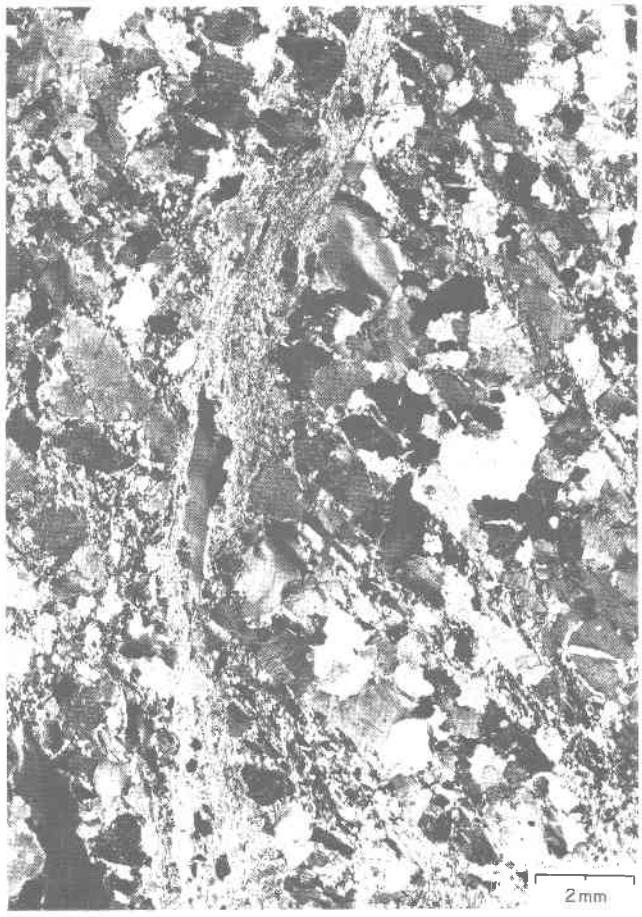

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quadrangle, this thrust fault appears to be terminated by a high-angle fault. The thrust fault could not be traced beyond the high-angle fault, but probably continues northeastward beneath the alluvium along Goodwin Creek into the subsurface within the cataclastic rocks (Plate 1, cross section A-A′).

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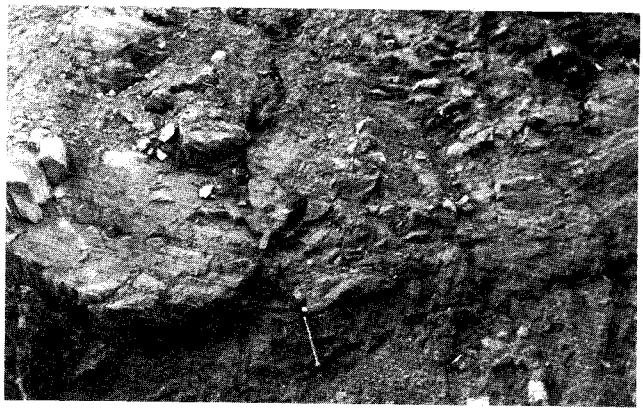


Figure 36. Southeastward-plunging fold in cataclastic rocks exposed at stop 5, road log cumulative miles 19.5; northwestward-trending axial surfaces are nearly vertical to overturned to the southwest; these folds have refolded earlier recumbent folds (Figure 34). (Photograph by T. M. Gathright II.)

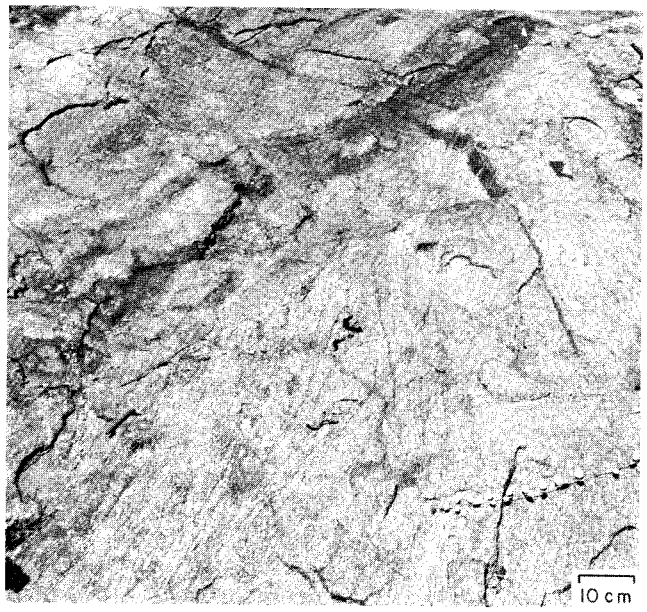


Figure 37 Northwestward-trending fold in steeply dipping mylonitic gneiss. Developed in steeply dipping shear zone within poorly layered granulite gneiss near sample location R-6797. (Photograph by T. M. Gathright II.)

broad warping that produced the Cooks Hollow dome bent the first-phase folds in the Pauls Creek and Goodwin Creek areas (Plate 1) and produced the Ramsay transitional-type interference outcrop pattern (Ramsey, 1967, p. 531, figures 10-13, form E) in the Pauls Creek and Big Levels areas (Plate 2), which probably formed after both later Paleozoic thrusts and younger, high-angle, northeastward-trending faults.

Two types of either late Paleozoic or post-Paleozoic faults which postdate thrusting are present in the quadrangles. The older of these are a series of nearly vertical to steeply southeastward-dipping faults that have a trend of N. 60° to 70° E., which is slightly oblique to the regional trend in this area. These faults had both horizontal and vertical components of movement as shown by slickensides on minor shear surfaces near some of the faults. Apparent vertical offsets along these faults appear contradictory; some show that the southeast side was downthrown, whereas there is evidence that others had the southeast side upthrown. In charnockitic rocks of the Blue Ridge core adjacent to these faults, extensive high-angle shear zones are developed. They are up to 200 feet (61 m) wide, and large amounts of calcite are present in rocks (R-6498) within them. Some of the better exposed shear zones are along Little Stony Creek; some are folded (Figure 37), suggesting that similar faults that have a trend of about N. 20° E. probably formed at the same time.

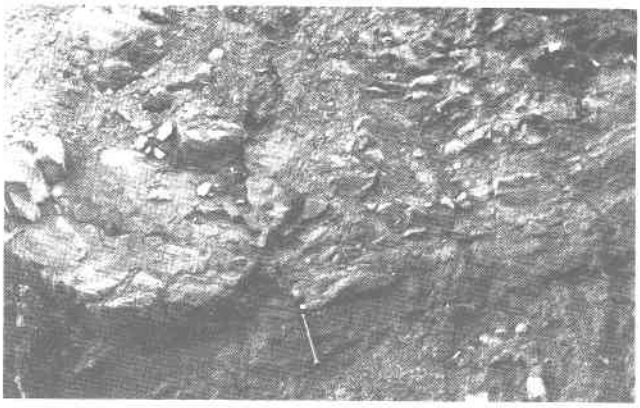
Subparallel to these faults is a well-developed joint set found primarily in Catoctin greenstone and to a lesser degree in the Pedlar Formation. The number and close spacing of high-angle faults is evidence that these subparallel, widely spaced joints may have resulted from the same stress system that caused the faults. The age of these high-angle faults and joints is unknown, but indirect evidence appears to support a late Paleozoic or early Mesozoic age. First, the relatively large offsets (several hundred to about 1,000 feet or 305 m) on each fault, extensive shearing in the adjacent granite, and possible contemporaneous joint development in greenstone suggest that the faults were formed during a major deformational period, none of which is known in the Appalachian Mountains after the Triassic. Secondly, these faults appear to be folded by northwestward-trending folds (Plate 1, cross section B-B′) that do not appear to affect Triassic dikes. Other high-angle, northeastward-dipping faults that have a trend of approximately N. 30 W. are also present in the Sherando and Greenfield quadrangles. These faults do not have extensive shear zones developed adjacent to them, and movement was probably less than several hundred feet. They are probably younger than the northeastward-trending, high-angle faults.

ECONOMIC GEOLOGY

There is no current commercial development of mineral resources in the Greenfield and Sherando quadrangles, but there may be potential for development of clay or sand and gravel in the northwestern part of the Sherando quadrangle or in the Rockfish Valley. Iron, manganese, and copper were commercially mined in the past.

CLAY, SAND, AND GRAVEL

Although no commercial operations are active at the present time, clay, sand, and gravel deposits have



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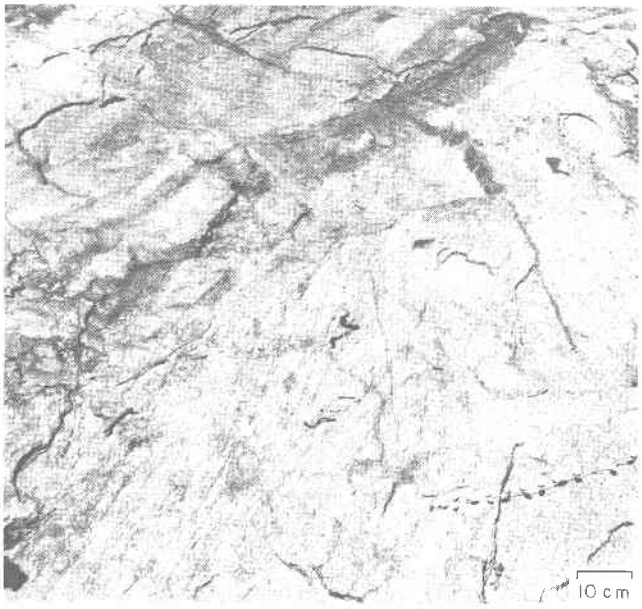

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CLAY, SAND, AND GRAVEL

Although no commercial operations are active at the present time, clay, sand, and gravel deposits have

been quarried in the adjacent Vesuvius 15-minute quadrangle (Werner, 1966). There, deposits have been found in the lateral continuation of the bajada in the northwestern portion of the Sherando quadrangle. Much of this land is currently part of a game reserve and, hence, commerical development is unlikely in the near future. The wide alluvium-filled portion of Rockfish Valley from Wintergreen to Nellysford is also a potential source of sand and gravel.

IRON AND MANGANESE

Iron and manganese were recovered in commercial quantities from two locations: the abandoned Lyndhurst mine and the abandoned mines of the Mount Torry tract (Plate 2). The operations at these mines are well summarized by Stose and others (1919, p. 99-102) and Knechtel (1943, p. 167, 181-187). In addition, a few shallow pits and trenches were excavated in the residuum that formed on the Antietam Formation east of Sherando. The date of this testing is unknown. Both iron and manganese oxides were found on slag piles adjacent to these test pits.

According to Knechtel (1943, p. 181-183) the Lynhurst mine operated intermittently from 1859 to the late 1800's. He indicates that 12 prospect holes drilled in 1942 were the last attempts to locate ore at this location.

According to Stose and others (1919, p. 101) the original "lower workings" of the Mount Torry tract were mined for iron ore in the early and middle 1800's. The ore was smelted at the historic Mount Torry furnace on the south side of Torry Ridge along Back Creek. Manganese was subsequently mined intermittently from the late 1800's to the early 1940's when the last prospect holes were drilled and the Tullidge cut was made (Knechtel, 1943, p. 186-187). Mine workings in the tract, which includes Turkeypen cut (Werner, 1966), consist of 8 open cuts, 1 large trench, and 2 small trenches and 8 shafts, 26 prospect pits, and 13 drill holes (Knechtel, 1943, his Plate 30).

COPPER

According to local tradition, copper was mined at the Allen mines from about 1885 to about 1905. These mine workings, which consist of several tunnels, are located on the steep eastern slope of Crawford Knob near the eastern edge of the Sherando quadrangle. Numerous test pits were also found here and in the adjacent portion of the Greenfield quadrangle. According to tradition the narrow tunnels were dug by hand into the mountain for a distance of about 100 feet (31 m). The ore was then transported to the valley by a shuttle car system that used the weight of a loaded car descending by gravity to pull an unloaded car back up to the mines. The ore was mined from the Catoctin Formation.

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GLOSSARY[1]

amygdule—A gas cavity or vesicle in an igneous rock that is filled with secondary minerals.

amygdaloidal—Said of rocks containing amygdules.

anatectic—Said of rock resulting from partial or complete melting of preexisting rock.

bajada—A broad, continuous alluvial surface adjacent to and extending from the base of a mountain range out into an inland basin, formed by lateral coalescence of a series of separate but confluent alluvial fans.

blastomylonite—Medium- to fine-grained, coherent cataclastic rock whose texture is the result of concurrent cataclasis and neomineralization.

cataclasis—Process by which rocks are broken and granulated due to stress and movement during faulting.

cataclastic—Said of rocks affected by cataclasis.

charnockite—A hypersthene-bearing granite commonly found only in granulite-facies terranes; high temperature and pressure thought to be essential for its formation.

debris-avalanche—The very rapid and usually sudden sliding and flowage of masses of initially incoherent, unsorted mixtures of soil and rock.

fluxion structure—A cataclastically produced, directed penetrative texture or structure commonly involving a family or set of s surfaces.

granitic gneiss—A massive gneiss with little megascopically visible signs of metamorphism and with preserved texture and mineralogy similar to granite.

granulite facies—Gneissic rocks formed by deep-seated regional, dynamothermal metamorphism at high temperatures and pressures.

granulite gneiss—A rock formed within granulite facies of metamorphism with granoblastic texture and crude segregation layering.

Grenville age—Time of Grenville orogeny, a major plutonic, metamorphic, and probably deformational event dated radiometrically as between 880 and 1,000 million years ago and affecting a large portion of southeastern Canada and adjacent New York and New England.

massif—A massive topographic and structural feature in an orogenic belt commonly formed of basement rocks consolidated during earlier orogenies.

metamorphism—Mineralogical and structural changes in solid rocks due to imposed physical and chemical conditions different from both those at the time of origin of the rock and at the earth's surface.

migmatite—A composite rock composed of igneous or igneous-appearing and/or metamorphic materials which are generally distinguishable megascopically.

mylonitic (augen) gneiss or schist—A medium- to coarse-grained coherent cataclastic rock whose texture is the result of concurrent cataclasis and neomineralization; augen structure is characteristic.

orogenesis—Literally, the process of formation of mountains.

poikiloblastic—Said of metamorphic texture due to development, during recrystallization, of a new mineral around numerous relicts of original minerals.

porphyroblast—A large crystal developed during metamorphism by neomineralization and or recrystallization.

porphyroclast—A large fragment of a grain in a cataclastic rock.

pyroxenite—An ultramafic plutonic rock chiefly composed of pyroxene.

rhythmite—An individual unit of rhythmic succession or of beds developed by rhythmic sedimentation.

roof pendant—A downward projection into an igneous intrusion of the country rock that forms its roof.

spilitic—Said of a group of extrusive balaltic rocks that characteristically have a high albite content.

tholeiitic—Said of a group of basalts primarily composed of plagioclase, pyroxene, and iron-oxide phenocrysts in a glassy groundmass with little or no olivine present.

tuff—Consolidated volcanic ash deposits.

ultramafic—Said of igneous rock composed chiefly or wholly of mafic minerals.

volcanic breccia—A pyroclastic rock consisting of angular volcanic fragments larger than 2 mm in diameter.

xenolith—An inclusion in igneous rock to which it is not genetically related.

[1]Definitions predominantly adapted from American Geological Institute (1972), Higgins (1971), MacDonald (1972), and Spry (1969). The definition of a particular word is that pertaining to this report and not to its possible multiple uses.

APPENDIX

ROAD LOG

The following road log is a guide to exposures of important geologic features along or near highways in the Greenfield and Sherando 7.5-minute quadrangles. Distances between points of interest as well as the cumulative mileage are shown, and the stops are places where detailed structures, distinctive lithologies, minerals, and fossils may be seen.

The collection of rock samples is permissible along state highways and on National Forest lands, but permission to collect samples within the boundaries of the Blue Ridge Parkway must be obtained in writing beforehand from the parkway headquarters in Asheville, North Carolina. Permission to stop at places along the Blue Ridge Parkway marked "No Parking on Shoulders" can be obtained at the visitor center near Humpback Gap or from the local Ranger Supervisor. Permission should also be obtained to enter and collect samples on private property before entering said property; failure to obtain such permission constitutes trespassing and is punishable under existing Commonwealth laws.

The Blue Ridge Parkway is frequently closed to vehicular traffic during the winter because of snow and ice; it may also be advisable to check with the local ranger headquarters to determine driving conditions before entering this route in foggy or rainy weather.

Cumulative miles (km)	*Distance*	*Explanation*
0.0 (0.0)	0.0 (0.0)	Begin road log in the Greenfield quadrangle at Avon (intersection of State Highways 6 and 151, and State Road 638). Proceed southeastward on State Road 638; terrace deposits cover cataclastic rocks for the first 0.6 mile (1.0 km).
0.85 (1.37)	0.85 (1.37)	Intersection of State Roads 636 and 638 at Onan; turn to the southeast (left) on State Road 636.
1.10 (1.77)	0.25 (0.40)	Intersection of State Roads 611 and 636; turn south (right) on State Road 611.
1.15 (1.85)	0.05 (0.08)	Cross Andersons Creek. For the next few hundred yards cataclastic rocks folded about northwestward-trending axes are exposed in the roadcut on left of State Road 611. For the next 2.2 miles (3.6 km) mylonitic gneiss and schist are poorly exposed in saprolite and small outcrops along the road.
3.4 (5.5)	2.25 (3.62)	In the saprolitic outcrops on left of State Road 611 a younger, northeastward-trending foliation can be observed extending across the northeastward-trending fluxion structure (Figure 35).
4.15 (6.68)	0.75 (1.21)	Approximate location of thrust fault contact between Lovingston mylonitic (augen) gneiss and cataclastic rocks. The cataclastic rocks northwest of the fault are principally mylonitic two-mica schist and gneiss, whereas the Lovingston mylonitic gneiss southeast of the fault is mainly a biotite augen gneiss. Typical Lovingston mylonitic gneiss is well-exposed to the south along Perry Creek and State Road 611.
4.7 (7.6)	0.55 (0.88)	Bridge over Perry Creek.
5.05 (8.13)	0.35 (0.56)	Intersection of State Roads 611 and 635; turn to the right (southwest) on State Road 635.
5.8 (9.3)	0.75 (1.21)	Intersection of State Roads 633 and 635; turn to the left (southeast) on State Road 633.
6.2 (10.0)	0.4 (0.6)	*STOP 1.* Pull off on left side of State Road 633. Outcrops here and for the next 0.5 mile (0.8 km) are atypical examples of Lovingston mylonitic gneiss adjacent to the thrust fault

Cumulative miles (km)	*Distance*	*Explanation*
		at road log mile 4.15. The very coarse pods of gneiss preserved within the augen gneiss about 0.3 mile (0.5 km) southeast of this stop are not found elsewhere within the quadrangle. Cataclasis generally decreases southeastward away from the fault and this coarse augen gneiss is very close to the gradational contact between the Lovingston mylonitic gneiss and the Lovingston massive granitic gneiss. An alternative explanation of the coarse pods is that they are relict cobbles and boulders from a small thrust slice or infold of cataclastic metaconglomerate of the Mechum River metasediments. The nearest known occurrences of Mechum River metasediment is about 6 miles (9 km) northeast at Batesville. Return to car and continue southeastward on State Road 633.
6.75 (10.87)	0.55 (0.88)	Approximate location of the gradational contact between the massive granitic gneiss and the mylonitic gneiss of the Lovingston Formation. The Lovingston massive granitic gneiss is well exposed in outcrops along the road and stream for the next 0.6 mile (1.0 km).
7.15 (11.51)	0.4 (0.6)	Intersection of State Roads 633 and 692; stay on State Road 633.
7.4 (11.9)	0.25 (0.40)	Terrace gravels are well exposed here. Additional terrace deposits also occur upstream and represent at least two different levels; this is the higher level.
8.0 (12.9)	0.6 (1.0)	*STOP 2.* Pull off on right shoulder of State Road 633. Good exposure of the Lovingston massive granitic gneiss on left. Note that biotite is the main mafic mineral and that a faint foliation is present. This rock has all the characteristics of the traditional Lovingston granite, namely biotite, blue quartz, and white feldspar. A nonpenetrative chlorite s surface is also present in this rock. Elsewhere several sets of both biotite and/or chlorite surfaces are found. Return to car and continue southeastward on State Road 633.
8.1 (13.0)	0.1 (0.2)	A lower level terrace is well preserved on the south side of Taylor Creek.
8.7 (14.0)	0.6 (1.0)	A typical debris-avalanche chute is visible high on the hillside south of Taylor Creek. This chute developed on the Lovingston massive granitic gneiss during Hurricane Camille in 1969.
9.75 (15.7)	1.05 (1.69)	Outcrop of Lovingston granitic gneiss on left side of State Road 633.
9.95 (16.01)	0.2 (0.3)	The gradational contact between Lovingston massive gneiss and poorly foliated granulite gneiss is in the nearby ravine.
10.0 (16.1)	0.05 (0.08)	Boundary between Albemarle and Nelson counties.
10.3 (16.6)	0.3 (0.5)	The poorly foliated granulite gneiss is well exposed on the south side of Taylor Creek.
10.55 (16.97)	0.25 (0.40)	Intersection of State Roads 633 and 634 at Heards. Turn left (north) on State Road 634.
10.85 (17.46)	0.3 (0.5)	For the next 1.1 miles (1.8 km) poorly foliated granulite gneiss is well exposed in roadcuts. Along this road are numerous northeastward-trending shear zones of mylonitic mica gneiss which cut across the older rock. Note that in a number of places the characteristic poorly developed pyroxene foliation may be absent or consist of biotite due to the biotite and/or hornblende replacing pyroxene.
11.45 (18.42)	0.6 (1.0)	Tool Gap.
11.7 (18.8)	0.25 (0.40)	A typical diabase dike is exposed for about 100 feet (30 m) along and in the road. It intrudes poorly foliated granulite gneiss.

Cumulative miles (km)	*Distance*	*Explanation*
11.8 (19.0)	0.1 (0.2)	Approximate edge of mountain-stream alluvial deposit.
12.8 (20.6)	1.0 (1.6)	Approximate edge of large terrace deposit covering Lovingston massive granitic gneiss.
13.45 (21.64)	0.65 (1.05)	Boundary between Albemarle and Nelson counties. Just north of the boundary is the northern end of a large terrace deposit.
13.95 (22.45)	0.5 (0.8)	Intersection of State Roads 634 and 635; turn right (northeast) on State Road 635. Lovingston mylonitic gneiss exposed near intersection.
14.1 (22.7)	0.15 (0.24)	Boundary between Albemarle and Nelson counties.
14.75 (23.74)	0.65 (1.05)	Intersection of State Roads 635 and 736; turn left (northwest) on State Road 736.
14.9 (24.0)	0.15 (0.24)	*STOP 3.* Pull off onto right edge of State Road 736. A blastomylonite zone about 100 feet (30 m) wide is exposed in the ditch. The thrust fault at this point places Lovingston mylonitic gneiss to the south over Lovingston massive granitic gneiss to the north. Return to car and continue north on State Road 736.
15.15 (24.38)	0.25 (0.40)	Outcrop of massive granitic gneiss on right side of State Road 736.
15.45 (24.86)	0.3 (0.5)	A poorly exposed, thin layer of fine-grained granitic gneiss is interlayered with the Lovingston Formation. A similar larger body of granitic gneiss is found along State Road 635 at the eastern edge of the quadrangle.
15.8 (25.4)	0.35 (0.56)	Road crosses over small stream. A large diabase dike extends across the road.
16.25 (26.15)	0.45 (0.72)	*STOP 4.* Pull off onto right side of State Road 736. Massive charnockite of the Lovingston massif is exposed along this stream valley on the dirt road north of the stream, and northward along State Road 736 for about 0.3 mile (0.5 km). Contacts between the massive charnockite and the surrounding Lovingston massive granitic gneiss are relatively sharp. North of this mass in the next stream valley, typical Lovingston Formation rocks are found. Return to car and continue to the northeast on State Road 736.
17.1 (27.5)	0.85 (1.37)	Another lens of massive charnockite of the Lovingston massif is exposed in State Road 736.
17.2 (27.7)	0.1 (0.2)	Intersection of State Roads 636 and 736; turn left (west) on State Road 636.
17.85 (28.73)	0.65 (1.05)	Saprolite of Lovingston mylonitic gneiss exposed in roadcuts on left.
18.9 (30.4)	1.05 (1.69)	Boundary between Albemarle and Nelson counties.
19.5 (31.4)	0.6 (1.0)	*STOP 5.* Intersection of State Roads 636 and 728; pull off onto right side of State Road 728. This excellent exposure of cataclastic rock (mylonitic gneiss) is the *only* place within the quadrangle where the micaceous fluxion structure that was formed during early Paleozoic cataclasis can be seen folded about a very tight fold with a recumbent axial surface (Figure 34), which is itself folded about younger northwestward-trending folds Figure 36). PLEASE DO NOT DESTROY THIS UNIQUE FOLD. Return to intersection and proceed to the west on State Road 636.

Cumulative miles (km)	*Distance*	*Explanation*
19.8 (31.9)	0.3 (0.5)	Intersection of State Roads 611 and 636; stay on State Road 636 (west).
20.0 (32.2)	0.2 (0.3)	Intersection of State Roads 636 and 638 at Onan; turn left (southwest) on State Road 638.
21.1 (34.0)	1.1 (1.8)	Intersection of State Highway 6/151 and State Road 638; turn left (south) on State Highway 6/151. A rather large mass of recognizable Lovingston massive granitic gneiss is exposed within the cataclastic zone. The outcrop along the creek just south of this point contains Lovingston mylonitic gneiss with a chloritic fluxion structure. Chlorite forms the dominant mica both here and in the cataclastic rocks north of Goodwin Creek and west of State Highway 6/151. Biotite is generally lacking in these rocks but forms the micaceous fluxion structure in the cataclastic rocks east of State Highway 6/151. This suggests that a biotite isograd may be subparallel to the highway in this area.
21.15 (34.04)	0.05 (0.08)	Intersection of State Highway 6/151 and State Road 609; stay on State Highway 6/151 (south).
21.6 (34.8)	0.45 (0.72)	High-level terrace deposits unconformably overlie cataclastic rocks.
22.4 (36.1)	0.8 (1.3)	Intersection of State Highway 6/151 and State Road 709; turn right (west) on State Road 709. Approximate location of early Paleozoic Rockfish Valley thrust fault. Massive Pedlar charnockite is well exposed for the next 2.2 miles (3.4 km) along this road up Cooks Hollow.
23.75 (38.23)	1.35 (2.17)	*STOP 6.* Pull off onto right shoulder of State Road 709. The only ultramafic dike (Figure 18) in the quadrangle is exposed along the left (south) side of this curve. The uphill contact is concealed, but the lower contact is fairly well-exposed in the ditch. Note the changes in grain size and mineralogy from the interior to the margin of the dike. Return to car and continue south on State Road 709.
23.95 (38.55)	0.20 (0.32)	*STOP 7.* Pull off onto left shoulder of State Road 709. A 10-foot (3-m) layer of layered granulite gneiss (Figure 4) is exposed in the right bank. This rock has been completely retrograded to the greenschist assemblage of quartz, sericite, and actinolite. Similar, but smaller, zones of retrograded granulite gneiss are exposed in the roadcuts for the next 0.4 mile (0.6 km). The massive Pedlar charnockite in this region generally contains more garnet than does the charnockite farther west within the Pedlar massif. Return to car and continue to the southeast on State Road 709.
24.7 (39.8)	0.75 (1.21)	A diabase dike has intruded massive Pedlar charnockite here. The gradational contact between massive charnockite and very coarse grained, layered granulite gneiss is in the ravine just east of this point.
26.0 (41.9)	1.3 (2.1)	Intersection of State Highway 6/151 and State Road 709; turn right (south) on State Highway 6/151.
26.3 (42.3)	0.3 (0.5)	Intersection of State Highway 6/151 and State Road 633; turn right (west) on State Road 633. Cataclastic rocks are exposed along the road 0.15 mile (0.16 km) west of this intersection.
26.85 (43.22)	0.55 (0.88)	Approximate location of the Rockfish Valley thrust fault. Cataclastic rocks overlie strongly layered granulite gneiss. The gneiss is exposed in roadcuts and in the stream bed for the next 0.8 mile (1.3 km).
27.6 (44.4)	0.75 (1.21)	*STOP 8.* Park near the "End of State Maintenance" sign; lock your vehicles. Walk about 500 feet (152 m) upstream (west) along the trail and then walk about 50 feet (15 m) left (south) to the junction of the first two tributaries. Along this stream the strongly layered

Cumulative miles (km)	*Distance*	*Explanation*
		granulite gneiss is well exposed. At this locality the east-west segregation layering is refolded about southwestward-trending axial surfaces. A careful examination of the outcrop reveals a few isoclines of Grenville age, which have been refolded about the later surfaces to form a Ramsay type-3 interference pattern (Figure 33). If the broad northwestward warping is removed so that the segregation layering would trend northeasterly (instead of easterly), then the chevron folds correspond with other folds developed during the Paleozoic metamorphism. Note the several generations of nonpenetrative chlorite s surfaces and quartz veins. The granulite gneiss here has a typical mineral assemblage indicative of the granulite facies. Return to the cars, turn around, and drive eastward on State Highway 6/151.
28.9 (46.5)	1.3 (2.1)	Intersection of State Highway 6/151 and State Road 633; turn right (south) on State Highway 6/151.
29.5 (47.5)	0.6 (1.0)	Community of Greenfield; stay on State Highway 6/151 south.
30.25 (48.68)	0.75 (1.21)	Intersection of State Highways 6 and 151; turn left (east) on State Highway 6. Lovingston mylonitic gneiss is exposed along the right side of State Highway 6 for the next 0.3 mile (0.5 km).
30.95 (49.81)	0.7 (1.1)	Cross North Fork of Rockfish River. Excellent exposures of Lovingston massive granitic gneiss on left side of State Highway 6 and along Rockfish River next 0.7 mile (1.1 km).
31.65 (50.94)	0.7 (1.1)	*STOP 9.* Pull off onto right shoulder of State Highway 6. Small granitic xenoliths in outcrop of Lovingston massive granitic gneiss on left side of highway are offset by nonpenetrative biotite-coated s surfaces (Figure 12). Similar good exposures at road log cumulative miles 31.9 (51.3 km) and 32.1 (51.7 km). Return to car and continue southeastward on State Highway 6.
32.6 (52.5)	0.95 (1.53)	Intersection of State Highway 6 and State Road 810; turn left (southeast) on State Road 810.
33.05 (53.19)	0.45 (0.72)	*STOP 10.* Park on left side of State Road 810 and lock your vehicles. Walk about 500 feet (151 m) through bushy field upstream (east) along the north side of stream valley to where the poorly layered granulite gneiss is well exposed (Figure 6). Pyroxene is the dominant mafic mineral that forms the foliation. Directly across the stream valley to the south a small Catoctin metabasalt dike, 3 feet (1 m) thick, is exposed in the scoured stream bank. A hike up this stream valley and across the gap into the head of the valley to the north reveals an interesting array of well-exposed geologic features. These include metabasalt, diabase, and mafic dikes, the contact between poorly layered granulite gneiss and migmatitic granulite gneiss, folded zones of near-vertical mylonitic (augen) gneiss, and debris-avalanche chutes. The hike is difficult, so wear boots and allow several hours for the round trip. Return to vehicles and continue south on State Road 810.
33.8 (54.4)	0.75 (1.21)	Intersection of State Road 810 with State Highway 6. Both pyroxene and hornblende are found in the massive charnockite exposed on the southeast side of this intersection. Note the strong physical resemblence to massive Pedlar charnockite. Turn left (south) and proceed on State Highway 6.
33.95 (54.66)	0.15 (0.24)	Cross south boundary of Greenfield quadrangle; continue south on State Highway 6.
34.25 (55.14)	0.30 (0.48)	Intersection of State Highway 6 with State Road 634; turn right (west) on State Road 634.
34.4 (55.4)	0.15 (0.24)	Cross Rockfish River. Excellent exposures of Lovingston massive granitic gneiss along State Road 634 for the next 0.7 mile (1.1 km).

Cumulative miles (km)	*Distance*	*Explanation*
37.1 (59.7)	2.7 (4.3)	Junction with State Road 629; bear right and continue to the northwest on State Road 634.
37.5 (60.4)	0.4 (0.6)	Reenter Greenfield quadrangle; continue to the northwest on State Road 634. Poor exposures of Lovingston mylonitic gneiss in next mile (1.6 km).
38.3 (61.7)	0.8 (1.3)	*STOP 11.* Cross bridge over South Fork of Rockfish River; park on right side of State Road 634 and walk back across bridge. Mylonitic (augen) Lovingston gneiss is exposed on the east side of the road and beneath the bridge. Rocks exposed in the stream bed have been subjected to strong cataclasis. The cataclastic foliation trends obliquely across the foliation of granitic gneiss. About 900 feet (274 m) northwest of the bridge the fault that separates myolinitic gneiss of the Lovingston Formation from the cataclastic rocks may have caused the cataclasis. Return to vehicle and continue to the northwest on State Road 634. Return to car and continue to the northwest on State Road 634.
38.45 (61.95)	0.15 (0.24)	Approximate location of thrust fault separating mylonitic gneiss of the Lovingston Formation on the southeast from the cataclastic rocks on the northwest. Continue northwestward on State Road 634.
38.65 (62.23)	0.2 (0.3)	Intersection of State Highway 151 and State Road 634 at Nellysford. Food and rest-room facilities are available at this intersection. Turn left (southwest) on State Highway 151.
38.8 (62.5)	0.15 (0.24)	Cross boundary of Greenfield quadrangle into Sherando quadrangle; continue to the southwest on State Highway 151. For the next 0.5 mile (0.8 km) the road crosses the present-day flood plain developed by southward-flowing Stony Creek. Approximately a mile (1.6 km) to the north are dissected terraces and abandoned stream channels of the former eastward-flowing drainage system of Stony and Little Stony creeks.
39.2 (63.1)	0.4 (0.6)	Cross Stony Creek bridge. For the next 0.6 mile (1.0 km) note the high-level terraces which are well developed about 40 to 50 feet (12 to 15 m) above the present flood plain on the right (north) side of the road. All of the hills left (south) of Rockfish Valley are underlain by the augen-gneiss facies of the Lovingston Formation. A few outcrops of cataclastic rocks are exposed along State Highway 151.
39.8 (64.1)	0.6 (1.0)	Intersection of State Highway 151 and State Road 751; turn right (north) onto State Road 751. Poor exposures of the cataclastic rocks are found for the next 0.40 mile (0.64 km).
40.2 (64.7)	0.4 (0.6)	Approximate location of the contact between the cataclastic rocks and granulite gneiss. Massive and layered gneiss is well exposed in outcrops for the next 0.7 mile (1.1 km) to the north along the road.
40.9 (65.9)	0.7 (1.1)	Apex of old, large, dissected alluvial fan built by Little Stony Creek. Note that the fan has an easterly slope and is abruptly truncated by southward-flowing Stony Creek.
41.1 (66.2)	0.2 (0.3)	Little Stony Creek. Debris-avalanches appear to be the likely explanation of how this small creek has transported the numerous large boulders found in both its present bed and the ancient fan. The writer hiked this gorge shortly after Hurricane Camille in 1969 and saw firsthand that numerous automobile-size boulders had been transported various distances by the debris-avalanches. Note that Little Stony Creek is currently perched on the north edge of its fan which is about 50 feet (15 m) above the adjacent flood plain of the larger Stony Creek. Some of the best exposures of xenoliths of strongly layered granulite gneiss, massive Pedlar charnockite, faults, shear zones, Swift Run metaconglomerate, and Catoctin metabasalt flows and dikes are found along the lower 1.5 miles (2.4 km) of Little Stony Creek upstream from this point. The hike is along extremely rugged boulder-strewed terrain and several hours may be needed for a round trip.
41.85 (67.38)	0.75 (1.21)	End of pavement and State Road 751. The dirt road which continues up Stony Creek gorge is on private property. The lower, very steep slopes on the surrounding mountains

Cumulative miles (km)	*Distance*	*Explanation*
		are all underlain by the strongly layered granulite gneiss, whereas the upper, less steep, slopes are underlain by metabasalt. Nearly flat metabasalt flows are exposed in vertical cliffs near the tops of the mountains. TURN AROUND AND PROCEED SOUTH ON State Road 751. Note the change in the valley from the typical hummocky terrain underlain by mountain-stream deposits to a broader, flat, alluvium-filled valley.
43.85 (70.60)	2.0 (3.2)	Intersection of State Highway 151 and State Road 751. Turn right (west) onto State Highway 151.
44.15 (71.09)	0.3 (0.5)	Intersection of State Highway 151 and State Road 627 at Wintergreen. Turn right (northwest) onto State Road 627.
44.7 (96.6)	1.55 (2.50)	*STOP 12.* Park in turnout on left (south) side of State Road 627. The Catoctin Formation is exposed along this road to the northwest (uphill). Typical Swift Run metaconglomerate is exposed on the north side of road approximately 500 feet (152 m) back down road. The metaconglomerate contains elongated quartz pebbles and fragments of tuff-phyllite. Bedding is not apparent in this outcrop. Note that most of the matrix is altered to metamorphic minerals and that the rock displays a well-developed foliation. Turn around and proceed southeast on State Road 627 toward Wintergreen.
44.9 (72.3)	0.2 (0.3)	*STOP 13.* Pull off onto right shoulder of State Road 627. Outcrop of sheared Pedlar charnockite on left (north) side of road. Shear surfaces have a steep southeasterly dip suggesting that their development probably coincided with the development of the N. 60° E.-trending, high-angle faults. Return to car and continue to the southeast on State Road 627.
45.0 (72.4)	0.10 (0.16)	Red saprolite developed on top of massive Pedlar charnockite.
45.4 (73.1)	0.4 (0.6)	Typical mountain-stream deposit to the left (northeast).
45.5 (73.2)	0.10 (0.16)	Outcrops of sheared Pedlar charnockite.
45.7 (73.6)	0.2 (0.3)	Good exposures of the strongly layered granulite gneiss on small knoll (private property) next to the right (south) side of State Road 627. In the roadcut note the steeply dipping compositional layering and the younger shears and chlorite foliation surfaces that cut across the layering. The strongly layered granulite gneiss is found in all the outcrops along the road for the next 0.2 mile (0.3 km).
45.95 (73.95)	0.25 (0.40)	Approximate location of the contact between the cataclastic rocks and strongly layered granulite gneiss in ravine to the right (southwest).
46.15 (74.27)	0.2 (0.3)	Cataclastic rocks metamorphosed to biotite grade during the Paleozoic Era are exposed along State Road 627 for the next 0.2 mile (0.3 km).
46.2 (74.4)	0.05 (0.08)	A diabase dike of Triassic age is exposed in the right bank of State Road 627 and in the roadcut around the hill to the southwest on State Highway 151. The dike cuts the cataclastic rocks in both locations. The thick quartz vein nearby, which is typically 4 to 6 feet (1 to 2 m) wide, can be traced for more than a mile (1.6 km) laterally. In one exposure the vein is folded and the axial surfaces of the folds parallel other Paleozoic fold surfaces.
46.3 (74.5)	0.10 (0.16)	Intersection of State Highway 151 and State Road 627; turn right (southwest) onto State Highway 151.
46.9 (75.5)	0.6 (1.0)	Cross South Fork of Rockfish River; continue southwest on State Highway 151.

Cumulative miles (km)	*Distance*	*Explanation*
47.3 (76.1)	0.4 (0.6)	Cross boundary of Sherando and Horseshoe Mountain quadrangles.
47.6 (76.6)	0.3 (0.5)	Intersection of State Highway 151 and State Road 664. Turn right (west) onto State Road 664.
48.65 (78.30)	1.05 (1.69)	Reenter Sherando quadrangle at junction with State Road 767; continue west on State Road 664.
48.85 (78.61)	0.2 (0.3)	Intersection with State Road 715; stay on State Road 664. Note higher terraces to the right (north) across the stream.
50.85 (81.84)	2.0 (3.2)	Junction of State Roads 664 and 680; stay on State Road 664. The valley is characteristic of a low-gradient stream. The alluvium covers the bedrock of the valley floor to a depth of at least several yards.
51.9 (83.5)	1.05 (1.69)	Large alluvial fan at the mouth of a high gradient mountain stream to the right (north). This present-day stream intersects Pond Hollow valley at a substantially higher elevation than the valley floor. The fan is a typical mountain-stream deposit and is probably the result of numerous floods and debris-avalanches.
53.35 (85.86)	1.45 (2.33)	*STOP 14.* Park in turnout on left (west) side of State Road 664 where a tributary joins the main stream. The debris-avalanche generated at road log cumulative miles 54.70 moved down this tributary and entered the main stream at this point. This particular avalanche was partially blocked about 0.5 mile (0.8 km) upstream where the debris was spread out over a relatively flat area adjacent to the stream. Good exposures of the massive Pedlar charnockite and younger small felsic dikes can be seen in the stream bed to the right (east). A felsic dike, which was intruded after Grenville-age metamorphism, can be seen in the tributary stream several hundred years upstream. This dike appears to have been slightly altered, perhaps by Paleozoic metamorphism. Return to car and continue north on State Road 664.
53.50 (86.1)	0.15 (0.24)	Typical massive Pedlar charnockite is exposed along the stream and road for the next 0.2 mile (0.3 km).
53.8 (86.6)	0.3 (0.5)	Road to right (east) is the southern Pond Hollow access road to the Wintergreen development (private property). Note the typical mountain-stream deposits in these new roadcuts. West and northwest of the stream this entire hollow is covered by such deposits, which exceed 50 feet (15 m) in thickness at many places.
54.05 (86.99)	0.25 (0.40)	Northern access road to the Wintergreen development.
54.15 (87.15)	0.1 (0.2)	The thrust-fault contact between sheared Pedlar charnockite and Catoctin metabasalt follows this ravine uphill. The sheared, platy Pedlar is distinctly different from the massive Pedlar charnockite found at the last stop.
54.70 (88.04)	0.55 (0.89)	Debris-avalanche chute developed in Catoctin metasediments uphill to the right (north). Note the scars at heights of about 30 feet (10 m) on the trees downhill (left) from State Road 664.
55.05 (88.60)	0.35 (0.56)	Junction of State Road 664 and the Blue Ridge Parkway. Continue northwestward on State Road 664 across parkway.
55.20 (89.16)	0.15 (0.24)	Purple tuffaceous slate with chlorite porphyroblasts in the Catoctin Formation on right side of State Road 664.
55.45 (89.57)	0.25 (0.40)	Massive Catoctin basalt on right side of State Road 664. Poor exposures of the Catoctin Formation for the next 1.4 miles (2.3 km).

Cumulative miles (km)	*Distance*	*Explanation*
56.70 (91.58)	1.25 (2.01)	*STOP 15.* Park on right shoulder of State Road 664. Good exposures of metasedimentary rocks (meta-arkose, varved purple slate, argillite, and conglomerate) in the Catoctin Formation in left bank and ditch. Columnar jointing in saprolite on right side of roadbed (Figure 24). The metasedimentary rocks underlying (downhill) the metabasalt are overturned; small-scale folds have produced limbs which are right side up locally. Cross-bedding is found in many of these arkosic metasedimentary rocks. Note that here, similar to *STOP 17,* many of the metasiltstone beds are purplish gray. Return to car and continue northwestward on State Road 664.
56.9 (91.6)	0.2 (0.3)	Approximate location of fault contact between the Catoctin and Harpers formations.
57.05 (91.82)	0.15 (0.24)	Junction of State Roads 664 and 814; turn left (southwest) onto State Road 814.
57.2 (92.1)	0.15 (0.24)	Harpers mudstone-phyllite is well exposed behind (northwest) the Mountain View Mennonite Church on the right (northwest) side of State Road 814. Park in church parking lot for *STOP 16.*
57.3 (92.2)	0.10 (0.16)	*STOP 16.* Steeply dipping quartzite beds and mudstone-phyllite of the middle member of the Harpers Formation in contact with the lower member of the formation. Downward in the section, beneath the quartzite, siltstone-phyllite (typical of the lower member of the Harpers Formation) is interbedded with metasandstone. Note the steeply dipping foliation developed in the mudstone-phyllite. This outcrop is near the axis of an overturned syncline which was formed during Paleozoic metamorphism and folding. Good exposures of the lower member of the Harpers Formation are found along the right (northwest) side of State Road 814 for the next 0.7 mile (1.1 km).
58.3 (93.8)	1.0 (1.6)	*STOP 17.* Park on the shoulder on the right (northwest) side of State Road 814. In roadcut on right (northwest) side are interbedded meta-arkose (cross-bedded) and coarse-grained arkosic siltstone-phyllite of the upper Catoctin Formation. These beds appear to be in depositional contact with both the overlying lower member of the Harpers Formation (probably laterally equivalent to the coarser grained Weverton Formation) and the underlying volcanics of the Catoctin Formation. The lithologic change between the metasedimentary beds and the lower member of the Harpers Formation is sharp, suggesting that they may be separated by a disconformity. The Harpers and Weverton typically contain clasts of greenstone in the coarser beds whereas no greenstone fragments have been found in these arkosic beds. Likewise, the latter are very similar to the numerous metasediments interbedded with the Catoctin volcanics. Note that immediately underlying these arkosic beds to the southwest is a volcanic slate which in turn rests on metabasalt. Return to car and continue southwestward on State Road 814.
59.1 (95.1)	0.8 (1.3)	Cross southwest boundary of Sherando quadrangle.
60.3 (97.0)	1.2 (1.9)	Community of Love; turn left (south) on access road to Blue Ridge Parkway.
60.45 (97.28)	0.15 (0.24)	Junction of access road and Blue Ridge Parkway; turn left (northeast) onto parkway.
61.15 (98.41)	0.7 (1.1)	Reenter Sherando quadrangle.
61.4 (98.8)	0.25 (0.40)	*STOP 18.* Park on right shoulder of parkway. Debris-avalanche chute on right (southeast) side. This debris-avalanche originated in saprolite and bedrock of massive Pedlar char-

Cumulative miles (km)	*Distance*	*Explanation*
		nockite. Unlike most of the avalanches, it was blocked at the lower end about 100 feet (30 m) left (northwest) of the parkway. The slide blocks and outcrops along the chute are exceptionally fresh and provide an excellent opportunity for observing numerous small-scale features in the Pedlar; note the uniform grain size and texture as well as the lack of gneissic layering. Both xenoliths and autoliths are present as well as numerous small dikes. Evidence of Paleozoic metamorphism includes widely scattered epidote- and chlorite-filled veins. Return to car and continue northeastward on the parkway.
61.7 (99.3)	0.3 (0.5)	Good exposures of Pedlar charnockite on right (southeast) side of road. Several sets of shear surfaces with slickensides can be observed. These shears are probably younger than the nearby fault (Road Log mile 51.8) and are related to high-angle faulting.
61.8 (99.5)	0.1 (0.2	Approximately 150 feet (46 m) northeast of the parkway "mile 14" marker on the left (northwest) side, the fault which truncates the metasediments can be located by float to within 30 feet (9 m). Sheared Pedlar charnockite float is found south of the fault. The fault can be traced south-westward subparallel to the parkway to the edge of the quadrangle.
62.3 (100.3)	0.5 (0.8)	*STOP 19.* Intersection of State Road 664 and the Blue Ridge Parkway. A small ledge of rock crops out approximately 200 feet (61 m) east of intersection in field behind stone wall. Ledge is a tuff-phyllite unit in the Catoctin Formation; float of another tuff-phyllite unit can be found farther east at the top of the hill near edge of field. Both tuff-phyllite units are believed to dip gently to the east and contain small (1 cm) muscovite amygdules. The small knoll in the field southwest of the intersection is underlain by metasediments which have a southwestward dip and were traced westward along a series of knolls for 0.4 mile (0.6 km) until they are terminated by a fault. These metasediments are directly overlain by another tuff-phyllite bed that crops out along the southern flanks of the knolls. Return to car and continue northeastward on the parkway.
62.7 (100.9)	0.4 (0.6)	Typical Catoctin metabasalt flows on right (southeast) side of the parkway. Gently dipping layering is probably flow-on-flow contact.
63.3 (101.9)	0.6 (1.0)	*STOP 20.* Park in pull-off between cliffs on right (southeast) side of the parkway. Catoctin metabasalt flows are exposed both to the northeast and southwest of pull-off. These metabasalts are mostly greenstone with only minor masses of epidosite. The greenstone contains numerous penninite amygdules elongated downdip on the prominent foliation surface. Note the penninite-coated, widely spaced (1.0 to 2.0 feet or 0.3 to 0.6 m) cleavage surfaces and the subparallel, closely spaced cleavage (2-5 cm) surfaces. Several sets of joints can also be seen in these outcrops. Return to car and continue northeastward on the parkway.
63.85 (102.76)	0.55 (0.89)	On right (southeast) side of parkway is a hugh block of metabasalt in mountain stream deposit near head of temporary stream. Note two foliation surfaces, which weathering has accentuated, on the east side of block.
64.2 (103.3)	0.35 (0.56)	Hickory Springs parking area on right (southeast) side of the parkway. The spring issues from a metasediment aquifer within the Catoctin Formation. Float from metarkose and arkosic metasandstone is found along the relatively flat bench just behind (southeast) of the spring.
65.2 (104.9)	1.0 (1.6)	*STOP 21.* Turn northwest off the Parkway into Raven Roost Overlook and park. This is one of may scenic overlooks along the parkway. The bajada (large, low-relief, wooded area) along the base of Torry Mountain in the western foreground and the other mountains to the north and west, can be seen in the near distance. Detrital material that forms the bajada consists chiefly of clasts of metaquartzites derived from the mountains to the west that are mostly capped with Chilhowee Group clastics. Present-day topography is

Cumulative miles (km)	*Distance*	*Explanation*
		believed to reflect structure in that the valleys north of Torry Mountain are probably synclinal and the ridges anticlinal. Bedrock beneath the bajada is believed to be Cambrian and younger carbonates of the Valley and Ridge province. The small knolls just north of the bajada are underlain by Cambrian sandstones. The talus slope to the northwest, in the foreground, consists of blocks of Antietam quartzite. The low foothills between the Blue Ridge and Back Creek are underlain by Catoctin metasediments folded into overturned to recumbent folds bordered on both sides by thrust faults. The hills in the northeast foreground are all underlain by Chilhowee Group clastics exposed in a series of overturned folds, which extend northward beyond the line of vision. Note that the wall at this and most other overlooks consists of massive Pedlar charnockite and granulite-facies gneiss. Return to car and continue northeastward on the Blue Ridge Parkway.
65.5 (105.4)	0.3 (0.5)	*STOP 22.* Park in Rock Point Overlook on left (northwest) side of parkway. Catoctin metabasalt flows across the road differ from those at *STOP 20* in that these have abundant, large (2.0 to 3.0 feet or 0.6-0.9 m), irregularly shaped pods and masses of epidosite. These masses are usually associated with flows which contain abundant, large amygdules filled with coarse-grained quartz, epidote, penninite, and feldspar. Smaller, penninite-filled amygdules are also present. Of the two visible cleavages the gently dipping one appears to parallel probable flow-on-flow contacts. Return to car and continue northeastward on the Blue Ridge Parkway.
66.3 (106.7)	0.8 (1.3)	Laurel Springs Gap. Mountain Laurel perfers soils developed from Catoctin metasedimentary and tuff-phyllite beds, and rhododendron prefers soils developed from metabasalt. Thus, many of the thin metasedimentary units can be traced by using vegetation as a guide. The metasedimentary unit here can be traced for about 0.5 mile (0.8 km) northeastward by its distinctive belt of vegetation and float.
66.4 (106.9)	0.10 (0.16)	Gently dipping cleavage in a Catoctin outcrop to the right (east) of the parkway is parallel to the southeastward-dipping contact with the overlying metasedimentary unit. Note the more steeply dipping penninite foliation and the numerous epidosite pods and associated large amygdules.
67.0 (107.8)	0.6 (1.0)	*STOP 23.* Turn off to the left (northwest) into Greenstone Overlook. Good view of the bajada to the west. Greenstones at southeast corner of parking area have deformed amygdules which can be viewed in three dimensions. Note that they are elongated down-dip (foliation), and that two foliation surfaces are present. Return to car and continue northeastward on the Blue Ridge Parkway.
67.4 (108.5)	0.4 (0.6)	Turn off to Picnic Area (closed in winter) on right (south) side of the parkway. The picnic area has running water and toliet facilities as well as picnic tables (no camping sites). The metasedimentary unit at Laurel Springs Gap extends across the parkway near the entrance to the picnic area, then down the ravine (northeast), up another ravine, and across the parkway about a mile farther east. Float from this unit and several others can be seen along the trail to the scenic western summit of Humpback Mountain. The trail starts at the southeast corner of the picnic area.
68.6 (110.4)	1.2 (1.9)	*STOP 24.* This is one of the better stops. (Note: permission to park on the right side of the parkway must be obtained from the ranger supervisor or the vistors center at road log mile 69.9). Climb the low knoll on the west (left) side of the parkway. Note the numerous amygdules along the trail. Exposed in the roadcut on the opposite side of the parkway is a rare example of discernable folds in Catoctin metabasalt (Figure 23). Note that the axial surfaces of these third-order folds are essentially horizontal as is the axial-plane foliation. Also note that the northeast (upper) limbs of the antiforms are much longer than the overturned limbs. The thin metasedimentary unit which outlines the folds can be traced

Cumulative miles (km)	*Distance*	*Explanation*
		around a larger, second-order fold at the base of the outcrop where the metasediment is overturned and has thinned to only a few centimeters in thickness. On the upper limbs of the folds the metasedimentary rock is overlain by flow breccia and large epidosite pods are developed directly over these basal flow breccias suggesting that epidosite formation may be a function of porosity and possibly of water content (in this case water trapped in the sandstone lense may have had greater mobility by being able to migrate upward through the breccia and thus provide a greater water content in the overlying basalt during metamorphism). Note the large quartz-filled amygdules in the lower flow (beneath the metasediment). Similar amygdules can be examined in the rocks on the northern side of the small knoll on which you are standing. Exposed in the roadcut at the base of the knoll is a purple phyllite which, although not similar to most others, is probably a metatuff. It is overlain by flow breccia that can easily be examined closeup. Note the abundant chert in the breccia and also the way that foliation in the phyllite bends. The metasandstone lense has apparently pinched out between the two exposures. Return to car and continue northeastward on the Blue Ridge Parkway.
69.7 (112.2)	1.1 (1.8)	Turn right (east) into Humpback Gap Overlook. Trail to Humpback Rocks, labeled The Rocks on Plate 2, starts from this parking area. Note that even at a distance of 0.25 mile (0.40 km) two foliations are visible in Humpback Rocks (the large protruding outcrop uphill to the west). Humpback Rocks are believed to be on the upper sheet of a thrust fault and Humpback Gap on the lower sheet. Float from Catoctin metasedimentary rocks and tuff-phyllite beds can be found along the left (east) side of the overlook and in the adjacent woods. These units can be traced by float approximately 0.3 mile (0.5 km) southwestward and about a mile (1.6 km) northeastward to the east side of Dobie Mountain. Water for the nearby Visitors Center issues from a metasedimentary aquifer, as do the nearby springs just north of the Blue Ridge Parkway and about 0.3 mile (0.5 km) to the west.
69.9 (112.5)	0.2 (0.3)	First turn off to Visitors Center (closed in winter). Running water, toiliet, and picnic facilities are available here as well as information on camping, motels, stores, and towns.
70.05 (112.73)	0.15 (0.24)	Second turnoff to Visitors Center. Metasedimentary float is found on grassy knoll east of the center and in the woods to the right (east) of the parkway.
70.75 (113.86)	0.7 (1.1)	Approximate location of contact between metabasalts and thick (folded ?) sequence of rhythmites (Figure 29) in the upper Catoctin Formation.
70.9 (114.1)	0.15 (0.24)	A few small outcrops of steeply dipping siltstone-phyllite (rhythmite) are found along the right (east) side of the parkway. Numerous small folds can be seen in these outcrops suggesting that much of the outcrop width (0.2 mile or 0.3 km) may be the result of folding. These rhythmite beds can be traced continuously for about 1.5 miles (2.4 km) northeastward to the edge of the quadrangle. Graded bedding and small scour marks indicate that "up" is to the northwest.
71.0 (114.3)	0.10 (0.16)	Approximate location of fault(?) contact between rhythmite and the Weverton Formation. The contact parallels the Blue Ridge Parkway for the next 0.7 mile (1.1 km) and appears to trend slightly oblique to bedding in the adjacent rocks.
71.1 (114.4)	0.10 (0.16)	Weverton Formation. These finer-grained metasandstone and metasiltstone beds are more characteristic of the lower member of the Harpers Formation that in this area grades into the coarser, underlying Weverton Formation.
71.35 (114.82)	0.25 (0.40)	Connecting road to State Road 610 on left (north) side and parking area on right (south) side; continue northeastward on the parkway.
71.50 (115.06)	0.15 (0.24)	The best exposures of rhythmite is on the south slope of the small knoll about 300 to 1,000 feet (92 to 308 m) due east of the parkway.

Cumulative miles (km)	*Distance*	*Explanation*
71.55 (115.14)	0.05 (0.08)	*STOP 25.* Pull off onto shoulder on right (south) side of the parkway. A small boulder-strewn mound on the opposite side of the road is underlain by coarse-grained pebble metaconglomerate, a lithology characteristic of the Weverton Formation. This linear mound trends obliquely to the nearby Catoctin-Weverton fault(?) contact. Note that mountain laurel also has a preference for soil developed on top of Chilhowee metasediments. Return to car and continue northeastward on the parkway.
71.75 (115.47)	0.2 (0.3)	Blue Ridge Parkway "mile 4" marker on left (northwest) side.
72.45 (116.59)	0.7 (1.1)	*Turn left (northwest) off Blue Ridge Parkway onto dirt road* opposite *private* paved driveway on right (southeast) side of parkway.
72.55 (116.75)	0.10 (0.16)	*Turn left (southwest) off dirt road onto paved State Road 610.*
72.95 (117.40)	0.4 (0.6)	*STOP 26.* Park at spring on left (east) side of State Road 610. This spring issues from a metasedimentary aquifer in the Catoctin Formation. Outcrops uphill (east) are metasedimentary beds interlayered with some tuff-phyllite. Outcrops approximately 30 feet (9 m) west of the spring are tuff-phyllite. This particular metatuff bed can be traced several miles northeastward and is exceptionally well exposed in the roadcut on the southwest side of Interstate Highway 64 in the Waynesboro East quadrangle.
73.05 (117.56)	0.10 (0.16)	Exposure of 8-foot- (2-m-) thick diabase dike on left (southeast) side of State Road 610 (this dike was found after the geologic map was printed).
73.75 (118.69)	0.7 (1.1)	Connecting road to parkway on left (east) side; continue straight ahead on State Road 610.
73.9 (118.9)	0.15 (0.24)	*STOP 27.* Good exposures of right-side-up, cross-bedded Weverton metasandstone in outcrops on left (southeast) side of State Road 610. The entire Chilhowee sequence is generally overturned. Intraformational folding suggested in this outcrop makes most estimates of stratigraphic thickness questionable in this area. Return to car and continue southwestward on State Road 610.
74.1 (119.3)	0.2 (0.3)	Small saddle in mountains. Approximate location of gradational contact (overturned) between the lower member of the Harpers Formation to the right (northwest) and the underlying Weverton Formation to the left (southeast).
74.2 (119.4)	0.10 (0.16)	Good exposures of the lower member of the Harpers Formation are found both in the roadbed and roadcuts of State Road 610 for the next 1.3 miles (2.1 km).
75.5 (121.5)	1.3 (2.1)	Approximate location of concealed, overturned, gradational contact between the coarser grained lower member and the finer-grained middle member of the Harpers Formation. Note that the contact is vertically gradational over an interval of about 30 feet (9 m). Good exposures of the middle member (mudstone-phyllite) are found in the roadbed and roadcuts for the next 0.3 mile (0.5 km). The prominent southeastward-dipping surfaces are foliation surfaces and not bedding.
75.7 (121.8)	0.2 (0.3)	*STOP 28.* Park in pull-off on left (south) side of State Road 610 at George Washington National Forest boundary. Outcrops across road are typical mudstone-phyllite of the middle Harpers Formation. (Note: do not dig in the northern end of the outcrop; this is *private* property.) For about 150 feet (46 m) east (national forest lands) note that the southeastward-dipping foliation frequently changes attitude. Also note that bedding is difficult to discern in outcrop, but can be seen in float, and is not generally parallel to the foliation. This would suggest that intraformational folds are also common in this unit, which could account for its widening outcrop pattern (Plate 2) to the northeast.

Cumulative miles (km)	*Distance*	*Explanation*
76.1 (122.5)	0.4 (0.6)	Approximte location of concealed, gradational contact between the middle and upper members of the Harpers Formation.
76.5 (123.1)	0.4 (0.6)	Approximate location of overturned, gradational contact between the upper member of the Harpers Formation to the east and the overlying Antietam Formation to the west.
76.55 (123.19)	0.05 (0.08)	*STOP 29.* Park on right (north) side of State Road 610. Good exposures of southeast-dipping (overturned) vitreous quartzite beds near the base of the Antietam Formation. Some thin beds of quartzose sandstone also crop out in this roadcut, but few of the interbedded siltstone and mudstone beds are exposed.
76.85 (123.68)	0.3 (0.5)	Intersection of State Roads 610 and 623 (on left or south side); stay on State Road 610.
76.95 (123.84)	0.10 (0.16)	Bridge over Back Creek.
77.05 (124.00)	0.10 (0.16)	*STOP 30.* Junction of State Roads 610 (east-west) and 664 (north-south). Turn right (north) onto State Road 664 and park across from the Sherando Grocery. Antietam quartzite breccias are well exposed in Back Creek along the right (east) side of State Road 664. Note that the alignment of some of the breccia fragments form a crude layering in which bedding in adjacent blocks is subparallel. The historic Mount Torry Furnace, built in 1804, is located on the northwest side of State Road 664, 2.5 miles (4.0 km) south of this intersection. Approximate 800 feet (244 m) northeast of the furnace Antietam quartzite with *Scolithus* tubes is exposed on the northwest side of State Road 664.
77.5 (124.7)	0.45 (0.72)	Road ascends high terrace approximately 40 feet (12 m) above present flood plain.
78.0 (125.5)	0.5 (0.8)	Dirt road to right (southeast) descends to flood plain and passes location of the abandoned Lyndhurst mine (*private property*). Note that State Road 664 is on a high terrace and that remnants of terraces of similar elevation can be seen in the distance to the left (west). Also note that adjacent to the road (left) is a lower level terrace. Elsewhere, several other terrace levels are also known to exist.
		END OF ROAD LOG. Continue north on State Roads 664 and 624 for 5.1 miles (8.2 km) to Interstate Highway 64 at Waynesboro.

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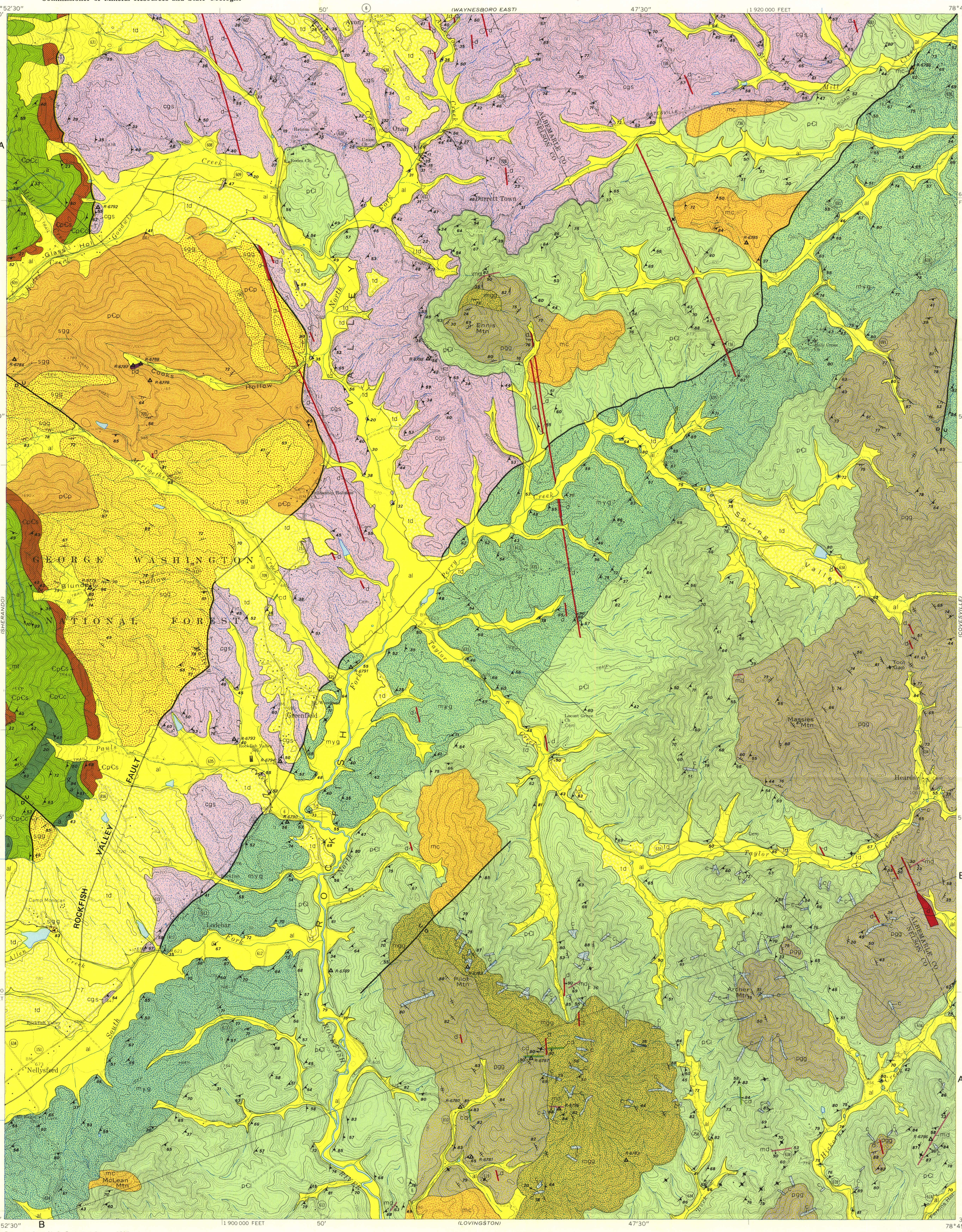
COMMONWEALTH OF VIRGINIA
DEPARTMENT OF CONSERVATION AND ECONOMIC DEVELOPMENT
DIVISION OF MINERAL RESOURCES
James L. Calver
Commissioner of Mineral Resources and State Geologist



Base map from U. S. Geological Survey, 1967
Greenfield Quadrangle, 7½-minute series

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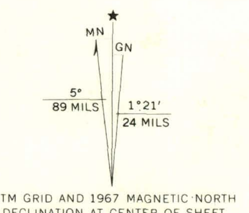
GEOLOGIC MAP OF THE GREENFIELD QUADRANGLE, VIRGINIA

Geology by Mervin J. Bartholomew



UTM GRID AND 1967 MAGNETIC NORTH DECLINATION AT CENTER OF SHEET

SCALE 1:24 000

1 ½ 0 1 MILE

1000 0 1000 2000 3000 4000 5000 6000 7000 FEET

1 .5 0 1 KILOMETER

CONTOUR INTERVAL 20 FEET
DATUM IS MEAN SEA LEVEL

1977

QUADRANGLE LOCATION

EXPLANATION

CENOZOIC — QUARTERNARY

al — Alluvium
Gravel, sand, silt, and clay; boulder and cobble deposits in steep-gradient stream beds.

td — Terrace deposits
Cobbles in sand, silt, and clay matrix.

MESOZOIC — TRIASSIC

d — Diabase dikes
Medium- to coarse-grained, black diabase.

PRECAMBRIAN

p€Cc, mt, a — Catoctin Formation
Dark-green, massive metabasalt with irregular light-green epidosite. mt, *medium- to dark gray felsic tuff-phyllite interbedded with arkosic metasandstone.* a, *light greenish brown to pink, coarse-grained meta-arkose and arkosic metasandstone, and metaconglomerate.*

cd — Metabasalt
Dark-green metabasalt dike.

p€Cs — Swift Run Formation
Medium greenish gray, medium- to coarse-grained lithic and quartzose sandstone, conglomerate, and phyllite.

md — Mafic dikes
Dark-gray to black amphibolite.

pd — Pyroxenite dike
Black, coarse, granular pyroxene - spinel rock.

p€p — Pedlar Formation
Dark-gray to dark greenish gray, massive, garnet-bearing charnockite, greenish unakite occurs locally.

mc — Massive charnockite
Medium- to dark-gray, coarse-grained, massive charnockite with abundant white feldspar porphyroblasts.

myg, p€l — Lovingston Formation
Medium- to dark-gray, coarse-grained, biotite-bearing, massive granitic gneiss. myg, *medium- to dark-gray, medium- to coarse-grained, biotite-bearing mylonitic gneiss.*

sgg, pgg, mgg — Layered granulite gneiss
sgg, *dark greenish gray to dark-green quartzo-feldspathic gneiss;* pgg, *medium- to dark-gray quartzo-feldspathic gneiss with poorly defined layering;* mgg, *medium- to dark greenish gray to dark-gray, coarse-grained gneiss with large white feldspar porphyroblasts and numerous aligned xenoliths.*

cgs — Cataclastic rocks
Interlayered light- to dark-gray, muscovite-biotite mylonitic gneiss, schist and blastomylonite.

c — Landslide area
Chute developed during Hurricane Camille on August 20, 1969.

CONTACTS

Exposed or approximate

FOLDS

10 — Direction and angle of plunge of minor fold

FAULTS

U D T — Black line where exposed or approximate; gray line where covered or inferred; tick mark indicates direction of dip; tick mark across fault trace indicates vertical attitude; U, upthrown side, D, downthrown side; T, upper sheet

DIKES

63 — Strike and direction of dip of dike (strike shown in color)

ATTITUDE OF ROCKS

20 — Strike and dip of beds

48 — Strike and dip of overturned beds

FOLIATION

30 — Strike and dip of schistosity

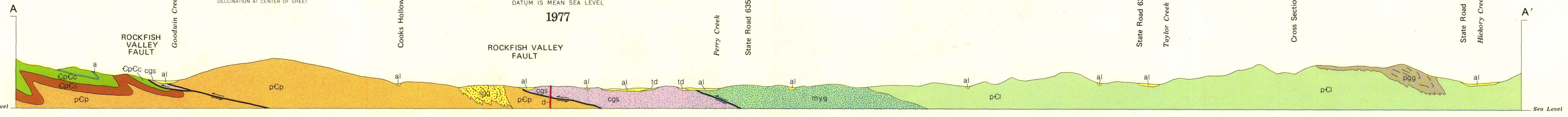
Strike of vertical schistosity

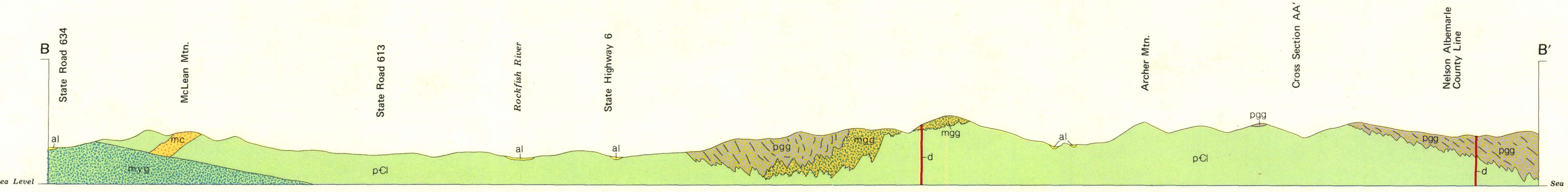
82 — Strike and dip of compositional segregation layering

Strike of vertical compositional segregation layering

SAMPLE LOCATIONS

Δ R-6578 — R, repository number of sample





CROSS SECTION DESIGN:

1. No vertical exaggeration.
2. Subsurface structure interpreted from surface measurements.
3. Thickness of terrace deposits, colluvium, and alluvium diagrammatic.

COMMONWEALTH OF VIRGINIA
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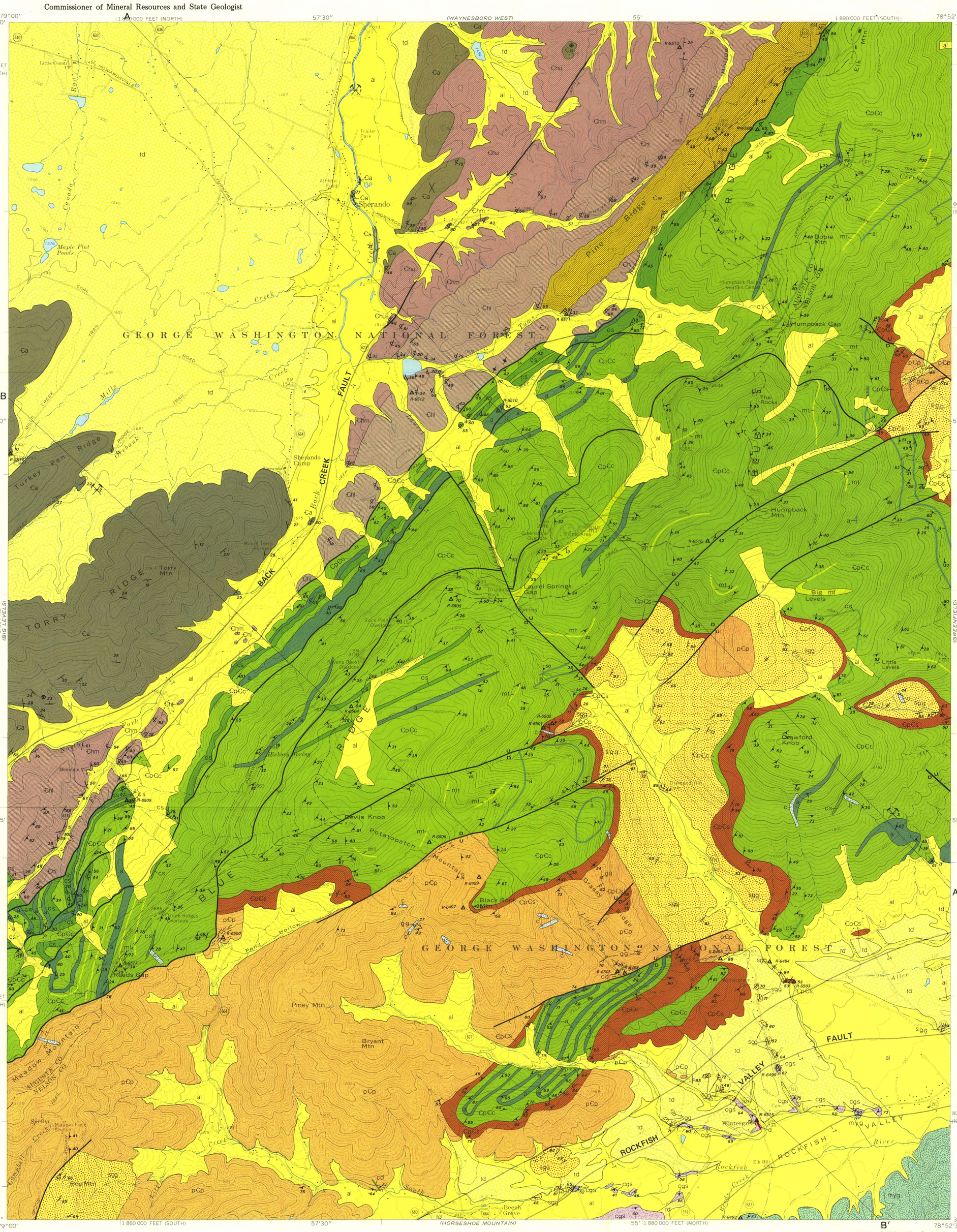
PUBLICATION 4
SHERANDO QUADRANGLE
PLATE 2



Base map from U. S. Geological Survey, 1967
Sherando Quadrangle, 7½-minute series

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GEOLOGIC MAP OF THE SHERANDO QUADRANGLE, VIRGINIA

Geology by Mervin J. Bartholomew

1977

MN GN 5° 89 MILS 1°16' 23 MILS
UTM GRID AND 1967 MAGNETIC NORTH DECLINATION AT CENTER OF SHEET

SCALE 1:24 000
1 ½ 0 1 MILE
1000 0 1000 2000 3000 4000 5000 6000 7000 FEET
1 .5 0 1 KILOMETER
CONTOUR INTERVAL 40 FEET
DATUM IS MEAN SEA LEVEL

VIRGINIA
QUADRANGLE LOCATION

EXPLANATION

CENOZOIC — QUATERNARY

al — Alluvium
Gravel, sand, silt, and clay; boulder and cobble deposits in steep-gradient stream beds.

td — Terrace deposits
Cobbles in sand, silt, and clay matrix.

MESOZOIC — TRIASSIC

d — Diabase dikes
Medium- to coarse-grained, black diabase.

PALEOZOIC — CAMBRIAN

Ꞓwb — Waynesboro Formation
(In cross section A-A′ only)

Ꞓs — Shady Formation
(In cross sections A-A′ and B-B′ only)

Ꞓa — Antietam Formation
Gray, tan, and pink quartzite interbedded with gray to light-tan, fine-grained quartzose sandstone; quartz-pebble conglomerate occurs locally; medium-brown to tan and green interbeds of fine-grained siltstone and mudstone near the top; Scolithus *tubes locally.*

Ꞓhu, Ꞓhm, Ꞓhl — Harpers Formation
Ꞓhu, *upper member: Dark greenish-gray to medium-brown interbedded metasiltstone and fine-grained metasandstone; quartzite and reddish-brown ferruginous metasandstone interbeds locally near top.* Ꞓhm, *middle member: Dark grayish green mudstone-phyllite.* Ꞓhl, *lower member: Dark greenish-gray, fine-grained metasiltstone interbedded with dark greenish gray to medium-brown and light-tan, fine-grained metasandstone and coarse-grained metasiltstone.*

Ꞓw — Weverton Formation
Dark greenish brown to brown, fine- to coarse-grained quartzose metasandstone, quartzite, and graywacke; lithic pebble metaconglomerate and metasiltstone locally.

PRECAMBRIAN

cs, a, pꞒcc, a, mt — Catoctin Formation
Dark-green, massive metabasalt with irregular light-green epidosite; light-green to reddish-brown metavolcanic breccia locally. cs, *light- and medium-gray to purple, medium- to very fine grained siltstone-phyllite (rhythmite) near the top interbedded with the metabasalt.* a, *light greenish brown to pink, coarse-grained meta-arkose and arkosic metasandstone, and metaconglomerate.* mt, *medium- to dark-gray felsic tuff-phyllite and lithic tuff-phyllite in the middle and lower part interbedded with metabasalt and medium- to fine-grained arkosic metasandstone and metaconglomerate.*

cd — Metabasalt
Dark-green metabasalt dike.

pꞒcs — Swift Run Formation
Medium greenish gray, medium- to coarse-grained lithic and quartzose sandstone, conglomerate, and phyllite; light-gray, felsic tuff and phyllite, and boulder and cobble metaconglomerate containing metatuff and purple quartz fragments locally.

gg, pꞒp — Pedlar Formation
Dark-gray to dark greenish gray, massive, garnet-bearing charnockite; greenish unakite occurs locally. gg, *granulite gneiss containing garnet and pyroxene.*

myg — Mylonitic gneiss (Lovingston Formation)
myg, *medium-gray to black, foliated, biotite-bearing gneiss with blue quartz and feldspar augen.*

sgg — Layered granulite gneiss
Dark-gray to dark greenish gray, strongly layered, garnet- and pyroxene-bearing quartzo-feldspathic gneiss.

cgs — Cataclastic rocks
Interlayered light- to dark-gray, muscovite-biotite mylonitic gneiss, schist and blastomylonite.

C — Landslide area
Chute developed during Hurricane Camille on August 20, 1969.

CONTACTS
Exposed or approximate

FAULTS
Black line where exposed or approximate; gray line where covered or inferred; tick mark indicates direction of dip; U, upthrown side; D, downthrown side; ↑, upper sheet

BRECCIA
Collapse or tectonic breccia

SHEAR ZONE

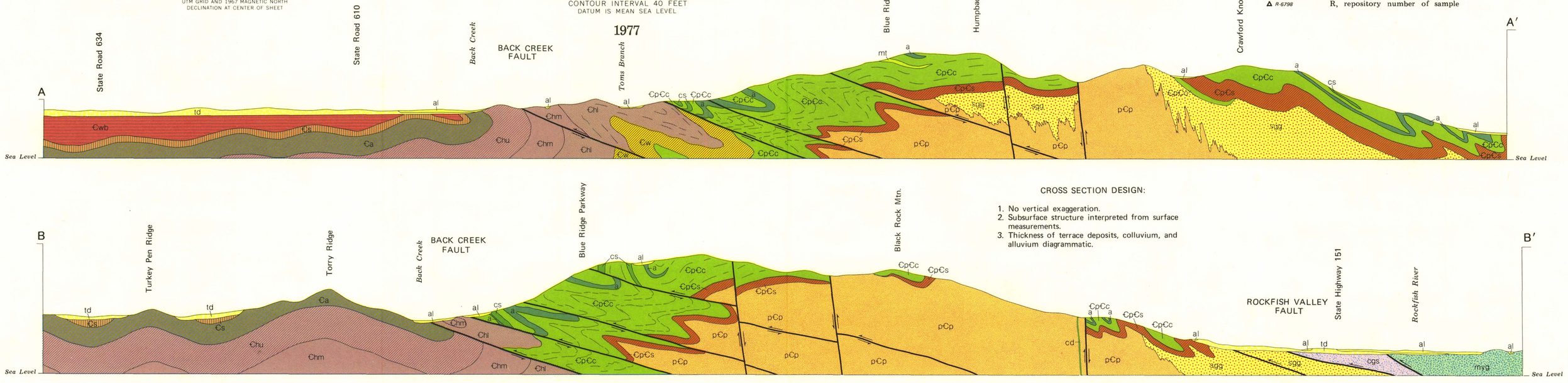
DIKES
Strike and direction of dip of dike (strike shown in color)

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

FOLIATION
40 — Strike and dip of schistosity
Strike of vertical schistosity
40 — Strike and dip of parallel schistosity and bedding
80 — Strike and dip of compositional segregation layering
Strike of vertical compositional segregation layering

MINES AND PROSPECT
Abandoned mine
1. Lyndhurst mine (iron and manganese)
2. Mount Torry mine (iron and manganese)
3. Allen mine (copper)
Prospect
Iron and manganese

SAMPLE LOCATIONS
R-6798 — R, repository number of sample



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