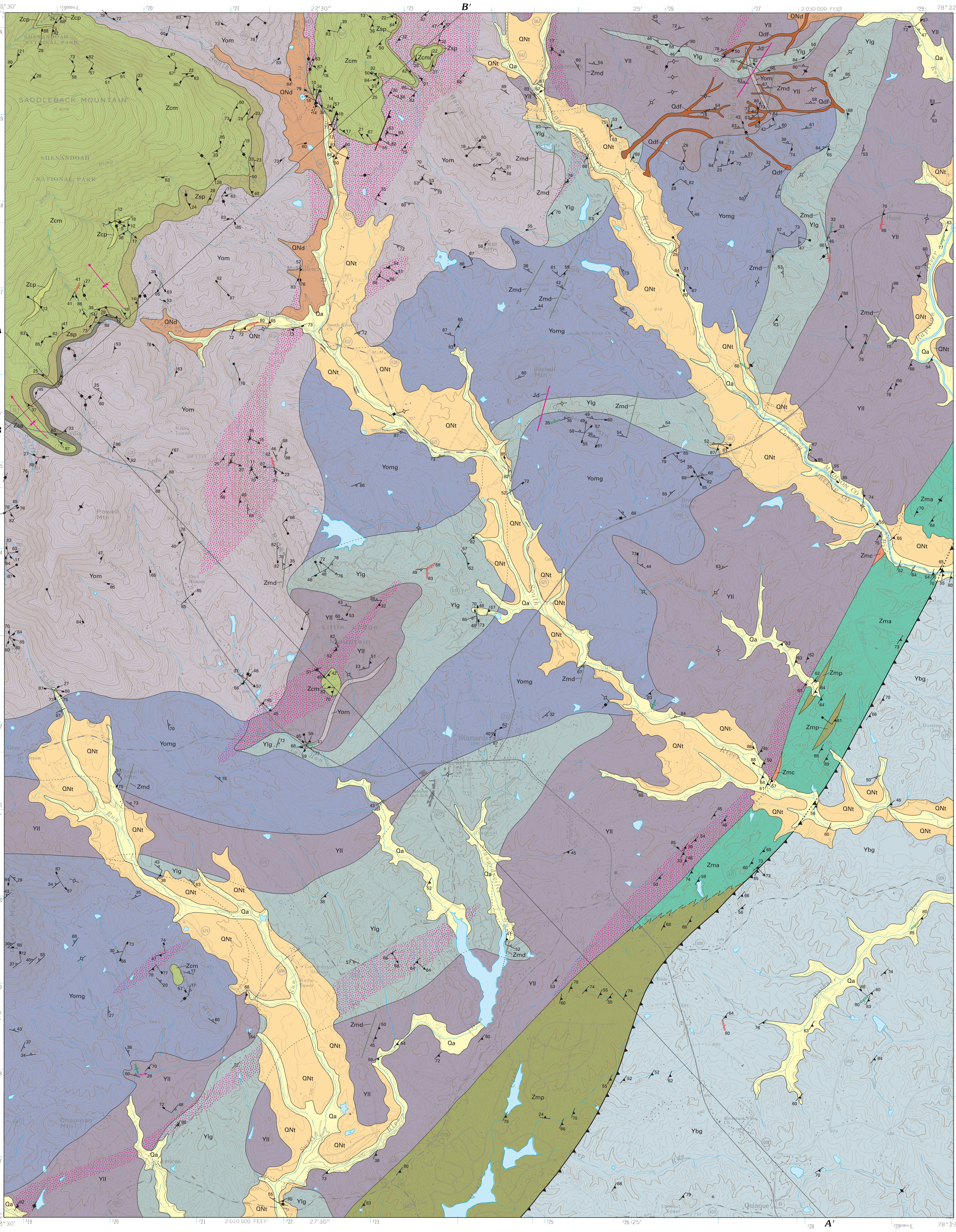
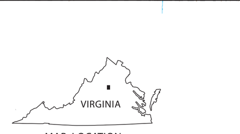


Base from U.S. Geological Survey, 1987
1927 North American datum
10,000-foot grid ticks based on Virginia coordinate system, north zone
1000-meter Universal Transverse Mercator grid ticks, zone 17N, shown in blue

APPROXIMATE MEAN DECLINATION, 2012

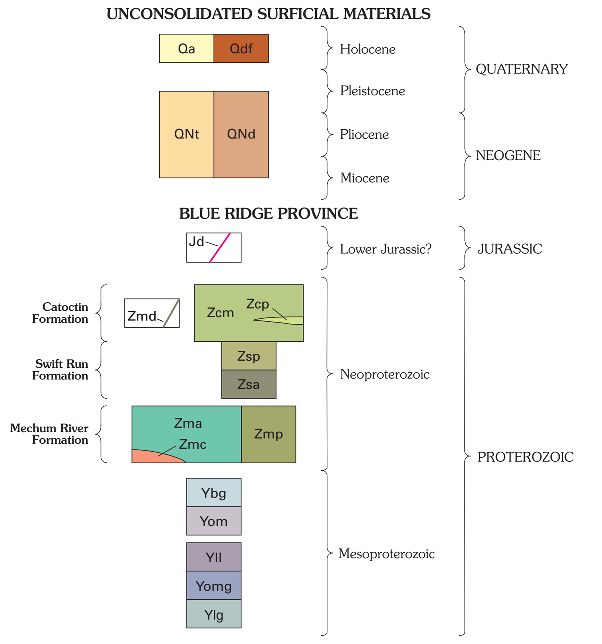
SCALE 1:24000

CONTOUR INTERVAL 20 FEET
NATIONAL GEODETIC VERTICAL DATUM OF 1929



Geology mapped by William C. Burton (2006–2008) and Christopher M. Bailey (1997)
GIS database by William C. Burton with E. Allen Crider (2011–2012)
Cartography by E. Allen Crider (2012)
Publication approved on September 26, 2012

CORRELATION OF MAP UNITS



DESCRIPTION OF MAP UNITS

UNCONSOLIDATED SURFICIAL MATERIALS

Qa **Alluvium (Holocene)**—Unconsolidated silt, sand, cobbles, and boulders. Located along streams, flood plains, and alluvial plains. Thickness is as much as 12 m. Alluvium in the highlands is mostly boulders and is transitional with debris fans on lower slopes

Qdf **Debris-flow deposits (Holocene)**—Debris-flow scars and tracks in the Blue Ridge highlands resulted from high rainfall associated with a tropical storm in June 1995. Consists of boulder deposits on chutes in bedrock and residuum

QNt **Terrace deposits (Quaternary and Neogene)**—Unconsolidated sand, gravel, cobbles, and boulders along major rivers. Terraces adjacent to present flood plains contain deposits 0 to 9 m thick. Unit also includes elevated terraces as much as 60 m above present flood plains

QNd **Debris-fan deposits (Quaternary and Neogene)**—Diamicton consisting of subrounded pebbles, cobbles, and boulders of local rocks supported in a matrix of unstratified clay, silt, sand, and pebbles. Forms fans and sheets on lower slopes and valleys. Includes debris fans that are as much as 36 m above the adjacent alluvium. Thickness is as much as 30 m

ROCKS OF THE BLUE RIDGE PROVINCE

[Minerals listed in increasing order of abundance]

Jd **Diabase dikes (Lower Jurassic?)**—On the basis of float, these dikes have a distinctive orange or "buckskin" weathering rind typical of Jurassic diabase dikes. They have original igneous mineral assemblages, which include small plagioclase laths in a mostly unaltered fine-grained, clinopyroxene-bearing groundmass

Zmd **Metadiabase dikes (Neoproterozoic)**—Fine-grained, massive to schistose magnetite-chlorite-quartz-epidote-plagioclase-actinolite greenstone (approximated from float)

CATOCTIN FORMATION

Zcp **Phyllite (Neoproterozoic)**—Fine-grained, silvery-white magnetite-muscovite-quartz tuffaceous phyllite and schist

Zcm **Metabasalt (Neoproterozoic)**—Fine-grained, massive magnetite-chlorite-plagioclase-epidote-actinolite greenstone

SWIFT RUN FORMATION

Zsp **Phyllite (Neoproterozoic)**—Fine-grained, silvery-white magnetite-muscovite-quartz tuffaceous schist and phyllite

Zsa **Meta-arkose (Neoproterozoic)**—Fine- to medium-grained, buff to gray chlorite-sericite-epidote-quartz granofels and schist

MECHUM RIVER FORMATION

Zmp **Phyllite (Neoproterozoic)**—Fine-grained, finely foliated magnetite-biotite-muscovite-quartz phyllitic metasiltstone and metamudstone

Zma **Meta-arkose (Neoproterozoic)**—Epidote-biotite-muscovite-plagioclase-quartz arkosic metawacke and lesser metasiltstone. Bedding locally preserved, but metamorphic foliation more common

Zmc **Metaconglomerate (Neoproterozoic)**—Clast-supported cobbles of blue and white quartz and uncommon lithics in a fine-grained epidote-muscovite-quartz phyllitic matrix. Occurs as lenses at base of formation

MESOPROTEROZOIC BASEMENT

[Map labels and uranium-lead ages from USGS Open-File Report 2009–1153]

Ybg **Biotite monzogranite (Mesoproterozoic)**—Light-gray to buff, fine- to medium-grained, weakly to moderately foliated biotite-quartz-microcline-plagioclase metagranitoid (~1,040–1,028 Ma). Microcline content 0 to 20 percent and quartz content 5 to 25 percent. Locally contains undeformed aplite veins and xenoliths of fine-grained biotite gneiss

Yom **Orthopyroxene monzogranite (Mesoproterozoic)**—Greenish-gray, medium- to coarse-grained, massive to weakly foliated orthopyroxene-quartz-plagioclase-microcline charnockite (~1,050–1,043 Ma). Intrudes gneisses and was largely undeformed by ~1.1 to 1-Ga Grenville orogeny. Pyroxene commonly retrograded to amphibole, biotite, and opaques due to Paleozoic metamorphism

Yll **Biotite granite gneiss (Mesoproterozoic)**—Light-gray to buff, fine- to medium-grained, weakly to strongly foliated biotite-quartz-plagioclase-microcline granite gneiss (~1,163 Ma). Where retrograded includes sphene, magnetite, and apatite as accessory minerals

Yomg **Orthopyroxene monzogranite gneiss (Mesoproterozoic)**—Gray to greenish-gray, medium-grained, strongly foliated orthopyroxene-quartz-plagioclase-microcline charnockite gneiss (~1,177 Ma). Pyroxene commonly retrograded to amphibole, biotite, and opaques due to Paleozoic metamorphism

Ylg **Porphyroblastic granite gneiss (Mesoproterozoic)**—Light-gray to buff, coarse-grained, weakly to moderately foliated porphyroblastic biotite-plagioclase-quartz-microcline leucogranite (~1,183–1,175 Ma). Where Paleozoic retrogression occurred includes sericite, epidote, sphene, magnetite, and apatite as accessory minerals

EXPLANATION OF MAP SYMBOLS

Contact—Approximately located; dotted where concealed by water or surficial materials

FAULTS

[Approximately located; dotted where concealed by water or surficial materials]

Paleozoic thrust fault—Sawteeth on upper plate

Paleozoic shear zone

FOLD

[Direction of plunge indicated where known or inferred]

Axial trace of Paleozoic (post-S_1) syncline

PLANAR FEATURES

[May be combined with other planar and (or) linear features; where features are combined, intersection of symbols marks point of observation]

Strike and dip of bedding
52 Inclined
64 Overturned

12 **Strike and dip of Paleozoic axial surface (post-S_1)**

Strike and dip of Neoproterozoic diabase dike
35 Inclined
Vertical

Strike and dip of Mesoproterozoic foliation or gneissosity
50 Inclined
Vertical

Strike and dip of Paleozoic mylonitic foliation (S_1)
82 Inclined
Vertical

Strike and dip of Paleozoic schistosity (S_1)
74 Inclined
Vertical

Strike and dip of Paleozoic(?) quartz vein
68 Inclined
Vertical

Strike and dip of joint
88 Inclined
Vertical

Strike and dip of joint set
84 Inclined
Vertical

LINEAR FEATURES

[May be combined with planar features; where features are combined, intersection of symbols marks point of observation]

28 **Bearing and plunge of Mesoproterozoic fold axis**

54 **Bearing and plunge of Paleozoic mineral lineation**

64 **Bearing and plunge of Mesoproterozoic mineral lineation**

DISCUSSION

INTRODUCTION

The Stanardsville 7.5-minute quadrangle is located about 30 kilometers (km) north of Charlottesville, Virginia, in the eastern foothills of the Blue Ridge and within the Blue Ridge physiographic province. The quadrangle contains a small part of the eastern margin of Shenandoah National Park along Saddleback Mountain (elevation 3,079 feet (ft)) just north of Swift Run Gap and stretches of Swift Run and the South, Conway, and Rapidan Rivers. The broad valleys occupied by these southeast-draining streams alternate with ridges as much as 1,700 ft high to produce a varied topography, with the 3,000- to 4,000-ft-high Blue Ridge defining the western horizon.

The bedrock geology of the quadrangle was mapped at a scale of 1:24,000 as part of the Geology of Shenandoah National Park Project (which was conducted from 1995 to 2008) of the U.S. Geological Survey National Cooperative Geologic Mapping Program. The results of the mapping were incorporated in the *Geologic Map of the Shenandoah National Park Region, Virginia* (Southworth and others, 2009; USGS Open-File Report 2009–1153). The Mesoproterozoic rocks and Catoctin and Swift Run Formations were mapped by W.C. Burton from 2006 to 2008, and the Mechum River Formation was mapped by C.M. Bailey (College of William and Mary) and students in 1997. A surficial map of the region at scale 1:100,000 was published by Morgan and others (2004). E.A. Crider added the surficial deposits in 2012, based on the mapping of Southworth and others (2009) and Morgan and others (2004). Previous bedrock geologic mapping in the area was at a scale of 1:62,500 by Gathright (1976) and Allen (1963).

BEDROCK LITHOLOGIES

MESOPROTEROZOIC ROCKS

The oldest rocks in the Shenandoah National Park region are Mesoproterozoic and range in age from about 1.03 to 1.18 Ga, according to recent uranium-lead (U-Pb) dating (Southworth and others, 2009). These "basement" rocks occupy the core of the Blue Ridge-South Mountain anticlinorium, a northeast-trending regional tectonic structure. The Stanardsville quadrangle is located west of the central axis of the anticlinorium, the western limb of which is represented by the topographic Blue Ridge. Prior to the recent work, only two basement units had been mapped in the quadrangle (Allen, 1963), whereas five are now recognized that span the entire known age range of Blue Ridge basement (see Southworth and others 2009) for sample localities). All of the basement rocks are intrusive in origin and broadly granitic in composition—two are charnockitic—and range in texture from gneissic for the older units to mostly massive for the younger ones. The intrusion of the protoliths occurred prior to or during the 1.0- to 1.2-Ga Ottawan and Shawinigan orogenies, which attained granulite- to upper-amphibolite-facies metamorphic conditions; the degree of development of high-grade tectonic foliation (gneissosity) is broadly related to age and deformation experienced by each unit during and following intrusion. The three older units, which have gneissic textures and intruded during the interval 1.18 to 1.16 Ga (Southworth and others, 2009), include porphyroblastic granite gneiss (Ylg), orthopyroxene monzogranite gneiss (Yomg), and biotite granite gneiss (Yll). The two younger units intruded between approximately 1.05 and 1.03 Ga (Southworth and others, 2009), lack gneissic textures, and consist of orthopyroxene monzogranite (Yom) and biotite monzogranite (Ybg). These younger rocks preserve evidence of intrusive contacts; in particular, the mapped boundary of Yom is irregular and crosscuts gneissic contacts, and two dikes of Yom that intrude older units were mapped. Ybg locally contains undeformed inclusions of biotite gneiss, the sources of which are not known.

NEOPROTEROZOIC ROCKS

The Neoproterozoic metasedimentary cover sequence to the Mesoproterozoic basement is represented in the Stanardsville quadrangle by the Swift Run, Catoctin, and Mechum River Formations. The Catoctin Formation, a metamorphosed flood basalt, extruded during the opening of the Iapetus Ocean around 570 Ma (Badger and Sinha, 1988) and is one of the dominant bedrock lithologies in Shenandoah National Park. Paleozoic deformation under lower greenschist-facies conditions has transformed the Catoctin Formation into a massive to schistose greenstone (Zcm) in which no relict igneous textures are preserved in the Stanardsville quadrangle. Thin layers of lustrous silvery-white, fine-grained muscovite phyllite in the greenstone (Zcp) are interpreted as felsic metatuffs or tuffaceous metasediments. The Swift Run Formation is an epiclastic deposit of irregular extent and thickness that is stratigraphically just below the Catoctin (Southworth and others, 2009); the dominant Swift Run lithology in the quadrangle is a fine-grained silvery-white phyllite (Zsp) that appears lithologically identical to the phyllites in the Catoctin (Zcp). The base of the Swift Run is locally represented by a meta-arkose (Zsa) that measures 10 to 12 meters (m) thick just to the west in the Swift Run quadrangle (Fichter and others, 2010). The Swift Run Formation is thin to absent underneath the Catoctin in the northwest corner of the quadrangle and in small inliers of Catoctin to the southeast.

To the east of the exposures of cover sequence rocks, metadiabase dikes of presumed Neoproterozoic age (Zmd) intrude the basement rocks. They closely resemble in appearance and composition Neoproterozoic dikes elsewhere in the Blue Ridge basement, which are thought to be feeders to the Catoctin flood basalt (Reed and Morgan, 1971; Burton and Southworth, 2010). Most dikes are mapped by float and are shown on the map as lines to convey indeterminate length and width. A few exposures of dike in contact with country rock, depicted by station symbols, show them to be typically several meters wide. There are likely more in the field area than shown on the map. The original basaltic igneous mineralogy in the dikes was completely replaced during Paleozoic regional greenschist-facies metamorphism by typical albite-epidote-actinolite "greenstone" assemblages. No dikes of felsic composition have been found.

The Mechum River Formation occupies a narrow, linear, northeast-trending belt about 85 km long (Bailey and others, 2007) that intersects the southeast part of the quadrangle, where it is 0.5 to 1.5 km wide. The formation has been subdivided into three units in the quadrangle: arkosic metawacke (Zma), metasiltstone and metamudstone (Zmp), and metaconglomerate (Zmc). The metasiltstone is interpreted as grading into the metawacke along strike to the northeast, and the metaconglomerate forms basal lenses in the metawacke on the northwest margin of the belt. The age of the Mechum River Formation and the nature of its relation to the cover-sequence deposits in the northwestern part of the quadrangle (Catoctin and Swift Run Formations) are unknown. Farther northeast along the belt (outside the map area), metadiabase dikes similar in composition to the Catoctin feeder dikes intrude Mechum River metasediments, suggesting a minimum age of 570 Ma, and a maximum age is indicated by Mechum River metaconglomerates that contain clasts of 730-Ma granite (Bailey and others, 2007).

JURASSIC DIKES

Two diabase dikes of presumed Jurassic age (Jd) were mapped in the area based on float. These have a distinctive orange or "buckskin" weathering rind typical of Jurassic diabase dikes and have retained their original igneous mineral assemblages, which include small plagioclase laths in a mostly unaltered fine-grained, clinopyroxene-bearing groundmass.

SURFICIAL DEPOSITS

The surficial deposits shown on the map are modified from the maps of Southworth and others (2009) and Morgan and others (2004). Two types of stream-related deposits are mapped in the Stanardsville quadrangle, mostly along the flood plains of the South, Conway, and Rapidan Rivers and Swift Run: Holocene alluvium (Qa), consisting of contemporary silt, sand, and gravels that occupy the channels immediately adjacent to the current drainages, and Quaternary and Neogene lowland terrace deposits (QNt) that underlie the river floodplains. Debris-fan deposits (QNd) are mapped in drainages upstream from the alluvium and terrace deposits and are a cumulative product of prehistoric storms similar in intensity to the June 1995 event in Madison County that produced severe flooding and triggered debris flows in the Blue Ridge foothills north of Stanardsville. Debris flows from the 1995 event (Qdf) are shown on the east and west slopes of Allen Mountain in the northeast part of the quadrangle.

STRUCTURE AND METAMORPHISM

MESOPROTEROZOIC STRUCTURE AND METAMORPHISM

The three Mesoproterozoic basement units in the Stanardsville quadrangle mapped as gneisses are porphyroblastic granite gneiss (Ylg), orthopyroxene monzogranite gneiss (Yomg), and biotite granite gneiss (Yll). All have U-Pb intrusive ages greater than 1.15 Ga; therefore they predate and experienced the Ottawan orogeny, which occurred in the Blue Ridge between 1.1 and 1.0 Ga (Tollo and others, 2004), and possibly an earlier phase (Shawinigan?) that is recognized in the northern Blue Ridge between 1.1 and 1.15 Ga (Burton and Southworth, 2004). This high-temperature, moderate-pressure deformation produced the gneissic fabric in these rocks (open foliation symbol), which is expressed in outcrop and thin section as aligned quartz, feldspar, and ferromagnesian minerals (biotite, orthopyroxene, hornblende) in a granoblastic texture. Grenville-age gneissosity generally trends northeast but also locally trends northwest, as elsewhere in the Blue Ridge. The two younger non-gneissic units, orthopyroxene monzogranite (Yom) and biotite monzogranite (Ybg), either intruded during the Ottawan orogeny and experienced the waning effects of it or postdated that deformation. A high-temperature fabric is locally present in these rocks (open symbol) but is not as well expressed as in the gneissic rocks; it could represent either an igneous foliation or a weak tectonic fabric. The contact relations between the gneissic units could be controlled by crosscutting relations, regional deformation, or both. Only one outcrop-scale Mesoproterozoic fold was observed, near the southwest corner of the map, which locally folds the contact between two gneissic units. As stated above, the contact of the orthopyroxene monzogranite (Yom) with the other basement rocks is very irregular and interpreted as primarily intrusive in nature; the contact of biotite monzogranite (Ybg) with other units is obscured by the intervening belt of Mechum River Formation but must be faulted in part (cross section *A–A′*).

Two of the Mesoproterozoic map units, Yom and Yomg, are charnockitic in composition and originally had orthopyroxene and microcline in textural equilibrium, indicating regional granulite-facies metamorphic conditions during Mesoproterozoic deformation, as is typical for Blue Ridge basement. No other mineral assemblages diagnostic of Mesoproterozoic metamorphic grade were observed in the basement rocks, due largely to their granitic compositions.

PALEOZOIC STRUCTURES AND METAMORPHISM

Paleozoic deformation produced the regional-scale Blue Ridge-South Mountain anticlinorium, which was transported westward along an underlying thrust fault during the Alleghanian orogeny (Evans, 1989; Southworth and others, 2009). The anticlinorium is a broad, northeast-trending, northwest-verging, gently north-plunging complex fold with associated regional, southeast-dipping axial-planar cleavage (S_1); the Stanardsville quadrangle is situated between the central axis of the anticlinorium and its western limb. The axial planar cleavage or S_1 (closed foliation symbols on map) formed under lower greenschist-facies metamorphic conditions and overprints high-grade foliation in the Mesoproterozoic rocks and bedding in the Neoproterozoic rocks. In the Stanardsville quadrangle the Paleozoic cleavage is easily distinguished by its generally northeast trend and southeast dip and associated greenschist-facies mineralogy; it is the penetrative fabric in the Neoproterozoic rocks and commonly also the dominant fabric in outcrops of Mesoproterozoic rocks.

Basement rocks

The Paleozoic S_1 cleavage is locally strong enough to be a mylonitic foliation and defines a number of northeast-trending, curvilinear shear zones in the basement, shown on the map by stippled overprint. These are part of a regional network of northeast-trending high-strain zones that occur in the Mesoproterozoic core of the Blue Ridge-South Mountain anticlinorium (Southworth and others, 2009). At some localities in the quadrangle the foliation is accompanied by a downdip mineral lineation, expressed by muscovite, biotite, or chlorite, that indicates slip direction. According to Bailey and others (2006) the predominant sense of motion in these high-strain zones is reverse (southeast-side-up). In the Stanardsville quadrangle, one particularly well-developed, fine-grained mylonite (phyllonite) with downdip lineations has asymmetric feldspar boudins that define a c-s shear geometry of this movement sense. At the southeast corner of the cover-sequence inlier near the northern boundary of the quadrangle, a small fault thrusts basement northwest over cover and is accompanied by the same type of mylonitic fabric with downdip lineation.

Several of the shear zones in the quadrangle are spatially associated with inliers of Catoctin Formation that are located as much as several kilometers southeast of the main Blue Ridge belt of Catoctin. These inliers are in depositional contact with basement and probably represent the erosional remnants of northwest-verging downfolds in the cover-sequence rocks during formation of the anticlinorium (cross section *A–A′*). The shear zones reflect the accommodation of the basement to the regional compressive stress that both folded and faulted the cover-sequence units.

Northwestern cover sequence

Post-regional cleavage (post-S_1) folds were mapped in the cover-sequence rocks in the northwest part of the Stanardsville quadrangle. These are of two types: outcrop-scale, north- to northwest-trending, west- to southwest-verging minor folds in S_1 cleavage, shown by station map symbols, and map-scale, northwest-trending upright folds, shown by fold-axis symbols, that are defined by swings in the basement-cover contact and local dip reversals in S_1 cleavage. These two fold types both document principal compressive stress in an east-west to northeast-southwest direction, in contrast to the southeast-northwest trend of the contractional event that produced the anticlinorium. The compression was post-S_1 because S_1 cleavage is folded, and therefore it postdates formation of the anticlinorium. Cross section *B–B′* is roughly parallel to the northeast-trending basement-cover contact and shows gentle undulations of the contact, which are a cumulative product of post-S_1 folding, syn-S_1 deformation, and perhaps predepositional topographic relief.

Mechum River Formation

The belt of Mechum River metasediments (Zm) in the southeastern part of the quadrangle has been interpreted by Bailey and others (2007) as a northwest-verging syncline that is unconformable on basement on its northwest margin and is bounded by a southeast-dipping thrust fault on its southeast margin. Along the northwest margin are lenses of conglomerate in Mechum River metawacke (Zma) that could be interpreted as basal facies above an unconformity. Several overturned beds in metawacke were mapped on the overturned southeastern limb of the syncline, supporting the model by Bailey and others (2007) of a southeast-dipping thrust fault as the southeastern boundary. Penetrative schistosity internal to the belt is nearly all northeast-striking and southeast-dipping and is therefore likely axial-planar to the syncline. Orientations of Zm schistosity are similar to Paleozoic S_1 schistosity in the surrounding basement rocks, and it is reasonable to assume that the syncline and Zm schistosity are also approximately of S_1 age and that they formed during the same regional contractional event that produced the anticlinorium. The southeast-bounding thrust fault, however, is not accompanied by mylonitization; it truncates the penetrative schistosity internal to the Mechum River Formation and is therefore post-S_1. Bailey and others (2007) consider the fault to be an out-of-sequence brittle thrust fault formed during emplacement of the Blue Ridge thrust sheet late in the Alleghanian orogeny.

JOINTS

In the Stanardsville quadrangle, 852 joints were measured, most of which belong to sets of multiple, parallel joints. Of these, 353, or 41 percent, were measured in the charnockite Yom, suggesting that it is the most fractured of the formations mapped in the quadrangle. Of course, measurement of joint abundance in each formation is highly dependent upon areal extent of the formation and how well exposed it is. Eighty-eight percent of the joints measured have dips greater than 60 degrees, but this percentage is biased by the fact that most outcrops have greater horizontal than vertical extents. No quarries or natural large vertical rock faces exist in the quadrangle that might yield more insight into the prevalence of near-surface, subhorizontal exfoliation joints.

Figure 1*A* shows a rose diagram (circular histogram of azimuths only) of all of the measured joints. The data are fairly well dispersed in azimuth, although there are two weak maxima in the northwest direction. Figure 1*B* shows the joints measured in Yom, which shows one weak maximum in the northwest direction. The tectonic significance of these trends is uncertain; however, they likely reflect regional orogenic stresses synchronous with and (or) following the Alleghanian orogeny, perhaps including Mesozoic extension during the breakup of Pangea.

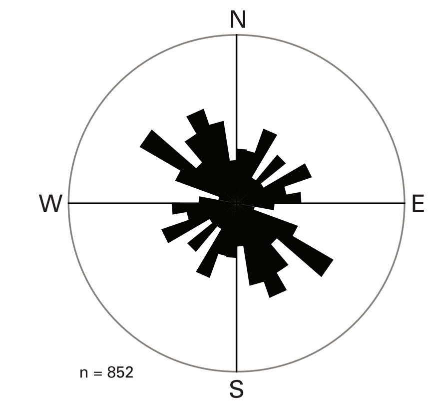


Figure 1*A*.—Rose diagram showing all measured joints in the Stanardsville quadrangle. Interval is 10 degrees. n, number of joints measured. Circle represents 15 percent of n.

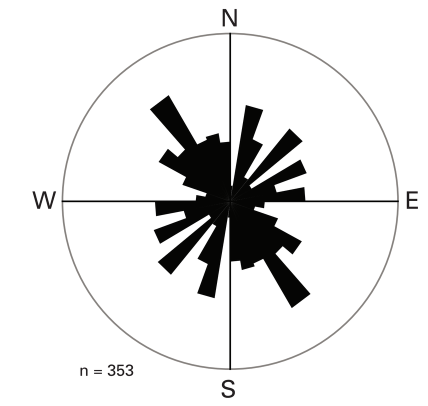


Figure 1*B*.—Rose diagram showing joints measured in orthopyroxene monzogranite (unit Yom). Interval is 10 degrees. n, number of joints measured. Circle represents 15 percent of n.

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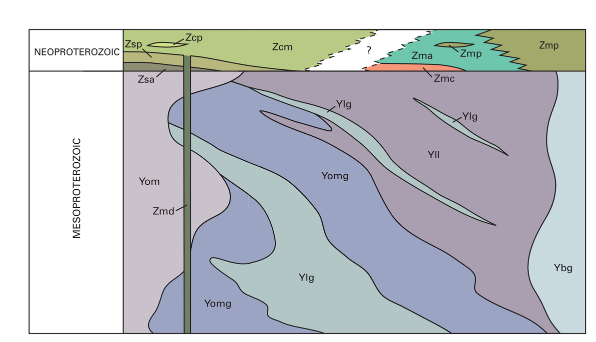
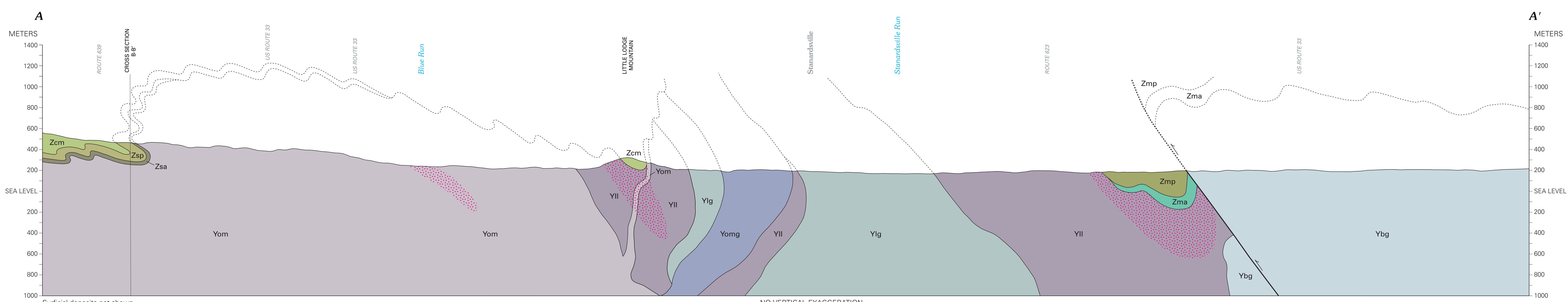
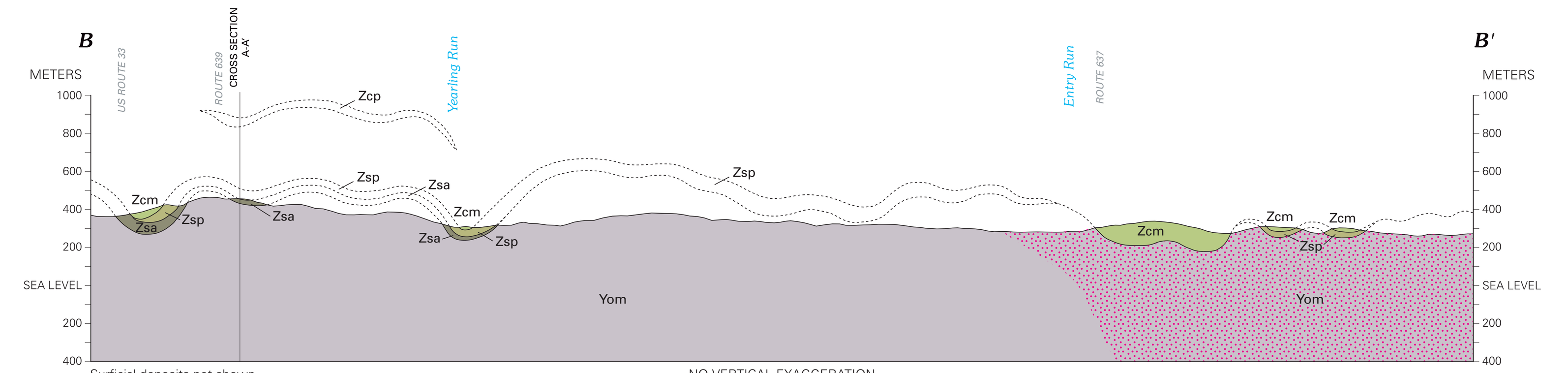


Figure 2.—Inferred pre-Paleozoic relations of Mesoproterozoic and Neoproterozoic rocks.





Preliminary Geologic Map of the Stanardsville 7.5′ Quadrangle, Greene and Madison Counties, Virginia

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2012

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Suggested Citation: Burton, W.C., Bailey, C.M., and Crider, E.A., 2012, Preliminary geologic map of the Stanardsville 7.5′ quadrangle, Greene and Madison Counties, Virginia: U.S. Geological Survey Open-File Report 2012–1190, one sheet, scale 1:24,000 [http://pubs.usgs.gov/of/2012/1190/].