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Geology of the Upperville 7.5-Minute Quadrangle, Fauquier and Loudoun Counties, Virginia

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DISCUSSION

Introduction

The geology of the Upperville quadrangle was mapped as part of a larger project to map the geology of the Washington West quadrangle at 1:100,000 scale. Many workers previously have reported on various aspects of the geology in nearby areas (Lukert and Banks,1968; Lukert and Nuckols, 1976; Mitra,1978, 1979; Espenshade and Clarke, 1976; Lukert and Halladay, 1980; Lukert and Clarke, 1981; Espenshade, 1986; Tollo and others, 1991; and Kline and others, 1990). Eric R. Force mapped the northeastern part of the quadrangle (fig. 1), but did not publish his map. He has allowed me to use his data.

The author wishes to express his deepest appreciation to the numerous land owners and farm managers who allowed him access to their properties within the Upperville quadrangle and who were most helpful in many other ways as well. I also wish to acknowledge the many geologists of the U.S. Geological Survey who have been working in near-by areas, also as part of the Washington West mapping project, for their helpful discussion and field conferences.

General Geology

The quadrangle is underlain by crystalline rocks of the Blue Ridge anticlinorium, a major structure that extends northeasterly from North Carolina through Virginia, Maryland, and into southern Pennsylvania (Espenshade, 1970; and Rodgers, 1970). Colluvium as a thin veneer is widespread throughout the quadrangle and undivided colluvial and alluvial deposits are present along most streams. The principal drainage for the quadrangle is the easterly flowing Goose Creek and its tributaries.

Within the Upperville quadrangle Late Proterozoic metavolcanic rocks together with some metasedimentary rocks form the Blue Ridge anticlinorium's west flank. These metamorphosed layered rocks lie unconformably on Middle Proterozoic plutonic rocks (Yaw) in the northwest part of the quadrangle. Rocks of the Robertson River Igneous Suite together with Middle Proterozoic porphyroblastic granite gneiss (Yaw) comprise most of the anticlinorium's core in the Upperville quadrangle. The core also contains lesser amounts of Middle Proterozoic paragneisses, granitoids, and granitic gneisses. A mafic dike swarm also intrudes the plutonic gneisses. These dikes, which comprise a high percent of a given area, are interpreted to represent feeder dikes for some Late Proterozoic metavolcanic rocks underlying the northwest part of the quadrangle. A few exposures, some too small to be mapped, of very fine-grained rhyolite dikes are also present.

Although all the oldest plutonic rocks underlying the Upperville quadrangle have not been dated, some rock units described below have preliminary radiometric dates that suggest they correlate with other rocks elsewhere in the anticlinorium that range from 1,500-1,000 my (Tilton and others, 1960; Rankin and others, 1983; Herz and Force, 1984; Sinha and Bartholomew, 1984; Aleinikoff, USGS written commun., 1991). Tollo and Lowe (1990) reported that rocks of the Robertson River Igneous Suite, which intrude the Middle Proterozoic gneisses, range in age from 735-700 Ma.

Each mapped unit is described and its structural characteristics mentioned, but the structural details for the mapped units are collectively described under the deformation section.

Middle Proterozoic Rocks

Felsic gneiss (Yfg)

The felsic gneiss, which is commonly mixed with lesser amounts of granitoid, underlies a large area in the eastern part of the quadrangle. The dominant lithology is a pinkish gray, fine-grained, thinly and faintly layered biotite-quartz-feldspar gneiss, commonly with plagioclase and potassium feldspar porphyroblasts. The layers are light pink, pinkish gray, and gray, and the rocks characteristically contain bluish quartz disks and veins together with granitic and pegmatitic pods and lenses; feldspathic segregations are widespread. Widespread faintly foliated, light-gray, fine-to medium-grained granitoid is interlayered with the felsic gneiss, and rarely with dark-gray thinly layered, fine-grained biotite schist.

The felsic gneiss contains very-thin folia of biotite and has a characteristic strong foliation. Exposures commonly display a gneissic layering that varies in width. The biotite lenses and segregations are very thin, seldom more than 3 mm wide, and the felsic layers and included quartz ribbon-like bands are wider and most commonly range between 1-5 cm but some are wider. In places the foliation is contorted and the felsic gneiss has been isoclinally folded around northeast trending axes. Fold amplitudes and wave lengths are generally less than 1 meter in length. This folding has not been observed over a wide area and does not seem to have influenced the regional trends of the major map units.

Some of the granitoid was locally separated out as a distinct map unit (Ygf) and is described below. Other small amounts of widely separated porphyroblastic granitic gneiss (Yae) with coarse feldspar augen, as well as some equigranular Marshall metagranite (Ym), both of which are described below, are included in the felsic gneiss, but because of insufficient exposures they could not be mapped separately at the map scale.

Numerous exposures display narrow ductile deformation zones (Mitra and Lukert, 1982) that are seldom greater than 5 mm wide. These zones have various orientations that invariably cross-cut foliation planes. A distinctive shear zone, upwards of 2 meters wide, separates the felsic gneiss from rocks of the Robertson River Suite near Kerfoot. This shear zone is shown as an unnamed inferred fault on the map; its relative displacement is unknown.

The rock unit distribution pattern on the map together with the structural data suggests the felsic gneiss was intruded by the 1144 Ma old coarse granite gneiss (Yae) described below. However, I have not been able to positively confirm this from cross-cutting relations in rock exposures, and their relative ages are uncertain. Radiometric Pb/Pb zircon age studies for the felsic gneiss show it contains zircon populations with differing ages, making its age difficult to interpret. The oldest Pb/Pb age is about 1144 Ma (Aleinikoff and others, 1993) and is interpreted to represent the age of the felsic gneiss. The younger ages are believed to represent intrusives such as the Marshall Metagranite and granitoid. Alternatively the oldest age may be from zircons that had retained the age of an older rock after incorporation into the felsic gneiss. If this is true the 1144 Ma eastern porphyroblastic gneiss (Yae), which is described below, would be older than the felsic gneiss (Yfg).

The felsic gneiss extends north and northeasterly, and in the adjacent Bluemont quadrangle to the northeast. Southworth (1994) mapped these well-layered gneisses as the Granite Gneiss (Ylg). Southworth indicated that these rocks in the Bluemont quadrangle have Pb/Pb ages ranging from 1092 to 1139 Ma. W.C. Burton (USGS, Oral commun. 1992) suggested the felsic gneiss might be an equivalent to some unnamed paragneiss in the Waterford area that was partially melted by a 1060 Ma garnet monzogranite. I have interpreted the protolith of the layered felsic gneiss to be a sequence of felsic volcanic rocks, which were subsequently intruded by various granitic rocks that were later homogenized during Grenvillian high-grade regional metamorphism.

Granitoid (Ygr)

The granitoid layers, which are widespread within the previously described felsic gneiss, range from about 3-5 cm upwards to a meter or more wide. The granitoid is mostly light gray, fine-grained, and is moderately to indistinctly foliated; it commonly contains flattened bluish quartz disks and grains. The southeast part of the quadrangle has several areas where the light gray granitoid is exposed, but many scattered exposures that are too small to be shown at the map scale are widespread within the felsic gneiss northward toward Kerfoot.

Charnockite (Ych)

Charnockite underlies an area in the northeastern part of the quadrangle south of Upperville where it forms an elongate northwest-trending intrusion into the felsic gneiss. The contacts between the Charnockite and the enclosing gneisses are concealed and were located by the distribution of float. One exposure, however contains a dikelet of charnokite intruding aplite. The charnockite, which is mostly coarse and massive, is faintly foliated locally. It is poorly exposed but consists mostly of plagioclase, altered pyroxene, and minor quartz. Radiometric age dates are not available for the Charnockite and its age relations to some rocks units is unknown.

Eastern porphyroblastic granite gneiss (Yae).

The eastern porphyroblastic granite gneiss is exposed in several areas in the southeastern part of the quadrangle east and southeast of rock exposures of the Robertson River Igneous Suite near Delaplane. Isolated exposures are also present within the previously described Mixed Felsic Gneiss and Metagranite unit farther to the northeast. The eastern porphyroblastic granite gneisses have mineralogies, and structural and textural features that are similar to those characteristics described below for the western porphyroblastic granite gneiss (Yaw) and will not be described here. The eastern and western porphyroblastic gneisses, which are not juxtaposed anywhere in the quadrangle, are lithologically very similar and difficult to differentiate in field exposures.

A preliminary U-Pb zircon and monazite age for the eastern porphyroblastic gneiss, exposed south of the quadrangle, is 1144 +/- 2 Ma (Aleinikoff and others, 1993).

Marshall Metagranite (Ym)

The Marshall metagranite is principally exposed in the southeastern part of the quadrangle, mostly east and southeast of Delaplane, where it is mapped separately. Elsewhere to the north along the eastern part of the quadrangle, the Marshall is present as small unmapped exposures within the felsic gneiss and mixed rock unit. The Marshall is widespread in the adjoining Rectortown quadrangle to the east and in the Marshall quadrangle to the southeast (Espenshade 1986). The Marshall is mostly a gray to dark gray, quartz, potassium feldspar, metagranite with lessor amounts of epidote, sericite, and biotite.

Foliation is only moderately developed: some exposures display a distinct planar structure while in other outcrops it is poorly developed. Some exposures display numerous narrow, generally less than 1 cm wide, ductile deformation zones that intersect with each other and post-date the foliation. Late fractures cut all planar fabrics.

Espenshade (1986) reported a 207Pb/206Pb age of 1,010 my age for the Marshall metagranite. Later work by Aleinikoff (USGS written commun. 1994), however, indicated that two samples of Marshall metagranite have zircon 207Pb/206Pb ages of 1111 and 1112 my respectively. Aleinikoff's work includes radiometric dates on two samples with almost identical results and are the ages used in this report.

Tongues of the Marshall intrude the felsic gneiss unit (Yfg), but field observations cannot determine the age relations between the Marshall and the Eastern porphyroblastic granitic gneiss within the Upperville quadrangle. However, in the adjoining Rectortown quadrangle, Peter Lyttle (USGS oral commun. 1995) observed small bodies of Marshall-like rocks in the eastern porphyroblastic gneiss. Radiometric age determinations show the Marshall to be younger than the 1144 my (Aleinikoff, USGS written commun. 1994) Eastern porphyroblastic gneiss.

Flint Hill Gneiss (Yf)

The Flint Hill Gneiss (Lukert and others, 1977) is present just west of Little Cobbler Mountain as a narrow northeast-trending rock unit that extends into the quadrangle from near the central part of the southern border. It is exposed within a belt that is almost 5 km long and its average width is about 0.6 km. In the Upperville quadrangle the Flint Hill is completely surrounded by rocks of the much younger Robertson River Igneous Suite.

The Flint Hill is principally a well-foliated quartzo-feldspathic-biotite gneiss with a distinct augen fabric. Very-thin dark hornblende-biotite folia alternate with quartz feldspar layers to define a prominent foliation. Streaks of biotite which are seldom thicker than 2 mm alternate with thicker felsic layers that rarely exceed 1.5 cm in thickness. Both the mafic and felsic layers are discontinuous and the foliation is wavy around augen of either feldspar or aggregates of feldspar and quartz. Commonly large microcline augen as much as 3 cm long are present within the felsic layers. Some Flint Hill exposures show discrete linear lenses of feldspar and quartz aggregates that may be as much as 10 cm long, and locally thin 2-5 cm thick quartz ribbon-like bands, which may exceed 2 m in length. These linear bands parallel the foliation.

Rare, thin, discontinuous layers of quartzite are interlayered with the diagnostic quartzo-feldspathic gneiss of the Flint Hill. These quartzite layers, which are as much as 2 m wide and contain thin lenses of the diagnostic Flint Hill lithology, are interpreted to represent metasedimentary rocks. The quartzite contacts with the surrounding Flint Hill are concealed. Also present in the Flint Hill, but in minor proportions are a dark gray biotite gneiss. Thin, fine-grained hornblende granitic lenses are irregularly dispersed within the Flint Hill, and are interpreted to represent small intruded bodies of the Robertson River Igneous Suite.

The Flint Hill has a 1081 Ma Pb 207/206 age that was done on bulk zircon separates (Clarke, 1984). Since this age was made on bulk zircon separates, it may actually record an age younger than might be expected by using more modern methods of zircon dating. Therefore the relative age between the Marshall metagranite and the Flint Hill is uncertain.

Western porphyroblastic granitic gneiss (Yaw).

A large part of the western half of the quadrangle is underlain by porphyroblastic granitic gneiss characterized by large pink microcline crystals and/or augen. These rocks form a belt, about 2.4 km wide along the north border of the quadrangle that widens considerably to the southwest. On the northwest side these gneisses are unconformably overlain by the Late

Proterozoic Swift Run (Zs) and Catoctin Formations (Zc); on the southeast side they are in contact with the main belt of igneous rocks named the Robertson River Igneous Suite, recognized by other workers (Tollo, 1986, 1993; Tollo and Arav, 1987; Mose and Nagle, 1984; Lukert and Banks, 1984). A large, somewhat irregular, body of the Laurel Mills Granite of the Robertson River Igneous Suite intrudes the western porphyroblastic gneiss in the area centered near Naked Mountain.

Both the eastern and western porphyroblastic gneisses were polydeformed and in places display two foliations. The older of the two foliations strikes west to northwesterly, dips steeply either north or south, and is interpreted to represent a Grenville structure. This foliation is not commonly observed and is only positively identified where a later foliation, which generally trends northeast, is also present. The older foliation seems to be more distinctly streaked by alternating mafic and felsic layers than does the younger fabric, and the biotite of the younger foliation appears to be more chloritized.

A distinct phacoidal or augen texture also characterizes the eastern and western Porphyroblastic gneisses. Microcline crystals or aggregates of feldspar and quartz form the augen and commonly thin wisps of biotite and or chlorite appear to surround or outline the augen to form a wavy foliation. The microcline augen are as much as 5 cm long and 2 cm wide. The augen or phacoids are interpreted to result from superposition of the later foliation upon the earlier Grenville planar fabric. In places the intersection of these structures has also formed an easterly plunging lineation.

Normative mineral determinations show that a sample of western porphyroblastic gneiss contains about 7 percent less quartz, 3-4 percent more orthoclase, and about 3 percent more mafic minerals than does a gneiss sample collected in the southeastern part of the quadrangle. Additionally the eastern porphyroblastic granitic gneiss appears to contain more quartz and less mafic minerals than those in the western belt. These results are tentative, however, since they are based on only a few analyses. Chemical analyses may indicate whether significant differences do exist between these western and eastern granitic gneisses.

Some exposures show these rocks to be highly sheared, and they display brittle and ductile fabrics. Shear bands are present locally, but shear sense indicators are somewhat equivocal and most indicators suggest an east over west sense of movement. Narrow, commonly discontinuous, mylonitic zones with varying orientations are present in many exposures of the porphyroblastic gneisses. The distributation of mylonite zones does not suggest that they relate to faults that could be shown at the map scale. They are thin, commonly less than 5 mm wide, anastomosing, and in places intersect each other to form a network or rock mosaic. Espenshade (1986) called similar features in the adjacent Marshall quadrangle to the southeast tectonic breccia.

Many thin sections also show tiny mylonite and recrystallized zones, as well as mortar-textured zones. Some thin sections suggests that some shearing was localized in zones now dominated by aggregates of very fine-grained dark biotite and chlorite. Mylonitization was followed by brittle deformation in some rocks as large grains in a protomylonite have been fractured along with the mylonitic matrix.

A preliminary zircon U/Pb age for the western porphyroblastic gneiss (Yaw) is 1055 +/- 5 Ma (Aleinikoff and others, 1993), which is considerably younger than the similar appearing eastern porphyroblastic gneiss (Yae) with an age of 1144 +/- 2 Ma.

Late Proterozoic Rocks

Robertson River Igneous Suite (Zrl and Zrc)

Intrusive rocks of The Robertson River Igneous Suite (Tollo and Lowe, 1990) underlies a larger area of the quadrangle than any other mapped unit. Rocks of the suite extend across the entire quadrangle from the southwest to the northeast; along the southern border their outcrop width is almost 8.3 km and along the north border their outcrop width is almost 1.3 km. An irregularly shaped western belt of the Robertson River, the Laurel Mills Granite (Zrl), underlies Naked Mountain north of Markham and areas north of there. This rock body intrudes the western porphyroblastic granite gneiss.

Rocks of the Robertson River Igneous Suite range from granite to alkali syenite (Tollo and Lowe, 1990). In the Upperville quadrangle only the Laurel Mills Granite (Zrl) and the Cobbler Mountain Alkali Syenite (Zrc) of the Robertson River Suite (Tollo and Lowe, 1990) are present. Except for the area west, north, and northwest of Kerfoot the Cobbler Mountain Syenite and the Laurel Mills Granite are undivided, but elsewhere they are mapped separately. These rocks were emplaced into older rock sequences that are exposed to the east and the west.

The granitic body that underlies Naked Mountain appears to be a major body of the Late Proterozoic anorogenic Laurel Mills Granite (Tollo and others, 1991) that has not been heretofore recognized. Its contact with the western porphyroblastic gneiss, although concealed, is interpreted to be intrusive. The northwestern most exposures of the Laurel Mills appears to have intruded the western porphyroblastic gneiss as several northerly trending finger-like bodies. Elsewhere, also north of Naked Mountain, the north border of this Laurel Mills body generally trends northwesterly across the regional structural trend of the porphyroblastic gneiss. South of Markham, a shear zone, which is part of the Front Royal fault (Lukert and Nuckols, 1976), separates the Naked Mountain body of Laurel Mills from the main body of the Laurel Mills underlying the central part of the quadrangle.

Rocks of the Robertson River have been locally, severely deformed and intensely sheared. In the Upperville quadrangle, foliation is well-displayed in the medium-to coarse-grained Laurel Mills Granite, but is only observed in a few scattered outcrops in the Cobbler Mountain Alkali Syenite. A faint northeast-trending and steeply east-dipping cleavage also penetrates a few rocks. The age of this fabric is unknown but may be related to one of the two cleavages observed in the Catoctin Formation. In places a post- foliation deformation has produced narrow ductile shear zones that seldom exceed 2 mm in width. These deformation zones penetrate the rocks and, where extensively developed, form intersecting networks. Thin sections usually show both ductile and brittle deformation features; tiny discontinuous mylonite and blastomylonite zones are commonly observed and numerous feldspar and quartz grains are fragmented.

Large parts of the Laurel Mills Granite possess fabrics that more closely resemble those of the porphyroblastic gneisses than those of the Cobbler Mountain Alkali Syenite of the same igneous suite. These physical characteristics indicate that the Laurel Mills had a more complex deformational history than other rocks of the suite. Radiometric studies show that the Robertson River rocks were intruded during an interval spanning the range from 735 to about 700 My ago (Tollo and Lowe, 1990).

Fine-grained metagranite and associated granite dikes (Zgr)

A few small fine-grained metagranite plutons and thin fine-gained granitic dikes intrude the Cobbler Mountain alkali syenite in the northeastern part of the quadrangle. Some exposures contain an indistinct foliation, interpreted to be a primary flow fabric. The age of the granite is uncertain; contacts with other rocks have not been observed and their relative ages are unknown.

Swift Run Formation (Zs)

Rocks of the Swift Run Formation is exposed in several relatively small areas in the northwestern part of the quadrangle. The Swift Run unconformably overlies the western porphyroblastic gneiss and is overlain by the Catoctin Formation. Jonas and Stose (1938) described metasedimentary rocks on the western side of the Blue Ridge anticlinorium between the underlying older plutonic rocks and the overlying Catoctin as the Swift Run Formation. Stose and Stose (1946) also applied the name to quartzite and slate between the older plutonic rocks and the overlying Catoctin in Maryland, close to the Potomac River.

A greenish gray to light olive gray phyllite with small dark gray to black clasts of mudstone and some lenses and pebbles of quartz comprise the Swift Run in the Upperville quadrangle. In some areas in the lower part of the Swift Run the phyllite contains quartz as veins, lenses, and irregular sized clasts that locally makes up a high percent of an outcrop. Here the phyllite and its cleavage has been highly deformed, but this deformation is localized and does not seem to be related to folding. This suggests deformation possibly related to faulting may have occurred near the base of the Swift Run possibly at or near the contact with the middle Proterozoic rocks. There is no evidence, however, for faulting in the underlying granitic gneiss (Yaw), nor has evidence for faulting been observed in the adjacent Catoctin Formation. This deformation, therefore, must have been confined to the lower part of the Swift Run Formation.

Catoctin Formation (Zc)

Metabasalt lava flows (greenstones), metatuffs, and metasedimentary rocks underlie the northwestern part of the Upperville quadrangle and comprise the Catoctin Formation in the Upperville quadrangle. Geiger and Keith (1891) first used the name Catoctin schist for rocks overlying the Swift Run Formation, and Keith (1894) first mapped the Catoctin schist (greenstone) in the Blue Ridge anticlinorium. Espenshade (1986) mapped the Catoctin on the east side of the anticlinorium in the adjoining Marshall quadrangle. And Lukert and Nuckols (1976) mapped the Catoctin Formation on the west side of the anticlinorium in the nearby Linden and Flint Hill quadrangles.

The basalt flows range from massive, amygdaloidal, and fragmental; some rhyolite metatuff may be present, but has only been observed sporadically as float. However rhyolite metatuff does crop out in Ashby Gap just north of the quadrangle. Some of the lava is fragmental and elsewhere is massive with no discernable layering. Chemical studies by Espenshade (1986) showed that a low-titanium suite of basalts is present near the base of the Catoctin in the nearby Marshall quadrangle and that these in turn are overlain by a high-titanium suite of basaltic rocks.

Parts of some weathered exposures of amygdaloidal lava have rounded surfaces that may represent pillows. Rarely these surfaces are separated from each other by small areas of clastic metasediments, containing mostly metasiltstone or metatuffaceous material, and which appears to flow around and between the amygdaloidal lava. As such the clastic material may represent inter-pillow material. Alternatively these clastic materials may represent small clods of mud mixed in with the lava flows during deposition. Quartz veins and small, but striking, crystal fiber quartz veins up to 7.5 cm. wide are common in the lava flows, as are epidote veins and large epidote clots. Small areas of fine-grained yellowish-green epidote are widely disbursed.

A small lens of metasedimentary rocks, mostly chloritic phyllite, is also mapped in the lower part of the Catoctin, but the contact relations with the lava flows of the Catoctin were not determined. Some discontinuous very fine grained, greenish gray, thinly laminated phyllitic rocks are present near the lower part of the Catoctin. These rocks, which can not be shown at the map scale, contain mostly chlorite, sericite, epidote, very fine-grained opaque minerals, and some plagioclase and quartz. Some lava flows contain thin discontinuous streaks of very fine-grained phyllitic material. The origin of this material is enigmatic; they may represent contemporaneous deposition of clastic sediments and lava flows, or original muds upon which the Catoctin was deposited, or possibly they may represent post depositional shearing at or near the base of the Catoctin where the basalts were tectonically mixed with other rock materials.

Small shear zones are present in some exposures. Two northeast striking cleavages are present in some of the lavas; these cleavages strike within 20 degrees of each other and both dip southeast. These cleavages are not well developed and are not easily seen in some exposures. Shear sense indicators could not be determined from these fabrics. The Catoctin metabasalt has a Rb-Sr whole rock age of 570 +/-36 Ma (Badger and Sinha, 1988).

Metarhyolite

Metarhyolite dikes are fine-grained, medium gray, contain small quartz grains and are characterized by small feldspar phenocrysts in a groundmass of feldspar and quartz. They commonly occur in close proximity to diabase dikes and have similar trends. Most of the metarhyolites are to small to show on the map and are principally exposed in the eastern part of the quadrangle. But rhyolitic tuff float has been found within mapped areas of the Catoctin Formation in the western part of the quadrangle, and, as previously mentioned, rhyolitic tuffs are exposed in Ashby Gap just north of the quadrangle.

Exposures of the metarhyolite dikes are about 2 m wide but their lengths are undetermined. Along with the metarhyolites, fine-textured metadiabase intrudes the Robertson River rocks. E. R. Force (USGS written commun. 1990) suggests these intrusive dikes are close in age. Since rhyolite dikes are abundant in the Catoctin farther to the north in Maryland, the metarhyolite dikes are probably related to the Catoctin basalts and may be comagmatic with the lavas. Metarhyolite that is closely associated with Catoctin lava flows in the nearby Bluemont quadrangle, has a U-Pb age of 600 Ma (Aleinikoff and others, 1991; Southworth, 1994).

Late Proterozoic metamorphosed basaltic lava flows, interlayered rhyolitic tuffs, and sedimentary rocks of the Catoctin and the Swift Run Formations form the cover sequence over the Middle Proterozoic Blue Ridge basement. Together the basaltic and rhyolitic rocks form a bimodal volcanic suite that is relatively rare in rocks of this age in the Blue Ridge basement of the Appalachian Mountains. Three similar basalt-rhyolite occurrences in cover rocks of the Blue Ridge basement are known; the Mount Rogers area of southern Virginia, the South Mountain area of southern Pennsylvania and Maryland, and the Sutton Mountains, Quebec, Canada (Rankin 1975). The Upperville quadrangle is probably at or near the southern terminus of the nearby South Mountain basalt-rhyolite occurrence. All of these bimodal volcanic occurrences are in

Appalachian salients that developed during the initial breakup of the ancient North American continent prior to the formation of the Iapetus ocean (Rankin, 1975).

An interesting feature is the occurrence of Late Proterozoic metadiabase dike swarms and associated but rare metarhyolite dikes that intrude the Middle Proterozoic basement in the Upperville quadrangle. In places the diabase dikes are highly concentrated and occupy a large percent of the land area. This suggests they were probably intruded into the basement rocks during a tensional regime in the Late Proterozoic. This extension in the basement may represent early rifting associated with Iapetan breakup that preceded the opening of the Iapetus ocean (Rankin and others, 1994).

Metadiabase and gabbro (Zd)

Metadiabase dikes are widely dispersed in the study area. Also included with the dikes and shown on the map are several small plutons having diabase-like outer portions and gabbroic interiors. The dikes vary widely in size, commonly one to eight or nine meters thick, but some may be as much as 15 m thick. They have a wide but erratic distributation and could not be satisfactorily shown on the map. They appear as dike swarms, particularly in the northeastern part of the quadrangle where their concentration is the highest, estimated to be as much as 45 percent of the bedrock. Since it was not feasible to map individual dikes, an overprint on the map outlines the area underlain by a large number of dikes. The mafic dikes may have been feeders for some of the Catoctin basalt flows. These metadiabase dikes intrude all the older rock units, however, they are more abundant in the Middle Proterozoic rock units than in rocks of the Robertson River Igneous Suite.

The dikes vary from massive to those with a shear foliation. This foliation is associated with the mineral assemblage epidote, chlorite, and sericite, but epidote is also present in the massive dikes. Epidosite fills gash veins in massive dikes. Locally prehnite is an alteration mineral.

The attitude of shear foliation in the metadiabase seems to be a function of dike orientation; foliation is commonly parallel to dike walls, especially where the country rock is massive.

Apparently the dikes absorbed much of the strain where the wall rocks were competent.

Cenozoic Deposits

The valleys and streams contain unconsolidated coarse to fine -textured boulders, cobbles, gravels, sand, and clay. Alluvial deposits, present in all stream valleys, are thickest in the larger streams. Along steeper valleys colluvium is commonly mixed with alluvium, and colluvium is exceptionally common along steep hill sides that are underlain by the Catoctin Formation on the east side of the Blue Ridge. These unconsolidated deposits, which form a thin veneer over the bedrock, are not shown on the map. Coarse- debris are present along some steep slopes underlain by the Catoctin Formation and may be the result of rock slides.

Metamorphism

Several metamorphic-deformation events are recorded in the rocks of the Upperville quadrangle. An early prograde granulite-facies metamorphism affected the Middle Proterozoic rocks. Paleozoic greenschist-facies metamorphism of the Late Proterozoic rocks also retrograded of some of the Middle Proterozoic rocks. Evidence for the age or ages of various metamorphic\deformation events that have imprinted the rocks underlying the study area is discussed below. The Middle Proterozoic rocks contain a high-grade mineral assemblage that includes coarse-grained alkali feldspars such as mesoperthite, rod, bleb, and patch microperthite, calcic oligoclase to andesine plagioclase, garnet, uralitized pyroxene, reddish brown biotite, and blue to gray-blue quartz, which commonly occurs as lenticular aggregates or as disk-like lenses aligned in the foliation. This assemblage is similar to granulite facies minerals that typically include pyroxenes, perthitic feldspars, sillimanite, garnet and quartz.

The Middle Proterozoic rocks underlying the Upperville quadrangle were probably prograded to the granulite facies during a Grenville metamorphic/deformation event. Kline (1991) studied rod and bleb microperthites in the northern Virginia Blue Ridge and suggested they formed in a granulite terrane. Garnet, which is present in some of the Middle Proterozoic rocks, is also present in some similar rocks in the adjoining Marshall quadrangle where Espenshade (1986) indicated that it probably formed during Middle Proterozoic high grade metamorphism (Lukert and Nuckols, 1976; Bartholomew, 1977). Charnockite, a granulite facies hypersthene-bearing rock, has been mapped in the adjoining Linden and Flint Hill quadrangles as the Pedlar Formation (Lukert and Nuckols, 1976; Clarke, 1984). A small Charnockite body (Ych) is also present within the felsic gneiss unit (Yfg) underlying the northeast part of the Upperville quadrangle. The charnockite in and adjacent to the study area implies that the Middle Proterozoic rocks underlying the Upperville quadrangle were subjected to granulite-facies metamorphism. This high-grade metamorphic event in the Blue Ridge anticlinorium in northern Virginia has been referred to as the Pedlar event (Mitra and Lukert, 1982), and probably represents the Middle Proterozoic Grenville orogeny. Sinha and Bartholomew (1984) indicate that the Middle Proterozoic rocks underlying the Virginia Blue Ridge were subjected to granulite-facies metamorphism approximately 920 m.y. ago.

The lava flows of the Catoctin Formation (Zc) contain characteristic greenschist-facies minerals; greenish chlorite, epidote, quartz, albite, white mica, and actinolite. Irregular masses of epidosite are common. The interlayered sedimentary rocks within the lower part of the Catoctin lava flows have been altered to sericitic schists, similarly rocks of the Swift Run Formation (Zs) have also been altered to quartz sericitic schists that locally contain chlorite and some green biotite. These Late Proterozoic rocks were regionally metamorphosed to greenschist facies during the Paleozoic. Kline and others (1991) indicate that greenschist metamorphism occurred in the Late Proterozoic. Herz (1984) suggested the greenschist metamorphism occurred 520 to 583 m.y. ago. Bartholomew and others (1981) thought the age of Paleozoic metamorphism was Middle Paleozoic; Mose and Nagle (1984) suggested it was Taconic in age, and Mitra and Lukert (1982) suggested that it was a late Paleozoic (Alleghenian) event. Nearby, Kunk and others (1993) date the penetrative fabric in the cover rocks as Late Paleozoic Alleghanian.

Considerable portions of the Middle Proterozoic gneisses have been retrograded to greenschist-facies minerals; these minerals include abundant chlorite and discontinuous patches of greenish biotite flakes, along with some magnetite and a very dark fine-grained almost opaque material all of which replace the higher- grade reddish brown biotite. Some of the biotite is rutilated. These greenschist minerals form and define the northeasterly trending foliation. Locally the greenschist metamorphism has partly or completely altered hornblende, and garnet in the older rocks to chlorite or to patches or rims of chlorite. Plagioclase has been saussuritized to mixtures of epidote minerals, albite, and white mica (sericite). Some parts of granitic gneisses have been completely altered to thin zones of quartz sericite phyllonite, a feature also present in nearby areas (Espenshade, 1984; Kline and others, 1991). In areas where the high-grade minerals have been altered, microperthite is not present, but not all high-grade minerals have been retrograded and, therefore, greenschist-facies metamorphism did not go to completion in the older rocks.

The age of the retrograde greenshist minerals and associated fabrics in the Middle Proterozoic basement rocks is uncertain. The most prominent foliations (see below) in the basement consist of greenschist minerals. Since this foliation strikes generally parallel to the Paleozoic cleavage trends of the Late Proterozoic cover rocks in the Virginia Blue Ridge, the greenschist retrogression is generally thought to be of Paleozoic age. However Kline and others (1991) have shown that pre-Paleozoic greenschist fabrics deform Late Proterozoic rocks underlying areas close to the study area. In central Virginia, the Middle Proterozoic Lovingston gneiss also has greenschist fabrics that Evans (1984) believed formed during extension accompanying Late Proterozoic rifting. The dominant foliation in the basement is principally a shear fabric dominated by ductile and cataclastic textures (see below). Since this degree of shearing was not observed in the cover sequence (Zc and Zs), the greenshist retrogression in the basement sequence is interpreted to be older than that in the cover sequence, possibly equivalent to the pre-Paleozoic greenschist event of Kline and others (1991).

Deformation

Middle Proterozoic rocks (chiefly Yaw, Yae, Ygf, and Ym) and rocks of the Robertson River Igneous Suite (Zml and Zrc) underlie the Upperville quadrangle and form the core of the Blue Ridge anticlinorium (Cloos, 1947; Mitra, 1979; Clark, 1982). The unconformably overlying Catoctin (Zc) and Swift Run (Zs) Formations, which are exposed in the northwestern part of the quadrangle, form part of the west overturned flank of the anticlinorium. Cleavage and schistosity in the Catoctin and Swift Run Formations, and a northeast-trending foliation in the Middle Proterozoic rocks, are the most pervasive structures present in the rocks underlying the study area. These planar structures, collectively termed the Blue Ridge-South Mountain cleavage (Mitra and Elliot, 1980), uniformly strike northeasterly.

Planar structures

Cleavage and schistosity are present in most of the Late Proterozoic rocks. Some Catoctin metavolcanic rocks display two cleavages whose strikes intersect at a low angle, generally less than 20 degrees. These cleavages strike from north-northwest to northeast and they invariably dip moderately to steeply east to southeast.

Rarely a poorly preserved cleavage is present in some pre-Late Proterozoic rocks. This cleavage most commonly strikes northeasterly and dips moderately to steeply southeast. It is wider-spaced, but appears to be similar to cleavage observed in the Catoctin Formation and may have formed at the same time.

Some of the Middle Proterozoic plutonic rocks display two foliations and locally a very prominent coarse mineral lineation, however, it is not always easy to determine the relative age of these fabrics. The dominant foliation, which is mostly a shear or cataclastic fabric, strikes northeast and generally dips southeast. The other foliation, which is believed to be an older feature and which is not always observed in rock exposures, strikes westerly to northwesterly and dips steeply either north or south. The older foliation anastomoses in and out of the younger fabric. In some places shear sense indicators suggest the westerly-trending foliation is displaced by the northeasterly one. However, this relationship is not always seen and may not be true for all exposures. If the westerly-trending foliation is the oldest, it along with its associated linear fabric, probably formed during deformation associated with Grenville orogeny.

The older foliation is somewhat wavy and is defined by thin alternating discontinuous felsic and sparse biotite and chlorite streaks; the thickness of the felsic layers or lenses is variable, as much as 2 cm thick; the biotite-chlorite zones are more discontinuous, in places wisp-like, much thinner, and commonly range from 1-2 mm thick. The felsic layers consist principally of quartz, commonly bluish-gray, and feldspar, which is mostly microcline. Prominent augen of microcline and or quartz and feldspar aggregates form a distinct lineation in the older foliation. Where the lineation is well developed it tends to mask the older foliation.

The relationship between the earliest planar and linear fabrics in some of the Middle Proterozoic plutonic gneisses (Yae) and the planar fabric of the felsic gneisses (Yfg) is uncertain, they may have formed during the same metamorphic event.

The younger foliation, which is mostly a shear phenomenon, is a pervasive planar fabric defined by alternating mafic and felsic layers, and the foliation surfaces appear to be more thinly spaced than the older Grenville fabric. The laminar aggregates of inequant quartz and feldspar grains that comprise most of the felsic layers appears to be slightly thinner than similar layers of the older structure. Irregular concentrations of biotite and chlorite, which comprise most of the mafic layers, however, form highly irregular and slightly thicker very dark layers than are present in the older foliation. The age of the younger planar structure is uncertain. It displaces the Grenville foliation and, except for localized folding, has a regional northeast trend.

The younger foliation is characterized by greenschist-facies minerals and consists of mixtures of very-thin, discontinuous, somewhat irregular zones of ductile and cataclastic fabrics of quartzofeldspathic minerals that are adjacent to, or mixed with, lenses or discontinuous patches of chlorite, green biotite, epidote, and very-thin anastomosing very-fine-grained opaque materials. The ductile fabrics include mylonite, blastomylonite, and protomylonite. Some fractured feldspar grains are present within unfractured mylonite zones; possibly simultaneous ductile and brittle deformation acted upon the rocks during unequal stress conditions.

A compositional layering is visible in some garnet-bearing felsic gneisses (Yfg), but is not easily observed elsewhere. Compositional layering in the layered felsic gneiss seems parallel to foliation. Except for some small folded areas in a layered felsic gneiss, almost all layering strikes north to northeast, and is easterly dipping.

Narrow ductile deformation zones

Many plutonic rock exposures have been deformed by narrow cross cutting ductile deformation zones. In some places numerous cross-cutting deformation zones have formed a network of fragments bounded by narrow ductically deformed material. The long axes of the fragments appear to be elongated parallel to the regional foliation. Espenshade (1986) described this kind of a feature in the Marshall metagranite located just east of the Upperville quadrangle. Mitra (1979), Lukert and Halladay (1980), and Kline and others (1991) have discussed ductile deformation and breccia zones elsewhere in northern Virginia that are similar to the features seen in the rocks of the Upperville quadrangle. Espenshade (1986) suggested that the plutonic gneisses of the anticlinorium core localized Paleozoic movement along discrete ductile zones in contrast to the Catoctin volcanic rocks where movement was distributed along cleavage planes. Except for late fractures these small deformation zones are the youngest structures preserved in the rocks.

Faults

Two ductical deformation zones are shown as unnamed faults on the map. One, near Markham, strikes northeast to north and the other near Kerfoot strikes north-northwest. These are fault and shear zones that display mylonites, blastomylonites, protomylonites and some cataclasites.

The northeast-trending fault near Markham extends about 4.5 km from the quadrangle boundary south of Markham before evidence for shearing is lost. This fault juxtaposes the western porphyroblastic gneiss and the Laurel Mills Granite. The east- striking Front Royal fault (Nuckols and Lukert, 1976) merges into the northeast-trending fault about 1.3 km east of Markham. The north to northwest trending fault separates the felsic gneiss from undivided rocks of the Robertson River Igneous Suite. Mylonitic fabrics are estimated to extend for about 3 km along this fault until exposure is lost.

Elsewhere, isolated exposures display discontinuous narrow mylonite zones, but they could not be shown at the map scale. Some thin sections show thin mylonitic zones that were later fractured and displaced. Some exposures show small faults, with displacements measured in centimeters, that displace rocks but do not appear to be related to any major structure.

Recent seismic reflection surveys together with geologic studies have shown that great thrust sheets with northwest directed movement dominate the structural regime of the Appalachian Mountains from Georgia to Virginia and southern Pennsylvania (Cook and others, 1979, Harris and Bayer, 1979; Mitra, 1979; Root, 1970, 1973; Nelson and others 1987). The Blue Ridge anticlinorium in northern Virginia most probably is also allochthonous.

References Cited

Aleinikoff, J.N., Zartman, R.E., Rankin, D.W., Lyttle, P.T., Burton, W.C., and McDowell, R.C., 1991, New U-Pb zircon ages for rhyolite of the Catoctin and Mount Rogers Formations--More evidence for two pulses of Iapetan rifting in the central and southern Appalachians: Geological Society of America Abstracts with Programs, v. 23, no. 1, p. A-2.

Aleinikoff, J. N., Walter, Marianie, Lyttle, P. T., Burton, W. C., Leo, G. W., Nelson, A. E., Schindler, J. S., and Southworth, C. S. 1994, U-Pb Zircon and monazite ages o Middle Proterozoic rocks, northern Blue Ridge, Virginia: Geological Society of America Abstracts with Programs, v. 25, no. 2, p. A-2.

Badger, R.L., and Sinha, A.K., 1988, Age and Sr isotopic signature of the Catoctin volcanic province: Implications for subcrustal mantle evolution: Geology, v. 16, no. 8, p. 692-695. Bartholomew, M.J., 1977, Geology of the Greenfield and Sherando quadrangles, Virginia: Virginia Division of Mineral Resources Publication 4, 43 p.

Bartholomew, M.J., Gathright, T.M., II, and Henika, W.S., 1981, A tectonic model for the Blue Ridge in central Virginia: American Journal of Science, v. 281, no. 9, p. 1164-1183.

Clarke, J.W., 1982, The core of the Blue Ridge anticlinorium in northern Virginia (abs,): Geological Society of America Abstracts with Pograms, v. 58, no. 1 and 2, p.10.

____1984, The core of the Blue Ridge anticlinorium in northern Virginia, in Bartholomew, M.J., Force, E.R., Sinha, A.K., and Herz, N., eds., The Grenville Event in the Appalachians and Related topics: Geological Society of America Special Paper 194, p. 153-160.

Cloos, Ernst, 1947, Oolite deformation in the South Mountain fold, Maryland: Geological Society of America Bulletin, v. 58, no. 9, p. 843-917.

Cook, F.A., and others, 1979, Thin-skinned tectonics in the crystalline southern Appalachians; COCORP seismic-reflection profiling of the Blue Ridge and Piedmont: Geology, v. 7, no. 12, p. 563-567.

Espenshade, G.H., 1970, Geology of the northern part of the Blue Ridge anticlinorium, in Fisher, G.W., and others, eds., Studies of Appalachian geology, central and southern: New York Interscience Publishers, p. 199-211.

_____1986, Geology of the Marshall quadrangle, Fauquier County, Virginia: U.S. Geological Survey Bulletin 1560, 60 p.

Espenshade, G.H., and Clarke, J.W., 1976, Geology of the Blue Ridge anticlinorium in northern Virginia: Geological Society of America Northeast-Southeast Sections Joint Meeting Field Trip Guidebook No. 5, 26 p.

Evans, N.H., 1984, Latest Precambrian to Ordovician metamorphism in the Virginia Blue Ridge: An alternative explanation for the origin of the contrasting Lovingston and Pedlar basement terranes: unpublished Ph.D. dissertation, Virginia Polytechnic Institute and State University, Blacksburg, 313 p.

Geiger, H.R., and Keith, Arthur, 1891, The structure of the Blue Ridge near Harpers Ferry: Geological Society of America Bulletin, v. 2, p. 156-164.

Harris, L.D., and Bayer, K.C., 1979, Sequential development of the Appalachian Orogen above a master decollement; A hypothesis: Geology, v. 7, no. 12, p.568-572.

Herz, N., 1984, Rock suites in the Grenvillian terrane of the Roseland district, Virginia: Part 2. Igneous and metamorphic petrology, in Bartholomew, M.J., Force, E.R., Sinha, A.K., and

Herz, N. eds., The Grenville Event in the Appalachians and Related Topics: Geological Society of America Special Paper 194, p. 200-214.
Herz, N., and Force, E.R., 1984, Rock suites in Grenvillian terrane of the Roseland district, Virginia, in Bartholomew, M.J., Force, E.R., Sinha, A.K., and Herz, N., eds., The Grenville Event in the Appalachians and Related Topics: Geological Society of America Special Paper 194, p. 187-214.
Jonas, A.I., and Stose, G.W., 1938, Geologic map of Frederick County and adjacent parts of Washington and Carroll Counties: Maryland Geological Survey, scale 1:62,500.
Keith, Arthur, 1894, Geology of the Catoctin belt: U.S. Geological Survey 14th Annual Report, part 2, p. 285-395.
Kline, S.W., 1991, Provenance of arkosic metasediments in the Virginia Blue Ridge: constraints on Appalachian suspect terrane models: American Journal of Science, v. 291, p. 189-198.
Kline, S.W., Lyttle, P.T., and Schindler, J.S., 1991, Late Proterozoic sedimentation and tectonics in northern Virginia, in Schultz, Art and Compton-Gooding, E., eds., Geologic Evolution of the Eastern United States: Field Trip guidebook NE-SE Geological Society of America, 1991.
Kunk, M.J., Lyttle, P.T., Schindler, S.J., and Burton, W.C., 1993, Constraints on the thermal history of the Blue Ridge in northernmost Virginia: $^{40}Ar/^{39}Ar$ age dating results: Geological Society of America Abstracts with Programs, v. 25, no. 2. p. A-2.
Lukert, M.T., and Banks, P.O., 1968, Late Precambrian post-Grenville plutonism in the Virginia Piedmont (abs.): Geological Society of America Special Paper 121, p. 362-363.
Lukert, M.T., and Banks, P.O., 1984, Geology and age of the Robertson River pluton, in Bartholomew, M.J., Force, E.R., Sinha, A.K., and Herz, N., eds., The Grenville Event in the Appalachians and Related Topics: Geological Society of America Special Paper 194, p. 161-166.
Lukert, M.T., and Clarke, J.W., 1981, Age relationships in Proterozoic Z rocks of the Blue Ridge anticlinorium of northern Virginia: Geological Society of America Abstracts with Programs, v. 13, p. 29.
Lukert, M.T., and Halladay, C.R., 1980, Geology of the Massies Corner quadrangle, Virginia: Virginia Division of Mineral Resources Publication 17, text and 1:24,000 scale map.
Lukert, M.T., and Nuckols, E.B., III, 1976, Geology of the Linden and Flint Hill quadrangles, Virginia: Virginia Division of Mineral Resources Report of Investigations 44, 83 p.
Lukert, M.T., Nuckols, E.B., and Clarke, J.W., 1977, Flint Hill Gneiss; a definition: Southeastern Geology, v. 1, no. 1, p. 19-28.
Mitra, G., 1978, Ductile deformation zones and mylonites: The mechanical processes involved in the deformation of crystalline basement rocks: American Journal of Science, v. 278, p. 1057-1084.
_____1979, Ductile deformation zones in Blue Ridge basement rocks and estimation of finite strains: Geological Society of America Bulletin, Part I, v. 90, p. 935-951.
Mitra, G., and Elliott, D., 1980, Deformation of basement in the Blue Ridge and the development of the South Mountain cleavage, in Wones, D.R., ed., The Caledonides in the USA: Virginia Polytechnic Institute and State University Memoir no. 2, p. 307-311.
Mitra, G., and Lukert, M.T., 1982, Geology of the Catoctin-Blue Ridge anticlinorium in northern

Virginia, in Lyttle, P.T., ed., Central Appalachian Geology, NE-SE GSA 1982 Field Trip Guidebooks: American Geological Institute, Falls Church, Virginia, p. 83-108.

Mose, D.G., and Nagle, S., 1984, Rb-Sr age for the Robertson River pluton in Virginia and its implication on the age of the Catoctin Formation, in Bartholomew, M.J., Force, E.R., Sinha, A.K., and Herz, N., eds., The Grenville Event in the Appalachians and Related Topics: Geological Society of America special Paper 194, p. 167-173.

Nelson, A.E., Horton, J.W., Jr., and Clarke, J.W., 1987, Generalized tectonic map of the Greenville 1°x2° quadrangle, Georgia, South Carolina, and North Carolina: U.S. Geological Survey Miscellaneous Field Studies Map MF-1898, scale 1:250,000.

Rankin, D.W., 1975, The continental margin of eastern North America in the southern Appalachian Mountains: The opening and closing of the proto-Atlantic Ocean: American Journal of Science v. 275-A p. 298-336.

Rankin, D.W., Stern, T.W., McLelland, J., Zartman, R.E., and Odom, A.L., 1983, Correlation chart for Precambrian rocks of the eastern United States, in Harrison, J.E., and Peterman, Z.E., eds., Correlation of Precambrian rocks of the United States and Mexico: U.S. Geological Survey Professional Paper 1241, p. E1-E10.

Rankin, D.W., Miller, Julia. M.G., Simpson, Edward. L, 1994, Geology of the Mt. Rogers area, southwestern Virginia Blue Ridge and unaka Belt in Fieldguides to Southern Applachian structure, stratigraphy, and engineering geology, eds., Shults, A.P. and Henika, W.S.: Virginia Tech Department of Geological Sciences. Blacksburg, VA., p. 127-176.

Rodgers, J., 1970, The Tectonics of the Appalachians: Wiley Interscience, New York, 271 p.

Root, S.I., 1970, Structure of the northern terminus of the Blue Ridge in Pennsylvania: Geological Society of America Bulletin, v. 82, no. 3, p. 815-830.

Sinha, A.K., and Bartholomew, M.J., 1984, Evolution of the Grenville terrane in the central Virginia Appalachians, in Bartholomew, M.J., Force, E.R., Sinha, A.K., and Herz, N., eds., The Grenville Event in the Appalachians and Related Topics: Geological Society of America, Special Paper 194, p. 175-186.

Southworth, Scott, 1994, Geologic map of the Bluemont Quadrangle, Loudoun and Clarke Counties, Virginia: U. S. Geological Survey Quadrangle Map, GQ-1739.

Stose, A.J., and Stose, G.W., 1946, Geology of Carroll and Frederick Counties: Maryland Department of Geology, Mines, and Water Res., Carroll and Frederick Counties Report, p. 11-131.

Tilton, G.R., Wetherill, G.W., Davis, G.L., and Bass, N., 1960, 1,000-million-year-old minerals from eastern United States and Canada: Journal Geophysical Research, v. 65, no. 12, p. 4173-4179.

Tollo, R.P., 1986, Constituent granitoids of the Robertson River Formation in the northern Virginia Blue Ridge: Geological Society of America Abstracts with Programs, v. 18, p. 269.

Tollo, R.P., and Arav, S., 1987, Petrochemical comparison of two plutons from the Robertson River Formation in northern Virginia: Geological Society of America Abstracts with Programs, v. 19, p. 133.

Tollo, R.P., and Lowe, T.K., 1990, Compositional diversity in the Late Proterozoic Robertson River Suite, Blue Ridge province, Virginia: Geological Society of America Abstracts with Programs, v. 22, no. 7, p. A343.

Tollo, R.P., 1993, Geologic Map of the Robertson River Igneous Suite, Blue Ridge province, northern and central Virginia: U.S. Geologiacal Survey Miscellaneous Field Investigations Map MF-2229, scale 1:100,000.

EXPLANATION OF MAP UNITS

Zc Catoctin Formation (Late Proterozoic)-Massive basaltic lavas with some interbedded phyllite beds (Zcp), dark gray to greenish gray, amygdaloidal with small feldspar phenocrysts, groundmass fine-grained, contains plagioclase (albite), chlorite, actinolite, magnetite, epidote,sericite, some calcite, and minor quartz. Amygdules are commonly filled with quartz, calcite, epidote or sericite, contains numerous crystal fiber quartz veins

Zd Metadiabase dike swarm (Late Proterozoic)-Dark to greenish gray, fine-grained, equigranular. Dominant minerals plagioclase, actinolite, opaques, alteration minerals sericite, chlorite and epidote; locally grades into fine-grained metagabbro; dikes seldom over 12 m wide, individual dikes not shown but patterned area shows where dike concentrations are estimated to be as much as 45 percent of the rock volume

Zmr Metarhyolite dike (Late Proterozoic)- very fine-grained, groundmass microlitic to myrmekitic, mostly equigranular with small quartz and microperthite phenocrysts largely altered to sericite, also contains minor opaques, epidote, and green biotite which replaces original mafic minerals

Zs Swift Run Formation (Late Proterozoic)-Greenish gray to light olive gray phyllite, contains mostly chlorite and sericite, quartz as lenses or clasts, and dark gray mudstone clasts

Zgr Undivided metagranite (Late Proterozoic)-Metagranite fine-grained, mostly equigranular, light tan to light gray, contains principally quartz, plagioclase and potash feldspar, minor minerals include muscovite, abundant magnetite and sericite; includes some fine-grained granite dikes

Zr Robertson River Igneous Suite (Late Proterozoic)-Undivided Robertson River (Zr) includes Laurel Mills Granite (Zrl) and Cobbler Mountain Alkali Syenite (Zrc); Laurel Mills coarse-grained, inequigranular, greenish- to dark-gray, weathers to a maple sugar brown; locally contains myrmekite, principal minerals include subequal amounts of sericitized plagioclase An27-38,and potassium feldspar, phenocrysts of subhedral patch perthite, and less abundant microcline, quartz, biotite, hornblende, chlorite, epidote, sphene, magnetite, and zircon; Cobbler Mountain Alkali Syenite (Zrc) is medium-grained, locally porphyritic, with abundant potassium feldspar, plagioclase, hornblende, minor quartz, zircon and fluorite, and local rebeckite

Age Relations of some Middle Proterozoic
rocks uncertain

Yaw Western Porphyroblastic Granite Gneiss (Middle Proterozoic)-Coarse- to medium-grained, light to medium gray, weathers pinkish red, characterized by pink potassium feldspar augen up to 5 cm long, locally potassium feldspars are equigranular and subhedral; contains microperthite, microcline, plagioclase, quartz, biotite, chlorite, magnetite, epidote, minor white mica, sphene, a trace of garnet and zircon, plagioclase alters to sericite or saussurite. Small epidote-quartz and crystal fiber quartz veins common, a high chlorite content produces a pale greenish cast

Yf Flint Hill Gneiss (Middle Proterozoic)-Layered gneiss- Light quartzo-feldspathic layers alternate with darker mafic-rich layers. Gneiss is fine-to medium-grained, yellowish to light gray, strongly foliated;includes potassium feldspar, white or gray and some blue quartz, plagioclase, hornblende,biotite, magnetite, and epidote. Plagioclase saussuritized

Ym Marshall Metagranite (Middle Proterozoic)-Medium to dark gray, fine-to medium-grained, mostly equigranular but rarely inequigranular. Principal minerals are: bluish gray quartz, plagioclase (An 28), and potassium feldspar; less common minerals are biotite, muscovite, and opaques, probably magnetite, epidote and chlorite. Plagioclase is commonly sericitized and quartz strained

Yae Eastern Porphyroblastic Granite Gneiss (Middle Proterozoic)-Coarse- to medium-grained, light gray, weathers pink. characterized by augen of quartz and plagioclase aggregates as much as 5 cm long, groundmass feldspars subhedral and equigranular; common minerals are microperthite, microcline, plagioclase, blue to bluish gray quartz, biotite, chlorite, magnetite, epidote, minor white mica, sphene, some garnet, and zircon; plagioclase commonly sericitized or sausussuritized, small epidote-quartz veins and felsic segregations common, chlorite replaces biotite and gives green cast to rocks

Ych Charnockite (Middle Proterozoic)-Dark greenish gray, mostly medium-grained, equigranular to inequigranular, contains plagioclase, perthite, quartz, pyroxene with hornblende rims, and opaques

Ygr Granitoid (Middle Proterozoic)-Granitoid is faintly foliated, mostly equigranular, light gray, and fine-grained; principal minerals are plagioclase, potassium feldspar, and blue to bluish gray quartz, less common minerals include biotite, garnet, rare muscovite, and chlorite; small undivided lenses and layers of granitoid are included with the felsic gneiss (Yfg)

Ymf Undivided Marshall (Ym) and Felsic gneiss (Ygf), and granitoid (Ygr)

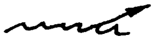
Yfg Felsic gneiss (Middle Proterozoic)-Equigranular to inequigranular, locally contains large quartz grains, and or disks that are commonly blue or bluish-gray, plagioclase as phenocrysts in fine-grained groundmass, proportions of quartz, oligoclase, potassium feldspar, and biotite vary greatly; less commonminerals include sericite, epidote and clinozoisite, tiny white mica grains, chlorite, magnetite, and garnet and uralite; biotite alters to chlorite and the plagioclase to sericite; in places mixed with Marshall (Ym), granitoid (Ygr), and rare unmapped mica schist

Map Symbols

Contact, dashed where approximately located,
short dash where inferred

Inferred fault

Small folds showing direction of plunge



Sheared rocks, arrow shows direction of dip

Cleavage

inclined

vertical

Paleozoic foliation

inclined

vertical

Proterozoic foliation

Lineation, may be combined with planar structures

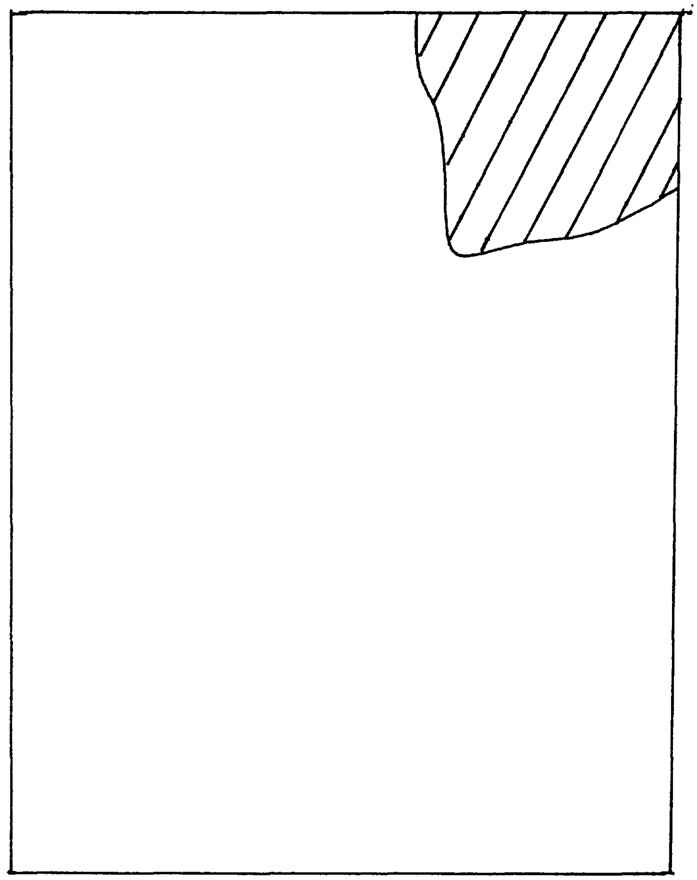


Figure 1. Shows approximate area mapped by Eric R. Force in the Upperville quadrangle.

Correlation of Map Units