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

GEOLOGIC MAP OF THE WESTERN PORTION OF THE RICHMOND 30 X 60 MINUTE QUADRANGLE, VIRGINIA

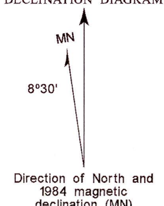
Geology by John D. Marr, Jr.

2002

Projection: Modified Plate Carree
lon 0 = -77.50000000
lat 0 = 37.50000000
k1 = 0.0174533
k2 = 0.0138466

Base map is a modified U. S. Geological Survey DRG, 1984 Richmond Quadrangle, Virginia, 30 x 60 minute series

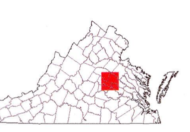
DECLINATION DIAGRAM



Direction of North and 1984 magnetic declination (MN) at center of map. Diagram is approximate

SCALE 1 : 100,000

CONTOUR INTERVAL 10 METERS



Map prepared in cooperation with the U. S. Geological Survey - STATEMAP Assistance Award Number 98HQAG2011

Digital conversion in cooperation with the Department of Geology, College of William and Mary, Williamsburg, Virginia

EXPLANATION

QUATERNARY (Holocene epoch)

al — **Alluvium**

The alluvium is 0 to 40 feet (0 to 13 m) thick and is composed of unconsolidated floodplain deposits consisting of rounded pebbles and cobbles in a crudely stratified sand, silt, and clay matrix.

QUATERNARY (Pleistocene epoch)

td — **Terrace deposits**

Terrace deposits range from 0 to 9 feet (0 to 3 m) in thickness. They are remnant fluvial deposits consisting of rounded to subrounded cobbles and pebbles in a crudely stratified matrix of sand and silt with subrounded quartz cobbles at the base.

TERTIARY (Miocene to Eocene epochs)

cu — **Coastal Plain sediments and terraces, undivided**

JURASSIC

d — **Diabase dikes**

The diabase dikes are dark-gray to black, fine- to medium-grained with sub-ophitic texture. The rock is composed of calcic plagioclase (labradorite) + clinopyroxene (augite) + magnetite. Diabase dike ages span the Jurassic-Triassic time boundary, (Fullager, 1971).

TRIASSIC

Taylorsville Basin (Weems and Olsen, 1997)

Newark Supergroup, Chatham Group, Doswell Formation

The late Triassic-age sedimentary rocks within the Taylorsville Basin have been assigned to the Doswell Formation of the Newark Supergroup (Weems, 1980). The Doswell Formation is comprised of the basal Stagg Creek Member, the overlying Falling Creek Member, and the uppermost Newfound Member. The Newfound Member consists of an upper sandstone/siltstone facies and a lower sandstone/conglomerate facies. The entire sequence is more conglomeratic toward the northwest border fault and grades to fine-grained, lenticular, fining-upward sequences eastward toward the center of the basin.

Ŧdns: **Newfound Member, siltstone facies:** 2000 feet (600 m) thick sequence of red-weathering siltstones and massive light-brown sandstones that are extensively bioturbated so that most of their primary depositional structures have been obliterated. The unit is anomalously soft and crumbly in outcrop. Angular cobble and boulder conglomerate occurs locally at the top of this facies.

Ŧdnc: **Newfound Member, conglomerate facies:** 1000 feet (300 m) thick, massive, cross-bedded, orange-brown to light-brown siltstone, light-brown to orange-brown shale, as well as green-gray or black siltstone and shale.

Ŧdf: **Falling Creek Member:** 1200 feet (360 m) thick, sequence of paludal to lacustrine, interbedded, flaggy sandstone, siltstone, shale; minor coal and conglomerate. Sandstone, light-brown to orange-brown; siltstone, light-brown to orange-brown, and shale, green, gray, or black. Some calcareous sandstone and shale. Fossils of clams, brachiopods, fish, and reptiles are common locally. The Falling Creek Member contains at least two horizons of coal and may be a potential hydrocarbon source.

Ŧds: **Stagg Creek Member:** Consists of about 600 feet (180 m) of massive, light-brown to orange-brown conglomerate and sandstone, minor blue to gray siltstone.

Richmond Basin

Newark Supergroup, Chatham Group
(Weems and Olsen, 1997)

The internal stratigraphy of the Richmond Basin was determined by Shaler and Woodworth (1899). This stratigraphy does not imply strict stratigraphic order as many of these units are in interfingering facies relationships and are time-correlative.

Ŧssh: **Vinita Beds:** 2000 to 6000 feet (600 to 1800 m) thick. Fine- to coarse-grained, gray, locally cross-bedded sandstone; gray siltstone; dark-gray to black shale. Minor conglomerates are locally present at the base of channels cut into underlying beds.

Ŧsh: **Shale:** Dark-gray, highly carbonaceous,micaceous, fissile shale with abundant plant fragments. Thin red sandstone interlayers (Goodwin, 1970).

Ŧcm: **Productive coal measures:** Described by Heinrich (1878), thickness unknown, 38% poorly sorted gray sandstone, 36% coal, and 26% shale and siltstone. The sandstone is gray and locally arkosic, poorly sorted, and contains rounded quartz grains that are silica- or calcite-cemented. The sandstone occurs as massive bodies or is interbedded with shale, siltstone, or coal. Shale comprises a small part of the section.

Ŧcg: **Conglomerate:** Coarse boulder breccia consisting of angular blocks from cobble- to boulder-sized brecciated rocks in a matrix of maroon sandstone. Believed to represent talus deposits deposited locally along the northwestern margin of the basin. Referred to as the **Boscobel boulder beds** by Shaler and Woodworth (1899).

MISSISSIPPIAN

Mfi — **Falmouth Intrusive Suite**

The Falmouth Intrusive Suite was named by Pavlides (1980) for exposures at the Fall Line along the north side of the Rappahannock River near Falmouth, Virginia. The Suite consists of dikes, sills and small irregular shaped plutons. It is predominantly granodioritic in composition. It includes strongly foliated to weakly foliated granitoid and coarsely-crystalline pegmatitic rocks. Mineralogy: quartz + plagioclase + microcline + biotite + muscovite + hornblende with lesser amounts of myrmekite + garnet + epidote + apatite + sphene. The granitoid rocks are marked by the exceptional developement of myrmekite. Pavlides and others (1982) have placed the crystallization age of the Falmouth Intrusive Suite at 300 to 325 Ma based on U-Pb dating of zircon by both Rb-Sr and Sr-Sr analyses.

Mpg — **Petersburg Granite**

Fine- to medium-grained, light-blue to light-gray, massive rock that ranges in composition from granite to quartz monzonite. The granite exhibits considerable textural variation that ranges from fine-grained massive to pegmatitic. Xenoliths of biotite gneiss are common. Mafic, felsic, and granitic dikes are commonly observed within the granite. Composed of quartz + microcline + oligoclase + orthoclase + biotite + muscovite, with accessory sphene, magnetite, apatite, zircon, and fluorite. Wright, Sinha, and Glover (1975) report an age of 330 ± 8 Ma based on a discordant U-Pb zircon date.

SILURIAN

SOeg — **Ellisville Granodiorite**

Light-gray, massive to faintly-banded, mesocratic, medium- to coarse-grained, equigranular to porphyroblastic plutonic rock. It is composed of plagioclase feldspar phenocrysts (andesine, Michel-Levy) up to 35 mm in dimension, + biotite + quartz + muscovite ± epidote ± apatite ± zircon ± ilmenite. Pavlides and others (1982) report the Ellisville Granodiorite as 440 ± 8 Ma based on Rb-Sr whole rock analyses.

ORDOVICIAN

Oq — **Quantico Formation**

Estimated (Pavlides, 1980) 300 feet (100 m) thick. Consists of gray to black, porphyroblastic staurolite-garnet-muscovite phyllite and schist. Locally may contain felsic metatuff, metagraywacke, and micaceous metaquartzite. Mineralogy: muscovite (acicular laths and felted mats) + brown biotite + chlorite + garnet (poikiloblastic) + kyanite ± plagioclase ± apatite. Unconformably overlies the Chopawamsic Formation and the Ta River Metamorphic Suite. Late Ordovician age based on fossils collected by Watson and Powell (1911) and more recently by Pavlides and others (1980).

OZll — **Mine Run Complex** (Pavlides, 1989; 1990)

Thick sequence, hundreds of feet, of light-brownish-gray, moderately deformed, fine- to medium-grained, biotite metagraywacke, mica schist, and phyllite as matrix that encloses exotic blocks of mafic and felsic metavolcanic rocks similar in composition to those found in the Chopawamsic Formation, as well as blastomylonitic tonalite and granodiorite.

CAMBRIAN

Chopawamsic Formation (Southwick and others, 1971)

Ꞓcv: **Chopawamsic Formation, undivided:** Several thousand feet thick. Consists of laterally discontinuous lenses and tongues of metamorphosed felsic, intermediate, and mafic volcanic and volcaniclastic rocks, with interlayered quartzite, quartzose graywacke, schist, and phyllite. Volcanic flows locally highly vesicular. Fragmental breccia and tuff are commonly intruded by granodioritic subconcordant plutons.

Ꞓcmv: **Mafic volcanic rocks:** Thin lenses and layers of dark-greenish-gray, fine- to medium-grained, lineated, dominantly greenstone metabasalts with blue-green amphibole + acicular actinolite + chlorite + albitic plagioclase + epidote + quartz.

Ta River Metamorphic Suite

Ꞓtb: **Ta River Metamorphic Suite, undivided:** Thousands of feet thick sequence consisting dominantly of greenish-gray to black, medium- to coarse-grained, poorly to well lineated, massive to well-layered amphibolite and amphibole-bearing gneiss and schist. Occupies a broad outcrop belt between the overlying Quantico Formation on the west and terminates against the Spotsylvania Fault System on the east. Includes interlayered biotite gneiss, ferruginous quartzite, and minor felsic metavolcanic rocks. Intruded by gabbro and granite. Quartz-epidote lenses and veins are common in amphibole-bearing rocks. The Ta River rocks have been intruded by plutonic rocks which range in composition from granite to tonalite.

Ꞓta: **Hornblende gneiss and schist:** Dominantly dark-greenish-black to black, medium- to coarse-grained, moderately to well lineated, moderately foliated, massive to well-banded, commonly pygmatic, amphibole gneisses interlayered with biotite gneiss in layers one to tens of feet thick. Quartz-epidote stringers are common. Mineralogy: hornblende + quartz + oligoclase + microcline + garnet ± chlorite.

Ꞓtfq: **Ferruginous quartzite:** Dark-reddish-gray, fine- to medium-grained, thinly banded, metamorphosed ironstone as thin discontinuous lenses within the amphibole gneiss. Mineralogy: magnetite + specular hematite + quartz + spessartine garnet. Associated with weathered massive sulfide zones (gossan).

Ꞓtbg: **Quartzo-feldspathic biotite gneiss:** Heterogeneous layered sequence consists of salt-and-pepper and segregation-layered biotite granite gneiss interlayered with dark-gray, medium-grained biotite schist. Includes lesser amounts of dark-gray to black, fine- to coarse-grained, thin- to thickly-laminated hornblende gneiss and schist, and minor quartz-muscovite schist. Mineralogy: quartz + microcline + plagioclase + biotite + muscovite + epidote + garnet.

PRECAMBRIAN

Yan — **Montpelier Metanorthosite**

Metamorphosed anorthosite pluton, intrudes Sabot Amphibolite and Maidens Gneiss. Two phases: coarse-grained, gray, nonfoliated, and granulated, medium-grained, foliated (Bice and Clement, 1982; and Clement and Bice, 1982). Mineralogy: coarse plagioclase megacrysts (25 to 35 cm) constitute 85 to 90% of the total + potassium feldspar + quartz + clinopyroxene + orthopyroxene + apatite + rutile + ilmenite + sphene + biotite + muscovite + garnet + numerous xenoblastic inclusions, uralitized pyroxenite, metagabbro (Sabot), and biotite gneiss (Maidens). The Montpelier Metanorthosite contains xenoliths identified as altered Maidens lithologies (Clement and Bice, 1982). Precambrian age 1045 ± 10 Ma, U-Pb, zircon (Aleinikoff and others, 1996) interpreted as time of anorthosite crystallization.

Ysf — **State Farm Gneiss**

Granodiorite pluton, light-gray, medium-grained, locally magmatitic, exhibits considerable textural variation, quartzo-feldspathic and pegmatitic segregations are common. Mineralogy: quartz + amphibole + pyroxene + clinozoisite + garnet + sphene (titanite) + zircon + magnetite. High titanium content is indicated by ubiquitous clusters of sphene (titanite) crystals. Ranges from granodiorite to tonalite, age; 1030 ± 94 Ma (Rb-Sr whole-rock analyses by Glover and others, 1978).

Po River Metamorphic Suite

Ya: **Sabot Amphibolite:** Approximately 2000 feet (610 m) thick, interval of amphibolite with interlayered biotite gneiss and schists. Unconformably overlies the State Farm Gneiss, upper contact with the Maidens Gneiss is gradational, and is defined by the disappearance of the interlayered amphibolite (Marr, 1985). The amphibolite is an equigranular, faintly banded, weakly foliated gneiss. Layers of quartz and plagioclase in a black hornblende matrix are characteristic. Fractures filled with epidote and/or chlorite are common. The biotite gneiss, which correlates with the Maidens gneiss, is dominantly a biotite-plagioclase-garnet gneiss, but also includes augen gneiss and migmatite gneiss. Other lithologies include garnet-kyanite-plagioclase-quartz-potassium feldspar leucogneiss and local calcsilicate lenses and boudins. The State Farm Gneiss which underlies the Sabot Amphibolite has been dated at 1031 ± 94 Ma (Glover and others, 1978). The State Farm Gneiss, Sabot Amphibolite, and Maidens Gneiss all underwent granulite-facies metamorphism prior to Late Paleozoic (?) retrograde amphibolite-facies metamorphism (Farrar, 1984). The Sabot Amphibolite has been intruded by the Montpelier Anorthosite, which is similar to anorthosites found in the Virginia Blue Ridge Complex. Considered to be Grenville in age.

Ym: **Maidens Gneiss:** Several thousand feet thick, heterogeneous layered sequence, dominantly biotite gneiss, augen gneiss, and migmatite gneiss. Thin discontinuous mica schist layers, hornblende-biotite-rich lenses and quartzo-feldspathic lenses are common locally. Other lithologies include feldspar gneiss with calc-silicate lenses. Mineralogy: **gneiss:** garnet + biotite + quartz + plagioclase; **leucogneiss:** garnet + plagioclase + potassium feldspar; **amphibole schists:** clinopyroxene + hornblende + plagioclase + amphibole, biotite + garnet + sillimanite + quartz + potassium feldspar; **granulite gneisses** (as lenses within amphibolite facies rocks): 1) orthopyroxene + clinopyroxene, 2) orthopyroxene + garnet + clinopyroxene, as well as 3) garnet + pyroxene in rocks of intermediate to mafic composition and 4) potassium feldspar + sillimanite + garnet + biotite + quartz + plagioclase in aluminous assemblages. Available evidence indicates that the Maidens is Grenville in age. The Maidens Gneiss has been intruded by the Middle Proterozoic age Montpelier Metanorthosite which is lithologically similar to the *Grenville*-age Roseland Anorthosite in the Virginia Blue Ridge (Herz and Force, 1984).

Granite and gneiss complex

PzYgrn: Several hundred feet thick granite and gneiss complex. Consists dominantly of light-gray to leucocratic medium- to coarse-grained, migmatitic paragneiss. Unit composed of interlayered biotite-rich and quartzo-feldspathic zones. Includes lesser amounts of biotite schist, muscovite schist, and thin discontinuous amphibole-rich lenses and layers. Unit intruded by numerous granitic plutons to the south of map area. Mineralogy: biotite + muscovite + plagioclase + potassium feldspar + quartz + garnet ± hornblende.

PzYa: Thin, discontinuous lenses and layers of hornblende schist and amphibolite. Composed of hornblende + quartz + oligoclase ± epidote ± chlorite.

PzYgr — **Unnamed granitic intrusives**

The eastern part of the Piedmont contains numerous unnamed granite plutons. Some of these may correlate with rocks along strike to the northeast, which were mapped as the Falmouth Intrusive Suite by Pavlides and others (1982). These include both fine- and coarse-grained granitoid rocks that occur as small plutons, tabular concordant sills, and lenses. Their compositions range from adamellite through granodiorite and tonalite. If the correlation with the rocks of the Falmouth Intrusive Suite is correct, the crystallization age of these rocks falls in the 300 to 325 Ma range (Pavlides and others, 1982).

ROCKS OF UNCERTAIN AGE

um — **Ultramafic rocks**

Scattered small plutons. Consists of light-greenish-gray, moderately foliated, discontinuous lens-shaped talc schist bodies. Composed of talc + tremolite or actinolite + chlorite ± magnetite.

ga — **Metagabbro**

Poorly exposed, semiconcordant elongate bodies. Common in the Ꞓtb unit. Dark-grayish-green, medium- to coarse-grained, massive to foliated, metamorphosed mafic plutonic rocks. Mineralogy: clinopyroxene + orthopyroxene + hornblende + plagioclase + magnetite ± garnet.

go — **Gossan**

Dark-brownish crumbly clay wad, composed of magnetite + hematite, represents weathered sulfide mineralization.

fcm — **Fine Creek Mills granite** (Poland, 1976)

Light-gray, medium- to coarse-grained, homogeneous, foliated, flow-banded granite. Possesses a distinct biotite foliation, which is locally kinked by plastic flow banding. Mineralogy: microcline + plagioclase + quartz + biotite ± apatite ± garnet ± fluorite ± zircon.

frg — **Flat Rock granite** (Poland, 1976)

Light-gray, medium- to coarse-grained, homogeneous, foliated granite. Mineralogy: microcline + plagioclase + quartz + biotite ± garnet ± apatite ± fluorite ± zircon. Possibly correlates with the Fine Creek Mills granite.

p — **Pegmatite**

Discordant granitic dikes, pods, and irregular masses. Leucocratic, coarse- to very-coarse-grained. Mineralogy: microcline + albite + quartz + muscovite + biotite + garnet + tourmaline ± sillimanite ± graphite ± rutile ± ilmenite and zircon. Pegmatites commonly occur as lenticular bodies intruding the Maidens Gneiss as small sweat pegmatites throughout the Maidens Gneiss, and as small plutons within the Ta River Metamorphic Suite.

my — **Mylonite**

Includes protomylonite, mylonite, and ultramylonite, as defined by Sibson (1977). The lithology is highly variable and is dependent upon the nature of the parent rock, degree of shearing, and the history of the deformation. The mylonite zones anastomose around lenses of undeformed rock. Since most contacts are gradational, the contact with undeformed rock is approximate.

NAMED FAULTS

Spotsylvania Fault System

Originally delineated as an aeromagnetic and aeroradiometric anomaly and interpreted as a major fault by Neushel (1970). Later recognized by Pavlides (1980) as a series of discontinuous *en echelon* faults. Synthetic Aperture Radar (SAR) imagery revealed the zone to be an anastomosing 1/3- to 3-km-wide network of subparallel linear images that coincided with the trace of the aeromagnetic and aeroradiometric imagery. Discrete shear zones, some less than 10 cm wide, were observed during this study along the trace of the SAR imagery. Several of the kinematic indicators indicate dextral shear. However, the dominant movement is interpreted as low angle thrusting to the west. To the southwest of the study area the fault trace is marked by the presence of mylonites.

Hylas Fault Zone

Originally recognized by Bobyarchick (1976) as an anastomosing network of mylonitic rock approximately 1 mile (1.6 km) wide. The zone is composed of mylonite and ultramylonite derived from hornblende gneiss, granite gneiss, biotite gneiss, and granite. Late Paleozoic ductile shearing produced the pervasive mylonite foliation (Bobyarchick and Glover, 1979). Superimposed on the mylonite foliation is a brittle overprint in the form of intense fracturing. Initial cataclasis within the zone postdates emplacement of the Petersburg Granite (330 +- 8 My, U-Pb zircon, Wright and others, 1975) and predates deposition of Triassic-age sedimentation within the Richmond and Taylorsville Basins (Bobyarchick and Glover, 1979).

KEY

CONTACTS

Solid where exposed or approximate, dotted where covered or inferred

FAULTS

Solid where exposed or approximate, dotted where covered or inferred; **thrust faults:** T on the upper plate, tick marks indicate dip direction; **normal faults:** U on the upthrown side, D on the downthrown side; **strike-slip faults:** arrows indicate direction of movement

FOLDS

Major antiform based on orientation of strike and dip; arrow denotes plunge direction

Major synform based on orientation of strike and dip; arrow denotes plunge direction

ATTITUDE OF ROCKS

Strike and dip of inclined bedding

Strike and dip of mineral foliation

Strike of vertical mineral foliation

Horizontal mineral foliation

Strike and dip of shear foliation

Strike of quartz vein

Bearing and plunge of mineral lineation

REFERENCES USED IN COMPILATION

Aleinikoff, J. N., Horton, J. W., Jr., and Walter, M., 1996, Middle Proterozoic age for the Montpelier Anorthosite, Goochland terrane, eastern Piedmont, Virginia: Geological Society of America Bulletin, v. 108, no. 11, p. 1481-1491.
Bice, K. L., and Clement, S. C., 1982, A study of the feldspars of the Montpelier Andesine Anorthosite, Hanover County, Virginia [abs.]: Geological Society of America, Abstracts with programs, v. 14, no. 1-2, p. 5.
Bobyarchick, A. R., 1976, Tectogenesis of the Hylas Zone and Eastern Piedmont near Richmond, Virginia [M. S. Thesis]: Virginia Polytechnic Institute and State University, Blacksburg, 168 p.
Bobyarchick, A. R., and Glover, L., III, 1979, Deformation and metamorphism in the Hylas zone and adjacent parts of the eastern Piedmont in Virginia: Geological Society of America Bulletin: v. 90, p. 739-752.
Clement, S. C., and Bice, K. L., 1982, Andesine Anorthosite in the eastern Piedmont of Virginia [abs.]: Geological Society of America Abstracts with Programs, v. 14, p. 419.
Farrar, S. S., 1984, The Goochland granulite terrane: Remobilized Grenville basement in the eastern Virginia Piedmont: *in* Bartholomew, M. J., and others, editors, The Grenville event in the Appalachians and related topics: Geological Society of America Special Paper 194, p. 215-227.
Fullagar, P. D., 1971, Age and origin of plutonic intrusions in the Piedmont of the southeastern Appalachians: Geological Society of America Bulletin, v. 82, p. 2854-2862.
Glover, L., III, Mose, D. G., Poland, F. B., Bobyarchick, A. R., and Bourland, W. C., 1978, Grenville basement in the eastern Piedmont of Virginia; Implications for orogenic models [abs.]: Geological Society of America Abstracts with programs, v. 10, no. 4, p. 69.
Goodwin, B. K., 1970, Geology of the Hylas and Midlothian quadrangles, Virginia: Virginia Division of Mineral Resources Report of Investigation 23, 51 p.
Heinrich, O. J., 1878, The Mesozoic Formation in Virginia: Transactions of the American Institute of Mining Engineers, v. 6, p. 227-274.
Herz, N., and Force, E. R., 1984, Rock suites in Grenvillian terrane of the Roseland District, Virginia; Part 1, Lithologic relations, *in* Bartholomew, M. J., and others, editors, The Grenville event in the Appalachians and related topics: Geological Society of America Special Paper 194, p. 187-200.
Marr, J. D., Jr., 1985, Geology of the crystalline portion of the Richmond 1° × 2° quadrangle: A progress report, *in* Geology of portions of the Richmond 1° × 2° quadrangle: Seventeenth Annual Virginia Geological Field Conference Guidebook, 22 p.
Neuschel, S. K., 1970, Correlation of aeromagnetic and aeroradiometric activity with lithology in the Spotsylvania area, Virginia: Geological Society of America Bulletin v. 81, no. 12, p. 3575-3582.
Pavlides, L., 1980, Revised nomenclature and stratigraphic relationships of the Fredericksburg Complex and Quantico Formation of the Virginia Piedmont: U. S. Geological Survey Professional Paper 1146, 29 p.
Pavlides, L, 1981, The central Virginia volcanic-plutonic belt: An island arc of Cambrian (?) age: U. S. Geological Survey Professional Paper 1231-A, 34 p.
Pavlides, L., 1989, Early composite melange terrane, central Appalachian Piedmont, Virginia and Maryland; Its origin and tectonic history: Geological Society of America Special Paper 228, p. 135-193.
Pavlides, L, 1990, Geology of part of the northern Virginia Piedmont: U. S. Geological Survey Open File Report 90-548.
Pavlides, L., Pojeta, J., Gordon, M., Parsley, R. L., and Bobyarchick, A. R., 1980, New evidence for the age of the Quantico Formation in Virginia: Geology, v. 8, p. 286-290.
Pavlides, L., Stern, T. W., Arth, J. G., Muth, K. G., and Newell, M. F., 1982,, Middle and Upper Paleozoic granitic rocks in the piedmont near Fredericksburg, Virginia: Geochronology, U. S. Geological Survey Professional Paper 1231-B, p. B1-B9.
Pavlides, L., Arth, J. G., Sutter, J. F., Stern, T. W., and Cortesini, H., Jr., 1994, Early Paleozoic alkalic and calc-alkalic plutonism and associated contact metamorphism, central Virginia Piedmont; U. S. Geological Survey Professional Paper 1529, 147 p.
Poland, F. B., 1976, Geology of the rocks along the James River between Sabot and Cedar Point, Virginia [M. S. Thesis]: Virginia Polytechnic Institute and State University, Blacksburg, 98 p.
Shaler N. S., and Woodworth, J. B., 1899, Geology of the Richmond Basin, Virginia: U. S. Geological Survey Annual Report 19, 1897/1898, part 2, p. 385-515.
Sibson, R. H., 1977, Fault rocks and fault mechanisms: Journal Geological Society of London, v. 133, p. 191-213.
Southwick, D. L., Reed, J. C., and Mixon, R. B., 1971, The Chopawamsic Formation - A new stratigraphic unit in the Piedmont of northeast Virginia: U. S. Geological Survey Bulletin 1324-D, p. D1-D11.
Watson, T. L., and Powell S. L., 1911, Fossil evidence of the age of the Virginia Piedmont slates: American Journal of Science, Series 4, v. 31, p. 33-44.
Weems, R. E., and Olsen, P. E., 1997, Synthesis and revision of groups within the Newark Supergroup, eastern North America: Geological Society of America Bulletin, v. 109, p. 195-209.
Weems, R. E., 1980, Geology of the Taylorsville basin, Hanover County, Virginia, *in* Contributions to Virginia Geology - IV, Virginia Division of Mineral Resources Publication 27, p. 23-38.
Wright, J. E., Sinha, A. K., and Glover, L., III, 1975, Age of zircons from the Petersburg Granite, Virginia; with comments on belts of plutons in the Piedmont: American Journal of Science, v. 275, p. 848-856.

Marr, J. D., Jr., 2002, Geologic map of the western portion of the Richmond 30 x 60 minute quadrangle,Virginia: Virginia Division of Mineral Resources Publication 165.

This map was compiled digitally. Digital conversion by Daniel E. Sheres and Kevin B. Jones. Digital editing by Kevin B. Jones, Daniel E. Sheres, Heidi M. Wadman, Natalie E. Uschner, and Elizabeth Campbell. The geospatially referenced files are available from the Division of Mineral Resources, P. O. Box 3667, Charlottesville, VA 22903.