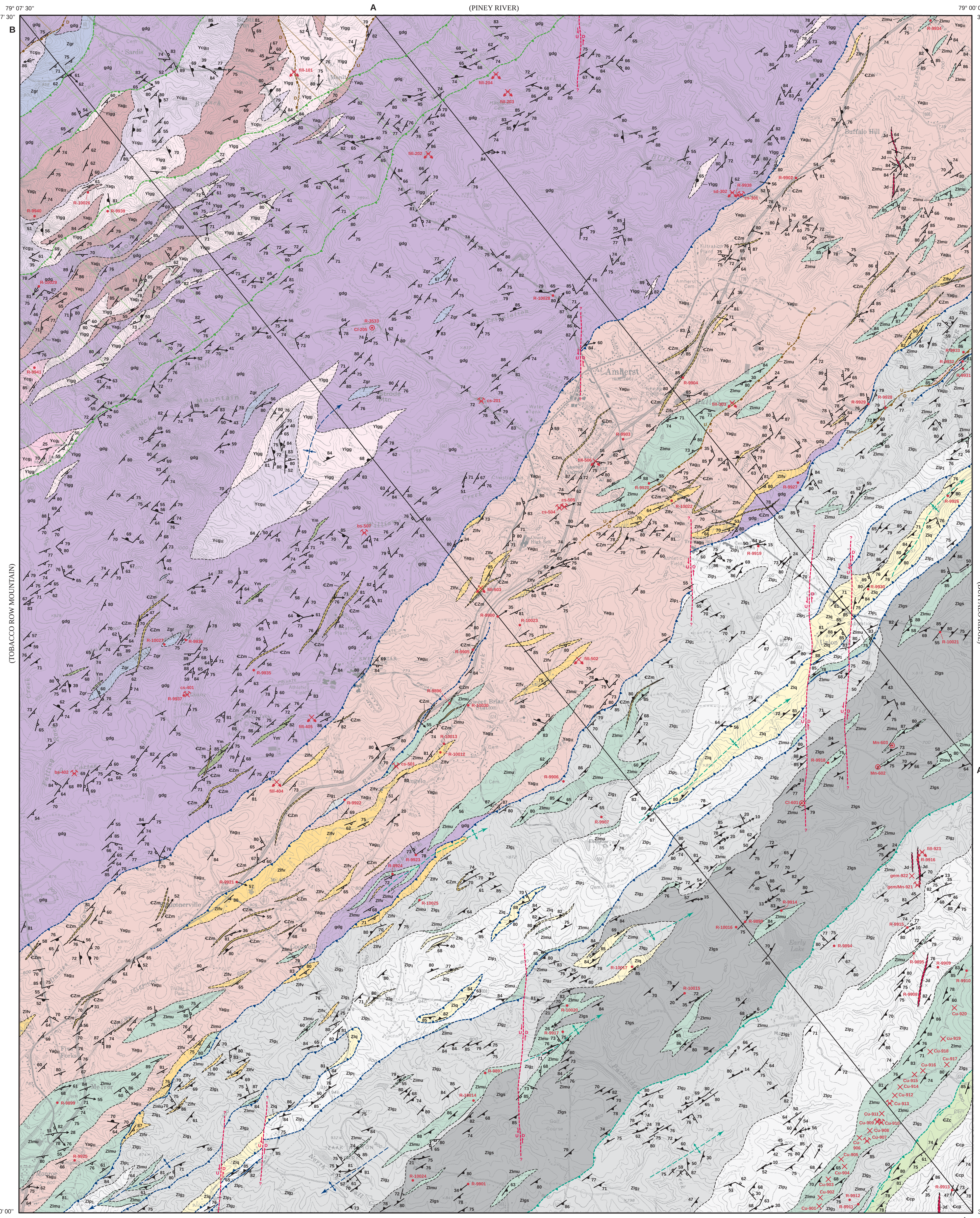
BEDROCK GEOLOGIC MAP OF THE AMHERST QUADRANGLE, VIRGINIA

MARK W. CARTER

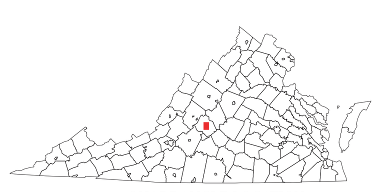
2008



Basemap modified from U.S. Geological Survey DRG
Am herst quadrangle, Virginia, 1963, Photorevised 1978
Projection: Modified UTM, NAD 1927 Datum
(rubber-sheeted to dimensions of paper quadrangle copy)
Digital Cartography by Mark W. Carter

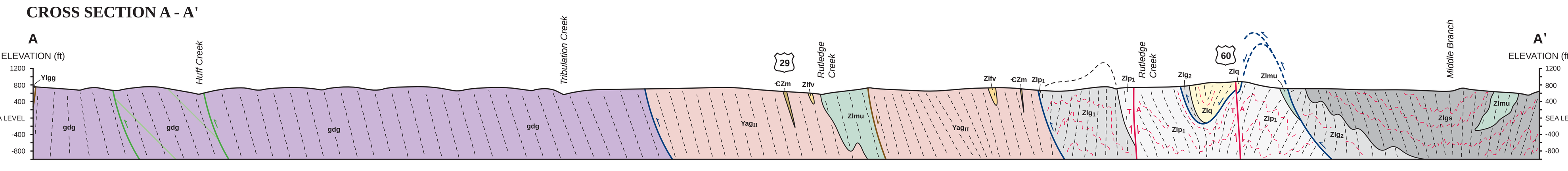
MN GN 9° 161 MILS 1° 11´ 21 MILS
2008 MAGNETIC NORTH DECLINATION AT CENTER OF SHEET ANNUAL VARIATION: 0° 1´ west per year

SCALE 1:24000
1 MILE · 1000 FEET · 1 KILOMETER
CONTOUR INTERVAL 20 FEET
NATIONAL GEODETIC VERTICAL DATUM OF 1929
Geology mapped from May 2004 to January 2007

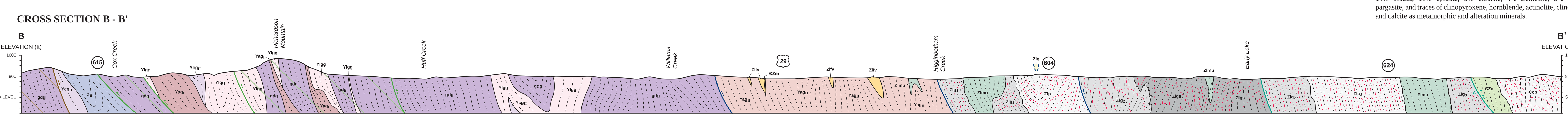


QUADRANGLE LOCATION

CROSS SECTION A - A'

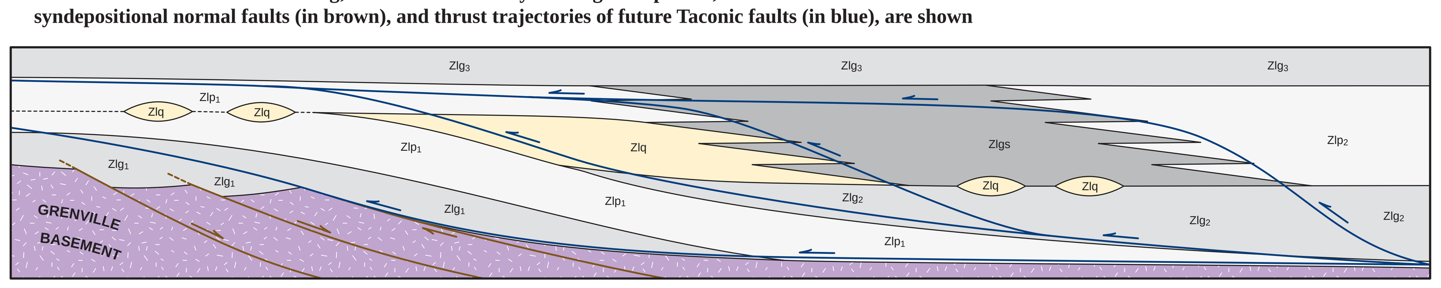


CROSS SECTION B - B'

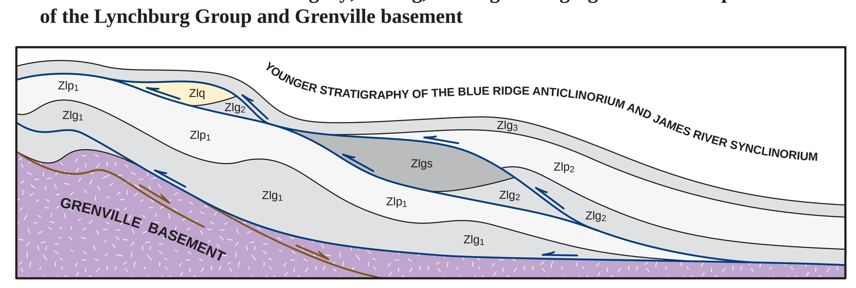


CROSS SECTIONAL SCHEMATIC OF THE LATE PROTEROZOIC TO MIDDLE PALEOZOIC TECTONIC EVOLUTION OF THE EASTERN BLUE RIDGE IN CENTRAL VIRGINIA

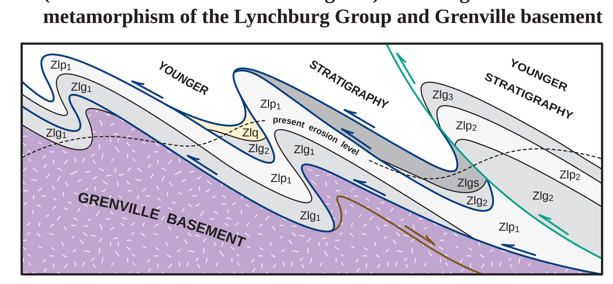
A. Late Proterozoic continental rifting; facies relations of Lynchburg Group units, syndepositional normal faults (in brown), and thrust trajectories of future Taconic faults (in blue), are shown



B. Middle Ordovician Taconic orogeny; folding, faulting and high-grade metamorphism of the Lynchburg Group and Grenville basement



C. Devonian Neoacadian orogeny; continued folding, faulting (Neoacadian faults are shown in green) and low-grade metamorphism of the Lynchburg Group and Grenville basement



DESCRIPTION OF MAP UNITS

MESOZOIC IGNEOUS INTRUSIVE ROCKS

Jd — **diabase and gabbro** – Igneous intrusive rocks of Mesozoic age; dark-green to black, weather to dark reddish-brown; fine- to medium-grained; diabase is aphanitic; gabbro is ophitic, subophitic, subidiomorphic, to porphyritic; typically contains abundant magnetite; modal analyses average 43% plagioclase, 33% augite, 6% magnetite, ilmenite, and other opaque minerals, 3% K-feldspar, and 1% quartz as primary minerals, and 5% biotite, 4% chlorite, 3% muscovite, 1% epidote, and 1% calcite as post-intrusive hydrothermal alteration minerals from primary mafic phases; occurs as dikes (and minor sills) that intrude older geologic units throughout the map area. Diabase and gabbro commonly weather to dense, spheroidally rounded boulders, which can be easily traced along strike when outcrop is absent. Several dikes portrayed on the geologic map are exaggerated, and many more are too small to map separately at this scale.

CAMBRIAN METASEDIMENTARY ROCKS

CANDLER FORMATION

€cp — **sericitic phyllite** – Sericitic phyllite of the Candler Formation is medium-gray, weathers to silvery-green; fine- to medium-grained; lepidoblastic; multiply foliated and crenulated; modal analyses average 26% quartz, 1% magnetite, ilmenite, and other opaque minerals, and 1% plagioclase as primary constituents, 1% zircon as an accessory mineral, and 37% muscovite, 17% biotite, 15% chlorite, 2% epidote, and a trace of garnet as metamorphic and alteration minerals. Muscovite-biotite metagraywacke is locally interbedded with sericitic phyllite, and is medium to dark gray, weathers to light gray; fine- to medium-grained; granoblastic to lepidoblastic, depending on mica content; well foliated; locally layered. Layering in metagraywacke ranges from several centimeters to several decimeters, and is likely primary bedding.

CAMBRIAN TO LATE PROTEROZOIC META-IGNEOUS ROCKS

CATOCTIN FORMATION

€Zc — **metabasalt** – Greenstone (metabasalt) is dark greenish-gray, weathers to light reddish-brown; fine-grained; nematoblastic to lepidoblastic, depending on mica and actinolite content resulting from intensity of alteration; well foliated. Greenstone is locally interlayered (meters to several meters) with metasedimentary phyllite and minor metagraywacke, similar to lithologies in the Candler Formation. Phyllite is locally mylonitic along the contact with the Lynchburg Group; mylonitization results in a distinctive "button" or "fish-scale" schist characterized by lenticular muscovite-aggregate porphyroclasts, about one centimeter long, which are flattened in the foliation plane. Brown (1958) correlates along-strike greenstone on the adjacent Lynchburg 15-minute quadrangle with the Catoctin Formation. The Catoctin Formation is dated at about 570 Ma by Badger and Sinha (1988).

€Zm — **metamorphosed mafic dikes and sills** – This unit consists of garnet-epidote-biotite schist, and lesser amphibolite. Schist is dark greenish-gray, weathers to dark reddish-brown; fine-grained; lepidoblastic; well-foliated; cross-biotite texture is common locally; modal analyses average 18% quartz and 4% plagioclase as primary constituents, 1% zircon and 1% apatite as accessory minerals, and 49% biotite, 23% epidote, 2% garnet, and 2% titanite as metamorphic and alteration minerals. Schist is the retrogressed metamorphic equivalent of amphibolite, which is dark greenish-gray, weathers to reddish-brown; fine- to medium-grained; nematoblastic to granoblastic to lepidoblastic, depending on mica content; weakly to well-foliated; cross-amphibole texture is common locally; modal analyses average 78% pargasite, 7% quartz, 4% plagioclase, and 4% ilmenite, magnetite and other opaque minerals as primary constituents, a trace of apatite as an accessory mineral, and 5% biotite and 2% epidote as metamorphic and alteration minerals. Both major rock types of this unit occur as dikes and sills that intrude older geologic units throughout the map area; most occur in Middle Proterozoic Yag$_{II}$ augen gneiss, but some occur in the western part of the Late Proterozoic Lynchburg Group and the eastern part of the biotite granodioritic porphyroclastic gneiss (gdg) unit. Brown (1970) and others interpret rocks of this unit to represent intrusive feeder dikes to extrusive Catoctin metabasalts. Many dikes and sills portrayed on the geologic map are exaggerated, and many more are too small to map separately at this scale.

LATE PROTEROZOIC METASEDIMENTARY ROCKS

LYNCHBURG GROUP

A heterogeneous sequence of interbedded and interlayered metasedimentary and metavolcanic rocks of Late Proterozoic age (Wehr, 1985; Wehr and Glover, 1985), between rocks of the Evington Group-Candler Formation (Espenshade, 1954) to the east, and Blue Ridge Basement Complex rocks to the west. On the Amherst quadrangle, metasedimentary rocks of the Lynchburg Group are divided into four major units based on dominant lithology: metagraywacke, mica schist, graphitic schist, and feldspathic quartzite. Metagraywacke and mica schist are further subdivided based on age relationships as determined by stratigraphic and structural field observations, and distinguishing characteristics within each subdivision. The unit descriptions below reflect the major lithologic divisions of the Lynchburg Group, rather than stratigraphic order.

Zlg$_3$, Zlg$_2$, Zlg$_1$ — **metagraywacke** – Muscovite-biotite gneiss is medium- to dark-gray, weathers light-gray; fine- to coarse-grained, locally granule conglomeratic and very rarely cobble conglomeratic; granoblastic to lepidoblastic, depending on mica content; multiply foliated and locally crenulated; locally layered. Layering ranges from several centimeters to about one meter, and may be primary bedding. All metagraywacke subunits are locally interlayered with mica schist, amphibolite, altered ultramafic rocks, and graphitic schist. Modal analyses of **Zlg$_3$** metagraywacke average 41% quartz, 7% K-feldspar, and 4% plagioclase as primary constituents, 1% apatite and a trace of zircon as accessory minerals, and 26% biotite, 14% epidote, 6% muscovite, and 1% garnet as metamorphic and alteration minerals. Subhedral to nearly euhedral plagioclase laths, with length-width ratios of approximately 3-to-1, within finer-grained quartz-mica-feldspar matrix, suggest a volcaniclastic origin for this metagraywacke unit, which is also locally mylonitic, especially along the contact with the Catoctin Formation. Modal analyses of **Zlg$_2$** metagraywacke average 45% quartz, 5% K-feldspar, 3% plagioclase, and a trace of magnetite, ilmenite and other opaque minerals as primary constituents, 2% apatite, 1% zircon, and a trace of allanite as accessory minerals, and 34% biotite, 9% muscovite, 1% epidote, and traces of garnet, titanite, and chlorite as metamorphic and alteration minerals. Zlg$_2$ metagraywacke conformably underlies feldspathic quartzite and graphitic schist in separate fault blocks. Modal analyses of **Zlg$_1$** metagraywacke average 41% quartz, 9% K-feldspar, 2% plagioclase, and 1% magnetite and ilmenite as primary constituents, 1% zircon and 1% apatite as accessory minerals, and 17% biotite, 16% muscovite, 8% epidote, 1% garnet, 1% graphite, 1% titanite, 1% leucoxene, and a trace of chlorite as metamorphic and alteration minerals. Composite granules of K-feldspar and quartz are common in this metagraywacke subunit, and thin interbeds of cobble metaconglomerate occur along, and stratigraphically near, the unconformable contact with underlying Blue Ridge Basement Complex rocks along the central-eastern edge of the quadrangle in the vicinity of Buffalo River. In addition, from US 60 north to the central-eastern edge of the quadrangle, and in the southwestern corner of the quadrangle, southeast of Melvor, centimeter- to decimeter-scale lit-par-lit-like amphibolites are locally intricately interlayered with metagraywacke, giving the rock a migmatitic appearance. Collectively, Zlg$_1$ metagraywacke, and interlayered felsic (Zlfv), mafic, and ultramafic (Zlmu) volcanic rocks within the metagraywacke are correlated with the Late Proterozoic Moneta Gneiss of Wang (1991) and Wang and Glover (1997), which have been dated at 607 ± 7 Ma by Southworth and others (2005).

Zlp$_2$, Zlp$_1$ — **mica schist** – Biotite-muscovite schist is medium-gray, weathers to light-gray; fine- to medium-grained; lepidoblastic to granoblastic, depending on quartz and feldspar content; multiply foliated, and commonly crenulated; locally layered. Layering ranges up to several centimeters, and is likely primary bedding. Both phyllite subunits are locally interlayered with metagraywacke, amphibolite and altered ultramafic rocks. Modal analyses of **Zlp$_2$** mica schist average 18% quartz, 2% K-feldspar, and 1% plagioclase as primary constituents, traces of zircon and apatite as accessory minerals, and 51% muscovite, 14% biotite, 7% epidote, 6% graphite, and 1% garnet as metamorphic and alteration minerals. Zlp$_2$ mica schist commonly exhibits a cross-muscovite or cross-biotite texture that overprints earlier-formed foliations and crenulations. Zlp$_2$ mica schist is correlative with the Charlottesville Formation of Nelson (1962) and Wehr (1983, 1985) to the north. Modal analyses of **Zlp$_1$** mica schist average 15% quartz and a trace of plagioclase as primary constituents, and 50% muscovite, 11% chlorite, 10% chloritoid, 6% graphite, 5% biotite, 2% epidote, and 1% talc as metamorphic and alteration minerals. Zlp$_1$ mica schist commonly exhibits a cross-chloritoid, cross-muscovite or cross-biotite texture, and is locally interbedded with feldspathic quartzite.

Zlgs — **graphitic schist** – Graphitic schist is very dark-gray to black, weathers to dark-gray; fine- to medium-grained; lepidoblastic; multiply foliated and crenulated; locally layered. Layering ranges up to several centimeters, and is likely primary bedding. Modal analyses of graphitic schist average 34% quartz, 2% plagioclase, and 1% K-feldspar as primary constituents, a trace of zircon as an accessory mineral, and 28% muscovite, 25% graphite, 7% biotite, 2% phlogopite, 1% garnet, and a trace of epidote as metamorphic and alteration minerals. Graphitic schist commonly exhibits a cross-biotite or cross-phlogopite texture, and is locally interlayered with mica schist, altered ultramafic rocks, feldspathic quartzite, amphibolite and metagraywacke. Graphitic schist is correlative with the Johnson Mill Formation of Nelson (1962), or the Johnson Mill Member of the Ball Mountain Formation of Wehr (1983, 1985) to the north, and the Lynchburg II unit of Wang (1991) and Wang and Glover (1997) to the south.

Zlq — **feldspathic quartzite** – Feldspathic to arkosic quartzite is light-gray, weathers to yellowish-gray; medium- to coarse-grained, locally granule conglomeratic; granoblastic to lepidoblastic; locally mylonitic; multiply foliated; locally layered. Layering ranges from several centimeters to about one meter, and is likely primary bedding. Modal analyses of feldspathic quartzite average 53% quartz, 26% K-feldspar, and 9% plagioclase as primary constituents, 1% zircon and 1% apatite as accessory minerals, and 8% muscovite, 1% epidote, 1% calcite, and traces of biotite, graphite and titanite as metamorphic and alteration minerals. As mica content increases, due primarily to deformation and alteration of feldspars to muscovite, feldspathic quartzite grades into quartz-rich phyllite (from northeast to southwest across the quadrangle). Feldspathic quartzite is locally interlayered with graphitic schist, phyllite and altered ultramafic rocks. Feldspathic quartzite is correlative with Ball Mountain Formation of Wehr (1983, 1985) to the north.

LATE PROTEROZOIC METAVOLCANIC AND METAPLUTONIC IGNEOUS ROCKS OF THE CROSSNORE PLUTONIC-VOLCANIC SUITE

The following felsic (Zlfv) and mafic, ultramafic, and ultrabasic (Zlmu) rocks occur as intrusive dikes, sills, pods, lenses, and interlayers within Late Proterozoic metasedimentary rocks of the Lynchburg Group, and Middle Proterozoic Yag$_{II}$ augen gneiss of the Blue Ridge Basement Complex. As such, these rocks are no older than Late Proterozoic. Those occurring interlayered with Zlg$_1$ metagraywacke of the Lynchburg Group and Yag$_{II}$ augen gneiss are probably equivalent, at least in part, to rocks associated with the Late Proterozoic Moneta Gneiss of Wang (1991) and Wang and Glover (1997), which have been dated at 607 ± 7 Ma by Southworth and others (2005). Many of the smaller dikes, sills, pods, and lenses portrayed on the geologic map are exaggerated, and many more are too small to map separately at this scale. These felsic (Zlfv) and mafic, ultramafic, and ultrabasic (Zlmu) rocks are also included with the Late Proterozoic Crossnore Plutonic-Volcanic Suite (Rankin and others, 1973; Rankin, 1975; Wang and Glover, 1997).

Zlfv — **felsic gneiss** – Leucocratic muscovite-biotite-quartz-feldspar granitic gneiss is yellowish-gray, weathers to light yellowish-gray; medium- to coarse-grained; granoblastic to porphyroclastic, locally lepidoblastic depending on mica content; well foliated. Felsic gneiss is intrusive into both Zlg$_1$ metagraywacke at the base of the Lynchburg Group, and Yag$_{II}$ augen gneiss of the Blue Ridge Basement Complex.

Zlmu — **metamorphosed mafic, ultramafic, and ultrabasic rocks** – mafic to ultrabasic meta-igneous rocks ranging from altered ultrabasic rocks (talc-serpentine schists), to talc-amphibole schists, to amphibolite and rare metagabbro; occur as intrusive dikes, sills, pods, lenses and interlayers throughout the metasedimentary package of the Lynchburg Group, and Yag$_{II}$ augen gneiss of the Blue Ridge Basement Complex, and in a continuous belt within the upper part of the Lynchburg Group in the southwest corner of the Amherst quadrangle. Mafic and ultrabasic rocks of this unit are distinguished from younger Jurassic diabase and gabbro by their foliated texture and retrogressive mineralogy. Amphibolite is the most common rock type, and is dark greenish-gray to black, weathers dark reddish-brown. Amphibolite is commonly coarse- very coarse-grained, with porphyroblastic to porphyroclastic megacrysts of pargasite up to several centimeter in diameter, but some varieties (mostly within the Lynchburg Group) are fine- to medium-grained, and nematoblastic. All textural varieties of amphibolite are weakly to well-foliated. Modal analyses of amphibolite in the Lynchburg Group average 62% pargasite, 16% quartz, 5% plagioclase, and 2% K-feldspar as primary constituents, traces of zircon, apatite, and rutile as accessory minerals, and 5% epidote, 4% ilmenite, magnetite, pyrite and other opaque minerals, 3% clinozoisite, 1% titanite, 1% biotite, 1% clinochlore, and traces of garnet, chlorite, and calcite as metamorphic and alteration minerals. Modal analyses of amphibolite in Yag$_{II}$ augen gneiss average 51% pargasite, 17% quartz, 8% plagioclase, and 2% K-feldspar as primary constituents, traces of zircon and apatite as accessory minerals, and 8% biotite, 5% epidote, 4% zoisite, 2% chlorite, 2% ilmenite, magnetite, pyrite and other opaque minerals, 1% muscovite, and traces of titanite and calcite as metamorphic and alteration minerals. Amphibolite commonly exhibits a cross-amphibole texture, consisting of distinct needles of acicular amphibole that overprint earlier-formed foliation surfaces, suggesting post-peak-deformation thermal metamorphism. Amphibolite is interpreted to be retrogressively altered metavolcanic rock (Rankin and others, 1973); some amphibolite in both the Lynchburg Group and Yag$_{II}$ augen gneiss is locally completely retrogressed to biotite gneiss and schist. Amphibolite within the Yag$_{II}$ augen gneiss is interlayered (meters to several meters) with amphibole-bearing biotite granitic augen gneiss (which is similar to rocks of the Yag$_{II}$ augen gneiss unit, except that amphibole is the dominant mafic mineral phase rather than biotite), and is indicative of assimilation of the country rock during intrusion. Within the Zlg$_1$ unit of the Lynchburg Group, centimeter- to decimeter-scale lit-par-lit-like, fine- to medium-grained, nematoblastic amphibolite is locally intricately interlayered with amphibole-bearing metagraywackes, giving the rock a migmatitic appearance. These amphibolites may have been mafic tuffs (Rankin and others, 1973), or calcareous sediments, before prograde metamorphism. Talc-amphibole schists are dark greenish-gray, weathering to light greenish-gray; fine-grained; lepidoblastic; locally mylonitic; well foliated; consist of about 4% quartz, 3% plagioclase, 1% rutile, and traces of K-feldspar, and magnetite, ilmenite, and other opaque minerals as primary constituents, and 34% tremolite, 28% anthophyllite, 21% talc, 5% chlorite, 2% biotite, 1% epidote, 1% titanite, and traces of zoisite and leucoxene as metamorphic and alteration minerals. Primary pyroxene has been nearly completely altered to amphibole in these schists, but locally, the schists are interlayered with less altered metagabbro. Talc-amphibole schists are interpreted to be retrogressively altered ultramafic rocks. Altered ultrabasic rocks are rare, but are dark greenish-gray, weathering to light greenish-gray; fine-grained; lepidoblastic; locally mylonitic; well foliated; consist of about 26% olivine and 6% magnetite, ilmenite and other opaque minerals as primary constituents, a trace of allanite as an accessory mineral, and 34% talc, 17% serpentine, 14% epidote, and 3% chlorite as metamorphic and alteration minerals.

MOBLEY MOUNTAIN GRANITE

Zgr — **foliated granite** – Leucocratic to mesocratic, amphibole-bearing, muscovite-biotite granite gneiss is light bluish-gray to yellowish-gray; fine- to medium-grained; granoblastic to porphyroclastic; typically foliated, locally massive; locally mylonitic; modal analyses average 29% quartz, 19% K-feldspar (microcline), 16% perthite, 10% plagioclase, 5% pargasite, and some biotite and muscovite as primary constituents, 1% zircon and traces of magnetite, ilmenite, apatite, rutile, and allanite as accessory minerals, and 10% biotite, 5% epidote, 3% muscovite, 1% garnet, and 1% chlorite as metamorphic and alteration minerals. Fluorite is also present in some outcrops. Zones of migmatitic layering, which range in thickness from several centimeters to about 0.5 meters, is common near the contact between the main body of granite on Mobley Mountain (on the adjacent Piney River quadrangle to the north) and surrounding country rocks. Weakly foliated pegmatitic, granitic and aplitic dike swarms cut the granite and extend as a halo into surrounding country rocks for about 2 kilometers away from the main body. Rocks of the Mobley Mountain Granite extend southward from the main body onto the Amherst quadrangle, approximately 0.5 kilometers west of Sardis. Granitoids that are lithologically identical to the Mobley Mountain Granite on the Piney River quadrangle also crop out as smaller stocks, plugs, dikes, and sills approximately 3 kilometers southeast of the main body on the Amherst quadrangle, on Paul, Kentucky and Strode mountains. Mobley Mountain Granite is dated at 652 Ma (Brock and others, 1987).

MIDDLE PROTEROZOIC META-IGNEOUS AND ALTERED META-IGNEOUS ROCKS OF THE BLUE RIDGE BASEMENT COMPLEX

Middle Proterozoic rocks of the Blue Ridge Basement Complex on the Amherst quadrangle consist of charnockites, associated mafic and ultramafic rocks, altered charnockites, augen gneisses, and granulitic orthogneisses. Much research has been conducted in this region at both the detailed- and reconnaissance-levels, and numerous nomenclatural and stratigraphic schemes have been proposed, based on geochronology and tectono-orogenic interpretations, since the seminal work of Bloomer and Werner (1955). The following subdivisions of these rocks are grouped primarily on lithology, rather than stratigraphic order.

CHARNOCKITIC ROCKS

Charnockitic rocks of the Blue Ridge Basement Complex on the Amherst quadrangle are subdivided on the basis of constituent feldspar. Charnockites of the Ycg$_I$ unit contain abundant perthite; Ycg$_{II}$ charnockites consist of plagioclase and microcline. Ycg$_I$ charnockites on the Amherst quadrangle are part of the antiquated Pedlar Formation of Bloomer and Werner (1955), and may be correlative with the Pedlar River Suite of plutons of Bartholomew (1977, 1981), Bartholomew and others (1981, 1991), and Bartholomew and Lewis (1984). Ycg$_{II}$ charnockites appear to be equivalent to the Turkey Mountain Suite of plutons of Herz and Force (1984,1987). Sinha and Bartholomew (1984) dated Pedlar charnockites at 1075 Ma; Herz and Force (1987) report a younger age of 1040 Ma. Herz and Force (1984,1987) also reported an age of 970 Ma for the Roses Mill Pluton (a unit that they interpreted to be stratigraphically equivalent to the Turkey Mountain charnockites on the Piney River and Massies Mill quadrangles to the north). Pettingill and others (1984) report an older age of 1027 Ma for these rocks. The approximate age and stratigraphic order of these charnockites on the Amherst quadrangle are confirmed by cross-cutting relationships on the adjoining Piney River quadrangle; there, plagioclase-rich Ycg$_{II}$ charnockites intrude older, perthite-rich charnockite of the Ycg$_I$ unit.

Ycg$_{II}$ — **plagioclase charnockite and charnockitic gneiss** – Hypersthene- and amphibole-bearing granodioritic gneiss of this unit is grayish-green to medium dark-gray; medium- to coarse-grained; hypidiomorphic-granular to coarsely porphyroclastic; massive to weakly foliated; modal analyses average 23% plagioclase, 21% quartz, 15% K-feldspar (microcline), 8% hypersthene, 4% ilmenite, magnetite, and other opaque minerals, 2% perthite, 1% myrmekite, and 1% hornblende as primary constituents, 2% apatite, 1% rutile, and traces of zircon and allanite as accessory minerals, and 7% chlorite, 4% tremolite, 4% actinolite, 3% epidote, 2% clinopyroxene, 1% pargasite, 1% biotite, and a trace of muscovite as metamorphic and alteration minerals. Herz and Force (1987) describe several additional lithologies within their Turkey Mountain and Roses Mill plutons, based on petrographic and geochemical criteria, including leucodiorite and ferrodiorite. These lithologies are not easily distinguished at this scale, and are collectively grouped into plagioclase charnockitic gneiss on this map. Plagioclase charnockite and charnockitic gneiss grade into, and are interlayered with biotite granodioritic porphyroclastic gneiss (gdg, described below) along common contacts, and represent the relatively unaltered protolith of the more widespread porphyroclastic gneiss unit.

Ycg$_I$ — **perthitic charnockite and charnockite gneiss** – Hypersthene- and amphibole-bearing granodioritic gneiss is bluish gray to dusky green; medium- to coarse-grained; hypidiomorphic-granular to coarsely porphyroclastic; massive to weakly foliated; locally coarsely layered, layering ranges from centimeters to several decimeters; grades into and is interlayered with mylonitic altered charnockite gneiss. In outcrop and hand specimen, blue quartz is common, as is uralitized pyroxene and saussuritized feldspars; modal analyses average 23% quartz, 14% perthite, 11% K-feldspar (microcline), 6% plagioclase, 3% ilmenite, magnetite, and other opaque minerals, 2% hypersthene, and 1% myrmekite as primary constituents, 2% apatite and a trace of zircon as accessory minerals, and 14% biotite, 11% epidote, 5% chlorite, 4% tremolite, 3% muscovite, 1% pargasite, and traces of clinopyroxene, hornblende, actinolite, clinozoisite, titanite and calcite as metamorphic and alteration minerals.

MIDDLE PROTEROZOIC META-IGNEOUS AND ALTERED META-IGNEOUS ROCKS OF THE BLUE RIDGE BASEMENT COMPLEX (CONTINUED)

ALTERED CHARNOCKITIC ROCKS

gdg — **biotite granodioritic porphyroclastic gneiss** – Biotite granodioritic porphyroclastic gneiss is brownish-gray to grayish olive-green; fine- to medium-grained; protomylonitic throughout, becoming mylonitic near and within high-strain zones; multiply foliated; locally exhibits a cross-muscovite or cross-biotite texture; modal analyses average 30% quartz, 11% plagioclase, 6% K-feldspar (microcline), 3% perthite, and 1% ilmenite, magnetite, and other opaque minerals as primary constituents, 1% apatite, and traces of zircon and allanite as accessory minerals, and 29% biotite, 10% epidote, 4% muscovite, 4% titanite, 1% penninite, and traces of garnet, chlorite, clinozoisite, and calcite as metamorphic and alteration minerals. Mylonitic rocks of this unit are characterized by sericitic phyllonite, which is silvery greenish gray, weathers to medium to dark brownish gray; fine- to medium-grained; lepidoblastic; mylonitic; well foliated. Biotite granodioritic porphyroclastic gneiss is locally interlayered with pods, lenses, and screens of charnockitic gneiss and leucocratic granitoid gneiss, and xenoliths of leucogranulite orthogneiss, most too small to show at this scale of mapping. Biotite granodioritic porphyroclastic gneiss represents a metamorphically altered derivative of the more massive, weakly foliated charnockite gneiss units, Ycg$_I$ and Ycg$_{II}$, as proposed by Evans (1987, 1991) and Bailey and Simpson (1993).

MAFIC AND ULTRAMAFIC ROCKS

Ym — **metamorphosed mafic and ultramafic dikes and sills** – Several metamorphosed mafic and ultramafic dikes and sills crop out in the vicinity of Paul Mountain, and consist of metagabbro, amphibolite, and chlorite-biotite gneiss and schist. Metagabbro is olive black, weathers to light olive gray; fine- to medium-grained; original texture is hypidiomorphic-granular to ophitic, but altered locally by metamorphism and deformation to a porphyroclastic-textured rock; massive to foliated; easily distinguished from younger Jurassic gabbro by its foliated texture and amphibolite-facies mineral assemblage. On the adjoining Piney River quadrangle, modal analysis of a similar metagabbroic rock indicates 7% quartz, 5% plagioclase, 3% ilmenite, magnetite and other opaque minerals, 1% hypersthene, and a trace of K-feldspar as primary constituents, and 25% epidote, 21% chlorite, 19% tremolite, 9% pargasite, 9% titanite, 1% zoisite, and traces of biotite and talc as metamorphic and alteration minerals. Amphibolite (retrogressed metagabbro) is dark greenish gray; medium-grained; nematoblastic. Garnet-chlorite-biotite gneiss and schist (retrogressed amphibolite) is dark greenish gray; fine- to medium-grained; granoblastic to locally lepidoblastic, depending on mica content. On the adjoining Piney River quadrangle, a similar chlorite-garnet-biotite orthogneiss occurs as a cross-cutting dike; modal analysis of this rock indicates 30% quartz, 16% plagioclase, 4% K-feldspar, and 1% ilmenite, magnetite and other opaque minerals as primary constituents, 1% zircon and a trace of allanite as accessory minerals, and 35% biotite, 5% muscovite, 5% epidote, 3% garnet, and traces of chlorite and clinozoisite as metamorphic and alteration minerals. Multiple foliations, garnet overgrowths, and highly strained quartz distinguish this orthogneiss dike from younger Late Precambrian to Cambrian-age mafic dikes of the Catoctin Formation. Herz and Force (1984, 1987) present field- and geochemical-evidence suggesting that nelsonite, ferrodiorite, and other mafic and ultramafic rocks in the region are cumulates that occur at the base of the Turkey Mountain and Roses Mill plutons, or are dike swarms of differentiated parent material intrusive into these plutons. If so, mafic and ultramafic rocks of this unit on the Amherst quadrangle are approximately equivalent in age to charnockites of the Ycg$_{II}$ unit.

AUGEN GNEISSES

Augen gneisses of the Blue Ridge Basement Complex on the Amherst quadrangle are subdivided on the basis of constituent feldspar. Augen gneisses of the Yag$_I$ unit, in the northwest corner of the quadrangle, are perthitic; Yag$_{II}$ augen gneiss crops out in a wide belt in the central portion of the quadrangle, and consists of abundant microcline. Yag$_I$ augen gneisses on the Amherst quadrangle are identical to Shaeffer Hollow Granite mapped by Herz and Force (1984, 1987) on the adjoining Piney River quadrangle to the north (Herz and Force report discordant ages of 1787 to 990 Ma for Shaeffer Hollow Granite). On the Amherst quadrangle, Yag$_I$ augen gneiss is associated both lithologically and structurally with similarly perthite-bearing layered granulitic gneisses (Ylgg) and perthitic charnockites (Ycg$_I$). Yag$_{II}$ augen gneiss is possibly equivalent, at least in part, to the Stage Road Layered Gneiss of Sinha and Bartholomew (1984). However, Sinha and Bartholomew (1984) suggest the Stage Road Layered Gneiss is paragneissic (and cite two distinct ages of detrital and metamorphic zircons - 1870 and 915 Ma); mesoscopically, Yag$_{II}$ augen gneiss on the Amherst quadrangle appears orthogneissic. Pettingill and others (1984) report a younger age of 1147 Ma for Stage Road Layered Gneiss. Yag$_{II}$ augen gneiss may also be correlative to the Marshall Metagranite of Espenshade (1986) to the north, which is similar in compostion (Clarke, 1984). Aleinikoff and others (2000) report an age of 1112 Ma for the Marshall Metagranite.

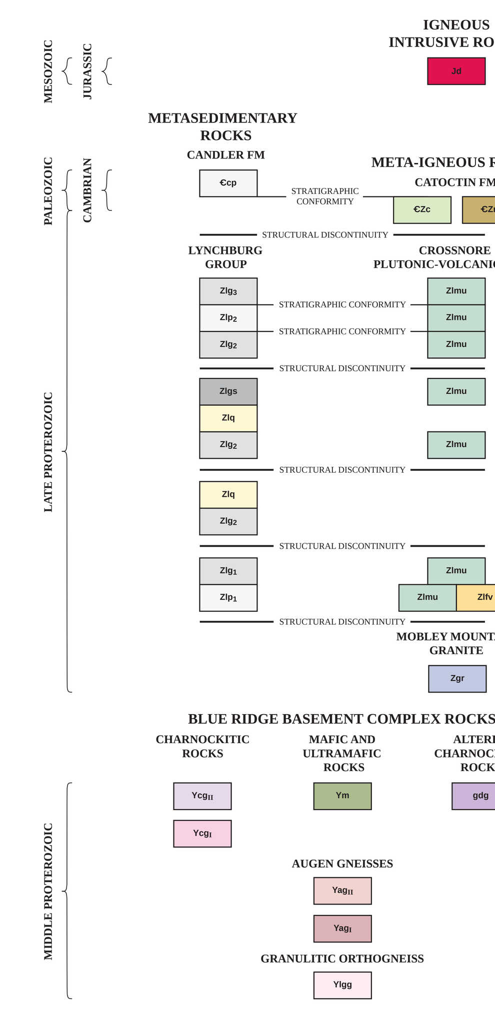
Yag$_{II}$ — **microcline-bearing augen gneiss** – The dominant rock type of this unit is biotite granitic augen gneiss, which is dark yellowish-brown to dark greenish-gray; medium- to very coarse-grained; generally protomylonitic throughout, but mylonitic along contact with altered charnockitic gneiss (gdg) to the west and Lynchburg Group rocks to the east; modal analyses average 38% quartz, 25% K-feldspar (microcline), 5% plagioclase, and traces of ilmenite, magnetite, and other opaque minerals as primary constituents, traces of zircon, apatite, and allanite as accessory minerals, and 20% biotite, 6% epidote, 4% muscovite, 2% titanite, and traces of garnet and chlorite as metamorphic and alteration minerals. Coarse- to very coarse-grained composite porphyroclasts of quartz and potassium feldspar, up to several centimeters in length, are diagnostic of this unit; as grain-size of the porphyroclasts decreases, biotite content increases and the rocks grade into biotite granitic gneiss. This unit is locally compositionally layered into coarse-grained quartzofeldspathic and finer-grained biotite-rich domains; layering ranges from several centimeters to several decimeters; protomylonitization disrupts compositional layering, but the earlier foliation is recognized by a cross-foliation alignment of quartz and feldspar porphyroclasts. Augen gneiss also locally exhibits a younger cross-muscovite or cross-biotite texture. Augen gneiss is interlayered with Late Proterozoic felsic gneiss and amphibolite (Zlfv and Zlmu). Rocks of this unit are distinguished from Late Proterozoic felsic gneiss in that the later is more felsic in composition, and contains more muscovite. Yag$_{II}$ augen gneiss is also distinguished from biotite granodioritic porphyroclastic gneiss (gdg) in that the later is generally finer-grained, more biotite-rich, and contain smaller porphyroclasts (generally about 0.5 centimeters in length) of dominantly plagioclase feldspar.

Yag$_I$ — **perthitic megaporphyritic augen gneiss** – Perthite-bearing augen gneiss is pale-blue to medium bluish-gray; coarse- to very coarse-grained; porphyritic, with perthitic-feldspar phenocrysts commonly up to five centimeters in length; becomes protomylonitic, with coarse-grained feldspar augen, near high-strain zones; massive to foliated; contains distinctive dark blue to violet quartz in matrix between phenocrysts or porphyroclasts; modal analyses average 32% K-feldspar (microcline), 28% perthite, 18% quartz, 7% plagioclase, 2% myrmekite, and 1% ilmenite, magnetite, and other opaque minerals as primary constituents, traces of zircon and apatite as accessory minerals, and 5% biotite, 4% muscovite, 2% epidote, 1% chlorite, and a trace of titanite as metamorphic and alteration minerals.

GRANULITIC ORTHOGNEISS

Ylgg — **layered granulitic orthogneiss** – leucocratic to mesocratic, layered granulitic orthogneiss is light bluish-gray to greenish-gray; medium- to coarse-grained; granoblastic to coarsely porphyroclastic, but locally hypidiomorphic-granular; massive to foliated; commonly compositionally layered into coarse-grained quartzofeldspathic and finer-grained biotite-, amphibole- and pyroxene-rich domains, layering ranges from several centimeters to several decimeters; modal analyses average 31% quartz, 19% K-feldspar (microcline), 19% perthite, 9% plagioclase, and traces of myrmekite and ilmenite, magnetite, and other opaque minerals as primary constituents, traces of zircon, apatite and rutile as accessory minerals, and 8% biotite, 8% muscovite, 4% epidote, 1% chlorite, and 1% titanite as metamorphic and alteration minerals. Meta-igneous textures and blue quartz in granulite orthogneiss suggest an igneous protolith; compositional and lithologic similarities (particularly medium- to dark-blue to violet interstitial quartz), and field relationships indicate an association with Yag$_{II}$ augen gneiss; occurs as map-scale xenoliths within biotite granodioritic porphyroclastic gneiss (gdg), and distinguished from those rocks by abundance of dark blue to violet quartz and common compositional layering. Although absolute ages of these rocks have not been determined, they are assumed to be Middle Proterozoic, and interpreted to be pre- or syn-metamorphic, Grenville-age plutons or hypabyssal subvolcanic rocks.

CORRELATION OF MAP UNITS



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MAP SYMBOLS

For all line symbols: lines are solid where the location is exact (located in field to within 50 feet, or 15 meters), long-dashed where the location is approximate (located to within 200 feet, or 60 meters); short-dashed where the location is inferred. For geologic observation symbols, observation sites are centered on the strike bar, or are at the intersection point of multiple symbols.

Line Symbols

- Stratigraphic contacts
- Fault contacts
  Queries used to indicate uncertainty about the existence of the fault beyond mapped locations
- Late Proterozoic normal fault - "U" on upthrown block; ornaments show dip direction
- Late Proterozoic high-strain zone, with "normal" sense of movement - "U" on upthrown block; ornaments show dip direction
- Taconic-Acadian reverse fault - ornaments show dip direction
- Acadian-Alleghanian reverse fault - ornaments show dip direction; arrows show possible strike-slip displacement
- Alleghanian high-strain zone - ornaments show dip direction
- Mesozoic tear fault - "U" on upthrown block; arrows show strike-slip displacement

Fold axes

- Trend and plunge direction of axis of Taconic-Acadian antiform
- Trend and plunge direction of axis of Acadian-Alleghanian antiform
- Trend and plunge direction of axis of Acadian-Alleghanian synform

Line Symbols in Cross Section

- Stratigraphic contact
- Form line of foliation in Late Proterozoic to Cambrian metasediments and meta-igneous rocks, and Middle Proterozoic basement rocks (eroded structure shown by form lines extending above topographic profile)
- Form line of bedding in Late Proterozoic to Cambrian metasediments (eroded structure shown by form lines extending above topographic profile)
- Late Proterozoic high-strain zone - arrows show relative displacement
- Taconic-Acadian reverse fault - arrows show relative displacement
- Acadian-Alleghanian reverse fault - arrows show relative displacement; for possible strike-slip motion, "T" indicates "toward, "A" indicates "away"
- Alleghanian high-strain zone - arrows show relative displacement
- Mesozoic tear fault - arrows show relative vertical displacement; "T" indicates "toward, "A" indicates "away"

Geologic Observations

- 54 — Strike and dip of inclined beds in Late Proterozoic to Cambrian metasedimentary rocks
- 75 — Strike and dip of overturned beds in Late Proterozoic to Cambrian metasedimentary rocks
- 73 — Strike and dip of inclined Taconic-Acadian foliations in Late Proterozoic to Cambrian metasedimentary and metavolcanic rocks
- 68 — Strike and dip of inclined bedding, parallel to Taconic-Acadian foliations, in Late Proterozoic to Cambrian metasedimentary rocks
- 37 — Strike and dip of inclined Acadian-Alleghanian crenulation axial-surfaces in Late Proterozoic to Cambrian metasedimentary rocks
- 65 — Strike and dip of inclined Late Proterozoic to Taconic-Acadian mylonitic foliations in Middle Proterozoic basement rocks, and Taconic-Acadian mylonitic foliations in Late Proterozoic to Cambrian metasedimentary and metavolcanic rocks
- 61 — Strike and dip of inclined compositional layering (earliest foliations) in Middle Proterozoic basement rocks
- 56 — Strike and dip of inclined joints and fractures in all rocks
- 64 — Trend and plunge of mesoscale fold hinges in all rocks
- 32 — Trend and plunge of Acadian-Alleghanian mesoscale axes of crenulation cleavage in Late Proterozoic to Cambrian metasedimentary rocks
- 51 — Trend and plunge of intersection lineations in Late Proterozoic to Cambrian metasedimentary and metavolcanic rocks
- 19 — Trend and plunge of mineral stretching lineations in all rocks

Geologic References

- R-9906 — Rock repository sample

Mineral Resources

Commodity letter symbol precedes identification number (identification numbers are preceded by "133D-" in Mineral Resources of Virginia database). Commodity letter symbols: bs - building and dimension stone; cl - clay; cs - crushed stone; Cu - copper; fill - saprolite or earth material; gem - gemstone; Mn - manganese; sd - sand

- Occurrence
- Prospect
- Abandoned mine or quarry
- Borrow pit
- Abandoned borrow pit