VIRGINIA DIVISION OF MINERAL RESOURCES
PUBLICATION 107

GEOLOGY AND MINERAL RESOURCES OF THE BOSWELLS TAVERN AND KESWICK QUADRANGLES, VIRGINIA

Darwin L. Rossman

COMMONWEALTH OF VIRGINIA

DEPARTMENT OF MINES, MINERALS AND ENERGY
DIVISION OF MINERAL RESOURCES
Robert C. Milici, State Geologist

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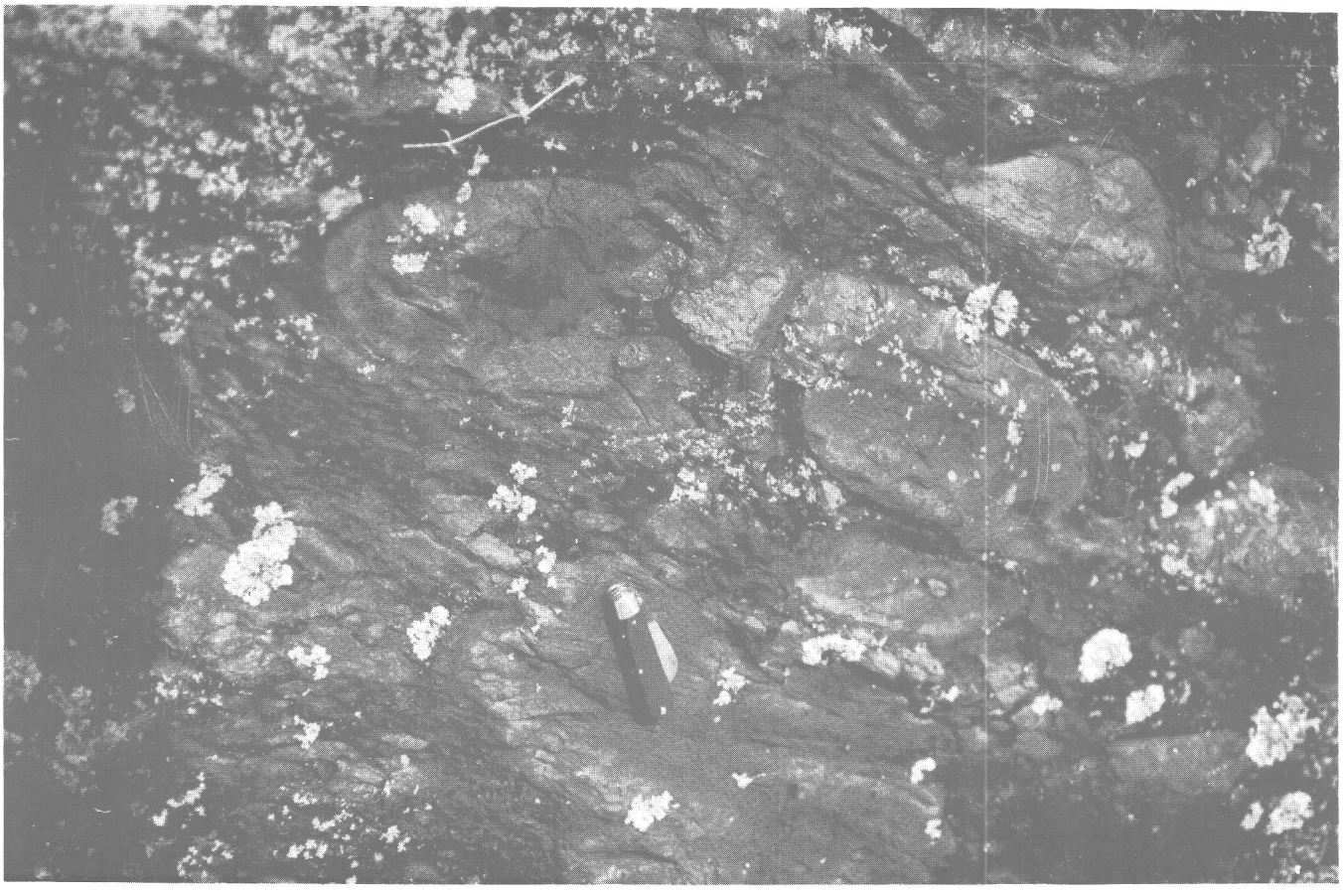

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FRONT COVER: Lenticular masses of metavolcanic rock in chlorite matrix from the Catoctin Formation.

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DEPARTMENT OF MINES, MINERALS AND ENERGY
RICHMOND
O. Gene Dishner, Director

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ABSTRACT

The Boswells Tavern and Keswick 7.5-minute quadrangles are located in eastern Albemarle and western Louisa Counties, in the Piedmont physiographic province of Virginia. The rocks present in the map area from west to east are rocks of the Blue Ridge anticlinorium, which lie northwest of the Mountain Run fault zone and include the Lynchburg Group, the Catoctin Formation, metasedimentary units bra and brb, and the Everona Limestone; and metasedimentary units of the Virginia Piedmont that lie within or are located east of the Mountain Run fault zone designated as units a, b, and c of the Mine Run Complex. An igneous complex, the Green Springs pluton is located in the southeast quadrant of the Boswells Tavern quadrangle.

The major deformation of the Mountain Run fault zone, lies east of the belt of Everona Limestone. It has sheared and extensively deformed the rocks and has obliterated all evidence that would establish the stratigraphic relationships of the Blue Ridge to those of the Inner Piedmont. The amount of displacement along the Mountain Run fault zone is unknown. Direction indicators show that right lateral displacement was followed by thrusting.

Gossan has been mined in the northwestern part of the Keswick quadrangle. Vermiculite is being mined (1990) in the Green Springs pluton. Geologic field investigation suggests that large tonnages of economically mineable vermiculite may be present, particularly in the northern part of the pluton.

INTRODUCTION

The geologic mapping of the Boswells Tavern and Keswick 7.5-minute quadrangles, completed under the auspices of the Division of Mineral Resources, is part of an ongoing program to map in detail the geology of selected areas that are of economic and scientific importance. The area mapped is located in central Virginia about 20 miles northeast of Charlottesville (Figure 1). The two quadrangles cover an area of about 117 square miles, bounded by 78°07'30" and 78°22'30" west longitudes and 38°00'00" and 38°07'30" north latitudes.

Land surface is low and rolling in the Boswells Tavern and southeastern Keswick quadrangles, and stream gradients are low. The underlying rocks are largely quartz-bearing phyllites of probable Cambrian age and slightly younger intrusive igneous rocks of the Green Springs pluton. The central and western parts of the Keswick quadrangle contain the Southwestern Mountains, which are underlain by metamorphosed mafic volcanic rocks of the Catoctin Formation of Cambrian-Precambrian age. The northwest corner of the Keswick quadrangle, a topographically low area, is underlain by paragneisses of the Lynchburg Group of Late Precambrian age.

In the exposed stratigraphic units containing distinctive lithologic horizons, the mapping is believed reliable. In contrast, the rocks that are lithologically indistinctive and poorly exposed can not be mapped with the same degree of reliability. All rock units except those exposed in the eastern part of the area have been extensively deformed into a complex system of refolded rock slices.

Samples collected during field investigations were studied in thin section and grain mounts were prepared to determine compositions of plagioclases. Numbers preceded by an R (R-4800) shown on Plate 1 correspond to sample localities. These samples are in the Virginia Division of Mineral Resources repository where they are available for examination.

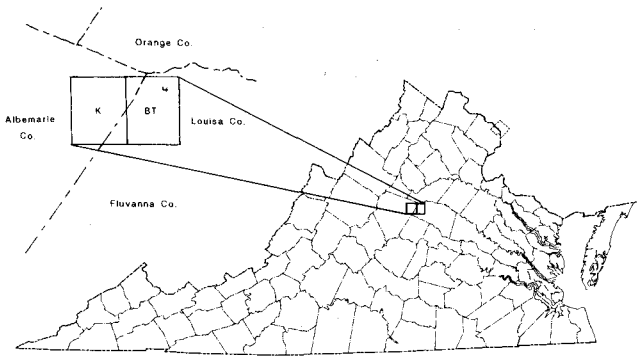


Figure 1. Map of virginia showing location of the Boswells Tavern (BT) and Keswick (K) 7.5 minute quadrangles.

ACKNOWLEDGMENTS

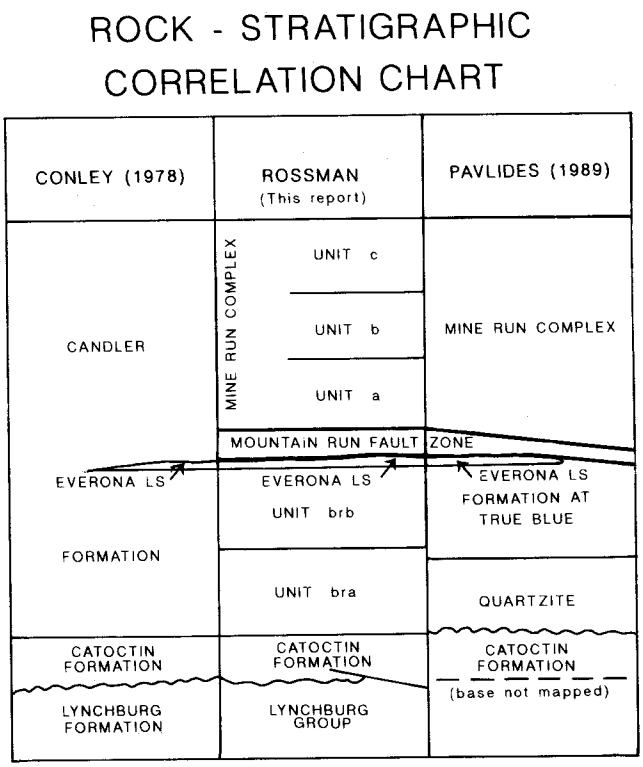
James F. Conley, Robert C. Milici, and Nicholas H. Evans have all made numerous extensive traverses with the writer. Their comments have been of considerable help in preparing this report.

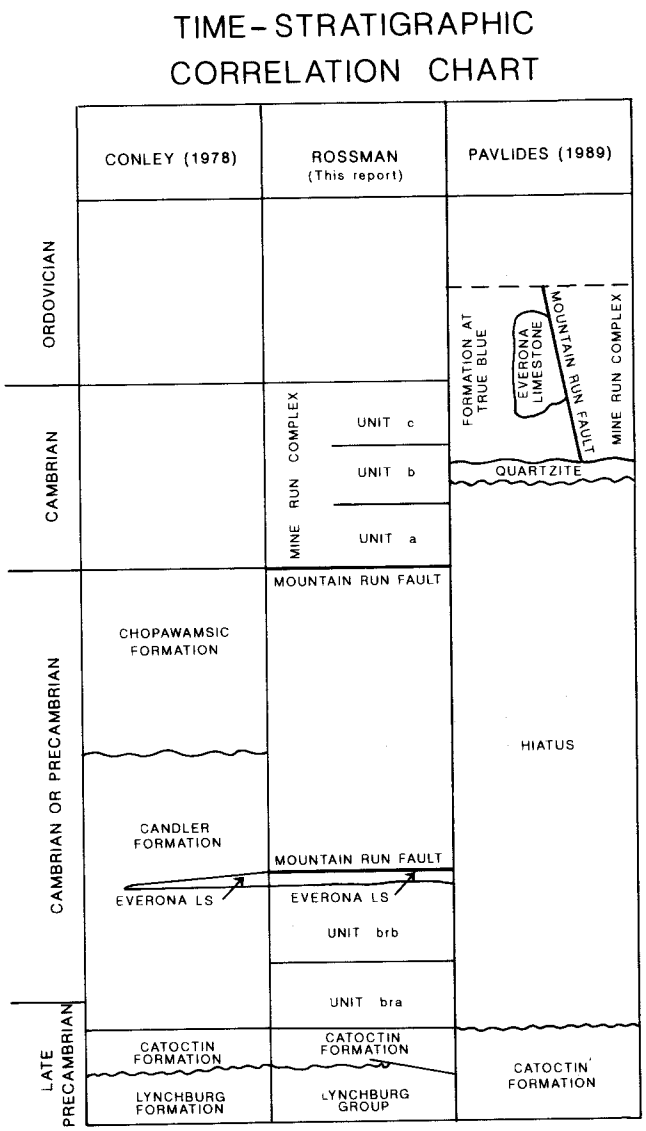
The writer wishes to express his thanks for the assistance of several hundred landowners in the mapped area who willingly granted permission to study the geology of their respective properties. The writer extends his special thanks and gratitude to Mr. and Mrs. Charles Mahanes of Campbell for their assistance in a potentially life-threatening situation experienced by the writer (allergic reaction to insect bite).

STRATIGRAPHY

The Mountain Run fault separates rocks of the Blue Ridge anticlinorium from rocks of the Virginia Piedmont.

Table 1. Principal rock units and nomenclature in map area.





Stratigraphic relationships between the rocks on either side of the fault cannot be determined with certainty. The sequence northwest of the Mountain Run fault zone includes the Lynchburg Group, the Catoctin Formation, and units bra and brb, which are regarded as parts of the Candler Formation (Conley personal communication, 1990), with the Everona Limestone at the top of the stratigraphic section. Pavlides (1989) and Pavlides and others (1983) have assigned rocks southeast of the Mountain Run fault in the Piedmont Province part to Melange Zone IV of the Mine Run Complex. In this report rocks of Zone IV are subdivided into units a, b, and c (Table 1). These rocks were originally included as parts of the Candler Formation by Conley (1978); however, his more recent mapping indicates that the Candler is a rock unit lying west of the Mountain Run fault zone (Conley, personal communication, 1990). All of the major rock units in these quadrangles have a general northeast trend and a southeasterly dip.

ROCKS OF THE BLUE RIDGE ANTICLINORIUM

LATE PRECAMBRIAN ROCKS

LYNCHBURG GROUP

The rocks of the Lynchburg Group crop out in a 1.7 square mile triangular-shaped area in the northwestern corner of the Keswick quadrangle. The succession was named the Lynchburg Formation by Jonas (1927, p. 845) and raised to group status by Furcron (1969). Conley (1978) reviewed the nomenclature, suggested subdivisions, and made correlations of the Lynchburg Group.

Only the upper part of the sequence is exposed in the map area and corresponds, in general, with a unit that Nelson (1962) called the Swift Run Formation. The rocks consist of interbedded quartz-mica gneiss and fine-grained biotite gneiss. These units are interlayered and are not shown as separate

units on Plate 1.

The quartz-mica gneiss makes up more than half of the rocks in the Lynchburg Group in the map area. The rock is medium grained (0.5 mm) and light gray on fresh surfaces. It tends to be massive, relatively resistant to erosion, underlies ridges, and generally forms prominent outcrops. Beds may range in thickness from an inch or less to over 10 feet. Quartz makes up from 40 to 70 percent of the rock. Plagioclase ranges from 10 to 40 percent, and orthoclase is commonly present in amounts of less than 5 percent, but may make up as much as 30 percent of the rock. Plagioclase composition ranges from An_{30} to An_{40} (andesine). Biotite and muscovite make up from 15 to 35 percent of the rock in a ratio of about 1 to 10. Accessory minerals, include sphene, chlorite, pyrite, magnetite, and graphite. The composition of the quartz-mica gneiss indicates the constituents were derived from erosion of rocks of felsic composition.

The fine-grained biotite gneiss is poorly exposed in the map area, but small outcrops and cobbles of the rock are found in the stream bed of Turkey Run. The rock is interbedded with the quartz-mica gneiss and the two rock types grade into each other. The fine-grained biotite gneiss contains the same mineral suite as the quartz-mica gneiss. It is finer grained, thinner bedded, and contains a greater proportion of biotite than the quartz-mica gneiss. The fine-grained biotite gneiss is slightly darker on fresh surfaces and is more easily eroded. Consequently, stream gullies tend to form along zones composed of this rock. Layers characteristically are thin and layers 0.25 inch thick are common. Original minerals are partially to totally recrystallized or reconstituted into new mineral phases. The micas are of metamorphic origin and show little evidence of post metamorphic deformation.

The fine-grained biotite gneiss is believed to have been deposited as silt and fine sand composed of quartz, feldspar, clay minerals, and a small proportion of ferromagnesian minerals. Carbonaceous material is also present. These were derived from the erosion of a felsic rock source.

CATOCTIN FORMATION

The Catoctin Formation, composed mainly of metamorphosed basaltic lava flows is one of the major rock units in the mapped area. The unit was named the Catoctin schist by Geiger and Keith (1891, plate 4). However, the unit as a formation was named by Bloomer and Bloomer (1947), and Conley (1978) summarized the unit's nomenclature. Regionally, the formation occupies both flanks of the Blue Ridge anticlinorium and crops out in two irregular-shaped subparallel belts that extend from the nose of the structure in southern Pennsylvania and northern Maryland southwestward into Virginia. The Catoctin pinches out on both flanks of the anticlinorium about 25 miles southwest of Charlottesville.

Within the study area the Catoctin is composed of the following succession from oldest to youngest: a basal zone consisting of metavolcanic flows, tuffs, and medium- to coarse-grained quartz-rich metasedimentary rocks; fine-grained metavolcanic breccia and volcanic flows; a succession composed of epidote-rich, foliated, altered basalt; a unit of extensively epidotized, foliated basalt interbedded with metavolcaniclastic rock, metaquartzite, and phyllite; laterally persistent narrow zones composed of lens-shaped metabasalt fragments; quartzite; foliated to schistose volcanic-sedimentary rock; and phyllite.

In Harris and others (1982) interpretation of a seismic profile along Interstate Highway 64, the Catoctin Formation is repeated by a series of overlapping thrust-fault slices. This stack of fault slices composed of Catoctin would be about 6000 feet thick. The Catoctin section mapped in this investigation also has an estimated thickness of about 6000 feet.

Rocks at the base of the Catoctin: The lower contact of the Catoctin Formation with the Lynchburg Group is locally faulted. The faults are probably of minor displacement. The basal part of the formation is about 2000 feet across in outcrop width. The lowest rock of the Catoctin is a schistose metabasalt. It is overlain by slightly recrystallized andesitic to basaltic metatuff interstratified with lesser amounts of impure coarse-grained metasandstone and meta-arkose. The lowermost metabasalt is several hundred feet across in outcrop and is in conformable (?) contact with the overlying metatuff. The metabasaltic flows are dense, fine-grained and medium to dark gray, and slightly schistose.

Metatuff is found in several zones interbedded with meta-arkose. The uppermost metatuff is in conformable contact with the overlying metabasalt breccia. The metatuff is light gray on exposed surfaces, weathers readily, and is easily eroded. The most common mineral assemblage in the metatuff is a mosaic of epidote, hornblende, altered plagioclase, albite, and minor quartz. Hornblende forms a decussate (criss-cross) texture and is present in all of the metatuff samples examined. Epidote occurs as crystals about 0.2 mm across. Little of the original plagioclase remains but that present has a composition of An_{30-32}. Quartz makes up 1 to 10 percent of the rock. Most quartz occurs as veinlets and knots as much as 0.5 mm across, and as sparse detrital grains. The quartz grains are recrystallized and some have hornblende crystals penetrating them. Green biotite is present. It is distorted in places as are some of the hornblende crystals. Mineral species, abundance, and grain size in the metavolcanic ash are listed as follows:

Mineral	Abundance (%)	Size (mm)
Hornblende	5-30	0.05-1
Epidote	20-70	0.03-0.5
Chlorite	10-30	0.01
Quartz	1-30	0.03-0.5
Actinolite	5-15	0.03-0.05
Sphene	5-15	0.03-0.1
Biotite	1	0.02
Plagioclase	2-5	0.02-0.03
Albite	Trace	Not determined

The metagraywacke and meta-arkose, are poorly bedded and medium- to coarse-grained, and poorly sorted. They contain rock fragments and detrital hornblende.

Metabasalt breccia: A metabasaltic breccia forms a zone

about 2500 feet in outcrop width at the base of the Catoctin east of State Highway 22 in the northeastern corner of the map area. The breccia is best exposed in the stream bed of Turkey Run. The rock is gray and breccia fragments are poorly defined, although individual fragments tend to stand out in relief or exhibit subtle differences in color. The fragments tend to be elongate and range from one tenth of an inch to two inches in length. Figure 2 is a negative photograph of the breccia in thin section. Some of the fragments show chilled margins. The ground mass makes up about 20 percent of the rock, but the constituents are too fine grained and too altered to be identified with a hand lens; originally they were probably volcanic ash.

Hornblende is widely present in the metabasalt breccia as crystals about 0.15 mm long that are partially altered to chlorite. A fine-grained (0.04 mm) mosaic of secondary quartz is also present, particularly in interstitial areas. Most, if not all, of the epidote found in the rock is secondary. Chlorite in grains as much as 0.15 mm across is altered from hornblende. Sphene is present. Shadowy plagioclase laths 2-4 mm long are partially replaced by amorphous material (kaolin?). Much of the plagioclase is albite, but some plagioclase grains show twinning with an optically determined composition of An_{30-32}.

Analyzed samples of the metabasalt breccia include samples numbered: R-8769, R-8770, R-8773 and R-8774. Compositionally these rocks are indistinguishable from the basaltic flows present in the rest of the Catoctin Formation.

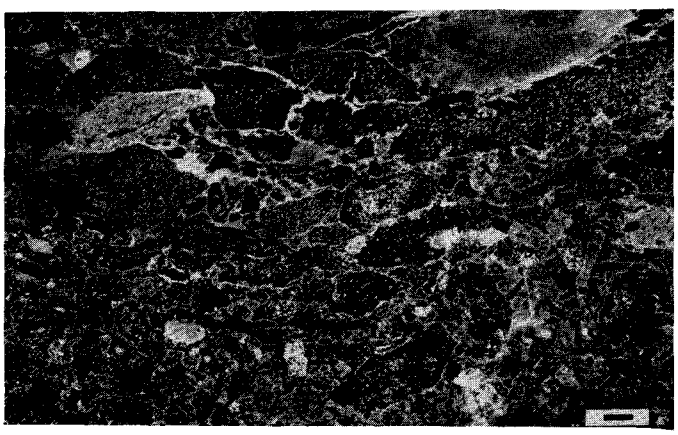


Figure 2, Negative print of metavolcanic breccia from the lower part of the Catoctin Formation. Dark areas in breccia fragment are mainly chlorite, hornblende, green biotite, chlorite, and epidote. White areas are unidentifiable amorphous material. Sample collected from point several hundred feet east of State Highway 22, Keswick 7.5-minute quadrangle in stream bed of Turkey Run. Metric grid 4,221,600 N, 731,700 E. Bar = 1mm.

Fine-grained metabasalts: Epidosite-bearing, fine-grained metabasalt makes up much of the rock in the Catoctin Formation. The metabasalt is fine grained and gray; banding is vague or indiscernible. Intensity of development of foliation increases eastward and the degree to which cleavage is developed depends on location. The rock may resemble a phyllitic metasediment where weathering accentuates the cleavage.

The metabasalt is too fine grained for any of the primary minerals to be positively identified megascopically. Plagioclase makes up 50 percent or more of the rock and the lath-shaped crystals may exhibit a preferred parallel orientation. The preferred orientation is primary, and was produced by flowage. The plagioclase is twinned and has a composition of An_{30}, based on angle of extinction measurements. The largest plagioclase crystal is 1.5 x 0.3 mm. Magnetite crystals tend to outline the plagioclase crystals and are not common within them. The magnetite crystals formed late (metamorphic?) and are euhedral with a uniform size of about 0.015 mm. Hornblende and chlorite compose 20 percent of the rock. The hornblende formed during metamorphism as needle-shaped crystals, the largest of which measures about 1.4 x .03 mm. Epidote is widely present as knots as much as a millimeter across and as small euhedral crystals, some replacing plagioclase.

Samples of the fine-grained metavolcanic rock analyzed for major elements are: R-8776, R-8791, R-8792, R-8796, R-8798, R-8799, R-8801 and R-8802 (Table 2).

Amygdaloidal metabasalt: Amygdaloidal metabasalt is common throughout the Catoctin Formation. The rock is more resistant to erosion than the interlayered metasedimentary rocks, and tends to form prominent outcrops. Individual flows differ from each other in their physical characteristics (such as texture, color, and resistance to erosion), thereby providing a valuable tool in geologic mapping.

The weathered metabasalt is gray with knots of epidote-filled amygdules standing out in relief. The appearance in outcrop and the chemical composition (Table 2) of the amygdule-bearing rock is much like that of the other basaltic flows, and differs only in that it contains amygdules. The amygdaloidal metabasalt also has the same composition as the fine-grained metabasalt and the metavolcanic breccia. Plagioclase is present as lath-shaped crystals as much as 1.5 mm long. Plagioclase composition is about An_{30} based on oil immersion measurements.

Magnetite, as equal-sized, small (0.005 mm), euhderal crystals, makes up 10 percent of the rock and is present in masses as much as one foot long. Metamorphic hornblende and associated chlorite comprise as much as 10 percent of the rock. The amygdules are composed of intergrown euhedral epidote crystals, chlorite, and quartz.

Metavolcaniclastic rock with interlayered metabasalt: One of the rock types, making up perhaps 10 percent of the stratigraphic succession in the Catoctin Formation on the eastern flank of the Southwestern Mountains, is composed of a mixture of volcanic and sedimentary detritus interlayered with metabasalt flows. In outcrop the metavolcaniclastic rock may show bedding and weak cleavage. This unit is easily eroded and is rarely found in natural outcrops. A sample of the volcaniclastic rock (R-8782) collected along State Road 640 is gray and fine grained (0.1 - 0.8 mm). The only mineral that can be recognized with a hand lens is plagioclase. The plagioclase can be observed as ragged elongate laths 0.1 to 0.75 mm long. The plagioclase is moderately altered but the original crystals are generally

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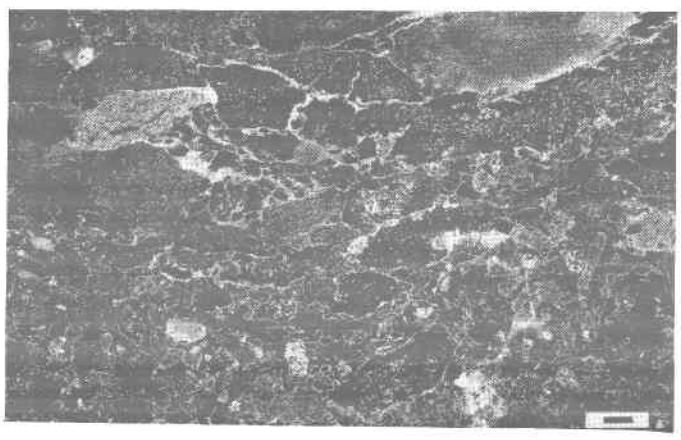

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Metavolcaniclastic rock with interlayered metabasalt: One of the rock types, making up perhaps 10 percent of the stratigraphic succession in the Catoctin Formation on the eastern flank of the Southwestern Mountains, is composed of a mixture of volcanic and sedimentary detritus interlayered with metabasalt flows. In outcrop the metavolcaniclastic rock may show bedding and weak cleavage. This unit is easily eroded and is rarely found in natural outcrops. A sample of the volcaniclastic rock (R-8782) collected along State Road 640 is gray and fine grained (0.1 - 0.8 mm). The only mineral that can be recognized with a hand lens is plagioclase. The plagioclase can be observed as ragged elongate laths 0.1 to 0.75 mm long. The plagioclase is moderately altered but the original crystals are generally

Table 2. Chemical analyses of rocks from the Catoctin Formation, Keswick quadrangle, Virginia (Analyst: Oliver M. Fordham. Analyses by X-ray flourescence. Fusion .5gm sample + 4.5 gm $Li_2B_4O_7$. Fundamental parameter for matrix difference. Mg and Na by atomic absorption. Loss of water (LOI) by pyrolysis). Rock types: VB = Volcanic breccia, V = Volcanic flow, E = Epidosite, HV = Hydrothermally altered volcanic, VS = Volcanic- sedimentary, LV = Lenticular volcanic, S = Sedimentary. (See text for descriptions, R-8769 = Repository No.).

	R-8769	R-8770	R-8771	R-8772	R-8773	R-8774	R-8775	R-8776	R-8777	R-8778	R-8779	R-8780	R-8781	R-8782	R-8783	R-8784	R-8785	R-8786
Rock Type	VB	VB	V	E	VB	VB	VB	V	V	E	HV	E	E	VS	VS	E	E	VS
SiO_2	48.91	50.61	48.23	46.04	46.60	48.15	45.22	46.15	48.13	46.38	68.65	61.95	58.61	53.46	49.02	65.97	48.07	51.52
Al_2O_3	14.70	12.56	13.96	3.86	15.84	14.10	14.20	14.70	14.31	15.62	14.32	10.91	11.26	12.93	13.86	10.33	15.54	12.99
Fe_2O_3	13.20	12.41	13.56	14.74	13.65	13.02	14.82	15.22	14.51	15.32	7.51	9.85	11.23	14.13	16.41	9.13	14.46	15.06
MgO	6.22	5.89	5.98	5.45	7.57	5.96	7.35	6.97	4.92	0.35	0.11	0.16	1.34	3.07	3.70	0.15	0.38	3.18
CaO	8.13	9.87	10.96	10.24	5.80	11.39	9.82	6.78	9.73	16.90	0.07	13.03	13.90	6.36	5.53	10.59	17.16	6.29
Na_2O	2.86	3.39	1.95	2.62	3.88	2.31	2.51	4.16	3.34	0.04	0.03	0.02	0.05	4.84	5.05	0.01	0.05	3.48
K_2O	0.69	0.73	0.55	0.22	0.17	0.43	0.17	0.14	0.53	0.11	0.06	0.09	0.06	0.25	0.34	0.04	0.06	1.50
TiO_2	2.08	1.91	1.86	2.08	2.09	1.82	2.12	2.63	2.10	2.64	2.52	1.97	1.88	2.72	2.75	1.95	1.98	2.64
MnO	0.20	0.17	0.20	0.20	0.22	0.29	0.25	0.29	0.18	0.10	0.01	0.13	0.14	0.19	0.19	0.10	0.22	0.17
P_2O_5	0.21	0.22	0.21	0.23	0.22	0.12	0.24	0.27	0.24	0.33	0.03	0.46	0.24	0.67	0.42	0.26	0.33	0.39
LOI	2.83	2.27	2.60	4.38	3.98	2.49	3.36	2.73	2.06	2.30	6.49	1.40	1.34	1.39	2.76	1.47	1.84	2.79

	R-8787	R-8788	R-8789	R-8790	R-8791	R-8792	R-8793	R-8794	R-8795	R-8796	R-8797	R-8798	R-8799	R-8800	R-8801	R-8802	R-8803
Rock Type	E	S	E	VS	V	V	V	LV	VS	V	E	V	V	LV	V	V	S
SiO_2	60.28	48.93	44.47	46.46	49.13	49.06	47.10	55.35	46.51	47.29	47.62	46.31	47.43	46.39	47.86	46.72	59.25
Al_2O_3	8.65	13.69	14.68	13.74	14.81	13.21	13.38	12.27	14.20	13.48	13.37	14.95	13.73	15.58	15.79	16.31	17.53
Fe_2O_3	15.26	15.86	20.26	15.75	10.17	14.62	15.00	10.03	15.51	15.96	14.92	12.82	15.48	14.72	12.28	12.91	7.02
MgO	1.85	3.46	0.33	5.27	3.53	4.45	4.85	5.49	5.32	4.28	2.03	7.32	4.87	5.87	3.71	6.38	1.90
CaO	9.23	8.26	15.12	9.09	12.58	9.39	10.03	9.29	7.21	7.39	17.02	10.72	7.57	6.25	12.93	8.16	2.65
Na_2O	0.91	4.01	0.01	2.24	2.37	1.82	1.77	1.89	3.70	4.48	0.07	2.55	3.54	3.23	2.39	3.03	3.79
K_2O	0.22	0.17	0.07	1.09	0.97	0.88	0.57	1.19	0.87	0.94	0.20	0.28	0.79	1.03	0.51	0.86	3.32
TiO_2	2.28	3.08	3.02	3.13	2.03	2.99	3.39	1.68	3.55	3.68	2.59	1.81	3.57	2.82	2.20	2.04	1.07
MnO	0.13	0.19	0.15	0.24	0.14	0.21	0.22	0.11	0.23	0.21	0.18	0.20	0.26	0.21	0.13	0.22	0.08
P_2O_5	0.34	0.47	0.32	0.47	0.24	0.56	0.53	0.22	0.51	0.77	0.44	0.22	0.54	0.41	0.28	0.28	0.26
LOI	0.88	1.92	1.62	2.55	4.04	2.87	3.20	2.51	2.43	1.56	1.63	2.89	2.25	3.53	2.01	3.11	3.01

preserved and have a composition of An_{37}, which is the most calcic plagioclase identified in the Catoctin Formation during this investigation. The quartz-feldspar ratio (excluding secondary quartz) is about 1 to 10. Most, if not all, of the quartz is recrystallized, but outlines of original quartz crystals, 0.15 mm in diameter, are clearly discernible under the microscope. Epidote (0.1 mm) is present and makes up less than one percent of the rock. A small amount of what appears to be original hornblende is present as blocky but ragged crystal fragments.

The original feldspar laths and other original grains are outlined by areas containing a concentration of euhedral crystals of what appears to be magnetite composing as much as 25 to 30 percent of the rock by volume (samples R-8782 and R-8783). A considerable amount of amorphous opaque and semiopaque material is present, some of which is probably sphene. Incipient crystallization of hornblende, actinolite, mica, epidote, and opaque minerals has taken place.

Samples of metavolcaniclastic rocks analyzed for major elements are: R-8782, R-8783, R-8786 and R-8790. None of the interlayered metabasalts were analyzed (Table 2).

Lenticular masses of metavolcanic rock in chlorite matrix: An unusual rock type forms several stratigraphic horizons within the eastern exposure of the Catoctin Formation. The best developed of which is near the top of the section. The rock that composes these horizons is distinctive in appearance, consisting of gray to yellowish-green, lens-shaped masses of metabasalt enclosed in a schistose dark-green chlorite matrix. The illustration on the front cover shows the rock in outcrop. The lateral persistence and abundance of outcrops make these rocks good stratigraphic markers. The lenticular fragmental masses in these horizons vary in average size both across and along the strike of the rock unit. The maximum length is on the order of several feet and two feet or less thick. All of the lens-shaped masses are composed of altered basalt that is so fine grained that individual grains are unidentifiable with a 10x hand lens.

The rock shows evidence of having undergone intense deformation. Relict plagioclase crystals are evident by their characteristic lath shape but are altered to zoisite and epidote. Scattered throughout are knots and irregular-shaped masses, 0.3 mm across, of secondary quartz, and a small amount (about 0.1 percent) of pyrite. The lenses are encased in a selvage of chlorite (penninite). Areas partly protected from the effects of deformation lie at the ends of the lenses. These contain secondary quartz, calcite, albite, chlorite, and pyrite.

Kline and others (1990) believe that the horizon near the top of the Catoctin section is composed of pillow lavas and hyaloclastite formed during a submarine extrusion of basalt. The present writer is inclined to believe that the lenticular basalt formed, or was modified as a result of deformation.

Samples of lenticular metavolcanic rock analyzed for major elements include R-8794 and R-8800 (Table 2).

Epidosite: Epidote has replaced basalt, basalt breccia, quartzite, conglomerate, and fine-grained volcaniclastic rock. Commonly, the original rock textures can be recognized in the epidosites. The epidosite that replaces metavolcanic rock shows the characteristic diabasic texture of the relict feldspar laths even though the feldspar has been replaced by epidote. Epidote preferentially replaces rock containing some quartz, such as a quartz-rich conglomerate, even though little quartz appears to have been involved in the transformation process. It is likely that the porosity and permeability of the original rocks may have been a factor in the formation of the epidosite. Breccia replaced by epidote may retain the morphology and rock structures of the original rock, and clastic sedimentary rock replaced by epidote, retains traces of the bedding and original rock fabric. Epidotization preferentially follows joints, fractures, and columnar joints in the basalts (Reed and Morgan, 1971, p. 529) and obviously took place after the lava had solidified. It is probably closely related to the regional metamorphism that the rocks of the Catoctin Formation have undergone.

Compositionally, the epidosites are distinctive (Table 2). They are rich in calcium, are nearly devoid of Na_2O and K_2O, and have a relatively high Si/Mg ratio. Figure 3 shows the chemical differences between epidosites and metabasalts. Samples of epidosites include: R-8778, R-8781, R-8784, R-8785, R-8787, R-8788, R-8789 and R-8797 (Tables 2 and 3).

Quartzite: Quartzite makes up a small percentage of the rock in the Catoctin Formation. It generally is found as rough-surfaced, low, rounded outcrops. Bedding is preserved, but is not distinct. The rock tends to break into angular, flat-sided fragments that are resistant to weathering and mechanical disintegration and are disproportionally abundant as float. Relict detrital quartz ranges from sand to pebble size, and is cemented tightly by interstitial quartz. Fractures form smooth concoidal surfaces.

Phyllite: Phyllite is interbedded with the other rocks in the upper 3000 feet of the Catoctin Formation. The rock weathers readily and only saprolite is exposed. Outcrops are rare and contacts with other rock types are approximate.

The phyllite in the Catoctin Formation is identical in appearance to phyllitic rocks found in stratigraphically higher rock units. Fresh surfaces are gray and weathered surfaces may be some shade of gray, yellow, red, or brown; reddish-brown color is typical. The rock is composed of muscovite, chlorite, and fine-grained quartz. Much of the phyllite, particularly near the eastern edge of the Catoctin Formation, contains a well-developed spaced cleavage.

Composition: The chemical composition of the rocks making up the Catoctin Formation is shown in Table 2. The samples for these analyses were collected at approximately evenly spaced intervals along a traverse extending across the formation. This traverse is located in the stream beds of Turkey Run and Turkeysag Creek, in the vicinity of State Road 640, Keswick quadrangle. Sample locations are shown on Plate 1.

Whole-rock analyses are difficult to compare, owing to the large number of elements involved. For comparison, rocks are commonly illustrated by means of chemical variation diagrams on which analytical data, such as oxide components, are plotted (Carmichael and others, 1974). In this investigation an approach is employed that makes use of a scheme developed for the construction of pseudo-liquidous

phase diagrams (O'Hara, 1968; Walker and others, 1972; Walker, 1979; Stolper, (1980) and Elthon, (1983). With this approach it is possible to geometrically display the chemical relationships to other chemically related basalts.

The method is as follows: the major oxides are reduced to moles and computed into the four minerals olivine, quartz, diopside, and plagioclase, which can be plotted as end points in a tetrahedron. The algorithm used in this report is based on one proposed by Elthon (1983). For portrayal in two dimensions, the calculated point is projected along a line extending from the apex of the tetrahedron through the point to the base. This projection has the effect of generally displacing the point outward. In this report the position of the point is viewed stereoscopically in its true geometric position within the tetrahedron. Elthon's (1983, Table 1, p. 50) algorithm follows: A = moles of (Al_2O_3+Fe_2O_3); C = moles of (CaO+Na_2O+K_2O); M = moles of (MgO+FeO+MnO-TiO_2); S = moles of (SiO_2); plagioclase* = A(*anorthite forms the apical mineral). Albite falls on the lower right front edge of the tetrahedron); clinopyroxene = C - A; Olivine = (M - C + A)/2; silica = S - (M + A + 3C)/2. The calculations for constructing the stereo images are not included.

Oxidation has affected the ferric/ferrous ratio. Analyses by different investigators have reported iron as ferric or ferrous. The greenstones are highly oxidized as can be seen in Reed and Morgan's analyses (1971), and the ferric/ferrous ratio effects the location of the calculated point on the tetrahedral diagram. To provide a basis for comparison, total iron is recalculated to a constant ferric/ferrous ratio of 0.15. The amount of plagioclase can be determined from the stereogram but the composition cannot. The normative An percentage is shown in Table 3.

Figure 3 is a stereographic plot of all rocks collected from the Catoctin Formation that were analyzed in the map area. The plots show a wide dispersal, owing to the fact that samples collected are of several rock types, including massive metabasalt, epidosite, and volcaniclastic rocks. Epidosites fall into two groups, one that replaces basalts and the other that replaces volcaniclastic rocks. Both groups fall outside of the tetrahedron on the right-hand side. A group of analyses was selected, based on petrographic and field data and Figure 3, and plotted with data from Reed and Morgan (1971), Espenshade (1986), and Gottfried and others (1983) on Figure 4 to provide a comparison. Figure 5 shows Ocean Floor Basalt (OFB), Low Potassium Tholeiite (LKT—Island arc basalts), Calc-Alkaline Basalt (CAB), Ocean Island Basalt (OIB), Continental Basalt (CON), and Shoshonite (SHO) (Pearce, 1976).

The points representing the averages of metadiabase dikes, (Reed and Morgan, 1971 and Espenshade, 1986) and island arc basalts (Pearce, 1976) all lie very close together. Epidosite, an altered basalt, lies outside of the tetrahedral plot. Calc-alkaline basalt (Figure 5) also lies close the same area.

The Catoctin metabasalt was deposited on crystalline rocks of the North American continental plate and is not part of an island arc system although, as shown, the Catoctin is similar in major element composition to the island arc basalts. Catoctin metabasalts clearly differ in major element composition from that of continental basalts as listed by Pearce(1976).

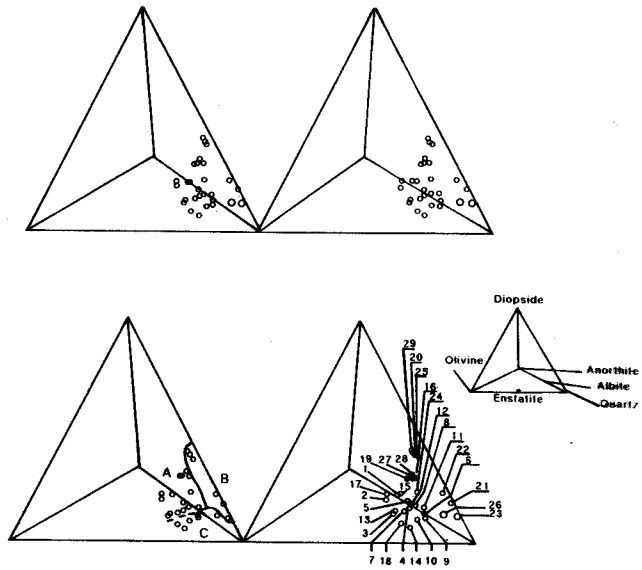

Figure 3. Steroscopic isomolar pseudo-liquidus phase diagram showing relative compositional relationships of rocks of the Catoctin Formation in southeastern limb of the Blue Ridge anticlinorium. Lower diagram - key to sample position identification, rock-type fields, and to tetrahedral parameters.

Figure number	Repository number
1	R-8772
2	R-8775
3	R-8776
4	R-8792
5	R-8793
6	R-8794
7	R-8795
8	R-8796
9	R-8782
10	R-8783
11	R-8786
12	R-8799
13	R-8802
14	R-8790
15	R-8771
16	R-8791
17	R-8798
18	R-8800
19	R-8801
20	R-8778
21	R-8780
22	R-8781
23	R-8784
24	R-8777
25	R-8785
26	R-8787
27	R-8788
28	R-8789
29	R-8797

Table 3. Normative mineral composition[1] of rocks from the Catoctin Formation, Keswick quadrangle, Virginia. Rock types: VB = Volcanic breccia, V =Volcanic flow, E = Epidosite, HV = Hydrothermally altered volcanic, VS = Volcanic-sedimentary, LV = Lenticular volcanic, S = Sedimentary. See text for descriptions). Minerals: Q = quartz, or = orthoclase, ab = albite, an = anorthite, C = corundum, di = diopside, hy = hypersthene, wo = wollastonite, il = ilmenite, hm = hematite, tn = titanite, ap = apatite. Percent anorthite is amount of anorthite in plagioclase. (R- 8769 = Repository No.).

	R-8769	R-8770	R-8771	R-8772	R-8773	R-8774	R-8775	R-8776	R-8777	R-8778	R-8779	R-8780	R-8781	R-8782	R-8783	R-8784	R-8785
Rock Type	VB	VB	V	E	VB	VB	VB	V	V	E	HV	E	E	VS	VS	E	E
Percent anorthite	99.8	56.1	57.3	62.1	64.2	57.3	38.5	26.8	98.4	56.9	37.3	99.4	69.6	23.8	24.9	99.7	99.0
Q	19.6	7.3	7.5	14.1	12.0	17.8	2.6	1.4	18.4	2.2	72.9	43.1	35.4	11.3	4.6	49.2	20.3
or	0.4	6.6	6.0	5.4	3.5	7.2	5.3	5.6	1.2	1.7	0.4	0.5	0.4	1.5	2.0	0.2	0.4
ab	14.9	14.1	15.5	13.6	13.8	12.6	14.5	13.7	13.6	15.4	15.3	11.0	11.4	13.1	14.2	10.5	15.8
an	40.4	24.8	28.1	26.0	27.7	22.0	20.0	14.1	36.1	29.3	0.2	29.6	30.7	13.0	14.5	28.4	42.8
C	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	15.2	0.0	0.0	0.0	0.0	0.0	0.0
di	1.8	6.3	19.8	6.5	6.8	14.2	1.1	4.5	11.1	14.2	0.0	0.9	7.3	4.4	1.4	0.8	2.1
hy	0.0	10.6	0.0	8.4	9.3	7.5	13.1	8.7	0.0	12.2	0.3	0.0	0.0	5.7	8.8	0.0	0.0
wo	8.9	0.0	1.7	0.0	0.0	0.0	0.0	0.0	10.0	0.0	0.0	7.8	9.2	0.0	0.0	6.5	13.7
il	0.3	0.5	0.3	0.5	0.5	0.2	0.5	0.5	0.4	0.4	0.3	0.3	0.3	0.4	0.4	0.2	0.5
hm	20.6	16.2	10.6	15.0	15.5	10.3	15.9	16.2	15.2	13.2	8.0	9.9	11.4	14.3	16.9	9.3	14.7
tn	3.1	3.2	2.1	3.1	3.5	1.7	3.6	3.7	2.6	1.9	2.7	2.0	1.9	2.8	2.8	2.0	2.0
ap	0.8	1.1	0.3	1.3	1.3	0.5	1.2	1.8	1.0	0.5	0.1	3.3	0.6	1.6	1.0	0.1	0.8

	R-8786	R-8787	R-8788	R-8789	R-8790	R-8791	R-8792	R-8793	R-8794	R-8795	R-8796	R-8797	R-8798	R-8799	R-8800	R-8801	R-8802
Rock Type	VS	E	S	E	VS	V	V	V	LV	VS	V	E	V	V	LV	V	V
Percent anorthite	34.3	71.0	35.7	51.0	37.1	62.7	52.9	43.5	57.9	56.0	37.4	44.3	99.2	39.1	47.7	60.4	52.5
Q	11.6	38.2	7.7	6.7	5.5	8.7	6.1	0.8	6.5	3.1	0.0	4.5	16.9	5.2	3.5	6.5	1.9
or	9.1	1.3	1.0	4.2	4.4	3.3	1.4	1.0	2.6	1.0	0.9	3.2	0.7	4.8	6.3	3.1	5.2
ab	13.4	8.7	14.0	15.1	12.8	14.3	14.3	16.5	14.4	14.7	15.1	14.6	16.0	14.0	16.1	6.1	16.8
an	15.8	19.0	19.2	26.0	17.3	28.4	26.1	26.3	27.5	27.9	21.6	23.0	43.1	19.7	25.9	31.5	29.3
C	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
di	3.8	10.1	7.3	5.9	19.6	15.7	14.6	0.0	18.9	11.2	2.3	14.0	1.9	2.6	0.0	19.3	3.3
hy	6.4	0.0	5.4	13.2	5.9	8.0	7.4	19.6	6.4	13.7	15.4	6.0	0.0	11.2	15.1	0.5	14.9
wo	0.0	1.9	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	12.1	0.0	0.0	0.0	0.0
il	0.4	0.3	0.4	0.5	0.4	0.4	0.4	0.5	0.6	0.6	0.6	0.4	0.2	0.6	0.5	0.3	0.5
hm	15.5	15.4	16.2	13.6	12.7	13.9	15.4	14.2	13.3	15.3	15.6	14.8	15.7	15.8	15.3	12.5	13.3
tn	2.7	2.3	3.1	2.1	2.0	1.9	2.2	2.2	1.9	2.2	2.7	2.1	2.7	3.7	2.9	2.2	2.1
ap	0.9	0.8	1.1	0.5	0.5	0.5	0.6	0.5	0.3	0.6	0.6	0.6	0.8	1.3	1.0	0.7	0.7

[1]Based on analyses recalculated to 100 percent volatile free.

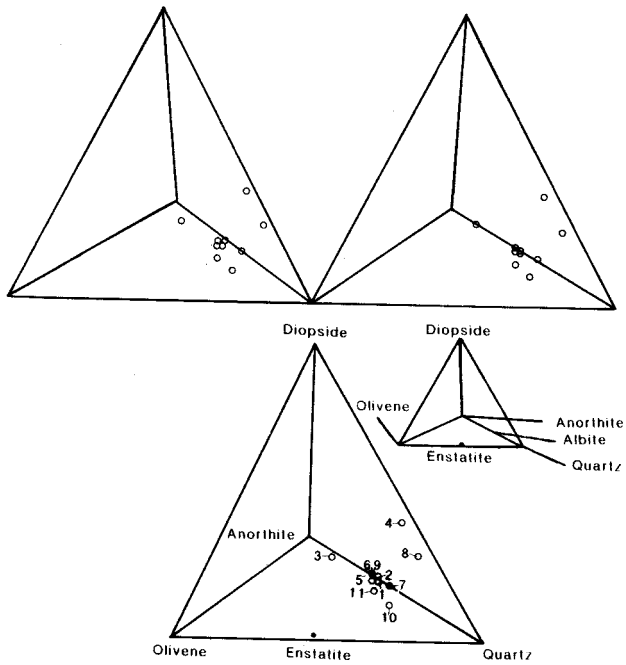

Figure 4. Stereographic tetrahedral plots showing averages of metabasaltic rocks from Reed and Morgan (1971), Espenshade (1986), Pearce (1976), Gottfried and others (1983), and Rossman (This report). 1 = Diabase dikes (Reed and Morgan); 2 = Metadiabase dikes (Espenshade); 3 = Low titanium metabasalt (Espenshade); 4 = Epidosite (Reed and Morgan); 5 = Low-potassium basalt = calc-alkaline basalt (Pearce); 6 = Metabasalt (Espenshade); 7 = Metabasalt (Rossman); 8 = Epidosite (Rossman); 9 = Calculated basalt (Reed and Morgan) Falls in same position as 6; 10 = Triassic basalts (Gottfried and others); 11 = Metabasalt (Reed and Morgan); iron ratio recalculated to Fe_2O_3/FeO = 0.15; included elements recalculated to 100 percent.

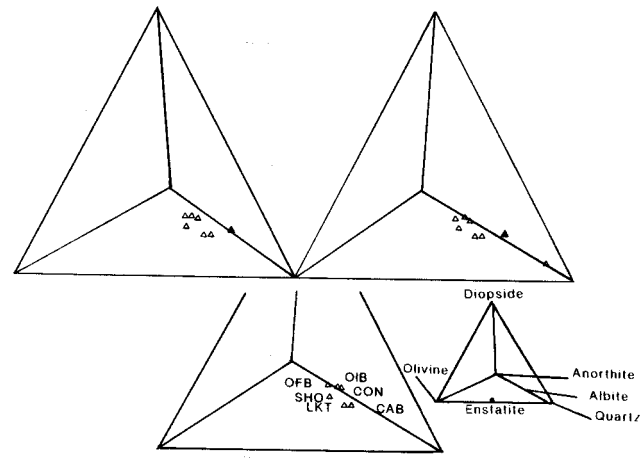

Figure 5. Stereographic tetrahedral plots diagram showing relative positions of basalt types (Pearce, 1976). CON = Continental basalts; OIB = Ocean Island basalts: OFB = Shoshonite; LKT = Lowpotassium tholeiite (from island arcs); CAB = Calc-alkaline basalts; iron recalculated to Fe_2O_3/FeO (mole) = 0.15; included elements recalculated to 100 percent.

CAMBRIAN (?) ROCKS

In this report an informal terminology for correlations and stratigraphic nomenclature is used for those metasedimentary rocks of the Blue Ridge anticlinorium that lie east of the Catoctin Formation and west of the Mountain Run fault. They are indicated simply as mapping units bra and brb.

The bra and brb units lie immediately above the Catoctin Formation. Conley (1978, Table 1) considered these rocks to be part of the Candler Formation (formally named by Espenshade, 1954, p. 15). Pavlides (1989) informally named the rocks lying between the Catoctin Formation and the Mountain Run fault zone, including the Everona Limestone, as "the formation at True Blue".

UNIT BRA

The bra unit includes a mappable belt of quartz-bearing metasedimentary rocks about 1200 feet across lying above the Catoctin Formation. The contact between these rocks and the underlying Catoctin is not exposed in the area mapped. However, a number of small outcrops are present within a few feet of the contact and the lack of evidence of faulting indicates that the contact is conformable. Rock types within the bra unit consist of metagraywacke and metasiltstone, marble, medium gray-green schistose phyllite (northern half of map area), and meta-arkose (Plate 1).

Metagraywacke and metasiltstone: Much of the unit bra is composed of quartz-bearing phyllitic metasiltstones and coarser metagraywacke. An 800-foot-wide zone containing considerable detrital quartz lies to the east of the Catoctin-bra contact and forms a northward-trending band that can be mapped across the two quadrangles. The amount of quartz in the zone decreases northward and the rocks in the northern half of the mapped area consist mainly of quartz-lean phyllite.

In the southern half of the unit the western-most rocks form a zone about 200 feet across consisting of fine-grained quartz-muscovite beds with black chlorite lamallae. Penetration foliation is developed parallel to the bedding and is cut by a spaced cleavage.

The above described rock grades eastward into metagraywacke interbedded with phyllite composed of alternating dark gray chlorite and muscovite-rich bands. Some metagraywacke beds, from one to a few centimeters thick, are graded with grain size becoming finer eastward (upward). Some beds contain rare small scale cross-bedding. The metagraywacke is composed of rounded and angular quartz, feldspar, and small, black, chlorite grains. Fragments of muscovite thought to be claystone clasts are also present. Most of the rocks, including quartz-rich beds, have a foliation parallel to the bedding and are cut by a spaced cleavage which is inclined

more steeply than is the bedding.

Marble: Marble is exposed only in the stream bed of Happy Creek where it is crossed by State Highway 231. The outcrop is small and exposed during times of low water. Contacts with enclosing rocks are covered. This marble is located near the base of the unit bra and is separated from the underlying Catoctin by a few feet of phyllite. The rock, first recognized by Conley and Johnson (1975a), is a white to pink, dense, dolomitic marble.

Schistose phyllite: A medium-gray schistose phyllite crops out about 300 feet east of the Catoctin-bra contact in the vicinity of Turkeysag and Happy Creeks, Keswick quadrangle. The rock has a greenish cast and may contain a high component of detritus derived from the Catoctin. The unit is of limited lateral extent.

Meta-arkose: A meta-arkose is the upper-most member of the bra unit. It is a persistent northeastward-trending zone several tens of feet wide, extending across the mapped area. This zone is lithologically distinctive, a ridge former, and because it is resistant to decomposition and erosion; it is commonly exposed. The rock is light to medium gray, coarse grained, and weathers to a rough surface. Quartz and feldspar in the coarse granule to fine pebble size range (3 to 6 mm across) are typical. In some exposures rock fragments, mainly fine-grained muscovite-rich material as much as one centimeter across, are present. The matrix consists of muscovite and isotropic material.

UNIT BRB

The brb unit lies conformably above the bra unit and is in fault contact with the Everona Limestone. It is composed of phyllite with minor amounts of a dark gray to black schistose phyllite. In shear zones developed along faults, the phyllite has been recrystallized to a pale green phyllonite .

Phyllite: Virtually all of the exposed phyllite of unit brb is weathered to saprolite. In outcrop, the rock weathers to light to medium brown, and with further weathering, primarily oxidization, it may turn light to medium red. Metamorphism and slight tectonism has masked the rock's primary structures such as original bedding. Compositional banding is well developed and bands range from a few tenths of a millimeter to a decimeter across. Typically they are two to five millimeters across. Most compositional bands superficially resemble beds, but, if traced out are extremely elongate lenses.

The phyllite is fine grained with most of the grains being less than 0.03 mm across (Figure 6). The mineral components are muscovite, quartz, and chlorite. Muscovite makes up over half of the rock and parallel orientation of mica crystals form a ubiquitous penetrative foliation generally parallel to compositional banding. Slightly larger, undeformed muscovite grains are present; these grains crystallized after the foliation had formed. Chlorite occurs as rare, small lenticular massesa millimeter or less in length. Quartz is present in minor amounts as slightly modified angular grains, as lenticular grains 0.05 mm long, and as secondary equigranular grains

Figure 6. Negative print of phyllite from Unit bra. Black band and black specks are quartz and white areas are mainly muscovite. Sample collected from area near State Highway 22, 4,950 feet east of junction with State Road 640. Metric grid 4,215,750 n, 7338,180 E. Bar = 1mm.

with mutually interfering grain boundaries. Locally thin lenticular layers of secondary quartz are present and may represent transposed relicts of original quartz-rich beds. Secondary quartz is commonly present in reentrant angles of microfolds and as quartz lenses. Wavy discontinuous lines (Figure 6) lie parallel to the compositional layers and are composed of altered iron-stained muscovite, amorphous material, and goethite. These wavy discontinuous lines represent planes of slippage.

Locally the penetrative foliation is translated by a spaced cleavage to form crenulations (Figure 7). The rock is fine grained and composed of pale green muscovite and chlorite. Parallel oriented muscovite crystals formed the original foliation and individual crystals are bent to produce the crenulations. Recrystallized elongated detrital quartz grains, (0.04 by 0.2 mm) lie parallel to the sigmoidal-shaped crenulations. The rock also contains scattered elongate masses (0.08 mm long) of chlorite interleaved with the muscovite.

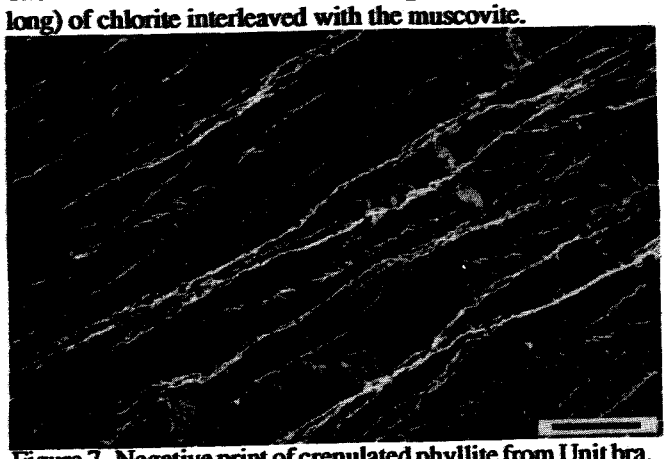

Figure 7. Negative print of crenulated phyllite from Unit bra. Black curved areas are deformed quartz grains. Rock from 4,700 feet due east of Cismont. Metric grid 4,214,900 N, 737,000 E. Bar = 1mm.

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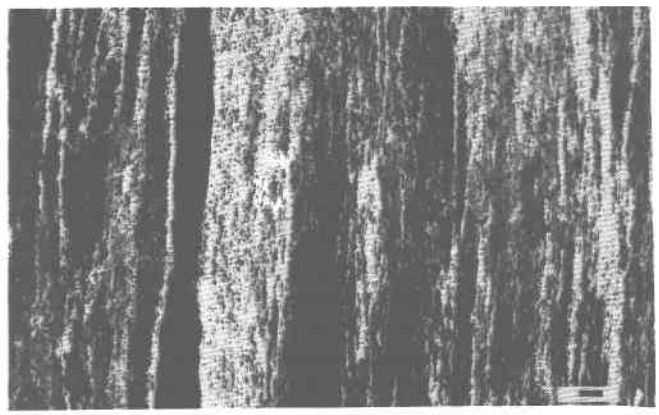

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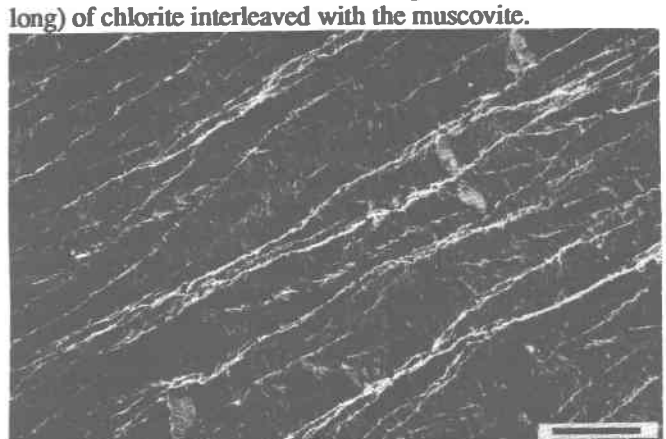

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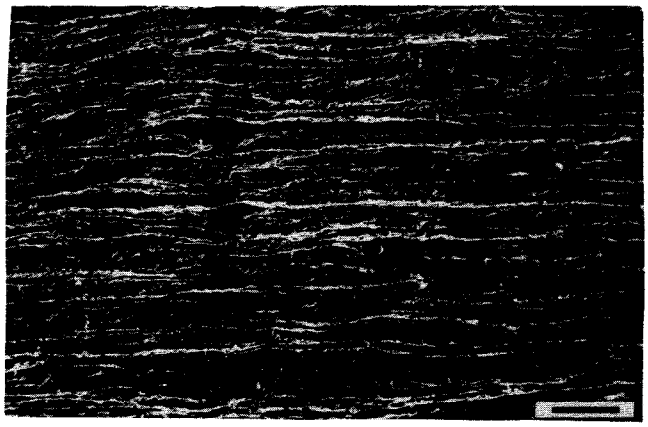

Figure 8. Negative print of dark-gray schist from Unit bra. Dark areas composed of muscovite and paragonite. Light lamallae are composed of fine grains of hematite. Sample from outcrop at the intersection of State Road 616 and the Chesapeake and Ohio Railroad. Metric grid 4,211,100 N, 731,550 E. Bar = 1mm.

EVERONA LIMESTONE

The Everona Limestone, named by Jonas (1927), lies along a linear depression that can be traced diagonally across southeastern Keswick and northwestern Boswells Tavern quadrangles. The rock is polydeformed by movement along the Mountain Run fault zone. Only eight outcrops of the limestone are present within the map area, six outcrops are in abandoned quarries that are largely filled but do contain a few exposures. Neither the upper nor the lower contact of the Everona is exposed. Highly deformed button schist lies within a few feet of the upper (eastern) contact of the Everona in the quarry at the intersection of State Highway 22 and Turkey Sag Creek in the eastern part of the Keswick quadrangle. Also, deformed phyllite occurs a few feet below the Everona at the top of the underlying brb unit exposed in an abandoned quarry adjacent to State Road 600 near Campbell. The limestone is about 700 feet across at both quarries.

The Everona is blue gray, thin bedded, and fine grained (Figure 9). Beds a millimeter or so thick are separated by thin, opaque, stylolitic seams, composed, in part, of pyrite and graphite (?). The calcite is fine grained (0.02 mm). Quartz, now recrystallized into small (0.04+ mm) grains makes up an estimated one to ten percent of the rock. Traces of muscovite are also present. The blue-gray color probably results from the presence of opaque minerals (pyrite and graphite (?)).

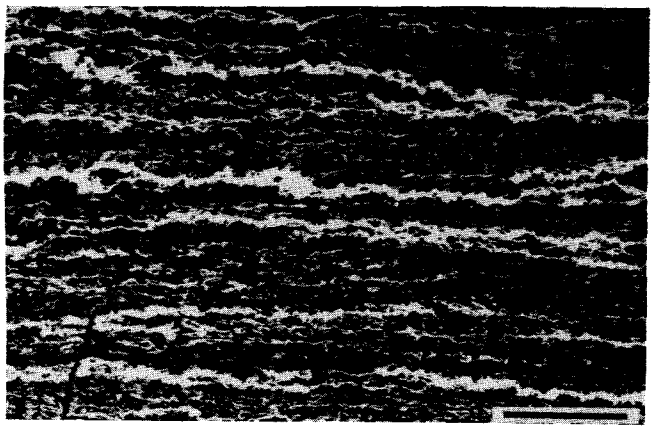

Figure 9. Negative print of Everona Limestone. White lines are composed of pyrite and graphite(?). Gray and black areas are composed of poorly crystallized calcite. Fine-grained quartz (0.04), not identifiable in figure, makes up an estimated 10 percent of the rock. Sample from Turkeysag Creek at intersection with State Highway 22. Metric grid 4,216,100 N, 739,360 E. Bar = 1mm.

ROCKS OF THE VIRGINIA PIEDMONT EAST OF THE MOUNTAIN RUN FAULT ZONE

Rocks that underlie the Virginia Piedmont east of the Mountain Run fault in the study area are mapped as part of the Melange Zone IV of the Mine Run Complex named by Pavlides (1989). In this report three units are recognized in Melange Zone IV. These units are simply designated as units a, b, and c.

CAMBRIAN ROCKS OF THE MINE RUN COMPLEX

UNIT A

Unit a lies next to the Everona Limestone in a shear zone that is less than 1000 feet across. The rock is a medium-grained, highly comminuted and polydeformed muscovite phyllonite that grades eastward into less deformed schistose phyllite. The lower contact of unit a with the Everona Limestone is unexposed but the extensive tectonism present indicates that the lower contact is a fault. The upper (eastern) contact with rocks of unit b is not exposed.

The rocks of unit a are lithologically very similar to those of the rocks in unit c. No evidence has been recognized that would indicate the stratigraphic position of the rocks in unit a. Because the rocks of unit a in the map area are lithologically similar to those in unit c, it is possible that the rocks of unit a are actually fault slices of rocks from unit c.

Figure 10 is a photograph of an intensely deformed rock from unit a collected from an area at the intersection of

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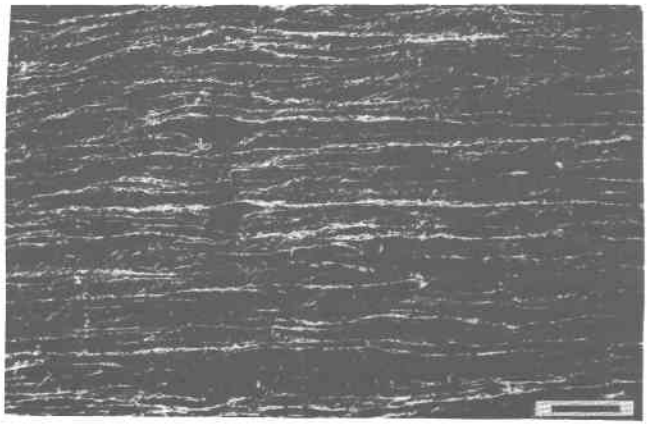

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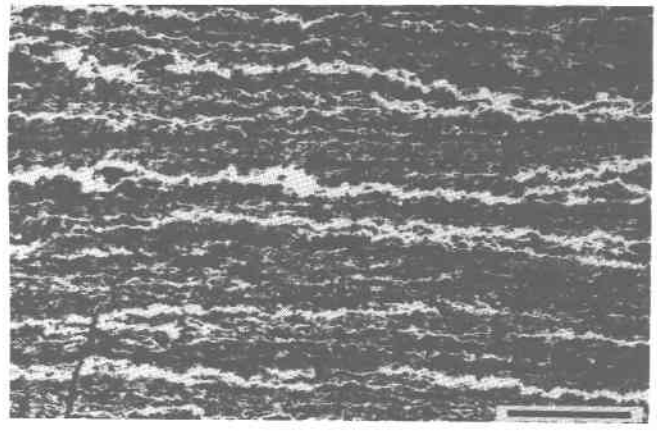

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Figure 10 is a photograph of an intensely deformed rock from unit a collected from an area at the intersection of

Turkey Sag and Mechunk Creeks near Cobham. Figure 11, a negative photograph of a thin section made from rock collected at a point 4100 feet farther southeast, in an area near the contact with the Everona Limestone. Shearing has entirely masked the rock's original fabric. Large (+ 12 inches) lenses of quartz and button phyllonites with "buttons" containing centers composed of quartz are typically present. No evidence of rotation of the lenses has been recognized either in outcrop or in thin section.

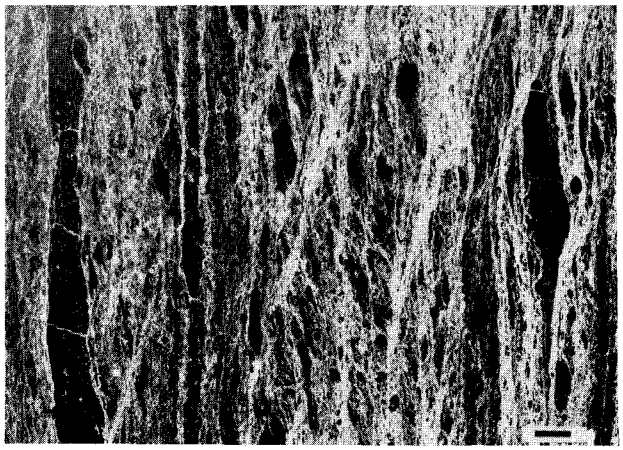

Figure 10. Negative print of highly deformed rocks of Unit mrb. Sample from an eastern segment of the Mountain Run fault. The subparallel white filaments consist of deformed muscovite and lesser amounts of chlorite. Dark bands composed of partially recrystallized, elongate, and strained quartz. Secondary quartz, muscovite, and chlorite are present at the ends of the quartz lenses. Some altered plagioclase is also present. Sample collected at the junction of Turkeysag and Mechunk Creeks. Metric grid 4,215,860 N, 739,680 E. Bar = 1mm.

UNIT B

Unit b is composed of metamorphosed coarse-grained arkose, graywacke, and several zones of paragonite-bearing, dark gray, well foliated, phyllite. This unit grades eastward into the more phyllitic rocks of unit c. The dispositional pattern of unit b, particularly as displayed in the northwestern corner of the Boswells Tavern quadrangle, suggests that the rocks of this unit are infolded with, and faulted against, the rocks of unit c. Some folds are cut and further deformed by later faults.

Figures 12 and 13 show examples of moderately deformed, coarse-grained meta-arkose from unit b Quartz grains are rounded, elongate, or fragmental, and about one millimeter in diameter. Commonly they are fractured and internally strained. Many show new growth at the ends of grains consisting of secondary quartz that contains an abundance of undeformed muscovite and biotite crystals. Plagioclase, now altered and replaced by sericite, may make up as much as one third of the detrital grains. Interstitial matrix material composes about 30 percent of the rock and consists of quartz, sericite, biotite, chlorite (repidolite), and unidentified amorphous material.

Figure 11. Photograph of deformed rock of Unit mrc. Highly sheared phyllite from an inferred fault lying east of the Everona Limestone. Rock consists of fragmental, bent, iron-strained muscovite (dark-gray) and lenticular quartz. Ends of the quartz lenses consists of secondary quartz and muscovite. Sample collected from 4,800 feet east of Cismont. Metric grid 4,214,900 N, 737,000 E. Bar = 1mm.

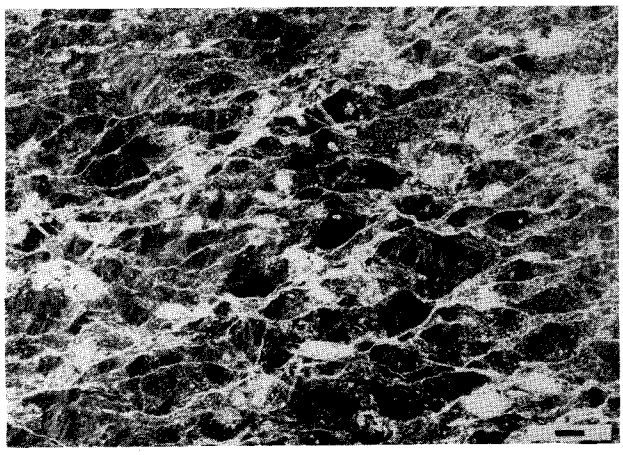

Figure 12. Negative print of moderately deformed arkose from Unit mrb. White network consists of iron-stained amorphous material, mica, and goethite. Quartz (dark) ranges from rounded to angular with borders embayed by secondary quartz. Interstitial material consists mainly of fine-grained granulated and recrystallized quartz. Some mica crystallized after deformation ceased. Sample from 6,100 feet S 30 °E of Cobham. Metric Grid 4,214,400 N, 740,330 E. Bar = 1mm.

Figure 14 is a negative print of rock from unit b which has undergone more intense deformation than rocks depicted in Figures 12 and 13. The former was collected from a zone of intense deformation along a fault whose trace lies along Beaverdam Creek in the southeastern part of the Keswick quadrangle (Plate 1).

A distinctive green, quartz-rich schistose arkose in unit b is widely present in the northwest quadrant of the Boswells Tavern quadrangle. The green color is due to the presence of the green chlorite. The chlorite is the magnesium-rich variety

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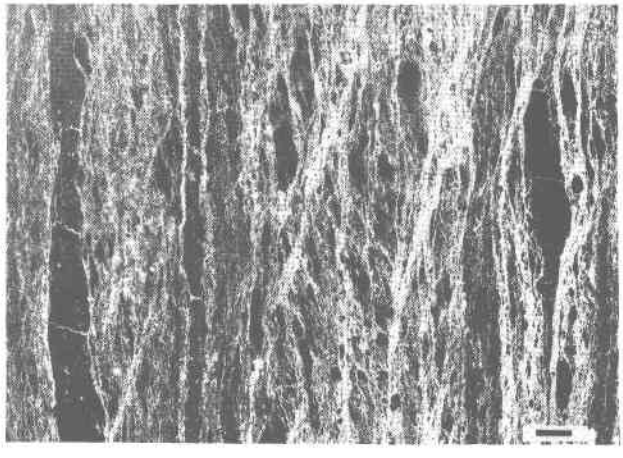

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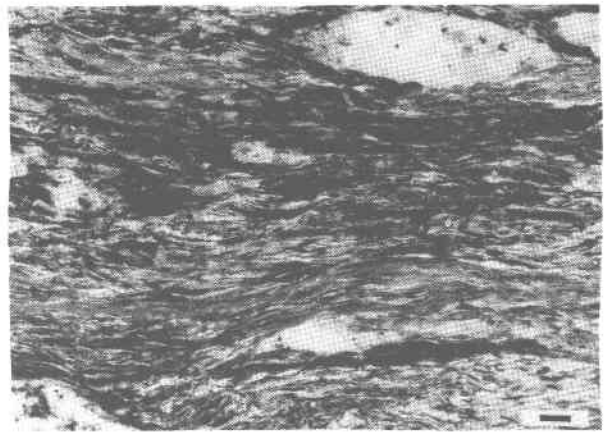

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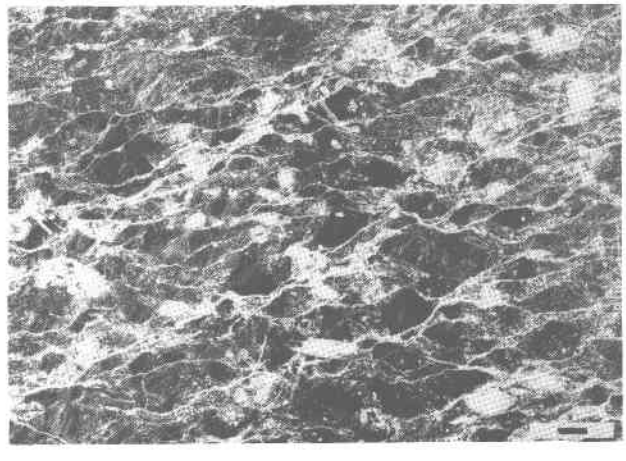

Figure 12. Negative print of moderately deformed arkose from Unit mrb. White network consists of iron-stained amorphous material, mica, and goethite. Quartz (dark) ranges from rounded to angular with borders embayed by secondary quartz. Interstitial material consists mainly of fine-grained granulated and recrystallized quartz. Some mica crystallized after deformation ceased. Sample from 6,100 feet S 30°E of Cobham. Metric Grid 4,214,400 N, 740,330 E. Bar = 1mm.

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A distinctive green, quartz-rich schistose arkose in unit b is widely present in the northwest quadrant of the Boswells Tavern quadrangle. The green color is due to the presence of the green chlorite. The chlorite is the magnesium-rich variety

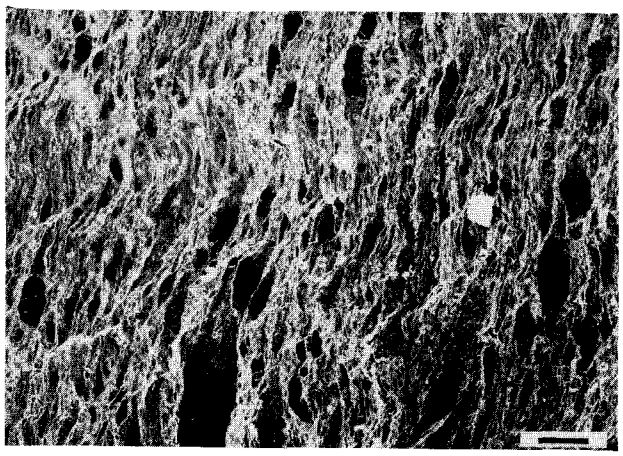


Figure 13. Negative print of deformed arkose from Unit mrb. Tectonized rock from a northeast-trending shear zone. The large lens-shaped quartz grains (dark) are strained (not evident in illustration) and contain secondary quartz in the pressure shadows at the ends of the grains. The white streaks are composed of iron-stained muscovite, goethite, and fine-grained secondary quartz. the elongate quartz grains define an older foliation, cut by a later spaced cleavage. Sample collected 1.2 miles southeast of the Everona Limestone, near the east edge of the Keswick quadrangle. Metric grid 4,214,340 N, 740,200 E. Bar = 1mm.

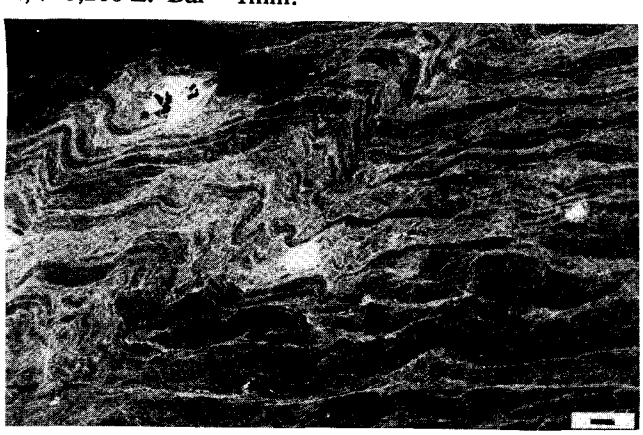


Figure 14. Negative print of polydeformed rock from Unit mrb. The white network consists of fine mica and isomorphous material. Dark bands are of highly granulated quartz with interstitial muscovite and biotite. Large white areas are goethite and pyrite. Sample collected from area of Beaverdam Creek at the south edge of the Keswick quadrangle. Metric grid 4,110,100 N, 738,440 E. Bar = 1mm.

penninite suggesting that some of the source material was mafic in composition.

Several large altered and foliated masses of mafic igneous rock lie along a segment of the Mountain Run fault zone in the area near Cobham. They appear to be dismembered blocks with no recognized evidence of their having been intruded as a magma at their present position. These rocks are too altered and deformed to be readily identified. In some places they resemble fine-grained greenstone; in other places, they vaguely resemble altered medium-grained, mafic plutonic rock and display irregular-shaped white and dark green patches. The white areas may be altered plagioclase, and the dark green areas an altered ferromagnesian mineral. Calcite makes up at least 10 percent of the rock and preferentially replaces the white altered material. The original rock, based on color and fabric, most likely was gabbro, diabase, or basalt.

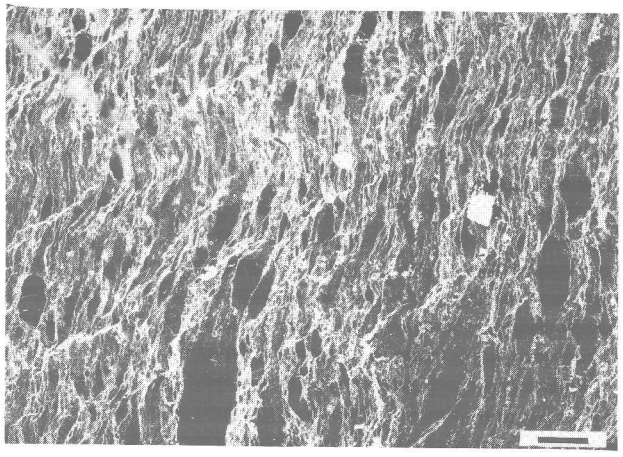
UNIT C

Unit c mainly consists of quartz-bearing phyllite. It lies stratigraphically above and generally to the east of unit b. Unit c contains lesser amounts of coarse-grained metasandstone and meta-arkose than unit b. It contains some zones of black phyllite and at least one mass of coarse-grained amphibolite. A thin-bedded phyllite lies within unit c, but is not sufficiently extensive to be shown as a separate unit. Many of the rocks of unit c in south-central Keswick and in the northwestern quarter of the Boswells Tavern quadrangles are infolded with, and are part of the fault slices containing the coarse-grained rocks of unit b. The rocks of unit c become progressively less deformed and less quartz rich eastward.

Phyllite: The phyllite of unit c is composed of muscovite, chlorite, and quartz. The muscovite is pale green to white with a pearly luster. Chlorite is sparse to absent. The included quartz grains make up from a few percent to 50 percent of the rock. Quartz grains are lenticular and may be several millimeters long. They tend to be flattened circular disks rather than ellipsoids and to lie parallel to the foliation. Being resistant to weathering, these quartz disks are preserved in saprolite. A sample from an area about one half mile east of U.S. Highway 15 and three quarters of a mile north of North Anna River shows foliation, produced by parallel muscovite grains, axial planar to a small fold (Figure 15). The fold in this case may have formed penecontemporaneous with the foliation.

Figure 16 is a negative print of thinly layered phyllite collected from the southwestern corner of the Boswells Tavern quadrangle. The layers range from 0.2 to 2 mm thick and consist of alternating light, and dark-colored lamallae. In outcrop they resemble varves. Most layers actually consist of extremely elongate lenses. The light-colored bands are composed mainly of equigranular, fine-grained (0.01 to 0.005 mm) unstrained secondary quartz crystals with mutually interfering, straight-sided grain boundaries. The dark-colored bands are composed of mica, actinolite, angular quartz (0.02 mm) and secondary quartz. Actinolite makes up an estimated 30 to 40 percent of the gray layers, and gives the rock a distinct greenish cast. The actinolite needles are undeformed and have a well-developed preferred orientation parallel to the layers. This actinolite formed from green chlorite (penninite) that occurs only in trace amounts in the present rock. Large (0.2 mm) relict quartz grains are sparsely present and many contain overgrowths of secondary quartz at the ends of the grains (pressure shadows).

Black phyllite: Black phyllite is poorly exposed but has been recognized in four places. Two exposures lie near the eastern edge of the northeastern part of the Boswells Tavern quadrangle. A third exposure is located near the intersection of



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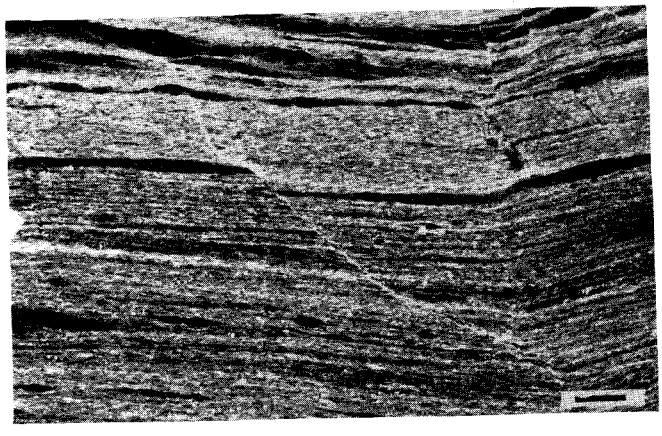

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U.S. Highway 15 and the North Anna River; a fourth is located in a small gully in the headwaters of Fielding Creek in the west-central part of the Boswells Tavern quadrangle. It is unlikely that the four outcrops are part of the same stratigraphic horizon. The rock is nearly black and somewhat schistose. Lithologically it is similar to the dark gray paragonite-bearing phyllite in unit bra.

Metasandstone: Metasandstone crops out in an arcuate belt extending from the South Anna River east of U.S. Highway 15, to a point near the northeastern corner of the Boswells Tavern quadrangle. Outcrops occur in the area east of Izac Lake, and along Lickinghole Creek. The unit is poorly exposed and its extent beyond the northeastern corner of the Boswells Tavern quadrangle has not been determined. The unit consists of a massive, thick bedded metasandstone.

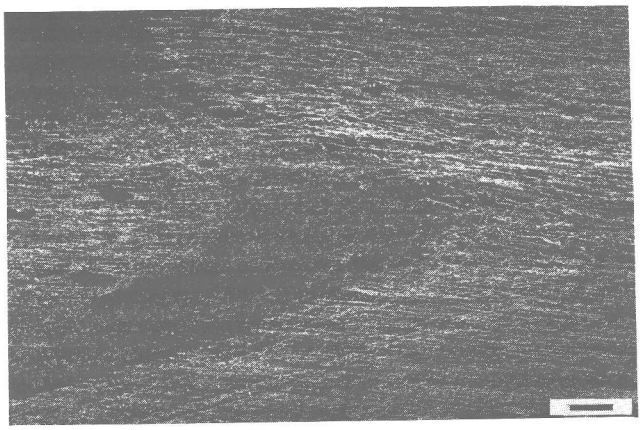
Amphibolite: Rock unit c contains a coarse-grained, dark gray amphibolite. It crops out along the northern edge of the Green Springs pluton along the south side of South Anna River, about one and a half miles west of the eastern edge of the Boswells Tavern quadrangle. A few other masses of amphibolite (unmapped) overlie the Green Springs pluton. One mass crops out on the east side of U.S. Highway 15 about one and one-half miles south of Boswells Tavern. The amphibolite has a decussate (criss-cross) texture and consists mainly of hornblende crystals as much as 2 centimeters long. In saprolite the hornblende may be partly replaced by vermiculite.

GREEN SPRINGS PLUTON

The igneous rocks making up the Green Springs pluton are of two types, an older diorite phase and a younger quartz diorite to granite phase. The quartz diorite-granite phase surrounds and intrudes the diorite phase as dikes and small apophyses. The pluton is flat topped, and its upper surface is coincident with the present land surface. Metasedimentary rocks, lithologically similar to those surrounding the pluton (unit c of the Mine Run Complex), lie on top of the pluton, and occur as xenoliths in it. The sedimentary rocks have been partially to totally assimilated into the igneous rocks. In many places a relict imprint of bedding is preserved in the partially digested masses of country rock at the top of the mafic portion of the igneous mass. The metasedimentary rocks that surround the pluton were also thermally metamorphosed during emplacement and cooling of the pluton. This is indicated by the presence of undeformed, randomly oriented, coarse-grained biotite and garnet found for distances of as much as one mile away from the intrusion. The evidence of assimilation, intrusion, and thermal metamorphism indicate that the Green Springs pluton is intrusive. Based on a gravity survey, Conley and Johnson (1975b) conclude that the igneous mass is rootless at depth.

DIORITE

In outcrop the diorite is light to dark gray, and the grain size ranges from fine (less than one mm) to coarse (+5 mm). Locally the recrystallization of the sedimentary rock resulted in the formation of coarse amphibolite containing large (0.5-1 cm) biotite crystals, and where the quartz diorite-granite phase of the pluton intruded the amphibolite, it further incre-



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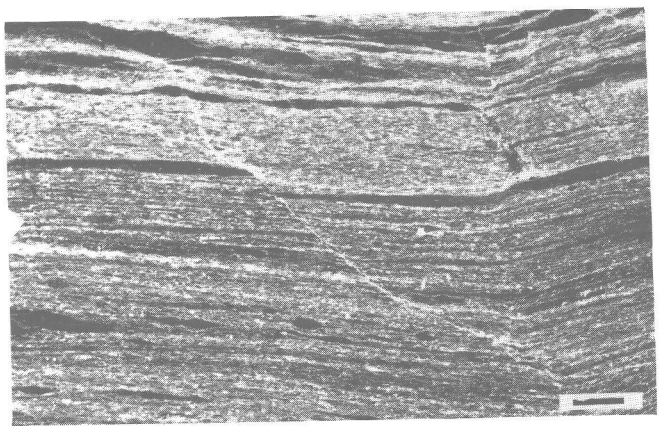

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Table 4. Chemical analyses of rocks and hornblende from the Green Springs Pluton, Boswells Tavern quadrangle, Virginia.(Analyst: Oliver M. Fordham. Analyses by X-ray flourescence. Fusion .5gm sample + 4.5 gm $Li_2B_4O_7$. Fundamental parameter for matrix difference. Mg and Na by atomic absorption. *Loss of water (LOI) by pyrolysis). Rock types: QD = Quartz diorite, D = Diorite, X = Xenolith in sample R-8768, H = Cleaned hornblende from sample R-8768, DD = Diabase from dike. (See text for description).

Repository No.	R-8762	R-8763	R-8764	R-8765	R-8766	R-8767	R-8768	R-8768	R-8769	R-8768
Rock Type	QD	QD	H	D	D	D	D	X	DD	H
SiO_2	68.64	68.50	46.24	46.19	56.22	50.84	51.44	45.82	46.09	50.20
Al_2O_3	17.69	15.40	8.60	8.90	15.21	16.60	17.61	13.54	15.71	7.00
Fe_2O_3	2.65	3.26	13.91	14.65	6.63	8.75	6.50	10.21	12.09	9.30
MgO	1.14	1.37	13.94	13.58	6.81	6.10	6.78	10.78	11.06	17.20
CaO	3.50	3.53	13.00	12.66	6.20	8.07	8.80	12.56	10.34	12.61
Na_2O	3.83	3.52	1.02	1.11	3.07	3.08	3.19	1.56	1.67	0.86
K_2O	0.62	2.61	0.80	0.94	3.60	2.94	2.30	1.30	0.39	0.57
TiO_2	0.32	0.48	0.79	0.83	0.60	0.95	0.48	0.84	0.48	0.41
MnO	0.05	0.05	0.27	0.25	0.12	0.15	0.10	0.15	0.19	0.21
P_2O_5	0.13	0.23	0.12	0.09	0.43	0.59	0.67	0.90	0.13	0.03
LOI*	1.40	1.01	1.22	0.71	1.04	1.92	2.08	2.29	1.80	1.39

ased the size of the biotite. Biotite also occurs in the diorite phase of the pluton as porphyroblasts as large as 1 cm across, but normally crystals are smaller (3 - 5 mm). The biotite is probably a secondary mineral and formed from the potassium-bearing minerals, hornblende and feldspar. Biotite is commonly hydrated to vermiculite.

The composition of the plagioclase in the mafic rock ranges from An_{30} to An_{70}. The most common composition is about An_{40}. Nearly all of the plagioclase is partially altered to epidote.

Hornblende composes 30 percent or more of the mafic rock. It is altered and the original crystals may be almost completely replaced by chlorite or biotite. An analysis of the hornblende is included in Table 4.

Orthoclase is present in mafic rocks that are adjacent to the quartz diorite-granite phase of the pluton. Some crystals are euhedral and as much as two centimeters across. They are commonly poikilitic and partly replaced by muscovite. Accessory minerals in minor amounts in the diorite phase include: zircon, apatite, sphene, garnet, pyrite, and magnetite. Quartz, may be present in the diorite as small subrounded grains that are completely enclosed in hornblende crystals (poikilitic texture). They are probably relicts of sedimentary origin.

Augite was found in rocks from two areas in the Green Springs pluton. One area is located 4000 feet N 45°W of the junction of Poore Creek and South Anna River. The other is 2000 feet due west of Poindexter, near the northern edge of the Zion Crossroads quadrangle. Hopkins (1960) reported finding enstatite-bearing rock in the proximity of this latter location, but no enstatite was found by the present writer.

Diopside is present locally in rock composed mainly of vermiculite and hornblende. In outcrop, this rock shows a relict primary foliation and probably represents a partial replacement of sedimentary rock. The diopside is interstitial to the vermiculite and hornblende.

Chemical analyses of the xenoliths in the diorite that are believed to be recrystallized sediments, and hornblende from the diorite are included in Table 4. The analyses confirm that the older intrusive rock is a diorite.

QUARTZ DIORITE-GRANITE

The quartz diorite and granite phase of the Green Springs pluton crops out on the east, south, (outside the map area) and west sides of the diorite portion of the pluton. In addition small apophyses and irregular shaped dikes intrude the diorite. These quartz diorite and granite rocks are light gray and medium to coarse grained. They are unfoliated and show no evidence of major deformation. The major composition of the rock is a quartz diorite based on IUGS classification (Streckersen and others, 1973). Quartz makes up more than half of the rock. The other major mineral constituents are plagioclase, up to 20 percent, and orthoclase, as much as 30 percent. Plagioclase ranges from oligioclase to low andesine. Biotite and muscovite are common accessory minerals, but are not abundant in the quartz diorite. Analysis of the quartz diorite-granite is included in Table 4.

AMPHIBOLITE DIKES

A few coarse-grained amphibolite dikes, associated with the diorite portion of the Green Springs pluton, intrude the metasedimentary rocks surrounding the pluton. Hopkins (1960) shows a number of these dikes on his geologic map, but most could not be located by the present writer. An amphibolite dike, crops out in the bed of a small stream located three-fourths mile southwest of Boswells Tavern. The rock is coarse grained and consists of blocky hornblende crystals imbedded in plagioclase. Its closeness to the Green

Springs pluton suggests that it may be derived from that source. This dike has been observed only at this one locality.

JURASSIC ROCKS

DIABASE

Diabase dikes are common throughout the Boswells Tavern and the southeastern part of the Keswick quadrangles. They are more numerous and larger in the southern part of the mapped area. All are near vertical and trend directions vary widely. Those in the northwestern corner of the Keswick quadrangle trend N 30°-45°E and a group in the vicinity of Beaverdam Creek in the southeastern part of the quadrangle trend N 0°-10°E. About 10 dikes in the southwestern corner of the Boswells Tavern quadrangle trend about N 30°W. An apparently through-going dike that has only been observed as float, has been traced in a N 10°W direction from Boswells Tavern to near the northern edge of the quadrangle. Diabase dikes intrude all older rocks including the Green Springs pluton.

Unweathered diabase is dark gray and massive, and upon weathering, tends to form rounded boulders, some as much as 3 feet in diameter. Outcrops of diabase are typically exposed in stream beds and on the lower valley slopes. They are rare to absent on high flat surfaces. As no significant natural transportation of boulders has taken place in the map area, even single boulders may indicate the presence of underlying dikes.

The diabases show only slight deuteric alteration. Dikes differ in the presence or absence of olivine, indicating that the original magma was not always of the same composition (Ragland and others, 1968).

Pyroxene is augitic in composition and the plagioclase ranges from An_{55} to An_{75}. The plagioclase is twinned and the rock shows the classic ophitic ("diabasic") texture

. A few dikes are offset by faults but are otherwise undeformed. The lack of deformation and trends of the dikes indicate that they were intruded in a non-compressive (tensional) environment. The dikes were probably feeders to the basaltic lavas preserved in Mesozoic basins. These lavas formed in Jurassic time (190 my) and once might have overlaid much of the Piedmont surface of Virginia.

STRUCTURE

FAULTS

Owing to the sparsity and small size of outcrops, actual exposed faults range from scarce to non-existent and their presence generally has been detected indirectly through changes in attitude of foliation, zones of intensely sheared rock, offset of lithologic units, and the presence of topographic lineaments.

Seismic and gravity surveys suggest that bedrock in the Virginia Piedmont consists of a series of southeasterly dipping and overlapping thrust-fault slices (Harris and others, 1982). The present investigation suggests that, in the map area, there has been considerable limited northwestward displacement by thrust faulting and folding. Thrusting has stacked up a series of poorly defined, overlapping, and folded fault slices in the northeastern part of the study area.

FAULTS RELATED TO THE INTRUSION OF THE GREEN SPRINGS PLUTON

Several steeply-dipping faults have displaced unit c of the Mine Run Complex in the area west of the Green Springs pluton. Most of these faults formed as a result of the dilation of cover rocks caused by intrusion of the igneous rocks and as a result, tend to lie parallel to the foliation. A fault present in the valley of Lickinghole Creek that trends parallel to the foliation and bedding, may mark the horizon along which the principal intrusion occurred.

FAULTING ALONG THE CATOCTIN-LYNCHBURG CONTACT

Some faulting has taken place along the contact between the rocks of the Lynchburg Group and the Catoctin Formation. The relative amount of movement cannot be determined within the map area, but outcrops a short distance to the south show that some of the gneissic horizons of the Lynchburg are truncated against the greenstone of the Catoctin.

MOUNTAIN RUN FAULT ZONE

A wide zone of shearing and displacement called the Mountain Run fault zone (Pavlides and others, 1983; Conley, 1987) trends northeastward across the map area. The western edge of the zone of faulting lies in the stream drainage of Mechunk Creek. The eastern edge of the zone extends from Beaverdam Creek at the south edge of the Keswick quadrangle to the lower end of Lake Gordonsville in the Boswells Tavern quadrangle.

The Mountain Run fault zone is a linear depression that is traceable completely across the map area. The zone consists of a number of roughly parallel or anastomosing fault traces containing highly deformed rocks of units a and b of the Mine Run Complex. The western edge of the fault zone lies near or against the upper contact of the Everona Limestone.

Small northeast-trending drag folds with nearly horizontal axes can be seen in several places east of Mechunk Creek. Striations on the surface of beds within these folds are nearly horizontal. This is interpreted to mean that drag folding was the result of strike-slip displacement. Conley (personal communication, 1989) believes displacement within the Mountain Run fault zone was in part right-lateral strike-slip based on intersection of S and C structures and the straight-line trace of the fault. Bobyarchick (1988) shows the Mountain Run fault to be a continuation of the Brevard strike-slip fault. This writer believes that the major faulting began as right lateral, strike-slip, later followed by minor thrust movement to the northwest within the fault zone.

Spur faults in the vicinity of Mechunk Creek appear to beminor thrusts originally of low dip to the southeast and northwest displacement.

OTHER FAULTS

A few normal faults have been recognized within the map area. All are steeply dipping and have a northwestward trend. One, located 1.5 miles northeast of Cismont on State Highway 231, offsets the rock units of the Catoctin Formation and the bra and brb units about 600 feet in a left-lateral sense.

A northwest-trending fault with about 200 feet of apparent left-lateral displacement offsets rock strata in the vicinity of Preddys Church, in the northwestern part of the Keswick quadrangle. Rocks along this fault zone are hydrothermally altered and may be capped with gossan.

FOLDS

No major folds have been recognized in the map area, but overturning of the rocks in the leading edges of thrust faults has been observed. Such folds occur in the area immediately southwest of Lake Gordonsville and in the area northwest of Beaverdam Creek.

The rocks in the area from northwest of Boswells Tavern to the northern edge of the Boswells Tavern quadrangle, are complexly folded. The folds are asymetrical, trend northeastward, and plunge at low angles to the northeast and to the southwest. Normally the western facing forelimbs are about half as long as the eastern facing backlimbs, and the rock of unit c of the Mine Run Complex may be infolded with the coarse-grained arkose of unit b of the Complex in this area.

ECONOMIC GEOLOGY

PYRITE AND IRON

The northwestern corner of the Keswick quadrangle in the vicinity of Stony Point, contains a few areas in which the rocks show sulfide mineralization. Rocks of the Lynchburg Group contain disseminated pyrite in the bed of Turkey Run 2200 feet downstream from State Highway 20. The mineralized zone crops out over a distance of a few tens of feet. The mineralized rock is white and material at the surface is soft. Pyrite may make up a few percent of the material present in the area exposed. No trace of copper or other minerals of value were visually detected. Another outcrop containing an estimated 10 to 15 percent pyrite lies about 400 feet south of the northern edge of the Keswick quadrangle, 1800 feet due west of State Highway 20 on the north valley flank of a small unnamed creek. The outcrop is only a few square feet in area and stands a foot or less above the general level of the surrounding terrain. A third zone which has been explored by pits and trenches lies on the top of a hill 2200 feet northwest of Preddys Church.

A relatively large area, located in the northwestern part of the Keswick quadrangle, contains a number of sulfide-enriched zones. These zones are, in part, gossan capped. The largest zone is about 7500 feet long and lies along a steeply dipping fault zone. Its maximum width is about 800 feet. A gossan-covered area about 2000 feet long branches off of the main zone. This branch contains some of the most massive gossan found. The hydrothermally altered underlying parent rock of this gossan is derived from the metavolcanic rocks of the Catoctin Formation. It is soft, and light gray to yellowish and the overlying gossan is black, dense, and in places, shows collaform structure. The composition of typical hydrothermally altered rock (R-8779) is shown in Table 3. X-ray analyses shows that the rock contains dickite.

STONY POINT COPPER-IRON MINE

The Stony Point copper mine is located on the northwest end of the large hydrothermally altered zone described above. Gossan, formed from alteration and weathering of the sulfides, was once mined as a source of iron (Watson, 1907). The deposit was first worked by Major Mason in 1878. An inclined shaft is reported to have reached a depth of 130 feet and 2500 carloads of gossan iron ore were shipped from the deposit (Nelson, 1962). According to a local resident, Mr. M. Norford (personal communication, 1987), a narrow gauge railroad was constructed along the valley of Turkey Run from Watts on the Southern Railway to the mine, a distance of about 3 miles. Estimating that small, mule drawn mining cars with a capacity of about 24 cubic feet or about two tons were used, about 5000 tons of gossan may have been mined and shipped.

The mineralized area was diamond drilled in 1936 by the American Metals Company, but the mineralization was not considered attractive enough to develop as a mine (Nelson, 1962). According to Nelson's report, the mineralized rock lies along a fissure and contains pyrite, sericite, and some chalcopyrite. It is not known whether the mineralized rock ever was analyzed for other elements of possible economic value. Nelson (1962) states that the deposit was traced for 1800 feet in an easterly direction and was cut off by a fault. This relatively short reported extent of the mineralized zone, as compared to its actual length of 7500 feet, suggests that the full extent of the mineralized zone may not have been known. Hydrothermally altered rock lie to the south of this main zone, and some crop out as much as 4000 feet beyond the western edge of the Keswick quadrangle. Some of these areas are capped by gossan, but no copper minerals were discovered.

LIMESTONE

An abandoned and flooded limestone quarry is located in the Everona Limestone near the north edge of the Boswells Tavern quadrangle. Dump material shows that the quarried rock was a thinly bedded (less than one cm) limestone. In addition to this larger quarry, a few small quarries lie along the limestone formation in the northeast to south-central part of the Keswick quadrangle, near Campbell. Some of these quarries have been filled and reclaimed and can no longer be detected visually. The Everona Limestone lies only a few feet above the water table, generally under swampy conditions. It has a minimum known thickness of 400 feet at the point where it crosses Turkeysag Creek. At the abandoned limestone quarry at the north edge of the map area, the limestone is about 750 feet across. Although not positively established, it is likely that the limestone is discontinuous along its length.

The limited width, calcium carbonate content averaging about 74 percent in the mapped area, and physically unfavorable location for exploitation, suggest that the limestone in the mapped area has little economic value for lime at the present time (Mack, 1965). Suitable material for crushed stone may be present.

STONE

The physical properties of rock for use in building and highway construction are important. The greenstone from portions of the Catoctin Formation have a grade "A" classification for use as highway aggregate (Parrott, 1954). From the known extent of the Catoctin Formation, the amount of material suitable for use as construction or aggregate is virtually limitless.

Thin-bedded, slaty limestone of the Everona Formation was quarried for use as crushed stone, from 1954 to the late 1960s at the Superior Stone Company quarry in the northern part of the Boswells Tavern quadrangle.

VERMICULITE

Vermiculite is present in great tonnages in much of the northern half of the area underlain by the mafic portion of the Green Springs pluton. The single deposit now being mined by Virginia Vermiculite Ltd. was not accessible to the writer for examination, and only those relationships observed in outcrops of limited size in other areas can be described.

Vermiculite is widespread and of mineable thickness over much of the northern half of the mafic portions of the pluton. Vermiculite is also present in the southeastern corner of the Boswells Tavern quadrangle as well as in the northern part of the Zion Crossroads quadrangle, which is located to the south of the map area. The vermiculite is restricted to a relatively thin zone less than 100 feet thick (?) at the top of the mafic portion of the Green Springs pluton. This zone has developed where the igneous rock has assimilated and recrystallized the overlying metasedimentary rocks of unit A of the Mine Run Complex.

Because only small exposures of vermiculite-bearing material have been examined, no firm conclusions on the genesis, size, or grade of the vermiculite deposit could be drawn. In outcrop, the vermiculite is intimately associated with coarse-grained hornblende amphibolite. Fresh rock is believed to be a coarse-grained hornblende-biotite rock, in which the biotite was altered to vermiculite. In places the original rock is intruded by felsic igneous rock. This intrusion of felsic rock may be a factor in producing the vermiculite. Where this has taken place both the hornblende and biotite crystals are considerably larger.

The vermiculite is mined from an open pit, washed, concentrated, dried and screened to produce four sizes. Crude vermiculite is shipped, unexfoliated, to North Carolina, West Virginia, Ohio and to other eastern states.

MARBLE

Pink and white dolomitic marble crops out in the stream bed of Happy Creek, just a few feet southwest of where State Highway 231 crosses the creek. Marble at the same stratigraphic horizon as the marble exposed in Happy Creek, namely just above the contact with the underlying Catoctin Formation, has been quarried for dimension stone on the southeast side of State Road 647 at Madison Run, northeast of Gordonsville. The marble is so poorly exposed along Happy Creek, that its extent is not known.

SLATE

A small quarry (abandoned) occurs in unit bra on the southwest slope of Happy Creek, just east of where State Highway 231 crosses the creek. The rock in this quarry is stratigraphically just above the dolomitic marble. Judging from the size of this excavation, it might have been for local use only. Phyllites that possess good slaty cleavage have been quarried in both units bra and brb since the area was first settled. Nelson (1962) reports that these slates were intermittently quarried at Esmont southwest of the study area between 1906 and 1957. The quarry produced stone for granules used in roofing shingles.

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

EXPLANATION

al

Alluvium

Thin deposits of gravel and sand, gray clay and partially decayed vegetative material.

d

Diabase

Dark-green to dark-gray diabase. Filled circles indicate either small outcrops of float.

Rocks east of the Mountain Run Fault Zone

gf | gm | h

Rocks of the Green Springs pluton

gf, light-gray granodiorite-granite; gm, coarse- to medium grained, diorite; CpCc overlay pattern indicates rock containing thermally metamorphosed and partly assimilated sedimentary rock; ⋮ overlay pattern indicates areas containing granodioritic dikes and apophyses; h, dark greenish-gray, coarse-grained hornblendite composed of blocky hornblende crystals and minor interstitial plagioclase (andesine).

mrc | am | mrc | s | mrc | bp | mrc

Mine Run Complex, Unit C

mrc, phyllite containing scattered detrital quartz.; ⋮ overlay pattern indicates areas containing rocks thermally metamorphosed by the Green Springs pluton; bp, black phyllite; s, metasandstone or arkose; am, coarse-grained amphibolite.

mrb | ma | mrb

Mine Run Complex, Unit B

mrb, coarse-grained meta-arkose, and metagraywacke interstratified with lesser amounts of metasiltstone, phyllite and quartzite; ma, highly deformed and altered mafic igneous rock.

mra

Mine Run Complex, Unit A

Phyllite interstratified with lesser amounts of metasandstone and detrital quartz-bearing phyllite.

Rocks of the Blue Ridge Anticlinorium

Cev

Everona Limestone

Dense, gray, thin-bedded metalimestone.

brb | gp | brb

Unit brb

brb, gray, fine-grained phyllite; gp, dark-gray paragonite-bearing schistose phyllite.

bra | m | bra | g | bra | a | bra

Unit bra

bra, medium to coarse-grained metagraywacke and metasiltstone; a, coarse-grained meta-arkose; g, gray schistose phyllite; m, white dolomitic marble.

CpCc | p | CpCc | v | CpCc | lv | CpCc | q | CpCc | p | CpCc

Catoctin Formation

CpCc, gray, massive, to schistose metabasalt and epidosite in upper and central part. Gray metabasalt breccia, light-gray meta-andesitic tuff interbedded with medium to coarse-grained meta-arkose, interlayered with dark greenish-gray, massive to schistose metabasalt in lower part; p, phyllite; q, light-gray, medium to coarse-grained quartzite; lv, light gray-green lenticular masses of basaltic rock imbedded in dark-green, schistose, chlorite, matrix; v, dark-gray massive basalt, amygdaloidal in part; p, light gray, reddish-brown or dark-gray hydrothermally altered metabasalt, containing dickite. Gossan capped in places.

pCly

Lynchburg Group

Gray, thick to medium-bedded, medium to coarse-grained quartz-mica gneiss, and thin to medium-bedded, medium to coarse-grained quartz- biotite-muscovite gneiss.

KEY

SHEAR ZONE

CONTACTS

Exposed or approximate, dashed where covered or inferred.

Anticline showing direction and angle of plunge.

Syncline showing direction and angle of plunge.

Direction and angle of plunge of minor anticline.

Direction and angle of plunge of minor syncline.

Axial plane of minor fold showing direction of dip axial plane, arrow indicates direction and angle of plunge of fold hinge.

FAULTS

U D A T

Solid line where exposed or approximate, dashed line where covered or inferred; U, upthrown side; D, downthrown side; T, upper sheet; Tick indicates direction of dip; arrows indicate direction of relative movement; ? direction of movement uncertain; T movement toward viewer, A movement away from viewer; cross section only.

ATTITUDE OF ROCKS

Strike and dip of beds. Does not imply beds are either upright or overturned.

Strike of vertical beds.

Horizontal beds.

FOLIATION AND CLEAVAGE

Strike and dip of foliation.

Strike of vertical foliation.

Strike and dip of compositional layers.

Strike of vertical compositional layers.

QUARRIES AND PROSPECTS

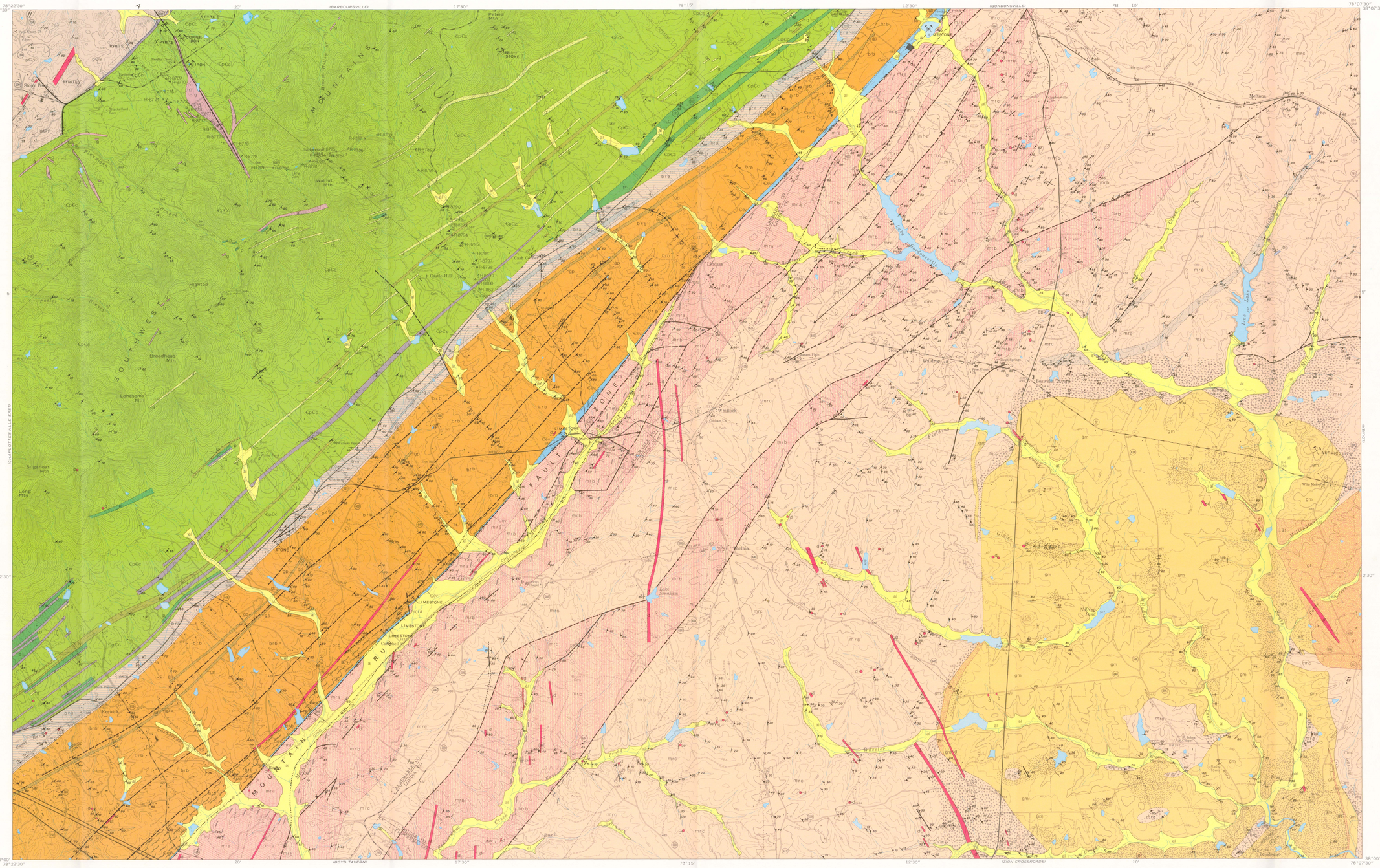
Active quarry

Abandoned quarry

Prospect or mineralized zone

SAMPLE LOCATIONS

R-8700, Repository number of sample



Base map from U.S. Geological Survey, 7.5-minute series
Keswick, 1964, PR 1978; Boswells Tavern, 1970, PR1978

SCALE 1:24 000

CONTOUR INTERVAL 20 FEET
NATIONAL GEODETIC VERTICAL DATUM OF 1929

UTM GRID AND 1987 MAGNETIC NORTH DECLINATION AT CENTER OF SHEET

QUADRANGLE LOCATION

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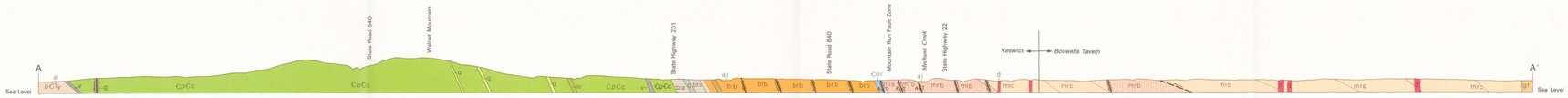
GEOLOGY OF THE KESWICK AND BOSWELLS TAVERN QUADRANGLES, VIRGINIA

Darwin L. Rossman

1991



CROSS SECTION DESIGN
1. No vertical exaggeration.
2. Subsurface structure interpreted from surface measurements.
3. Thickness of alluvium diagrammatic.