Geologic Map of the South Boston 30′ × 60′ Quadrangle, Virginia and North Carolina

By J. Wright Horton, Jr., John D. Peper, William C. Burton, Robert E. Weems, and Paul E. Sacks

Pamphlet to accompany

Scientific Investigations Map 3483

Supersedes USGS Open-File Report 93–244

U.S. Department of the Interior
U.S. Geological Survey

U.S. Geological Survey, Reston, Virginia: 2022
Supersedes USGS Open-File Report 93–244

Suggested citation:
Horton, J.W., Jr., Peper, J.D., Burton, W.C., Weems, R.E., and Sacks, P.E., 2022, Geologic map of the South Boston 30′ × 60′ quadrangle, Virginia and North Carolina: U.S. Geological Survey Scientific Investigations Map 3483, 1 sheet, scale 1:100,000, 46-p. pamphlet, https://doi.org/10.3133/sim3483. [Supersedes USGS Open-File Report 93–244.]

Associated data for this publication:
Horton, J.W., Jr., Peper, J.D., Burton, W.C., Weems, R.E., Sacks, P.E., and Crider, E.A., Jr., 2022, Database for the geologic map of the South Boston 30′ × 60′ quadrangle, Virginia and North Carolina: U.S. Geological Survey data release, https://doi.org/10.5066/P98AQDR7.

ISSN 2329-132X (online)

Cover. The layered gneiss of South Boston (Zclg; see Description of Map Units) is an informally named unit within the Neoproterozoic Country Line complex on the western flank of the Carolina terrane. This exposure at the South Boston quarry, Halifax, Virginia (Salem Stone Corporation), shows interlayered hornblende gneiss (right side) and less abundant felsic gneiss (left side) with a hammer (30 centimeters in length) for scale. Photograph by J. Wright Horton, Jr., U.S. Geological Survey.

Acknowledgments

This geologic map and report benefitted from reviews by geologists Mark Carter and Stephen Schindler (U.S. Geological Survey) and comments by Matt Heller (Virginia Division of Geology and Mineral Resources), Philip Bradley (North Carolina Geological Survey), and David Blake (University of North Carolina at Wilmington). Blake also provided helpful insights and information including geologic maps of nearby areas to the south in North Carolina. This geologic map also benefitted from discussions and field trips over the years with John Aleinikoff, Rick Berquist, David Blake, Philip Bradley, Robert Butler, Mark Carter, Robert Druhan, Stewart Farrar, James Hibbard, Michael Kunk, John Marr, Arthur Nelson, Brent Owens, Edward Stoddard, and others. We thank Allen Crider for digital cartography and geodatabase work, Linda Masonic for digital cartographic production, and Zachary Younger for editorial review that significantly improved the map and report.

Contents

Figure

Conversion Factors

International System of Units to U.S. customary units

Multiply	By	To obtain
	Length	
millimeter (mm)	0.03937	inch (in.)
centimeter (cm)	0.3937	inch (in.)
meter (m)	3.281	foot (ft)
meter (m)	1.094	yard (yd)
kilometer (km)	0.6214	mile (mi)
	Area	
square kilometer (km^2)	247.1	acre
square kilometer (km^2)	0.3861	square mile (mi^2)

Abbreviations

An	anorthite
Ar	argon
CAMP	central Atlantic magmatic province
IUGS	International Union of Geological Sciences
LA-ICP-MS	laser ablation inductively coupled plasma mass spectrometry
Ma	mega-annum (million years ago)
Nd	neodymium
Pb	lead
Rb	rubidium
Sr	strontium
TIMS	thermal ionization mass spectrometry
U	uranium

Geologic Map of the South Boston 30′ × 60′ Quadrangle, Virginia and North Carolina

By J. Wright Horton, Jr., John D. Peper,[1] William C. Burton, Robert E. Weems, and Paul E. Sacks

Abstract

This 1:100,000-scale geologic map of the South Boston 30′ × 60′ quadrangle, Virginia and North Carolina, provides geologic information for the Piedmont along the I–85 and U.S. Route 58 corridors and in the Roanoke River watershed, which includes the John H. Kerr Reservoir and Lake Gaston. The Raleigh terrane (located on the eastern side of the map) contains Neoproterozoic to early Paleozoic(?) polydeformed, amphibolite-facies gneisses and schists. The Carolina slate belt of the Carolina terrane (located in the central part of the map) contains Neoproterozoic metavolcanic and metasedimentary rocks at greenschist facies. Although locally complicated, the slate-belt structure mapped across the South Boston map area is generally a broad, complex anticlinorium of the Hyco Formation (here called the Chase City anticlinorium) and is flanked to the west and east by synclinoria, which are cored by the overlying Aaron and Virgilina Formations. The western flank of the Carolina terrane (located in the western-central part of the map) contains similar rocks at higher metamorphic grade. This terrane includes epidote-amphibolite-facies to amphibolite-facies gneisses of the Neoproterozoic Country Line complex, which extends north-northeastward across the map. The Milton terrane (located on the western side of the map) contains Ordovician amphibolite-facies metavolcanic and metasedimentary gneisses of the Cunningham complex.

Crosscutting relations and fabrics in mafic to felsic plutonic rocks constrain the timing of Neoproterozoic to late Paleozoic deformations across the Piedmont. In the eastern part of the map, a 5- to 9-kilometer-wide band of tectonic elements that contains two late Paleozoic mylonite zones (Nutbush Creek and Lake Gordon) and syntectonic granite (Buggs Island pluton) separates the Raleigh and Carolina terranes. Amphibolite-facies, infrastructural metaigneous and metasedimentary rocks east of the Lake Gordon mylonite zone are generally assigned to the Raleigh terrane. In the western part of the map area, a 5- to 8-kilometer-wide band of late Paleozoic tectonic elements includes the Hyco and Clover shear zones, syntectonic granitic sheets, and amphibolite-facies gneisses along the western margin of the Carolina terrane at its boundary with the Milton terrane. This band of tectonic elements is also the locus for early Mesozoic extensional faults associated with the early Mesozoic Scottsburg, Randolph, and Roanoke Creek rift basins.

The map shows fluvial terrace deposits of sand and gravel on hills and slopes near the Roanoke and Dan Rivers. The terrace deposits that are highest in altitude are the oldest. Saprolite regolith is spatially associated with geologic source units and is not shown separately on the map.

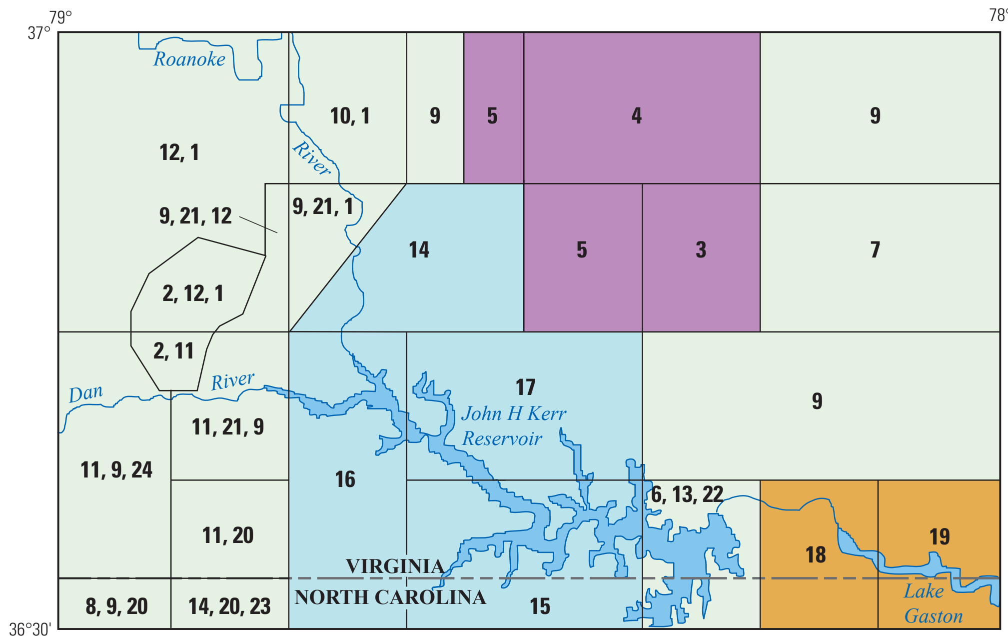
Mineral resources in the area include gneiss and granite quarried for crushed stone, tungsten-bearing vein deposits of the Hamme district, and copper and gold deposits of the Virgilina district. Surface-water resources are abundant and include rivers, tributaries, the John H. Kerr Reservoir, and Lake Gaston. Groundwater flow is concentrated in saprolite regolith, along fractures in the crystalline bedrock, and along fractures and bedding-plane partings in the Mesozoic rift basins.

Introduction

The South Boston 30′ × 60′ quadrangle (1:100,000 scale) is located in south-central Virginia and northernmost North Carolina. It covers an area of about 4,900 square kilometers in parts of Brunswick, Charlotte, Halifax, Lunenburg, and Mecklenburg Counties, Virginia, and parts of Granville, Person, Vance, and Warren Counties, North Carolina. The quadrangle contains most of John H. Kerr Reservoir (also known as Buggs Island Lake), much of Lake Gaston, segments of the Roanoke, Dan, and Meherrin Rivers, and two Virginia State parks (Occoneechee State Park and Staunton River State Park). Cities within the map area include Chase City, Clarksville, Kenbridge, South Boston, South Hill, and Victoria (all in Virginia). Most of the field work was done from 1991 to 1998. Recent efforts to complete the geologic map were supported by the National Cooperative Geologic Mapping Program FEDMAP component. Figure 1 shows sources of geologic data and areas of mapping and compilation responsibility.

This geologic map (and its associated data release [Horton and others, 2022]) supersedes an open-file, preliminary geologic map of Horton and others (1993b). A 1:100,000-scale geologic map is also available for the Virginia portion of the

[1]Deceased



EXPLANATION

Areas of mapping and compilation responsibility

- Burton
- Horton
- Peper
- Sacks

Sources of geologic data

(*Significant field investigations by author(s) specified for this area)

1. Baird (1989, 1991)
2. Bradley (1996)
3. Burton (1993)
4. Burton (1995b)
5. Burton*
6. Druhan and others (1994)
7. Bentley (1992), Farrar and Owens (2001)
8. Hibbard (2017)
9. Horton*
10. Horton, Sacks, and Weems*
11. Kreisa (1980)
12. Nelson and Nelson (1997)
13. Parker (1963)
14. Peper*
15. Peper and others (1996)
16. Peper and Olinger (1998)
17. Peper and Wygant (1997)
18. Sacks (1996a)
19. Sacks (1996b)
20. Tobisch and Glover (1971, fig. 2)
21. Weems*
22. Blake and others (2010)
23. Bowman (2010), Bowman and others (2013, fig. 3)
24. Hibbard and Bradley (2017), Hibbard and others (2017)

Figure 1. Index map of the South Boston 30′ × 60′ quadrangle, Virginia and North Carolina, showing sources of geologic data as well as areas of mapping and compilation responsibility. Within each map segment, the order of the numbers indicates the relative weighting of each source of data (left to right).

Danville 30′ × 60′ quadrangle to the west (Henika, 2002). Geologic sections and drill-hole data are available for the Emporia 30′ × 60′ quadrangle to the east (Weems and others, 2010). To the south and southeast, 1:100,000-scale geologic-data compilations are in progress for the Henderson and Roanoke Rapids 30′ × 60′ quadrangles in North Carolina, respectively (Rice and others, 2020).

This map area is located in the Piedmont Lowlands of the Piedmont physiographic province (Hack, 1982). The map area extends from the Raleigh terrane (Neoproterozoic and younger amphibolite-facies gneisses and schists) in the eastern Piedmont, crosses the Carolina terrane (Neoproterozoic and younger greenschist-facies volcanogenic rocks of the Carolina slate belt and their amphibolite-facies equivalents), and ends in the Milton terrane (Ordovician and younger amphibolite-facies gneisses and schists) in the western Piedmont. Intrusive igneous rocks in these terranes have a wide range of mafic to felsic compositions and range in age from Neoproterozoic to Jurassic.

Mineral resources in the South Boston 30′ × 60′ quadrangle include gneisses and granites that are quarried for crushed stone, tungsten deposits of the Hamme tungsten district (Parker, 1963; Gair, 1977; Casadevall and Rye, 1980; Foose and others, 1980), and copper and gold deposits of the Virgilina district (Laney, 1917; Sweet, 1976; Kish and Stein, 1989; Lesure and others, 1992; Lesure, 1993). The relations between groundwater resources and bedrock geology in the western part of the map area are discussed by LeGrand (1960).

Geologic Setting and Previous Work

The Raleigh and Carolina terranes in this region of the Piedmont have been interpreted as parts of the Carolina zone (Hibbard and others, 2002), peri-Gondwanan realm (Hibbard and others, 2005), Carolina superterrane (Hatcher and Merschat, 2006), or Carolinia (Hibbard and others, 2007). The last two names (Carolina superterrane and Carolinia) are associated with the interpretation that these terranes were amalgamated before being accreted to Laurentia (ancestral North America). Metamorphic mineral assemblages imply that exposed parts of the peri-Gondwanan terranes formed at different crustal levels such that amphibolite-facies rocks of the Raleigh terrane represent an infrastructural domain while lower-grade, mostly greenschist-facies rocks of the Carolina terrane represent a suprastructural domain (Blake and others, 2012; Stoddard and Blake, 2020). The Carolina terrane is separated from the Milton terrane by the Hyco and Clover shear zones of the central Piedmont shear system (Horton and others, 2016), which represents part of the central Piedmont suture (Hatcher, 1987). The Milton terrane is commonly interpreted as part of the central Virginia volcanic-plutonic belt (Pavlides, 1981; Virginia Division of Mineral Resources, 1993) or magmatic tract of Hibbard and others (2016).

The Raleigh terrane in this area is composed of amphibolite-facies (sillimanite-zone) schists and gneisses that were intruded by granitic plutons during the late Paleozoic Alleghanian orogeny (Farrar, 1985a; Russell and others, 1985; Stoddard and others, 1991). Locally, retrograde greenschist-facies metamorphism overprints the higher-grade rocks (for example, Stoddard and others, 1991). The Raleigh terrane was previously interpreted to be part of the Mesoproterozoic Goochland terrane (Farrar, 1984, 1985a, b; Horton and others, 1989, 1991, 1994). However, the dated gneisses have Neoproterozoic and younger uranium-lead (U-Pb) thermal ionization mass spectrometry (TIMS) zircon ages of about 546–461 Ma (mega-annum; Goldberg, 1994; Horton and Stern, 1994) and 560±2 Ma (Owens and Buchwaldt, 2009). The Raleigh terrane is here considered to be distinct from the Goochland terrane because of the age differences and because it is separated from the Goochland terrane by regional faults (Horton and others, 2016). The Raleigh terrane as used in Stoddard and others (1991), Sacks (1996a, b, 1999), Blake and others (2010), and Horton and others (2016) includes part of the Warren terrane as distinguished by Blake and others (2012) in North Carolina.

Complex zircon populations in gneisses of the Raleigh terrane continue to pose challenges for geochronology (Owens and Buchwaldt, 2009; Peach and others, 2017; Finnerty and others, 2019). Uranium-lead dating of detrital zircon populations by laser ablation inductively coupled plasma mass spectrometry (LA-ICP-MS) south of this map area suggests that some gneisses and schists that have been mapped as a single peri-Gondwanan Raleigh terrane may represent different structural blocks that have distinct peri-Gondwanan or Laurentian affinities (Peach and others, 2017; Peach, 2018; Finnerty and others, 2019; Blake and others, 2020; Finnerty, 2020).

Bordering this map area to the south and southeast in North Carolina, recent 1:24,000-scale geologic maps of the Littleton (Stoddard and others, 2011), Macon (Finnerty, 2020; Rice, 2021), Middleburg (Stoddard and others, 2016), and Warrenton (Blake and others, 2018, 2020) 7.5′ quadrangles provide detailed coverage from the Nutbush Creek mylonite zone eastward across parts of the Raleigh terrane. Geologic maps of other nearby areas to the south and southeast are available for the Afton (Peach, 2018; Nolan, 2020; Nolan and others, 2020), Hollister (Sacks and others, 2011), Inez (Morrow, 2015; Morrow and others, 2016), and Vicksboro (Stoddard and Bechtel, 2020) 7.5′ quadrangles in North Carolina.

The Carolina terrane contains felsic to mafic metavolcanic rocks, volcanogenic metasedimentary rocks, and intrusive rocks ranging in composition from granodiorite to gabbro (Secor and others, 1983; Horton and others, 1989, 1991; Hibbard and others, 2002). The greenschist-facies part of the Carolina terrane is known as the Carolina slate belt. The Carolina slate belt in this area contains the type areas of the Hyco, Aaron, and Virgilina Formations (in ascending stratigraphic order). On this map, stratigraphic nomenclature for these formations follows that of Harris and Glover (1988). The north-northeast-trending Virgilina synclinorium, originally recognized by Laney (1917) and named by Brown (1953), is a complex structure consisting of several synforms, antiforms, and internal faults (Glover and Sinha, 1973; Kreisa, 1980).

The Carolina terrane is bounded to the east by the Nutbush Creek mylonite zone (Casadevall, 1977), which lies along the western margin of the granite of the Buggs Island pluton (ℙbi). This pluton is bounded to the east by another major ductile fault zone of the eastern Piedmont fault system named the Lake Gordon mylonite zone (Horton and others, 1993a). The Lake Gordon and Nutbush Creek mylonite zones show late Paleozoic dextral strike-slip movement (Horton and others, 1993a; Druhan and others, 1994). The western margin of the Carolina terrane in this area is characterized by a steep metamorphic gradient (Tobisch and Glover, 1969), the Hyco and Clover ductile shear zones (Baird, 1988, 1989; Hibbard and others, 1998, 2016), and early Mesozoic extensional faults (Kreisa, 1980; Ramsey, 1982; Johnson and others, 1985; Goodwin and others, 1986).

The Milton terrane (Horton and others [1989, 1991]; first described by Butler [1980] as the Milton belt) is predominantly Ordovician in age. It contains amphibolite, felsic metavolcanic rocks, biotite gneiss, granitoid gneiss, mica schist, and smaller amounts of quartzite, calc-silicate gneiss, and marble (Hibbard and others, 2016). In the Milton terrane, metavolcanic rocks are more common in western parts of the terrane that are west of the South Boston map area (Henika, 2002), whereas biotite gneiss and mica schist are more common in the eastern parts of the terrane that are within the South Boston map area (Henika, 2002; Hibbard and others, 2016). The previously distinguished Milton and Chopawamic terranes (Horton and others, 1989, 1991) are now interpreted to form a contiguous, deformed and metamorphosed crustal domain without a major structural boundary between them (Henika, 2002; Hibbard and others, 2016). The Milton terrane is geochemically distinct from and younger than the predominantly Neoproterozoic Carolina terrane (Wortman and others, 1996; Hibbard and others, 1998, 2016; Coler and others, 2000), both of which are in contrast to previous interpretations (for example, Baird and Glover, 1997). Geologic mapping of the Milton terrane in this map area benefitted from previous mapping by Kreisa (1980), Bradley (1996), Nelson and Nelson (1997), Hibbard (2017), and Hibbard and Bradley (2017).

The structural style of gentle to moderate dip angles in the Milton terrane contrasts with the upright folds and steep dips along the western flank of the Carolina terrane. Isoclinal recumbent folds are refolded by more open upright folds, although an idealized regional nappe proposed by Tobisch and Glover (1971) and Tobisch (1972) is not supported by subsequent mapping. Rocks of the Milton terrane in this area are polydeformed and most are regionally metamorphosed to amphibolite-facies gneisses and schists. Stratigraphic relations among rock units within the Milton terrane are uncertain. Deformation and metamorphic recrystallization have destroyed or obscured primary features such as graded and cross bedding. Compositional layering is typically parallel to foliation and is interpreted to be transposed by deformation.

Mesozoic rift-related features in the map area include nonmarine sedimentary basins and intrusive dikes. Three early Mesozoic basins occur along and near a metamorphic gradient on the western flank of the Carolina terrane. From south to north, these are the Scottsburg, Randolph, and Roanoke Creek basins. Early Jurassic diabase dikes dip steeply and cut across older rocks throughout the Piedmont. This map extends the known distribution of Early Jurassic rhyolite porphyry dikes described by Stoddard and others (1986) and Stoddard (1992) into the southeastern part of the map area.

Surficial units in the map area include fluvial terrace deposits along the Roanoke River and Dan River, as well as alluvium that underlies present-day floodplains. Saprolite regolith is spatially associated with geologic source units and is not shown separately.

Field guides to regional geology in and near the South Boston 30′ × 60′ quadrangle are available in Kreisa (1980), Harris and Glover (1985), Goodwin and others (1986), Stoddard and others (1987), Druhan and others (1994), Sacks (1999), Farrar and Owens (2001), Hibbard and others (2001), Bradley and others (2006), Blake and others (2011, 2012), Bailey and Owens (2012), Hibbard and Pollock (2013), Hibbard and others (2017), and Owens and Bailey (2018). Airborne magnetic and radioactivity (gamma-ray) surveys are also available in U.S. Geological Survey (1971, 1978a, b, 1994a, b), Zietz and others (1977a, b), and Horton and Daniels (1999).

Raleigh Terrane

Layered and Stratified Rocks

The Raleigh terrane in the map area consists of variably migmatitic amphibolite-facies gneisses and schists east of the Lake Gordon mylonite zone (Sacks and Horton, 1993). The gneisses and schists are intruded by massive to foliated two-mica granites of probable Pennsylvanian and Permian age, including the Wise, South Hill, and Stones Mill plutons (Horton and others, 1993b). Uranium-lead TIMS zircon dates of ~546–461 Ma (Goldberg, 1994) and ~544 Ma (Horton and Stern, 1994) indicate a Neoproterozoic age for gneisses of the Raleigh terrane in North Carolina. Gneisses west of the Wise pluton correspond to the Raleigh gneiss (informal name) of Farrar (1985a, b), whereas gneisses and schists mostly east of this pluton correspond to the Macon formation (informal name) of Farrar (1985a, b). Sacks (1996a, b, c, 1999) used other descriptive map-unit terms for these rocks. The South Boston 30′ × 60′ quadrangle does not extend as far east or southeast as the Macon fault zone (for example, Horton and others, 2016, fig. 1; Morrow and others, 2016).

The metamorphic suite of South Hill (Neoproterozoic?) is here informally named for exposures near the town of South Hill in Mecklenburg County, Va. It includes rocks informally described below as the biotite-quartz-feldspar gneiss of Union Mill (Zrbg) and its mylonitic equivalent (Zrbgm), hornblende-biotite gneiss (Zrhg), muscovite schist and biotite-muscovite schist (Zrms), augen-biotite gneiss (Zrag), the sillimanite-mica schist of Great Creek (Zrss), biotite-muscovite gneiss (Zrbmg), manganiferous schist and gneiss (Zrmn), quartzite (Zrq), and biotite-muscovite schist and gneiss (Zrsg). These rocks in south-central Virginia and northern North Carolina have been informally described as Raleigh gneiss (for example, Farrar, 1985a, b; Owens and Buchwaldt, 2009). They are not Raleigh gneiss in the more restrictive sense of Blake and others (2012).

The biotite-quartz-feldspar gneiss of Union Mill (Zrbg), as here used informally, is equivalent to the Union Mill gneiss (informal name) of Farrar and Owens (2001, stop 10) at Union Mill Bridge over the Meherrin River in the Forksville 7.5′ quadrangle (see quadrangle index on map sheet). Geochemical data for this unit are consistent with broadly dacitic (or possibly graywacke) protoliths of a volcanic-arc setting (Cheek and Owens, 2007; Muller and Owens, 2020). A metadacite from the biotite-quartz-feldspar gneiss of Union Mill yielded a Neoproterozoic U-Pb TIMS zircon age of 560±2 Ma (lower concordia intercept), interpreted as the crystallization age, while the upper concordia intercept indicates inheritance from older, Mesoproterozoic continental crust (Owens and Buchwaldt, 2009). The map unit also includes rocks previously and informally described as biotite gneiss (Sacks, 1996a, b) and mixed gneisses and meta-intrusive rocks (in unit ZPmi) of Blake and others (2010).

The main body of hornblende-biotite gneiss (Zrhg) near Bracey, Va., is contiguous with rocks mapped south of this map area by Finnerty (2020) as Parktown gneiss (informal name of Blake and others [2018, 2020]). However, the main body of Zrhg is not contiguous with units described south of the map area as Middleburg gneiss (informal name of Peach and others [2017]) or Soul City gneiss (informal name of Blake and others [2020]).

The sillimanite-mica schist of Great Creek (Zrss) on the eastern side of the map appears to correspond to the informally named Mill Branch schist (Blake and others, 2018, 2020) as mapped south of the map area (Finnerty, 2020). Zircon age populations of ~2,711–322 Ma for a garnet-rich schist and ~1,955–356 Ma for a white mica schist (Finnerty and others, 2019) suggest complex mixtures of Mesoproterozoic to Neoproterozoic detrital grains, Paleozoic metamorphic grains, grains from Paleozoic granitic veins, and possibly mixed-age zoned crystals or polycrystalline grains.

Distinct from the metamorphic suite of South Hill, a unit of biotite-quartz-plagioclase gneiss (€Zbg) occurs on the western flank of the Raleigh terrane as a tectonic slice. It is located between the dextral Lake Gordon mylonite zone to the west, a dextral splay of the Lake Gordon mylonite zone to the east, and gneissic metagranitoid (Pzgg) to the north.

South of this map area, a LA-ICP-MS U-Pb age of 410.5±3.7 Ma is reported (Peach and others, 2017; Finnerty and others, 2019) for magmatic zircon from the intermediate to felsic Parktown gneiss (informal name of Blake and others [2018, 2020]) or Afton gneiss (informal name of Peach and others [2017]). This age suggests that interlayers (transposed dikes or sheets?) of Early Devonian meta-plutonic orthogneiss may be present there.

Intrusive Rocks

Intrusive igneous rocks in the Raleigh terrane include sporadic ultramafic rocks altered to talc schist and soapstone (Zt), gneissic metagranitoid east of Kenbridge (Pzgg), biotite metagranite (Pzgrb), muscovite granite (Pzmg), hornblende metadiorite (DShd), and biotite metatonalite (DSto). Biotite metatonalite (DSto) has a poorly constrained U-Pb TIMS zircon age of about 425–380 Ma (Horton and others, 1995), which is consistent with LA-ICP-MS U-Pb zircon ages of 403.2±3.2 Ma (Finnerty and others, 2019) for a quartz diorite gneiss and 410.5±3.7 Ma (Peach and others, 2017) for an orthogneiss south of the map area. The biotite metatonalite (DSto) of this map may correspond to a unit south of the map area that is informally called Possumquarter biotite tonalite, quartz diorite, and diorite (Blake and others, 2018; Finnerty, 2020) or Possumquarter biotite meta-monzodiorite to monzodiorite gneiss (Blake and others, 2020).

Sacks (1999) identified two general types of granite that intrude schist and gneiss of the Raleigh terrane in this region. The older type of granite occurs as elongate, moderately concordant bodies of garnet-bearing muscovite granite that locally contain biotite. This muscovite granite (Pzmg) is typically foliated and, in many cases, foliation at the margins of the granite is nearly concordant to foliation in the adjacent schist and gneiss. This unit may correspond, at least in part, to a unit south of the map area that is informally called Liberia granodiorite to granitic gneiss (Blake and others, 2018; Finnerty, 2020) or Liberia granodiorite and granodiorite gneiss (Blake and others, 2020). LA-ICP-MS U-Pb zircon ages of about 2,108–314 Ma for granitic gneiss migmatite from that unit are consistent with Mesoproterozoic inheritance and Pennsylvanian migmatization.

The other general type of granite identified by Sacks (1999), exemplified by the muscovite-biotite granite of Wise pluton (PIPw) and muscovite-biotite granite of South Hill pluton (PIPsh), is medium-grained, muscovite-biotite granite that occurs as large discordant plutons. These granites are weakly foliated and are considered younger than the garnet-bearing muscovite granite (Pzmg) because of cross-cutting relations. The presence of weak foliation in these granites indicates they are late syntectonic intrusions. Intrusive dikes, sheets, and thin pods of pegmatite are common in schists and gneisses of the Raleigh terrane.

Carolina Slate Belt of Carolina Terrane (Mainly Greenschist Facies)

Layered and Stratified Rocks

Layered and stratified rocks of the Carolina terrane, which extends from Virginia to Georgia, consist largely of metavolcanic and volcanogenic metasedimentary rocks. Geochemical and isotopic studies indicate that the rocks were deposited in a volcanic-arc setting (for example, Shervais and others, 1996). Secor and others (1983) proposed a peri-Gondwanan origin of the Carolina terrane that was exotic to Laurentia; this interpretation has been supported by paleontologic and paleogeographic studies (Samson and others, 1990), neodymium (Nd) isotopic signatures (Samson and others, 1995b; Wortman and others, 1996), and detrital-zircon age distributions (Samson and others, 2001).

Nomenclature on this map for the Neoproterozoic Hyco, Aaron, and Virgilina Formations (in ascending stratigraphic order) follows Harris and Glover (1988) and is commonly used in other publications (for example, Virginia Division of Mineral Resources, 1993; Hackley and others, 2007; Horton and others, 2016). Comparisons of this nomenclature with the earlier terminology of Laney (1917) and Kreisa (1980) are made in Berquist and others (1993, fig. 2) and in Hackley and others (2007, table 1). The informal collective term Virgilina sequence (for example, Bowman and others, 2013) is not used here because the word Virgilina is formally used in a much narrower sense for the Virgilina Formation, and we are aware of other nomenclatural variations in the literature (for example, Hibbard and Bradley, 2017).

The Hyco Formation (Neoproterozoic) consists of predominantly felsic to intermediate metavolcanic rocks. Map units Zhpm, Zhm, Zhg, Zhb, Zhqz, Zhph, Zhl, Zhd, Zhmm, Zhcs, Zhv, Zhst, Zhs, Zhar, Zhq, Zhc, Zhf, Zhvb, Zhfa, and Zhfm represent lithofacies within the formation independent of stratigraphic order. The Hyco Formation, as used by Kreisa (1980) and Harris and Glover (1988), is generally equivalent to the Hyco quartz porphyry (informal name) of Laney (1917). Horton and others (1999) reported essentially identical Neoproterozoic U-Pb TIMS zircon ages of 621±8 Ma and 616±4 Ma from two localities near the top of the Hyco Formation. Subsequent U-Pb TIMS zircon ages from the Hyco Formation are similar and include 615+3.7/-1.9 Ma for a dacitic metatuff (Wortman and others, 2000), 619.9+4.5/-3 Ma for a felsic gneiss (Wortman and others, 2000), and 616.5±1.2 Ma for a felsic metatuff near the top of the formation (Bowman and others, 2013).

The Aaron Formation (Neoproterozoic) is a sequence of predominantly metasedimentary rocks that is interpreted to have been deposited by turbidity currents in a deep, submarine fan setting (Harris, 1984; Harris and Glover, 1988). Map units Zaps, Zasg, Zag, Zapv, Zab, Zas, Zac, Zap, and Za represent lithofacies within the formation independent of stratigraphic order. The Aaron Formation, as redefined by Harris and Glover (1988), is equivalent to the Aaron slate of Laney (1917) and the lower member of the Aaron Formation of Kreisa (1980). Harris and Glover (1988) interpreted the contact between the Hyco and Aaron Formations as an unconformity based on evidence that sediments of the Aaron Formation included volcanic clasts derived from the Hyco Formation. Uranium-lead TIMS dating of zircons indicates an age gap of about 37 million years between the uppermost part of the Hyco Formation (616.5±1.2 Ma) (Bowman and Hibbard, 2010) and lowest part of the Aaron Formation (about 578 Ma) (Pollock, 2007; Pollock and others, 2010).

The Virgilina Formation (Neoproterozoic) consists of metavolcanic and tuffaceous metasedimentary rocks that overlie metasedimentary rocks of the Aaron Formation. Map units Zvgs, Zvg, and Zvs represent lithofacies within the formation independent of stratigraphic order. The Virgilina Formation, as defined by Harris and Glover (1988), is equivalent to the Virgilina greenstone and overlying Goshen schist of Laney (1917) and includes the informal middle member and upper member of the Aaron Formation as used by Kreisa (1980).

In the vicinity of the Nutbush Creek mylonite zone, rocks similar to those nearby in the Hyco and Aaron Formations are interpreted to be Neoproterozoic rocks of the Carolina terrane without precise stratigraphic correlation. Another unit, the distinctive gneiss of Kenbridge (Zkg), here informally named, consists of hornblende-biotite-quartz-plagioclase gneiss having mafic-to-intermediate and felsic interlayers. It occurs as a narrow, elongate, north-northeast-trending tectonic slice, is bounded by fault strands within the Lake Gordon mylonite zone, and is variably mylonitic and lineated near its contacts. The gneiss of Kenbridge may represent an epidote-amphibolite-facies equivalent of the Hyco Formation in the Carolina terrane, a part of the Raleigh terrane, or a transpressive slice of different rocks of undetermined peri-Gondwanan or Laurentian affinity within the Lake Gordon mylonite zone.

The stratigraphy and structure of greenschist-facies rocks in the Carolina terrane extend north of this map area across a metamorphic gradient and into correlative upper amphibolite-facies gneiss and schist (Achtermann, 1985; Burton, 1995b; Hackley and Peper, 1998; Horton and others, 1999; Peper and Hackley, 1999; Hackley and others, 2007). The Neoproterozoic greenschist-facies Hyco, Aaron, and Virgilina Formations were traced northward from their type localities near Virgilina, Va., along a simple, upright, northeast-trending isoclinal syncline. Rocks of the Aaron Formation unconformably overlie primarily felsic volcanic and volcaniclastic rocks of the Hyco Formation, as indicated by the truncation of internal contacts within the Hyco Formation on both limbs of the Dryburg syncline at the contact between the Hyco and Aaron Formations (Horton and others, 1993b, 2001; Peper and others, 1996; Peper and Wygant, 1997; Peper and Olinger, 1998; Hackley and others, 2007). This map shows a Zhvb-Zhf contact terminating against Za on the west side of the Dryburg syncline and a Zhc-Zhf contact terminating against Za on the east side.

Intrusive Rocks

Neoproterozoic intrusive rocks in the Carolina slate belt of the Carolina terrane range from mafic to felsic in composition. Uranium-lead TIMS zircon ages, in order of decreasing age, include 602±9 Ma for metagranite of Orgainsville (Zbg) near Clarksville (Horton and others, 1999), 583±3 Ma for hornblende diorite and gabbro (Zdg) near Wightman (Horton and others, 1995), 571±17 Ma for metamorphosed biotite granodiorite to leucogranite and quartz monzonite (Zvb) of the Vance pluton (LeHuray, 1989), 571±5 Ma for peralkaline granite of the North View pluton (Zgnv) (Horton and others, 1999), and 568±3 Ma for biotite granite (Zbgr) near Chase City (Horton and others, 1999). $^{40}Ar/^{39}Ar$ age spectra of hornblende from Kunk and others (1995) for hornblende gabbro (Zgh) show maximum ages for cooling through the closure temperature (about 500 °C) of ~600 Ma (at Beaver Pond Creek) and ~586 Ma (at Spewmarrow Creek). The Carolina slate belt in this area also contains granitoids of undetermined Proterozoic or Paleozoic age. The Devonian Buffalo granite (Db) of Laney (1917) and the Mississippian granite of Red Oak (Mro) have preliminary U-Pb TIMS zircon ages of 367±6 Ma and 354±3 Ma, respectively (Horton and others, 1999). Emplacement of Db and Mro was somewhat later than the Acadian orogeny in the northern Appalachians and earlier than emplacement of the Alleghanian plutons. Geochemical and isotopic studies in the Carolinas indicate that the Hyco, Aaron, and Virgilina Formations were deposited above an intra-oceanic subduction zone, while generation of Neoproterozoic magmatic rocks younger than about 600 Ma in the Carolina terrane involved a component of continental crust (Shervais and others, 1996; Ingle and others, 2003; Rogers and Coleman, 2010).

Western Flank of Carolina Terrane (Mainly Epidote-Amphibolite Facies to Amphibolite Facies)

Layered and Stratified Rocks

The westernmost unit of the Carolina terrane in this map area is the Country Line complex (informal name of Hibbard and others [1998]; also referred to informally as the Country Line Creek gneiss by Bradley and others [2006]). This unit was initially called the Country Line Creek complex (informal name of Shell [1996]) to the southwest in North Carolina, where it consists of amphibolite-facies mafic gneisses and lesser amounts of biotite gneiss, semipelitic schist, and felsic gneiss with metapyroxenite and granitic interlayers. It was subsequently mapped into southern Virginia (Hibbard and others, 1998). The Country Line complex is Neoproterozoic in age based on a zircon U-Pb TIMS discordant upper-intercept age of 614±9 Ma (Wortman and others, 1998).

The Country Line complex borders the westernmost Hyco Formation (Zhf, Zhfa, and Zhfm) on the western flank of the Carolina terrane and also represents the hanging wall of the Hyco shear zone (Hibbard and others, 1998). This complex encompasses rocks that are mapped and informally described here as layered gneiss of South Boston (Zclg), biotite-hornblende gneiss of Cluster Springs (Zcc), and mylonitic biotite-hornblende gneiss of Cluster Springs (Zcm). The layered gneiss of South Boston is exceptionally well exposed at the South Boston quarry (Salem Stone Corporation at Halifax, Va.), where it consists of hornblende-biotite gneiss and hornblende gneiss with felsic gneiss interlayers. Zircons from the layered gneiss of South Boston have U-Pb concordia upper and lower intercept ages of 613.9±9.3 Ma (Neoproterozoic, interpreted as the crystallization age of volcanic protolith) and 322.5±2.7 Ma (Mississippian, interpreted as the age of metamorphism and deformation) (Wortman and others, 1998), respectively. The latter age is consistent with an $^{40}Ar/^{39}Ar$ age of 322.9±7.8 Ma for hornblende, which is interpreted to represent cooling through the closure temperature (about 500 °C) following the thermal peak of metamorphism (Wortman and others, 1998). The Country Line complex structurally overlies footwall rocks of the Milton terrane in the hanging wall of the Hyco shear zone (Hibbard and others, 1998, 2016).

Intrusive Rocks

Intrusive rocks on the western flank of the Carolina terrane range from mafic to felsic in composition. They include rocks mapped as metagabbro or metadiorite (PzZgb), megacrystic biotite-quartz-feldspar orthogneiss (PzZgp), and undivided mica gneiss and metagranite (PzZgn). These intrusive rocks lack isotopic age constraints and are inferred to be Neoproterozoic or Paleozoic in age. Unit PzZgn includes a lenticular body of kyanite-mica schist (PzZks) of undetermined age and affinity.

Milton Terrane

Layered and Stratified Rocks

The Milton terrane contains gneissic metavolcanic and associated rocks that appear to be generally correlative with the Chopawamsic Formation (Ordovician) in central Virginia (Coler and others, 2000; Henika, 2002; Hibbard and others, 2016). The Cunningham complex (informal name of Shell [1996] in North Carolina, southwest of this map area) was geographically extended into Virginia by Hibbard and others (1998) and it represents footwall rocks of the Hyco shear zone. Rocks of the Cunningham complex are subdivided on this map into the biotite gneiss of Halifax (Omc) and the biotite gneiss and schist of Cedar Grove (Omm). Other layered and stratified rocks of the Milton terrane are shown on the map as biotite-hornblende gneiss of Ellis Creek (Omh), biotite felsic gneiss of Turnip Creek (Omb), biotite-quartz-feldspar gneiss (Omp), gneiss of Conner Lake (Omf), fine-grained felsic gneiss (Oml), and biotite metagranite and fine-grained felsic gneiss (Omg).

Interfingering of the different metamorphic units is common. This map includes several units adapted from Nelson and Nelson (1997), who mapped rock assemblages characterized by a dominant rock type plus varying proportions of other rocks. Almost all mapped units contain small, unmapped pegmatites, quartz veins, and quartz-feldspar segregations. The biotite gneiss of Halifax (Omc) consists of interlayered biotite gneiss, mica gneiss, and mica schist, and appears to be relatively high in alumina content. Nelson and Nelson (1997) interpreted these rocks as pelitic layers in a metasedimentary sequence, noting a correlation with rocks mapped and interpreted by Baird (1991) as pelitic schists and by Kreisa (1980) as biotite gneiss of sedimentary origin.

The fine-grained felsic gneiss (Oml) mainly consists of very fine grained, light gray, biotite-feldspar quartz gneiss with smaller amounts of fine- to medium-grained granite gneiss; protoliths are interpreted to be felsic volcanic tuffs or lava flows (Nelson and Nelson, 1997). Similar felsic gneiss described as metarhyolite west of this area near Danville, Va., has a U-Pb TIMS zircon age of 458.5+3.8/-1.0 Ma (Coler and others, 2000).

The biotite-hornblende gneiss of Ellis Creek (Omh) is intercalated with other rocks of the Milton terrane. Isolated lenses of Omh are also present in the Omc map unit. In similar fashion, isolated lenses and layers of Omc are also present within the Omh map unit. Those relations are interpreted by Nelson and Nelson (1997) as evidence that the units Omh and Omc form part of a stratigraphic assemblage. More geochronology and geochemistry in this assemblage could be useful, since unit Omh is lithologically similar to Neoproterozoic mafic gneiss of unit Zclg in the Carolina terrane (Bradley, 1996; Wortman and others, 1996).

Intrusive Rocks

Intrusive rocks of the Milton terrane include units mapped and described as altered ultramafic rock (Omu), amphibolitic metagabbro (Omi), undivided metagranite and mica gneiss of Shelton Formation (Osgr), and foliated biotite granite (Pzbg). Metagranite sheets and lenses of the Shelton Formation are generally concordant to foliation and gneissic layering (Henika and Thayer, 1977; Henika, 1980). Granitoid rocks of the Milton terrane have Ordovician U-Pb TIMS zircon ages of 463±14 Ma for Shelton granite of Hund (1987) and 450.0±1.8 Ma for granite gneiss of Coler and others (2000).

Late Paleozoic Intrusive Rocks

Late Paleozoic intrusive igneous rocks in the map area were emplaced during the Alleghanian orogeny and range in age from Middle Mississippian to Permian. Examples of these rocks include the metagranite of Saxe (ℙMgn) and biotite granite of Farmers Lake (ℙMgf), both as herein described informally. Other examples of these rocks include granite of the Buggs Island pluton (ℙbi) and granites of the Stones Mill (Pℙsm), South Hill (Pℙsh), and Wise (Pℙw) plutons. Other units are identified in the Description of Map Units and Correlation of Map Units.

Preliminary U-Pb TIMS zircon ages for the granite of the Buggs Island pluton (ℙbi) and for lineated muscovite-biotite metagranite (Pℙgl) at The Falls on the Nottoway River (5 kilometers [km] north of this map area) are about 315–295 Ma (Horton and others, 1995). Kish and Fullagar (1978) reported a rubidium-strontium (Rb-Sr) whole-rock age of 313±8 Ma for granite of the Buggs Island pluton. These rocks lie along or west of the Nutbush Creek and Lake Gordon mylonite zones in host rocks of the Carolina terrane.

Granites and granitic gneisses of inferred late Paleozoic age in the Raleigh terrane to the east include bulbous, discordant bodies of largely medium-grained, muscovite-biotite granite near Wise and South Hill (Sacks, 1996a, b) as well as Stones Mill. Weak foliation in these granites suggests late syntectonic emplacement (Sacks, 1996a).

Sinha and Zietz (1982) and Sinha and others (1989) suggested that the Alleghanian plutons in the central and southern Appalachian Piedmont represent a continental magmatic arc produced over a west-dipping subduction zone. However, evidence that appears inconsistent with a magmatic-arc interpretation includes (1) the dominance of granite with only minor amounts of rock that have mafic to intermediate compositions, (2) a lack of systematic geochemical variation across the strike of the orogenic belt, and (3) the relatively small volume of magmatic rocks when compared with other known continental magmatic arcs (Speer and others, 1994; Samson and others, 1995a). Pindell and Dewey (1982) instead proposed that magmatism resulted from crustal thickening caused by continent-continent collision. Samson and others (1995a) presented geochemical and isotopic evidence consistent with an origin by crustal anatexis and suggested magma generation due to lithospheric delamination or heat from the stacking of thrust sheets. Speer and others (1994) noted that Alleghanian magmatism and deformation were essentially syntectonic throughout the southern Appalachians. They pointed to the close spatial association of Alleghanian plutons with strike-slip faults as evidence that magma formation and emplacement were driven by transpressional deformation.

Mesozoic Rift-Related Rocks

In the South Boston 30′ × 60′ quadrangle, Upper Triassic nonmarine sedimentary rocks fill the Scottsburg, Randolph, and Roanoke Creek basins. The ~4.5×10.5 km Scottsburg basin, the ~3×10 km Randolph basin, and the ~4×23 km Roanoke Creek basin are small relative to the ~25×150 km Culpeper basin in northern Virginia (Virginia Division of Mineral Resources, 1993). These small rift basins may be erosional remnants of a much larger basin that once extended continuously northeastward from the Scottsburg basin to the present-day Briery Creek and Farmville basins north of the map area (Olsen, 1997; Horton and others, 2001). The Roanoke Creek basin has been mapped by Ramsey (1982) and the southern part of the Scottsburg basin has been mapped by Kreisa (1980). The geology, stratigraphy, and paleontology of these basins is summarized in Smoot (2016) and a somewhat generalized map showing the geology of the basins in this quadrangle is shown in Weems and others (2016). The basin strata are locally crosscut by Early Jurassic dikes (Marzoli and others, 2011) that are part of the central Atlantic magmatic province (CAMP), as shown in the Scottsburg and Randolph basins on this map. The formation of early Mesozoic basins followed by injection of crosscutting dikes represent early phases of rifting that led to opening of the North Atlantic Ocean basin.

Scottsburg, Randolph, and Roanoke Creek Basins

All sedimentary rocks within the Scottsburg, Randolph, and Roanoke Creek basins are assigned to the Chatham Group as used by Weems and Olsen (1997). This map only distinguishes lithofacies units in these basins as defined by criteria established in Smoot (1991) independent of stratigraphic order. These lithofacies are conglomerate (Ŧcm), pebbly sandstone (Ŧsc), and siltstone and sandstone (Ŧsis). Geologists who advocate a distinct lithostratigraphic nomenclature for the Newark Supergroup in each basin (for example, Huber and LeTourneau, 2006; Sues and Olsen, 2015) have not proposed any formal stratigraphic nomenclature for the Scottsburg, Randolph, or Roanoke Creek basins. Integrative stratigraphic nomenclature proposed by Weems and others (2016), which defines regional formations within the Newark Supergroup that apply throughout all of the basins, would place the lower strata of the Scottsburg basin and all strata in the Randolph and Roanoke Creek basins in the Doswell Formation; the upper strata in the Scottsburg basin (above unit TRsis) would be assigned to the Stockton Formation. However, the integrative stratigraphic nomenclature of Weems and Olsen (1997) is not used by those who favor distinct lithostratigraphic nomenclature for each Newark Supergroup basin (for example, Huber and LeTourneau, 2006; Sues and Olsen, 2015). Weems and others (2016) proposed extension of the integrative nomenclature from group level to formation level, but this is not used herein.

The siltstone and sandstone (TRsis) lithofacies mostly consist of interbedded fine- to medium-grained sandstones and siltstones interbedded with local shale and conglomerate beds. The maximum thickness of this unit is about 500 meters (m). The contact with the overlying pebbly sandstone (TRsc) lithofacies is a sharp disconformity. Fine- to medium-grained, feldspathic fluvial sandstones are interbedded and gradational with paludal to lacustrine siltstones and shales. Strata are thinly to thickly bedded, commonly laminated or cross-bedded with fining-upward or coarsening-upward sequences, and locally bioturbated. Sand-size grains are poorly rounded. The TRsis unit locally contains pollen, leaf impressions, petrified wood, ostracods, unionid bivalves, conchostracans, and fossil fish (Schaeffer and McDonald, 1978; Kreisa, 1980; Olsen and others, 1982; Robbins, 1985; Kozur and Weems, 2007, 2010). These fossils indicate that, when this unit was deposited, the climate was wet and tropical and that this lithofacies formed in meandering streams, swamps, shallow lakes, and local lake-fringe deltas. The presence of the fossil fish *Dictyopyge macrura* and the conchostracan *Laxitextella multireticulata* both indicate an early Carnian (Cordevolian) age for this unit, which is equivalent in age to the Vinita Shale in the Richmond basin of central Virginia (Kozur and Weems, 2007, 2010). In the map area, this lithofacies is exposed only in the Scottsburg basin.

The pebbly sandstone (TRsc) lithofacies consists of arkosic pebbly sandstone containing less abundant interbeds of conglomerate. Pebbles are well-rounded. The unit is well stratified and mostly shows trough or tabular cross bedding or planar lamination. In the Scottsburg basin, strata of the pebbly sandstone unit disconformably overlie the siltstone and sandstone unit (TRsis) and are up to 500 m thick. The pebbly sandstone unit grades westward into and intertongues with the conglomerate unit (TRcm). Fining upward sequences of conglomerate to sandstone are common. This unit is interpreted to have been deposited mostly by braided streams. The only fossils known from the pebbly sandstone unit are pieces of petrified wood referable to the conifer stem genus *Araucarioxylon*. This lithofacies occurs in the Scottsburg, Randolph, and Roanoke Creek basins.

The conglomerate (TRcm) lithofacies consists of poorly sorted, massive to poorly bedded conglomerate composed of a mixture of subrounded to subangular boulders, cobbles, and pebbles derived from nearby metamorphic and igneous source units. Clasts are embedded in a sandy matrix and vary from matrix supported to clast supported. In the Scottsburg basin, this unit reaches a maximum thickness of 400 m in a vertical transect near the western border fault. The conglomerate is here interpreted to have been deposited by debris flows and flash floods on medial to distal alluvial fans that originated from the upthrown side of syndepositional western basin border faults (Kreisa, 1980; Ramsey, 1982; Goodwin and others, 1986). In each basin, the strongly time-transgressive conglomerate lithofacies intertongues eastward with the pebbly sandstone (TRsc) lithofacies. The conglomerate lithofacies occurs along and near the western border of the Scottsburg, Randolph, and Roanoke Creek basins.

Dikes

Intrusive dikes of the CAMP are related to rifting during the breakup of Pangea that led to opening of the present-day Atlantic Ocean (McHone, 2000; Marzoli and others, 2011). They are common in much of the southern Appalachian Piedmont, including this map area, where they crosscut Triassic and older rocks (for example, Smoot, 2016). These dikes are typically tholeiitic in composition (Ragland and others, 1992). High-precision ^{40}Ar/^{39}Ar mineral ages (Jourdan and others, 2009) mostly range from 201.0±1.4 to 198.6±1.1 Ma (2σ), and high-precision U-Pb zircon ages (Blackburn and others, 2013) cluster tightly at 201.274±0.032 Ma to 200.916±0.064 Ma. The dikes mapped in this area include olivine diabase (Jdo), granophyre-bearing quartz diabase and monzodiorite (Jdq), undivided diabase (Jd), and diabase inferred from magnetic anomalies (Jdm). These dikes generally strike northeast to northwest, dip steeply, and range in thickness from about 0.5 to 150 m. Fine-grained basalt chill margins up to 5 centimeters thick occur locally. Spheroidally weathered residual boulders commonly have a rusty weathering rind.

Relatively sparse dikes of porphyritic rhyolite and alkali basalt (Jdp), initially described by Stoddard and others (1986) and Stoddard (1992), occur in a north-northwest-trending swarm on the eastern side of the quadrangle. These dikes typically strike 330°–350°, dip steeply, and reach a maximum thickness of 10 m. Sanidine from these dikes yielded ^{40}Ar/^{39}Ar plateau ages of 196.6±0.7 Ma and 196.3±0.7 Ma (Ganguli and others, 1995), which are interpreted as the age of Early Jurassic dike emplacement.

Unconsolidated Surficial Deposits

In the South Boston map area, unconsolidated surficial deposits of Neogene and Pleistocene age are mostly found along the sides and bottoms of the present-day Roanoke and Dan River valleys. The one exception to this pattern is the series of highest-level gravel deposits (Nm) in eastern Charlotte County (in the north-central part of the map); these deposits apparently fill remnants of a part of the Miocene channel of the Roanoke River reach that is locally known as the Staunton River (Weems, 1998; Weems and Edwards, 2007). When the Nm unit was deposited, the Roanoke River flowed eastward across the granite of Red Oak (Mro) into the present-day headwaters of the Meherrin River. Later in the Miocene, the Roanoke River immediately to the west of these deposits was captured by the Roanoke River-Dan River drainage system (Weems, 1998; Weems and Edwards, 2007). The map shows fluvial terrace deposits of sand and gravel on hills and slopes near the Roanoke and Dan Rivers. The highest terrace deposits are the oldest, and each lower terrace deposit is successively younger than the ones above it. These deposits formed between times of Piedmont regional uplift or sea level drops when the Roanoke and Dan Rivers had low gradients and their channels were able to meander and widen their valleys. In the Roanoke River drainage, *Skolithos*-bearing cobbles from Paleozoic sandstones west of the Blue Ridge are present in the low-level terrace gravels and possibly in older gravels as well. The Dan River gravels, which have source areas entirely east of the Blue Ridge, lack these cobbles.

The highest-level (and oldest) terrace deposits (Nm) are unconsolidated to moderately well consolidated ancestral channel and floodplain deposits of rounded quartz gravel, sand, and silt on hills and slopes near the Roanoke and Dan Rivers, and in eastern Charlotte County, Va., 65–85 m above the present-day river levels (186 m above sea level; see outlier near Wallaces Store, 20 km northeast of Roanoke River). In most areas, these deposits form inverted topography. Saprolitized clasts of metamorphic and igneous rocks are locally abundant in these deposits. Most heavy minerals (except zircon) have been leached away. These gravels are likely correlative in age with the Midlothian gravels to the northeast of the South Boston map area near Midlothian, Va., which lie unconformably above the middle and upper Miocene Choptank Formation (Weems and Edwards, 2007; Edwards and others, 2018). Deposits in eastern Charlotte County are likely the remnants of Miocene Roanoke River channel gravels that were deposited when the Roanoke River flowed eastward toward the present-day Meherrin River and before it was captured by the Roanoke River-Dan River drainage system.

High-level terrace deposits (Np_1) are unconsolidated to moderately well consolidated ancestral channel and floodplain deposits of gravel, sand, and silt on hills and slopes near the Roanoke and Dan Rivers, 45–60 m above the present-day river levels. Quartz clasts are by far the most common clast type in these deposits. The Np_1 terrace deposits gently slope downstream along the gradient of the Roanoke River valley into Coastal Plain terrace deposits associated with the Pliocene Yorktown Formation (Weems, 1998).

Intermediate-level terrace deposits (Qp_2) are unconsolidated to moderately well consolidated ancestral channel and floodplain deposits of gravel, sand, and silt on hills and slopes near the Roanoke and Dan Rivers, 20–45 m above the present-day river levels. Most preserved clasts in these deposits are quartz or quartzite; metamorphic and igneous clasts are mostly saprolitized to clays or sandy clays. The Qp_2 terrace deposits gently slope downstream along the gradient of the Roanoke River valley into Coastal Plain terrace deposits associated with the lower Pleistocene (Gelasian) Chowan River Formation (Weems, 1998).

The low-level terrace deposits (Qp_3) are consolidated to moderately well consolidated ancestral channel and floodplain deposits of gravel, sand, and silt on hills and slopes near the Roanoke and Dan Rivers, 5–20 m above the present-day river levels. Partially saprolitized clasts of metamorphic and igneous rocks are locally abundant. These terrace deposits slope gently downstream along the gradient of the Roanoke River valley into Coastal Plain terrace deposits associated with the lower Pleistocene (Calabrian) Bacons Castle Formation (Weems, 1998).

Quaternary colluvium (Qco) is present as unconsolidated deposits of rounded quartz gravel, sand, and silt on hills and slopes, located down-slope (and derived) from higher fluvial terrace deposits. Deposits are typically less than 3 m thick. Isolated occurrences are probably derived from former terrace deposits that were entirely removed from higher altitudes by erosion.

Holocene alluvium (Qal) consists of unconsolidated deposits of gravel, sand, silt, and clay on flood plains of creeks and rivers, generally less than 3 m above the channel of present-day streams. The unit contains variable amounts of organic debris in poorly drained areas. These deposits are only slightly weathered and have poorly developed soil profiles relative to older surficial deposits. Locally, soil profiles are well developed from alluvial parent material.

Regolith

Saprolite is unconsolidated, decomposed bedrock formed by isovolumetric chemical weathering. This material retains relict bedrock structure and internal geometry, but has other soil-like characteristics such as lower strength and cohesion as well as greater compressibility and permeability when compared to the original bedrock (Pavich and others, 1989). Saprolite is not compacted or transported and can be dug with a shovel. It grades into and contains remnant core stones of less weathered rock. Saprolite compositions and physical properties are related to the underlying bedrock source materials. Areal distributions are coincident with underlying bedrock and are not shown separately on the map. Saprolite is the most widespread sub-soil surficial material and surficial aquifer in the map area. The combined thickness of saprolite and soil in the map area ranges from about 0 to 46 m and has a mean of about 18 m (LeGrand, 1960).

Soil types as delineated on U.S. Department of Agriculture county soil surveys (https://www.nrcs.usda.gov/wps/portal/nrcs/surveylist/soils/survey/state/?stateId=VA) are commonly related to underlying rocks but are beyond the scope of this geologic map. A unit of low-potassium residual soil (QNr) is shown as an exception because it is thick enough to conceal underlying bedrock and saprolite in the field and is also conspicuous on airborne radiometric survey data (U.S. Geological Survey, 1978b). Printed soil-survey maps are available for some individual counties (for example, Hardison and Long, 1910; Henry and others, 1956; Stimpson and others, 1980).

Low-potassium residual soil (QNr) occurs on interstream divides north of the Meherrin River in the vicinity of the Lunenburg-Brunswick County line. This soil is delineated by low-potassium anomalies on an airborne gamma-ray survey (U.S. Geological Survey, 1978b); these anomalies contrast with anomalies associated with potassium-feldspar-bearing rocks, such as those herein described informally as the gneissic metagranitoid east of Kenbridge (Pzgg). This soil (QNr) is briefly described from field observations, but has not been studied further. While airborne radiometric surveys detect gamma rays that emanate from shallow sources less than a meter below the land surface (Duval and others, 1971), field observations indicate that this residual soil is commonly at least 1–2 m thick. The preservation of this residual soil on interfluves suggests possible removal by erosion of similar material from hillslopes and stream valleys. Representing the low-potassium residual soil for the first time on this map may bring it to attention for future investigation. Awareness of the unit may also be relevant for the interpretation of future airborne radiometric surveys in the eastern Piedmont.

Structure

The Raleigh, Carolina, and Milton terranes are separated by regional faults and high-strain zones. Discussion of structures in each terrane is followed by a review of major faults and high-strain zones.

Structure of the Raleigh Terrane

Rocks in the Raleigh terrane contain structures that indicate several phases of deformation (Farrar, 1985a; Sacks, 1996a, b, 1999). Much of the compositional layering (S_0) in gneisses and schists appears to be a transposed surface, and no primary sedimentary structures are recognized. The earliest recognized deformational structures are outcrop- to map-scale isoclinal folds (F_1) of compositional layering. Regional schistosity (S_1) is parallel to the axial surfaces of these isoclinal folds. The F_1 isoclinal folds vary in orientation due to refolding, but commonly plunge gently northwest or southeast. Away from F_1 fold hinges, the fold limbs are approximately parallel and are folded by outcrop- to map-scale open to tight F_2 folds. These F_2 folds deform the S_1 foliation. They generally trend north-northwest in the southeastern part of the map near Lake Gaston and trend north-northeast farther north near the Meherrin River. In the F_2 hinge areas, an axial planar foliation is locally expressed by aligned biotite in gneisses or crenulation cleavage in schists. A set of open folds (F_3) plunges gently west-southwest; however, these folds are more common east of the map area where interference of F_2 and F_3 folds locally affects outcrop patterns (Sacks, 1996c). An F_3 fold on this map crosses Lake Gaston near the Mecklenburg-Brunswick County line. Sparse westward-plunging open folds are tentatively designated F_4.

Structure of the Carolina Terrane

The most prominent map-scale structures of the Carolina terrane in this map area are F_1 folds such as the Virgilina synclinorium and its northern extension, the Dryburg syncline (Laney, 1917; Kreisa, 1980; Horton and others, 1993b, 2001; Peper and Olinger, 1998; Hackley and others, 2007). Evidence for the Dryburg syncline consists of the symmetry of stratigraphic units on opposite limbs and sedimentary facing criteria (Peper and Olinger, 1998). The northern end of the Dryburg syncline is overturned slightly to the west and is refolded in places by map-scale, south-southeast plunging folds in the north part of the map area (Hackley and others, 2007). Primary bedding features, including facing criteria, are locally preserved (Kreisa, 1980; Burton, 1995b; Peper and Olinger, 1998).

The main regional foliation (S_1) defined by micas and chlorite is axial planar to early folds (F_1) that deform primary compositional layering (S_0) and bedding features. The S_1 foliation generally strikes north-northeast and dips moderately to steeply southeast or northwest. Pressure-solution cleavage in conglomerate of the Aaron Formation is described in Hackley and others (2007). Outcrop-scale tight to isoclinal folds locally deform the main foliation and compositional layering. The S_1 foliation is commonly parallel or subparallel to compositional layering and mapped lithologic contacts; however, there are exceptions in the hinge areas of F_1 folds where it is locally at moderate to high angles to mapped contacts and to the axial trace of the Dryburg syncline. This observation is consistent with development of a penetrative fabric after regional synclinal folding of the stratigraphy during the ~620–575 Ma Virgilina deformation of Glover and Sinha (1973). Evidence of folds that pre-date the regional cleavage in the Lunenburg and Fort Mitchell quadrangles (see quadrangle index on map sheet) may be associated with the Virgilina deformation (Burton, 1995a, b). $^{40}Ar/^{39}Ar$ ages of foliation-defining minerals at higher metamorphic grades north of this map area primarily indicate Alleghanian growth (Burton and others, 2000).

Post-F_1 folds in the Carolina slate belt of the Carolina terrane deform the S_1 foliation. The F_2 folds are open to tight and mostly plunge gently north-northeast or south-southwest. The F_3 folds are sparse, gentle warps that plunge southwest or northeast. The F_4 open folds plunge gently northeast at high angles to the S_1 main foliation and are concentrated in the northern part of the map area.

Structure of the Milton Terrane

Foliation in the Milton terrane is strongly developed and no primary sedimentary structure are recognized in these rocks. The compositional layering (S_0) and main foliation (S_1) appear to be parallel. This foliation and parallel layering have gentle to moderate dip angles over relatively large areas and their strike orientations vary due to folding. The earliest folds (F_1) are isoclinal and recumbent, have subhorizontal to gently plunging hinge lines, and have axial surfaces parallel to the S_1 foliation. The F_2 folds are open to tight, upright to inclined, have moderately to steeply dipping axial surfaces, and commonly plunge gently northeast to east-northeast or southwest to west-southwest. In the northwestern part of the map area, foliation attitudes and map-unit patterns delineate the east-northeast trending Nathalie synform, an F_2 fold here interpreted to refold an isoclinal, recumbent F_1 antiform. Recumbent fold limbs are gently refolded around east-north-east-trending F_3 fold hinges. Based on outcrop-scale refolding of recumbent folds, Nelson and Nelson (1997) interpreted relatively gentle dips of layering and foliation to represent second or third generation folds superposed on the limbs of map-scale recumbent folds. This style of folding is also described for this region in Tobisch and Glover (1971) and Baird and Glover (1997).

Ductile shear fabrics are sparsely distributed over wide areas of the Milton terrane. The sense of shear along and west of the Hyco shear zone is east over west and the sheared rocks are locally high in chlorite and opaque minerals (Nelson and Nelson, 1997).

Lake Gordon and Nutbush Creek Mylonite Zones

The Lake Gordon and Nutbush Creek mylonite zones are major strands of the late Paleozoic (Alleghanian) eastern Piedmont fault system (Hatcher and others, 1977). A 5- to 9-km-wide band of late Paleozoic mylonite zones (Lake Gordon and Nutbush Creek) and associated granite separates the Carolina terrane from the Raleigh terrane on the eastern side of the map area (Horton and others, 1993a, b, 2001). The north-northeast-trending Lake Gordon mylonite zone lies along the eastern flank of the Buggs Island pluton (₽bi) and western margin of the Raleigh terrane. Mylonitic foliation strikes N. 10° E. to N. 25° E., dips subvertically to steeply northwest, and is parallel to the mapped boundaries of the zone. The intensity of mylonitization varies across the zone. A subhorizontal mineral-elongation lineation is common in the plane of mylonitic foliation. Asymmetric feldspar and quartz porphyroclasts, shear bands, and sigmoidal mica fish indicate dextral shear in the mylonitic rocks and associated gneisses and schists.

The Nutbush Creek mylonite zone has a length of at least 200 km in southern Virginia and central North Carolina (Casadevall, 1977; Farrar, 1985a, b; Horton and others, 1993b, 2016; Virginia Division of Mineral Resources, 1993; Druhan and others, 1994). Mylonitic foliation is generally parallel to the boundaries of the mylonite zone. Kinematic indicators include S-C composite foliations, shear bands (C′), rotated porphyroclasts, asymmetry of steeply plunging mesoscopic and microscopic folds, and subhorizontal mineral lineations (Druhan and others, 1994). These fabrics consistently indicate dextral strike slip along the entire length of the Nutbush Creek mylonite zone (Druhan and others, 1994). Estimates of the total horizontal displacement are as much as 160 km (Druhan and others, 1994). Mineral assemblages and textures indicate that the mylonitic fabrics formed under lower-greenschist to amphibolite-facies conditions (Druhan and others, 1994).

The highly elongate granite of the Buggs Island pluton (₽bi) is sandwiched between rocks of the Nutbush Creek mylonite zone to the west and rocks of the Lake Gordon mylonite zone to the east. Kinematic relations indicate that the granite emplacement was synkinematic with strain along the bounding mylonite zones and also suggest that strain in the mylonite zones influenced emplacement of this granite (Druhan and Rollins, 1984; Horton and others, 1993a; Druhan and others, 1994). This granite's Rb-Sr whole-rock age of 313±15 Ma (Kish and Fullagar, 1978) constrains the time of ductile shear in both zones. Postmylonitic brittle faulting is superposed on mylonitic rocks in both the Lake Gordon and the Nutbush Creek mylonite zones.

Hyco and Clover Shear Zones

The Hyco and Clover shear zones of the central Piedmont shear system represent zones of high strain along and near the boundary between the Carolina and Milton terranes (Horton and others, 2016). The Hyco shear zone has an arcuate trace that strikes north-northeast near the Virginia-North Carolina border and east-northeast south of the map area. Its dip changes from steeply southeastward along the east-north-east-striking segment south of this map area to moderately or gently eastward along the north-northeast-striking segment (Hibbard and others, 1998, 2001). They Hyco shear zone separates footwall rocks of the Milton terrane from hanging-wall rocks of the Carolina terrane, and high-strain fabrics extend several kilometers on each side (Bradley, 1996; Hibbard and others, 1998, 2001; Bradley and others, 2006). In Halifax County, Va., where the Hyco shear zone dips moderately to gently eastward, structural relations are consistent with thrusting of the Carolina terrane over the Milton terrane; however, along the east-northeast-striking segment south of this map area in North Carolina, stretching lineations and asymmetric fabrics indicate dextral strike-slip motion (Hibbard and others, 1998, 2001). High-strain fabrics of the Hyco shear zone in North Carolina indicate at least 35 km of displacement (Vines and others, 1998). Movement on the Hyco shear zone is attributed to the Alleghanian orogeny based on Late Mississippian to Early Pennsylvanian U-Pb TIMS zircon ages of 335 Ma, 327 Ma, and 320 Ma for early to late synkinematic granites in North Carolina (Wortman and others, 1998). Amphibolite-facies gneisses of the Country Line complex on the western flank of the Carolina terrane at the South Boston quarry contain ductile shear fabrics associated with the Hyco shear zone (Hibbard and others, 2001; Bradley and others, 2006).

The Hyco shear zone in this map area is generally characterized by gneissic (not mylonitic) rocks in which ductile shear fabrics are variably developed. The geologic map shows a major thrust contact within the Hyco shear zone that sharply separates rocks of the Carolina terrane from rocks of the Milton terrane. The shear zone has gradational, indistinct boundaries in this area such that its lateral extent beyond the thrust contact as well as its total width (possibly a few kilometers) are unclear. A broad interpretation of the lateral extent (for example, Hibbard and Bradley, 2017) would suggest that the Hyco shear zone overlaps the narrower Clover shear zone discussed below.

The Clover shear zone, named for exposures near the town of Clover in eastern Halifax County, Va. (Baird, 1989, 1991), strikes northeast along the western margin of the Carolina terrane and ranges in width on this map from about 2 to 4 km (Horton and others, 1993b, 2001). The zone is characterized by variably mylonitic to non-mylonitic ductile fabrics that show evidence of dextral shear and associated greenschist-facies retrogressive metamorphism (Baird and Glover, 1997). Most of the high-strain zone lies northwest of the granite of Red Oak (Mro), which is not offset, although mylonitic fabrics are locally present along its northwest margin. The mylonitic textures overprint parts of the Hyco and Aaron Formations, amphibolite-facies gneisses of the Carolina terrane in a northeastern extension of the Country Line complex, and intercalated granitic sheets (Baird, 1989, 1991; Horton and others, 1993b, 2001; Baird and Glover, 1997). Localization of the early Mesozoic Scottsburg, Randolph, and Roanoke Creek basins (as well as associated northeast-striking normal faults and brittle deformation superposed on Paleozoic ductile fabrics and metamorphic assemblages) indicate that the Clover shear zone persisted as a zone of crustal deformation. Mesozoic normal faults extend along strike from the western margins of the Randolph and Roanoke Creek basins. These faults separate the moderately southeast-dipping rocks of the Carolina terrane (which were affected by the Clover shear zone) from rocks of the Milton terrane (Hibbard and others, 2016) to the northwest, which show little if any fabric typical of the Clover shear zone (Nelson and Nelson, 1997; Horton and others, 2001).

This geologic map provides a foundation for further analysis of kinematic relations and evidence of tectonic inheritance. Aspects include relations among ductile shear (thrusting) in gneisses of the Hyco shear zone, ductile shear (dextral strike-slip) in mylonitic rocks of the Clover shear zone, and brittle dip-slip faults associated with early Mesozoic rifting.

Mesozoic Faults

Extensional faults associated with early Mesozoic rift basins locally coincide with older Paleozoic mylonite zones and disrupt the regional distribution of Paleozoic metamorphic zones (Horton and others, 2016). Normal faults associated with the early Mesozoic Scottsburg, Randolph, and Roanoke Creek basins (Kreisa, 1980; Ramsey, 1982; Johnson and others, 1985; Goodwin and others, 1986) are spatially associated with a 5- to 8-km-wide band of late Paleozoic tectonic elements; this band includes the Hyco and Clover shear zones, syntectonic granitic sheets, and amphibolite-facies gneisses along the western flank of the Carolina terrane (Horton and others, 2001). A northeast-striking, southeast-dipping zone of normal faults (here referred to as the Roanoke Creek fault zone) bounds the Roanoke Creek and Randolph basins to the northwest.

The Scottsburg basin straddles mylonitic rocks of the Clover shear zone and is bounded by Mesozoic faults on all sides. A well-constrained albite-to-oligoclase metamorphic isograd locally coincides with a normal fault that extends southwestward from the Scottsburg basin; this fault has metamorphic albite in the hanging wall and oligoclase in the footwall (Kreisa, 1980, fig. 5). These relations indicate that Mesozoic normal displacement discernibly affected the distribution of pre-Mesozoic metamorphic zones.

Metamorphism

Regional metamorphic effects of the Alleghanian orogeny are pervasive in the South Boston area, but there is little evidence here for any earlier metamorphic events. Alleghanian amphibolite-facies metamorphism in the Raleigh terrane is established by previous investigations of Farrar (1985a, b), Russell and others (1985), and Sacks (1999). Widespread replacement of sillimanite by chloritoid and white mica indicates a retrograde greenschist-facies overprint (Sacks, 1999). The earliest phase of folding and the thermal peak of metamorphism in the Raleigh terrane of this area probably predate the intrusion of the slightly foliated Wise and South Hill plutons as well as the development of the late Paleozoic Lake Gordon mylonite zone (Sacks, 1999).

Metamorphism in the Carolina terrane in this map area occurred during the Alleghanian orogeny at about 320–280 Ma based on cooling ages of foliation-defining metamorphic minerals (Horton and others, 1995; Kunk and others, 1995; Burton and Armstrong, 1997; Burton and others, 2000), although a significant older growth component is also present (Kunk and others, 1995). This Alleghanian metamorphism locally reached amphibolite facies, based on resetting of titanite and monazite ages to about 321–297 Ma (Horton and others, 1995). Rocks near the town of Virgilina, Va., are at lower greenschist facies (chlorite and biotite zones). An albite-to-oligoclase metamorphic isograd in the western part of the Carolina terrane spatially coincides with a Mesozoic normal fault that extends southwestward from the Scottsburg basin (Kreisa, 1980, fig. 5) along a contact between the Hyco Formation and the mylonitic biotite-hornblende gneiss of Cluster Springs (Zcm). North of this map area, the Hyco, Aaron, and Virgilina Formations increase in metamorphic grade to the northeast across a series of east-northeast-trending Barrovian metamorphic isograds. These isograds are defined by successive northward prograde appearance of garnet, then kyanite ± staurolite (Hackley and others, 2007, fig. 4), and then sillimanite (Burton and Armstrong, 1997) in aluminous rocks.

Rocks of the Milton terrane in this area are mostly in the sillimanite and kyanite zones of amphibolite-facies regional Barrovian metamorphism (Kreisa, 1980, fig. 5; Nelson and Nelson, 1997). Sillimanite is common in rocks that also contain layers or veinlets of metamorphosed granitic rock, which suggests that some sillimanite formed as a result of high temperatures associated with granitic magma or migmatite formation (Nelson and Nelson, 1997). However, lower grade (greenschist facies) rocks are present farther west in part of the Milton terrane near Danville, Va. (Henika and Thayer, 1977; Henika, 2002).

Regional metamorphism in and near the South Boston map area was formerly attributed to the Taconic orogeny (Glover and others, 1983; Baird and Glover, 1997). However, an igneous hornblende from the Carolina slate belt with an $^{40}Ar/^{39}Ar$ age of 586 Ma shows no evidence for a Taconic or Acadian thermal event (Kunk and others, 1995). Kunk and others (1995) also reported an $^{40}Ar/^{39}Ar$ cooling age of 313 Ma for hornblende from the western part of the Carolina terrane and an $^{40}Ar/^{39}Ar$ cooling age of 323 Ma for hornblende from the Milton terrane as evidence for cooling after the thermal peak of Alleghanian prograde metamorphism. Biotite along the axial-plane schistosity of late-stage minor folds in the Milton terrane is interpreted to have formed after the thermal peak of Alleghanian prograde metamorphism, which had temperatures high enough to form biotite (Ozdogan and others, 1997).

Tectonics

The Carolina and Raleigh terranes are interpreted as peri-Gondwanan terranes that are exotic to Laurentia (ancestral North America). Geochemical and isotopic studies indicate that the Hyco, Aaron, and Virgilina Formations formed above an intra-oceanic subduction zone, while formation of younger magmatic rocks in the Carolina terrane involved some preexisting continental crust (Shervais and others, 1996; Ingle and others, 2003; Rogers and Coleman, 2010). The Raleigh terrane on the eastern side of the map includes Neoproterozoic to early Paleozoic(?) polydeformed gneisses and schists. However, recent U-Pb detrital zircon geochronology south of this map area suggests that some gneisses and schists that have been interpreted as a single peri-Gondwanan Raleigh terrane represent different transpressional fault slices that have distinct peri-Gondwanan rather than Laurentian affinities (Peach and others, 2017; Finnerty and others, 2019; Blake and others, 2020; Nolan and others, 2020).

The Carolina terrane in the central part of the map contains Neoproterozoic metavolcanic and metasedimentary rocks at greenschist facies in the Carolina slate belt and at higher metamorphic grades on its western flank. Although locally complicated, the slate-belt structure across the map area is generally a broad, complexly structured anticlinorium of the Hyco Formation, here called the Chase City anticlinorium. This anticlinorium consists of shorter wavelength folds such as the Siddon anticline, Shiny Rock syncline, and Occoneechee anticline. The Chase City anticlinorium is flanked to the west and east by synclinoria, which are cored by the overlying Aaron and Virgilina Formations. Epidote-amphibolite-facies to amphibolite-facies gneisses on the western flank of the Carolina terrane extend north-northeast across the map. A pair of late Paleozoic mylonite zones (Nutbush Creek and Lake Gordon) of the eastern Piedmont fault system and associated syntectonic granite (Buggs Island pluton) separate the Raleigh and Carolina terranes in this area.

The Milton terrane on the western side of the map area is interpreted as part of the central Virginia volcanic-plutonic belt (Pavlides, 1981; Virginia Division of Mineral Resources, 1993) or the magmatic tract of Hibbard and others (2016). This terrane contains polydeformed metavolcanic and metasedimentary gneisses and schists along with metagranite of Ordovician age. Other felsic, mafic, and ultramafic Paleozoic intrusive igneous rocks also occur. The Milton terrane is separated from peri-Gondwanan terranes to the east by the Hyco and Clover shear zones of the central Piedmont shear system (Horton and others, 2016). A band of Alleghanian tectonism (which includes these two shear zones, syntectonic granitic sheets, and amphibolite-facies gneisses in the western part of the Carolina terrane) was the locus for early Mesozoic extensional faults. The early Mesozoic Scottsburg, Randolph, and Roanoke Creek basins along these faults may be erosional remnants of a formerly much larger rift basin, as previously discussed.

Mineral Resources

Mineral resources that show current or past production in the South Boston map area include crushed stone, tungsten, and copper. Crushed stone, for use in construction, is produced at the South Boston quarry (Salem Stone Corporation at Halifax, Va.) and at the Mecklenburg quarry (Vulcan Materials Company, west of South Hill, Va.).

The Hamme tungsten district straddles the state border between Virginia and North Carolina in the southern part of the map area. This district includes the Tungsten Queen mine in Vance County, N.C., which produced 7,200 metric tons of tungsten intermittently from 1943 to 1971 (Casadevall and Rye, 1980). The main tungsten mineral, huebnerite, occurs in quartz-huebnerite veins (Mqw) along and near the western margin of the Vance pluton (in unit Zvh). Associated minerals include quartz, pyrite, sphalerite, galena, chalcopyrite, tetrahedrite, and minor amounts of scheelite, fluorite, sericite, and carbonate (Espenshade, 1947; Parker, 1963; Casadevall and Rye, 1980; Foose and others, 1980, 1981; Chaumba and others, 2015). Additional information pertaining to the Hamme tungsten district and Tungsten Queen mine is available in Gair and Windolph (1975) and Gair (1977, 1981).

The Virgilina copper district was a source of copper in the late 1800s and early 1900s when about 750,000 pounds of copper were produced from four mines in Virginia (Laney, 1917; Sweet, 1976). The Virgilina and Aaron Formations in and near the Virgilina copper district are potential hosts for copper-gold deposits in quartz veins that contain subsidiary calcite, sericite, hematite, and sulfide minerals (Kish and Stein, 1989; Peper and others, 1996; Peper and Wygant, 1997). Studies by Lesure and others (1992) and Lesure (1993) indicate that mafic rocks host copper-rich veins whereas more felsic rocks host copper-gold veins. Copper and gold occur in the sulfide minerals bornite, chalcocite, and chalcopyrite. Kish and Stein (1989) reported a Rb-Sr whole-rock age of 340±6 Ma for the copper-bearing vein deposits and interpreted this age as evidence for a metasomatic origin.

Water Resources

This map area has surface water resources in the form of rivers, tributaries, and reservoirs, notably the John H. Kerr Reservoir and Lake Gaston. Groundwater resources are typical of the Piedmont regional aquifer system (Nelms and others, 2016), where much of the groundwater storage is in saprolite regolith. Groundwater in crystalline rocks mainly flows in the regolith and along bedrock fractures and joints; groundwater in the Mesozoic basins mainly flows along fractures, joints, and bedding plane partings (Nelms and others, 2016). The relation of groundwater resources to bedrock geology in the western part of the map area is discussed by LeGrand (1960), who reported good well-water quality from fracture zones in schists and gneisses and hard, mineralized groundwater from wells in Triassic sedimentary rocks of the Scottsburg basin. Hard groundwater is also typical of wells in greenstone (of the Virgilina Formation), gabbro, and hornblende gneiss in Halifax County, Va. (LeGrand, 1960). Pertinent to agriculture and forestry, the acidity (pH) and acid-rain buffering capacity of soils and surface waters in the map area may be influenced by bedrock types and derived soil compositions (Peper and others, 1995, 2001; Peper and Wygant, 1997; McCartan and others, 1998; Peper and Olinger, 1998).

Description of Map Units

Succession of minerals in composite rock names is in order of increasing abundance, whereas in rock descriptions, minerals are listed in order of decreasing abundance. Terminology for plutonic igneous rocks follows the International Union of Geological Sciences (IUGS) classification (Streckeisen, 1973). Characteristics of geologic map units on airborne magnetic and radiometric surveys are mentioned where particularly noteworthy. Where locations refer to 7.5′ quadrangle names, see the quadrangle index on the map sheet.

Regolith

Saprolite is unconsolidated, decomposed bedrock that forms by isovolumetric chemical weathering. This material retains relict bedrock structure and internal geometry but has soil-like characteristics such as lower strength and cohesion as well as greater compressibility and permeability when compared to the original bedrock (Pavich and others, 1989). Saprolite can be dug with shovel and grades into and contains remnant core stones of less weathered rock. The composition and physical properties of saprolite relate to the underlying bedrock. The areal distribution of saprolite is coincident with underlying bedrock and is not mapped separately. Saprolite is the most widespread subsoil component of the regolith and of the surficial aquifer in the map area. The combined thickness of saprolite and soil approximately equals well-casing depth; it varies locally from 0 to 46 meters (m) and has a mean value of 18 m on western side of map area (LeGrand, 1960, table 9).

Soil types closely relate to underlying bedrock or transported sediments. A review of these materials is beyond the scope of this geologic map. Soil series and individual soil types are delineated by U.S. Department of Agriculture county soil surveys. The following residual soil (QNr) is shown as an exception because it is thick enough to conceal the underlying bedrock and saprolite and is conspicuous on airborne radiometric survey data (U.S. Geological Survey, 1978b).

QNr **Low-potassium residual soil (Holocene to Miocene)**—Very-light-gray, sandy-silty soil rich in subangular quartz, lacking feldspar, and coincident with low-potassium airborne gamma-ray spectrometer survey anomalies. Occurs on interstream divides north of Meherrin River in vicinity of Lunenburg-Brunswick County line. At least 1–2 m thick. Approximately located; not a depositional unit

Unconsolidated Surficial Deposits

af **Artificial fill (Holocene)**—Fill material such as dirt, rubble, riprap, sand, and gravel emplaced for construction of roads, bridges, railroads, and dams

Qal **Alluvium (Holocene)**—Unconsolidated deposits of gravel, sand, silt, and clay on flood plains of creeks and rivers, generally less than 3 m above channel of present-day stream. Contains variable amounts of organic debris in poorly drained areas

Qco **Colluvium (Quaternary)**—Unconsolidated, transported regolith deposits of gravel, sand, and silt on hillslopes and at their bases. Characterized by heterogeneous particle sizes (commonly with angular rock fragments), poor sorting, and little or no stratification; typically less than 3 m thick. Formed by mass-gravity movement with water as a lubricant (Miller and Juilleret, 2020). May include occurrences derived from higher fluvial terrace deposits or former terrace deposits removed by erosion

Fluvial terrace deposits—Sand and gravel on hills and slopes near Roanoke and Dan Rivers. The highest and oldest of these deposits, Nm, is possibly Miocene in age (see below). The other deposits are numbered from highest (oldest) to lowest (youngest) as Np_1, Qp_2, and Qp_3. Np_1 may be equivalent to Yorktown Formation, Qp_2 may be equivalent to Chowan River Formation, and Qp_3 may be equivalent to Bacons Castle Formation of Atlantic Coastal Plain (Weems, 1998). In Roanoke River (reach locally known as Staunton River) drainage, *Skolithos*-bearing cobbles are present in Qp_3 gravels and possibly in older gravels; *Skolithos*-bearing cobbles are not present in the Dan River system

Qp_3 Low-level terrace deposits (Pleistocene)—Light-brown unconsolidated to reddish-orange moderately well consolidated deposits of gravel, sand, and silt on hills and slopes near the Roanoke and Dan Rivers. Partially saprolitized clasts of metamorphic and igneous rocks are locally abundant. Deposited in ancestral channels and floodplains 5–20 m above present-day river levels

Qp_2 Intermediate-level terrace deposits (Pleistocene)—Light-brown unconsolidated to reddish-orange moderately well consolidated deposits of gravel, sand, and silt on hills and slopes near the Roanoke and Dan Rivers. Quartz clasts are predominant over other clast types. Deposited in ancestral channels and floodplains 20–45 m above present-day river levels

Np_1 High-level terrace deposits (Pliocene)—Light-brown unconsolidated to reddish-orange moderately well consolidated deposits of gravel, sand, and silt on hills and slopes near the Roanoke and Dan Rivers. Quartz clasts are predominant over other clast types. Deposited in ancestral channels and floodplains 45–60 m above present-day river levels

Nm Highest-level terrace deposits (upper or middle Miocene)—Light-brown unconsolidated to reddish-brown moderately well consolidated deposits of rounded quartz gravel, sand, and silt. Located on hills and slopes near the Roanoke River and in eastern Charlotte County, Va. These deposits form inverted topography. Saprolitized clasts of metamorphic and igneous rocks are locally abundant; most heavy minerals except zircon have been leached away. Deposited in ancestral channels and floodplains 65–85 m above present-day river levels and at an elevation as much as 186 m above sea level south of Ontario, Va. Possibly correlative with Choptank Formation of Atlantic Coastal Plain (Weems and Edwards, 2007) or with gravels that unconformably overlie the Choptank Formation near Midlothian, Va. (Edwards and others, 2018). Deposits in eastern Charlotte County may be remnant of old Roanoke River (reach locally known as the Staunton River) valley prior to its capture by Dan-Roanoke drainage system

Mesozoic Rift-Related Rocks

Dikes

Jdp **Porphyritic rhyolite and alkali basalt (Early Jurassic)**—Dark-gray to black, aphanitic to porphyritic, locally amygdaloidal intrusive rocks ranging in composition from rhyolite to alkali basalt. Phenocrysts are mainly sanidine and quartz in rhyolite and are mainly plagioclase (labradorite) and clinopyroxene (pigeonite) in alkali basalt. Described by Stoddard and others (1986) and Stoddard (1992) as part of a distinct, geochemically coherent suite of post-metamorphic dikes having mineralogy and textures indicative of high-temperature, shallow crystallization. Sanidine has $^{40}Ar/^{39}Ar$ plateau ages of 196.6±0.7 Ma and 196.3±0.7 Ma (Ganguli and others, 1995). Dikes typically strike 330°–350°, dip steeply, reach a maximum thickness of 10 m, and occur in a north-northwest-trending swarm on the eastern side of the map area near Stones Mill pluton

Diabase (Early Jurassic)—Intrusive dikes of olivine diabase (Jdo), granophyre-bearing quartz diabase and monzodiorite (Jdq), undivided diabase (Jd), and diabase inferred from magnetic anomalies (Jdm). Dikes generally strike northeast to northwest, dip steeply, and range from about 0.5 to 150 m in thickness. Fine-grained basalt chill margins up to 5 centimeters (cm) thick occur locally. Spheroidally weathered residual boulders commonly have a rusty weathering rind. Part of central Atlantic magmatic province (CAMP), for which high-precision $^{40}Ar/^{39}Ar$ mineral ages mostly range from 201.0±1.4 to 198.6±1.1 Ma (2σ) (Jourdan and others, 2009), and high-precision U-Pb zircon ages cluster tightly at 201.274±0.032 Ma to 200.916±0.064 Ma (Blackburn and others, 2013)

Jdo Olivine diabase—Dark-gray to grayish-black, fine- to medium-grained, and massive olivine diabase. Composed mainly of labradorite, augite, and lesser amounts of olivine; contains accessory magnetite, green hornblende, biotite, and traces of chlorite and apatite. Most prevalent from Lake Gaston northward on the eastern side of the map. Generally equivalent to the olivine-spinel bearing group (OSB) of Cummins (1987) and olivine normative (OLN) magma type of Ragland and others (1992)

Jdq Granophyre-bearing quartz diabase and monzodiorite—Dark-gray to medium-gray and pinkish-gray, fine- to coarse-grained, massive diabase and monzodiorite. Composed of labradorite, pigeonite and (or) augite, and granophyre (grayish-pink-weathering intergrowths of potassium feldspar and quartz, also termed micropegmatite or symplectite); contains accessory magnetite, green hornblende, biotite, and traces of chlorite and apatite. Most common in the central part of the map. Generally equivalent to granophyre-bearing (GRB) group of Cummins (1987) and includes high-iron quartz normative (HFQ) magma type of Ragland and others (1992); includes rocks previously described as syenite and diorite (Laney, 1917), hypersthene tonalite (Parker, 1963), and hypersthene diorite (Peper and others, 1996). Large dike at Drakes Branch, Va., and en echelon dikes to the south are medium- to coarse-grained monzodiorite, quartz diorite, and quartz monzodiorite consisting of labradorite laths up to 8 millimeters (mm) in length, granophyric segregations up to 4 mm in length, augite, and bronzite

Jd Diabase, undivided—Dark-gray, commonly rusty weathering, fine- to medium-grained, massive diabase. Lacks petrographic or geochemical data for further characterization

Jdm Diabase inferred from magnetic anomalies—Dikes were mapped on the basis of linear high aero-magnetic anomalies (U.S. Geological Survey, 1978a, 1994b) similar to anomalies characteristic of known diabase dikes in the Southern Appalachian Piedmont

Scottsburg, Randolph, and Roanoke Creek Basins

[Lithofacies are independent of stratigraphic order within the Chatham Group]

Chatham Group (Upper Triassic)—Sedimentary rocks of the Scottsburg, Randolph, and Roanoke Creek basins are assigned to the Chatham Group as used by Weems and Olsen (1997). This map shows conglomerate (₸cm), pebbly sandstone (₸sc), and siltstone and sandstone (₸sis) lithofacies

₸sis Siltstone and sandstone—Grayish-red to yellowish-gray siltstone and fine- to coarse-grained, feldspathic sandstone interbedded and gradational in grain size. Located only in the Scottsburg basin. Well stratified, thinly to thickly bedded, commonly laminated or cross bedded. Has fining-upward and coarsening-upward sequences, and sandstone scour fills in siltstone. Grains are poorly sorted and poorly rounded. Locally bioturbated and locally contains petrified wood, leaf impressions, and fossil fish, ostracodes, bivalves, and conchostracans (Schaeffer and McDonald, 1978; Kreisa, 1980). Interpreted to include deposits of meandering or braided streams, shallow lakes, or deltas. Exposed only in the Scottsburg basin where maximum thickness is about 500 m

₸sc Pebbly sandstone—Grayish-red, arkosic pebbly sandstone containing less abundant interbeds of conglomerate. Pebbles are well rounded. Well stratified, commonly having trough or tabular cross bedding or flat lamination. Fining upward sequences of conglomerate to sandstone are common. Interpreted to have been deposited mostly by braided streams. Occurs in the Scottsburg and Randolph basins as well as in the Roanoke Creek basin north of the map area. Pebbly sandstones reach a maximum thickness of 500 m in the Scottsburg basin, where it disconformably overlies the siltstone and sandstone (₸sis)

₸cm Conglomerate—Grayish-red, poorly sorted, massive to poorly bedded conglomerate. Contains a mix of subrounded to subangular boulders, cobbles, and pebbles derived from nearby metamorphic and igneous rocks in sandy matrix; matrix supported to clast supported. Interpreted to have been deposited on medial to distal alluvial fans by debris flows and flash floods. Occurs in the Scottsburg, Randolph, and Roanoke Creek basins. In the Scottsburg basin, conglomerates reach a maximum thickness of 400 m near the western border fault

Miscellaneous Veins

q **Quartz vein**—White to very-light-gray, fine- to medium-grained, crystalline veins consisting mainly of quartz. Includes veins of massive, undeformed, and unmetamorphosed quartz of probable late Paleozoic to early Mesozoic age. Also includes veins of foliated, recrystallized quartz of probable late Paleozoic or older age. Vein thicknesses rarely exceed 3 m (Kreisa, 1980)

Mqw **Quartz-huebnerite vein (Mississippian?)**—Fine-grained, granular quartz veins with minor sericitic muscovite and accessory minerals including huebnerite. The veins have a banded texture; bands that pinch and swell are defined by muscovite concentrations and lenticular phyllite inclusions (Foose and others, 1980). Veins crosscut regional foliation. Rubidium-strontium whole-rock age is 340 Ma (Kish and Stein, 1989).

These veins are the principal ore of the Hamme tungsten district. Huebnerite, the main ore mineral, is associated with quartz; sporadic pyrite, sphalerite, galena, chalcopyrite, and tetrahedrite; and minor amounts of fluorite, sericite, and carbonate (Foose and others, 1980). Steeply dipping veins or dikes near the western contact of the Vance pluton (Zvh) formed by open-space fillings of faults or fractures. These veins or dikes were subsequently deformed by at least two episodes of folding and shearing (Foose and others, 1980). The Snead-Walker vein, which hosts the Tungsten Queen deposit at Tungsten in Vance County, N.C., is up to 10 m thick (Foose and others, 1980)

Miscellaneous Fault Rocks

fb **Fault breccia (Cenozoic or Mesozoic?)**—Highly faulted, fractured, non-cohesive, heterogeneous breccia that has angular fragments of adjacent host unit; lacks evidence of metamorphic mineral development or recrystallization. Interpreted to be post-metamorphic, possibly Triassic or younger. One small exposure on north shore of John H. Kerr Reservoir

JTRsb **Quartz cataclasite and silicified microbreccia (Jurassic or Triassic?)**—Very light gray, very fine grained, flinty quartz rock that has crisscrossing quartz-filled fractures and faults. Extensional fractures are locally coated by terminated quartz crystals. Similarity to cataclastic rocks along border faults of early Mesozoic basins suggests Triassic or Jurassic age. Includes silicified breccia of Parker (1963)

PMpu **Phyllonite and ultramylonite of Clover shear zone (Permian to Mississippian)**—Yellowish-gray, chlorite-bearing white-mica phyllonite and phyllonitic schist, and lesser amounts of intercalated very light gray, very fine grained, laminated ultramylonite. Derived from adjacent metasedimentary and metavolcanic rocks of Hyco and Aaron Formations. Predominantly very fine grained and commonly contains fabric elements such as lensoid white-mica “button” or “fish scale” aggregates, undulatory schistosity, secondary shear bands, and thin quartz ribbons

PMps **Phyllonitic white-mica schist (Permian to Mississippian)**—Very-light-gray to yellowish-gray, typically very fine to fine-grained phyllonitic schist of Lake Gordon and Nutbush Creek mylonite zones. Composed mainly of white mica and quartz, has minor biotite and chlorite, and has local accessory garnet and opaque minerals. Common fabric elements include lensoid white-mica “button” or “fish scale” aggregates, undulatory schistosity, secondary shear bands, and thin quartz ribbons. Includes chlorite-white mica phyllonite, mylonite, and ultramylonite unit (€Zvbm) of Blake and others (2010), which contains microlithons of highly strained, recrystallized, and altered granitoid from adjacent Vance pluton

PMmgs **Mylonitic gneiss and schist (Permian to Mississippian)**—Variably mylonitic gneiss and phyllonitic white-mica schist of Lake Gordon mylonite zone. Commonly contains minor chlorite. Common fabric elements include asymmetric augen, shear bands, and quartz ribbons. Derived from and gradational into adjacent gneiss units

Late Paleozoic Intrusive Rocks

PIPw **Muscovite-biotite granite of Wise pluton (Permian to Pennsylvanian)**—Medium-gray and light-gray, medium-grained, massive to foliated muscovite-biotite granite composed of microcline, plagioclase, quartz, biotite, and muscovite. Locally, plagioclase is more abundant than microcline. Microcline phenocrysts occur locally and reach a maximum length of 1.5 cm. Small masses of leucogranite consist of microcline, plagioclase, and quartz with minor muscovite and garnet (Sacks, 1996a). Outcrop- to map-scale xenoliths of metamorphic rocks occur sporadically throughout the pluton

PIPsh **Muscovite-biotite granite of South Hill pluton (Permian to Pennsylvanian)**—Medium-gray, medium-grained, massive to foliated muscovite-biotite granite composed of plagioclase, microcline, quartz, biotite, and muscovite, with accessory garnet (Sacks, 1996a, b)

PIPsm **Biotite-muscovite granite of Stones Mill pluton (Permian to Pennsylvanian)**—Medium-gray to light-gray, medium- to coarse-grained, foliated biotite-muscovite granite composed mainly of microcline, plagioclase, quartz, muscovite, and biotite, with accessory garnet. Equivalent to Stones Mill granite (informal name) of Meador (1949)

PIPgr **Biotite granite (Permian to Pennsylvanian)**—Medium-gray, medium-grained, massive to foliated biotite granite composed of microcline, plagioclase, quartz, biotite, and muscovite (Sacks, 1996a, b)

PIPgm **Mylonitic granite (Permian to Pennsylvanian)**—Medium-gray, medium-grained, foliated muscovite-biotite granite composed of plagioclase, microcline, quartz, biotite, and muscovite; variably mylonitic to non-mylonitic and commonly lineated in the Lake Gordon mylonite zone (Sacks, 1996a). Equivalent to unit PℙPgm of Sacks (1996a) and unit Pg2 of Blake and others (2010)

PℙgI **Lineated muscovite-biotite metagranite (Permian to Pennsylvanian)**—Medium-gray to light-gray, medium- to coarse-grained, lineated muscovite-biotite metagranite or granitic gneiss composed mainly of microcline, plagioclase, quartz, muscovite, and biotite. Ranges from biotite rich (medium gray) to leucocratic (light gray). Characterized by strong, subhorizontal mineral elongation lineation (L-tectonite having lineation more conspicuous than foliation). A sample from The Falls on the Nottoway River, 7 kilometers (km) north of the map area, yielded a preliminary U-Pb TIMS zircon age of about 315–295 Ma (Horton and others, 1995)

ℙgmg **Granitic mylonitic gneiss (Pennsylvanian?)**—Mostly fine- to medium-grained, well foliated and lineated, granitic mylonitic gneiss south of Buggs Island pluton. Composed of mylonitic granitic gneiss and interlayered muscovite-biotite-quartz-feldspar gneiss with sporadic interlayers of muscovite-biotite schist (locally containing fibrolitic sillimanite), biotite-amphibole gneiss, and amphibolite. Compositional layering is parallel to mylonitic foliation. Mylonitic muscovite-biotite granitic gneiss layers are mostly white to medium gray, commonly leucocratic, and vary in muscovite and biotite content, grain size, abundance of potassium feldspar porphyroclasts, and pegmatite concentrations. Muscovite-biotite-quartz-feldspar gneiss layers are darker gray, fine to medium grained, and typically range in thickness from centimeters to meters. Biotite enrichment of granitic gneiss is common in proximity to mica-rich schist and gneiss interlayers (Blake and others, 2011). Mapped as foliated granitic mylonitic gneiss (Pg_1) by Blake and others (2010). Characterized by high radiometric potassium anomalies (U.S. Geological Survey, 1994a; Horton and Daniels, 1999, fig. 1*B*)

ℙbmg **Biotite-muscovite granodiorite (Pennsylvanian)**—Medium-gray, fine-grained, massive biotite-muscovite granodiorite composed of plagioclase, quartz, potassium feldspar (0–15 percent), biotite, and muscovite (Burton, 1995b). Occurs as narrow northeast-trending unmetamorphosed dikes (1–5 m wide) that cut cleaved metamorphic host rock. $^{40}Ar/^{39}Ar$ ages of igneous biotite and muscovite from a post-cleavage dike suggest emplacement about 305 Ma (Burton and others, 2000). Shown as narrow linear polygons as well as dike symbols

ℙbim **Mylonitic granite of Buggs Island pluton (Pennsylvanian)**—Light-gray, medium- to coarse-grained, variably mylonitic to strongly foliated and lineated, muscovite-biotite granite of Buggs Island pluton. Major minerals are perthitic microcline, plagioclase, quartz, and biotite; secondary epidote and chlorite are common. Mylonitic equivalent of unit ℙbi

ℙbi **Granite of Buggs Island pluton (Pennsylvanian)**—Light-gray and buff-weathering, medium- to coarse-grained, massive to strongly foliated and commonly lineated muscovite-biotite granite. Composed of pink perthitic microcline, plagioclase, quartz, biotite, accessory muscovite, and local garnet. Secondary chlorite and epidote are common near the contacts. Characterized by high radiometric potassium anomalies (U.S. Geological Survey, 1994a; Horton and Daniels, 1999, fig. 1*B*). Contains fine-grained, biotite-muscovite-quartz-rich xenoliths and veins of aplitic pegmatite and quartz. Local patches of coarse- and fine-grained granodiorite occur on the western side of the pluton. Preliminary U-Pb TIMS zircon age is about 315–295 Ma (Horton and others, 1995) and Rb-Sr whole-rock age is 313±8 Ma (Kish and Fullagar, 1978)

PMg **Muscovite-biotite granite (Permian to Late Mississippian)**—Very-light-gray to white, medium-grained, weakly foliated to massive muscovite-biotite granite. Contains 3–10 percent muscovite and 3–5 percent dark-green biotite. Small phacolith exposed in wave-cut cliff on peninsula in John H. Kerr Reservoir, south of Panhandle Creek in the Clarksville South 7.5′ quadrangle (see quadrangle index on map sheet). Mapped as PMg by Peper and others (1996)

ℙMgf **Biotite granite of Farmers Lake (Pennsylvanian to Mississippian)**—Grayish-white to pinkish-gray, fine- to medium-grained, weakly to moderately well foliated biotite granite. Composed of microcline (30–45 percent), quartz (10–25 percent), plagioclase (5–15 percent), biotite (15–20 percent), and muscovite (2–5 percent). Weakly foliated rocks have “salt and pepper” appearance (Bradley, 1996). Equivalent to Farmers Lake granite (informal name) of Shell (1996) which yielded a U-Pb TIMS zircon age of 319.6±0.7 Ma (Wortman and others, 1998). Equivalent to map units Mfgr of Henika (2002) and Pflg of Hibbard and Bradley (2017)

ℙMgh **Hornblende granite (Pennsylvanian to Mississippian)**—Pinkish-gray to light-gray, mostly medium-grained, foliated hornblende monzogranite. Composed of grayish-pink to white microcline (30–50 percent), plagioclase (25–35 percent), quartz (25–35 percent), and dark-greenish-gray hornblende (5–10 percent). Hornblende is green in thin section. Granite occurs as northeast-striking dikes along and parallel to linear segments of Roanoke Creek and Twittys Creek between Randolph and Mossingford in Saxe 7.5′ quadrangle (see quadrangle index on map sheet). Interpreted to intrude the metagranite of Saxe (ⲢMgn). Mapped and described as a granite dike by Laney (1917)

ⲢMgn **Metagranite of Saxe (Pennsylvanian to Mississippian)**—Pinkish-gray to white and very-light-gray, fine- to coarse-grained, variably foliated and layered, gneissic leucogranite and muscovite-biotite granite. Composed mainly of plagioclase, quartz, and grayish-pink to white potassium feldspar; white mica and biotite are common minor constituents; accessory hornblende is sparse. Thin to thick layers parallel to foliation include fine- to medium-grained leucocratic felsic granofels alternating with and grading into medium- to coarse-grained leucogranite; thin, dark-gray, biotite-rich layers occur locally. Grayish-pink, medium- to coarse-grained potassium-feldspar augen (lenticular symmetric to asymmetric megacrysts) are concentrated in layers. Rock is flaggy to friable, less commonly laminated or mylonitic, and locally has subhorizontal quartz-feldspar mineral-elongation lineation. Foliated leucocratic pegmatite typically contains grayish-pink potassium feldspar, composes as much as 10 percent of most outcrops, and occurs both as concordant sheets and crosscutting irregular pods (which are locally folded and dismembered by boudinage). Unit includes lesser amounts of layered, medium-grained, non-leucocratic, gneissic biotite granite composed of alternating dark-gray biotite-rich layers and very-light-gray quartz-feldspar layers. Quartz ribbons and concordant, strongly foliated quartz veins are present near Roanoke Creek basin. Elongate, tabular sheets within and adjacent to layered gneiss of South Boston (Zclg) are semi-concordant with foliation. Not isotopically dated; tentative Mississippian to Pennsylvanian age designation is inferred from range of 335–320 Ma (Wortman and others, 1998) for early to late synkinematic granites in Hyco shear zone about 32 km southwest of the map area. Here informally named for exposures in vicinity of Saxe, Charlotte County, Va. (Saxe 7.5′ quadrangle). Previously mapped and described as Tanyard Branch granitic gneiss (informal name of Baird [1989]) and granitic gneiss (Baird, 1991)

Mgy **Gneissic biotite granite (Mississippian?)**—Very-light-gray, medium- to coarse-grained, well-foliated, polydeformed gneissic biotite granite. Similar to Yanceyville granite gneiss (informal name of Shell [1996]) 32 km southwest of the map area, which yielded a U-Pb TIMS zircon age of 335.4±2.2 Ma (Wortman and others, 1998). Includes biotite granite orthogneiss previously interpreted as Neoproterozoic (Hibbard and others, 1998, fig. 2) or Neoproterozoic to Mississippian (Hibbard and Bradley, 2017)

Raleigh Terrane

[The Raleigh terrane as used in Stoddard and others (1991), Sacks (1996a, b, 1999), Blake and others (2010), and Horton and others (2016); includes part of the Warren terrane as distinguished by Blake and others (2012) in North Carolina]

Intrusive Rocks

DSto **Biotite metatonalite (Devonian to Silurian)**—Very-light-gray to light-gray, fine- to coarse-grained, well-foliated biotite metatonalite. Composed mostly of plagioclase, quartz, biotite, and alkali feldspar; local accessory garnets up to 2 mm in diameter. Locally contains feldspar megacrysts up to 4×1 cm subparallel to biotite foliation. Part of a suite of metamorphosed tonalitic to granitic plutonic rocks of the Raleigh terrane and Central Piedmont that have U-Pb TIMS zircon ages of about 425–380 Ma (Horton and others, 1995). Occurs as small plutons in eastern Lunenburg County and western Brunswick County, Va. Age constraints are consistent with laser ablation inductively coupled plasma mass spectrometry (LA-ICP-MS) U-Pb zircon ages of 403.2±3.2 Ma (Finnerty and others, 2019) for a quartz diorite gneiss and 410.5±3.7 Ma (Peach and others, 2017) for an orthogneiss south of the map area. There, this unit may correspond to a unit informally described as Possumquarter biotite tonalite, quartz diorite, and diorite (Blake and others, 2018) or Possumquarter biotite meta-monzodiorite to monzodiorite gneiss (Blake and others, 2020)

DShd **Hornblende metadiorite (Devonian to Silurian?)**—Light-gray to medium-gray, fine- to coarse-grained, variably foliated metadiorite; plagioclase rich and contains xenoliths of adjacent gneiss. Age inferred through possible correlation of unit DSto

Pzmg **Muscovite granite (Paleozoic?)**—Light-gray to light-grayish-tan, coarse- to medium-grained, well-foliated to massive muscovite granite composed of microcline, plagioclase, quartz, muscovite, and variable amounts of biotite and garnet; margins are typically pegmatitic or very coarse grained and contain xenoliths of country rock (Sacks, 1996a, b). The unit may correspond, at least in part, to the informally named unit Liberia granodiorite to granitic gneiss (Blake and others, 2018) or Liberia granodiorite and granodiorite gneiss (Blake and others, 2020) south of the map area, for which LA-ICP-MS U-Pb zircon ages of about 2,108–314 Ma from granitic gneiss migmatite are consistent with Mesoproterozoic inheritance and Pennsylvanian migmatization

Pzgrb **Biotite metagranite (Paleozoic?)**—Medium-gray, medium-grained, well-foliated biotite metagranite composed of quartz, plagioclase, microcline, and biotite, with minor muscovite (Sacks, 1996b). Age undetermined

Pzgg **Gneissic metagranitoid east of Kenbridge (Paleozoic?)**—Very-light-gray to medium-gray, fine- to coarse-grained, well-foliated, metamorphosed granite, leucogranite, and granodiorite east of Kenbridge, Va. Composed of plagioclase, quartz, potassium feldspar, and minor biotite and muscovite. Accessory minerals include garnet and epidote. Locally contains potassium feldspar megacrysts. Locally mylonitic and lineated near Lake Gordon mylonite zone. Age undetermined

Zt **Talc schist and soapstone (Neoproterozoic?)**—Light-grayish-green, green or dark-green, fine- to medium-grained, foliated to massive talc schist, soapstone, and talc-actinolite schist. Composed of talc, serpentine, actinolite, chlorite, and sparse granules of black, rusty-weathering oxides. A massive talc-serpentine-actinolite rock, exposed south of Lake Gaston at western edge of the South Hill SE 7.5′ quadrangle (see quadrangle index on map sheet), contains pseudomorphs of olivine-clinopyroxene-orthopyroxene websterite (Sacks, 1996b). Occurs as altered ultramafic rock emplaced into the metamorphic suite of South Hill

Layered and Stratified Rocks

[Stratigraphic order undetermined]

€Zbg **Biotite-quartz-plagioclase gneiss (Cambrian or Neoproterozoic?)**—Medium-light-gray to medium-dark-gray, medium- to coarse-grained, well-layered biotite-quartz-plagioclase gneiss; locally contains potassium feldspar augen. Contains concordant minor interlayers of clinopyroxene-hornblende-quartz-plagioclase gneiss, foliated biotite metagranite, and pegmatite. Occurs on the western flank of the Raleigh terrane as a tectonic slice between the dextral Lake Gordon mylonite zone to the west, a dextral splay of the Lake Gordon mylonite zone to the east, and gneissic metagranitoid (Pzgg) to the north. Relation of this fault-bounded unit to the metamorphic suite of South Hill is undetermined

Metamorphic suite of South Hill (Neoproterozoic?)—Suite of gneisses and schists here informally named for exposures near the town of South Hill in Mecklenburg County, Va. Includes units Zrsg, Zrq, Zrmn, Zrbmg, Zrss, Zrag, Zrms, Zrhg, Zrbgm, and Zrbg. These rocks in south-central Virginia and northern North Carolina have been described informally as Raleigh gneiss (for example, Farrar, 1985a, b; Owens and Buchwaldt, 2009) but are excluded from Raleigh gneiss in the restrictive sense as used by Blake and others (2012). Neoproterozoic age is based on a U-Pb TIMS zircon age of 560±2 Ma (Owens and Buchwaldt, 2009) for biotite-quartz-feldspar gneiss of Union Mill (Zrbg). A LA-ICP-MS U-Pb zircon age of 410.5±3.7 Ma (Peach and others, 2017; Finnerty and others, 2019) for orthogneiss (informally named Afton gneiss of Peach and others [2017] or Parktown gneiss of Blake and others [2018]) south of the map area suggests that gneissic interlayers (possibly transposed dikes or sheets) of Early Devonian meta-igneous rock may be present

Zrbg Biotite-quartz-feldspar gneiss of Union Mill—Medium-gray to greenish-gray to yellowish-gray, mostly fine- to medium-grained, strongly layered biotite-quartz-feldspar gneiss and muscovite-biotite gneiss. Composed of quartz, plagioclase, biotite, and minor muscovite and garnet. Thin layers of light-gray mica schist are composed of quartz, muscovite, biotite, plagioclase, sillimanite, and minor garnet. Layers of microcline-biotite gneiss are composed of quartz, biotite, microcline, plagioclase, muscovite, and minor garnet. Dark grayish-green hornblende gneiss layers are composed of plagioclase, hornblende, quartz, biotite, and minor clinopyroxene and epidote; locally, biotite is partly replaced by chlorite and sillimanite is replaced by chloritoid.

Discontinuous foliation-parallel layers and lenses of white, leucocratic granitoid are common in the biotite-quartz-feldspar gneiss of Union Mill. Whole-rock chemical compositions of rocks from this unit that were previously described as Raleigh gneiss are consistent with dacitic (or possibly graywacke) protoliths of a volcanic-arc setting (Cheek and Owens, 2007; Muller and Owens, 2020).

A metadacite from the biotite-quartz-feldspar gneiss of Union Mill yielded a Neoproterozoic U-Pb TIMS zircon age of 560±2 Ma (lower concordia intercept), which is interpreted as the crystallization age; the upper concordia intercept indicated inheritance from Mesoproterozoic continental crust (Owens and Buchwaldt, 2009). The 560±2 Ma age appears to be more precise and reliable than previous U-Pb TIMS zircon ages of ~546–461 Ma (Goldberg, 1994) and ~544 Ma (Horton and Stern, 1994) from other rocks described as Raleigh gneiss near Raleigh, N.C.

Biotite-quartz-feldspar gneiss of Union Mill, as used here informally, includes exposures at Union Mill bridge over the Meherrin River (Farrar and Owens, 2001, stop 10; Owens and Bailey, 2018, stop 6) in the Forksville 7.5′ quadrangle (see quadrangle index on map sheet). This unit corresponds to Union Mill gneiss (informal name) of Farrar and Owens (2001), to biotite gneiss (bg) of Sacks (1996a, b), and to mixed gneisses and meta-intrusive rocks (ZPmi) of Blake and others (2010)

Zrbgm Mylonitic biotite-quartz-feldspar gneiss of Union Mill—Medium-gray to greenish-gray to yellowish-gray, mostly fine- to medium-grained, layered, variably mylonitic equivalent of unit Zrbg ranging from strongly foliated gneiss and mylonitic gneiss to protomylonite and mylonite. Composed largely of quartz, plagioclase, biotite, and muscovite. Thinly banded or horizontally lineated in places. Sporadic feldspar porphyroblasts are variably flattened, strung out, or asymmetric. Anastomosing interlayers and lenses of phyllonitic schist have wavy foliation and dextral shear bands

Zrhg Hornblende-biotite gneiss—Dark-grayish-green, medium- to coarse-grained, layered hornblende-biotite gneiss composed of plagioclase, biotite, hornblende, and quartz, with minor chlorite and epidote. Contains interlayers of brown biotite gneiss and tan muscovite-biotite gneiss composed of plagioclase, quartz, biotite, and variable amounts of muscovite; interlayers also consist of minor dark-brown or greenish-brown biotite schist. Locally contains thin layers of sooty, black-weathering manganiferous schist and gneiss (Zrmn). Occurs near Bracey, Va., and mapped by Sacks (1996a, b) as amphibole-biotite gneiss. Unit is contiguous with rocks mapped south of the map area by Finnerty (2020) as Parktown gneiss (informal name of Blake and others [2018])

Zrms Muscovite schist and biotite-muscovite schist—Silvery-gray, medium-grained schist composed of muscovite, quartz, plagioclase, biotite, sillimanite, and minor garnet; muscovite is typically more abundant than biotite. Portions of unit correspond to white-mica-rich schist (ZPwms) and biotite schist (ZPbs) units of Blake and others (2010). Equivalent to unit bs of Sacks (1996a)

Zrag Augen-biotite gneiss—Medium-gray, medium- to coarse-grained, well-foliated, porphyroblastic gneiss. Composed of microcline, plagioclase, biotite, and quartz, with minor titanite and zircon; some microcline occurs as porphyroblasts up to 5 mm in length. Equivalent to unit abg of Sacks (1996a, b)

Zrss Sillimanite-mica schist of Great Creek—Silvery-gray to greenish-gray, medium- to coarse-grained, pelitic sillimanite-mica schist. Composed of white mica, sillimanite, quartz, chloritoid, and minor plagioclase; contains accessory garnet, biotite, chlorite, and locally black tourmaline. Sillimanite (and pseudomorphs after sillimanite) occurs as fibrous masses and as coarse prismatic crystals and aggregates up to 4 cm in length. Sillimanite is commonly replaced by chloritoid and white mica and some biotite is replaced by chlorite. Contains minor layers and lenses of muscovite-biotite-microcline-quartz-plagioclase gneiss as well as sparse thin layers and lenses of black tourmaline-quartz rock and garnet-quartz rock. Upper amphibolite-facies garnet-sillimanite-potassium-feldspar metamorphic assemblages are overprinted by greenschist-facies muscovite-chlorite assemblages. Here informally named for exposures in vicinity of Great Creek north of Lake Gaston in Mecklenburg County, Va. (South Hill SE 7.5′ quadrangle). Schist is well exposed in vicinity of Great Creek and Lake Gaston. Equivalent to sillimanite-mica schist (ms) unit of Sacks (1996a, b, c). Appears to correspond to informally named Mill Branch schist (Blake and others, 2018, 2020) south of the map area, where zircon age populations suggest complex mixtures of Mesoproterozoic to Neoproterozoic detrital grains, Paleozoic metamorphic grains, grains from Paleozoic granitic veins, and possibly mixed-age zoned crystals or polycrystalline grains

Zrbmg Biotite-muscovite gneiss—Medium-gray, fine- to medium-grained, biotite-muscovite-quartz-feldspar gneiss that has gneissic foliation and parallel compositional layering. Some two-mica gneiss layers have more muscovite than biotite, while other layers have more biotite than muscovite. Feldspar is mostly plagioclase; potassium feldspar porphyroblasts and traces of sillimanite are locally present. Unit is interlayered with Zrss and locally contains subordinate interlayers of biotite-muscovite schist or granitoid gneiss

Zrmn Manganiferous schist and gneiss—Sooty, black-weathering, fine- to medium-grained schist and gneiss. The manganiferous schist is composed largely of biotite, quartz, and garnet. The manganiferous gneiss is composed predominantly of garnet, with quartz, hornblende, and opaque minerals. Occurs as thin layers in other units. Equivalent to unit mn of Sacks (1996b)

Zrq Quartzite—White, medium-grained, sugary-textured quartzite. Occurs as a layer about 1 m thick within biotite-muscovite gneiss (Zrbmg) near contact with sillimanite-mica schist of Great Creek (Zrss) in northeast part of La Crosse 7.5′ quadrangle (see quadrangle index on map sheet). Thickness of unit is exaggerated on map

Zrsg Biotite-muscovite schist and gneiss—Medium-light-gray to greenish-gray, fine- to medium-grained, interlayered two-mica schist (locally containing chlorite) and biotite-muscovite-quartz-feldspar gneiss (locally containing feldspar porphyroblasts). Includes minor interlayers of sillimanite-mica schist and muscovite-quartz schist, sparse talc schist and soapstone, and rare gondite (manganiferous garnet + quartz) having dark-brown manganese oxide weathering. Exposed at eastern edge of map area in the La Crosse and Forksville 7.5′ quadrangles (see quadrangle index on map sheet)

Carolina Slate Belt of Carolina Terrane (Mainly Greenschist Facies)

Intrusive Rocks

Mro **Granite of Red Oak (Mississippian)**—Granite to granodiorite in a large pluton that extends north and west of Red Oak in Charlotte County, Va. Southeast of U.S. Highway 15, white- to light-gray weathering, medium- to coarse-grained, strongly foliated muscovite-biotite granodiorite and granite. Contains numerous small inclusions of slate and felsic to mafic metavolcaniclastic rocks as well as mapped lenses of felsic crystal metatuff (Zhc) and greenstone (Zvg). Northwest of U.S. Highway 15, white- to light-gray-weathering, coarse- to very coarse grained (4–6 mm), weakly foliated to massive biotite-muscovite granodiorite; is mostly free of inclusions. The pluton is locally mylonitic along northwestern flank. Preliminary U-Pb zircon age is 354±3 Ma (Horton and others, 1999). The granite of Red Oak, as here used informally, was first mapped and described by Laney (1917) as Redoak granite, but the town for which it was informally named is spelled “Red Oak”

Db **Buffalo granite (Devonian)**—Light-gray, very coarse grained, strongly to weakly foliated, porphyritic biotite granodiorite. Composition ranges to monzogranite, quartz monzonite, and hornblende granodiorite. Dominant foliation is magmatic flow foliation, generally parallel to margins of circular pluton and to abundant tabular inclusions of Hyco Formation felsic and mafic metatuffs (including Zhf, Zhc, Zhd, and Zhb) present within many exposures. Granodiorite contains rectangular phenocrysts and aggregates of potassium feldspar (2–4 cm in length) in a groundmass of gray quartz crystals (about 4 mm in length) and rounded and tabular plagioclase and potassium feldspar grains (6–10 mm in length). Also contains 5–7 percent dark-green biotite (in books as much as 8 mm in length) and 0–2 percent hornblende. Contains 30- to 60-cm-thick dikes of fine-grained biotite aplite. Deeply saprolitized and poorly exposed; weathers to sandy soil containing residual feldspar phenocrysts. Informally named and described as Buffalo granite in the Buffalo-Lithia Springs area by Laney (1917, p. 36). Preliminary U-Pb TIMS zircon age is 367±6 Ma (Horton and others, 1999). Buffalo granite dikes crosscut the Abbeyville metagabbro (Zm)

Pzq **Pink quartz monzonite dikes (Paleozoic)**—Pink-weathering, medium-grained, equigranular, weakly foliated to non-foliated biotite quartz monzonite. Contains distinctive gray quartz grains (4–6 mm in length), pink feldspar, and biotite (3–5 percent). Found as dikes cutting Buffalo granite (Db), metagranite of Orgainsville (Zbg), and layered volcaniclastic rocks (Zhc, Zhf, Zhl)

PzZgl **Lineated leucogranite gneiss (Paleozoic or Neoproterozoic?)**—Very-light-gray, fine- to coarse-grained, commonly lineated and foliated, variably mylonitic to protomylonitic to non-mylonitic leucogranite gneiss. Occurs in Nutbush Creek mylonite zone along western flank of Buggs Island pluton; age and relation to Buggs Island and North View plutons is undetermined. Described as foliated felsic gneiss (€Zfgf) by Blake and others (2010), who noted that mylonitic fabric obscures protolith relations

PzZgd **Biotite granodiorite (Paleozoic or Neoproterozoic)**—White to pinkish-white, gray to white to orange-gray weathering, medium- to fine-grained, massive biotite granodiorite. Contains subequal amounts of quartz, plagioclase, non-perthitic microcline, and minor (less than 10 percent) biotite, sericite, epidote, and chlorite. Equivalent to unit gd of Burton (1993, 1995b)

Zbgr **Biotite granite (Neoproterozoic)**—Light-gray to medium-gray, gray- to pink- weathering, fine- to medium-grained, massive biotite granite and locally biotite leucogranite. Composed of microcline (25–35 percent), plagioclase, quartz, and biotite. Microcline locally occurs as megacrysts. A U-Pb TIMS zircon age is 568±3 Ma (Horton and others, 1999). Equivalent to unit bg of Burton (1995b)

Zgh **Hornblende gabbro (Neoproterozoic)**—Includes plutons at Eastland Creek, Beaver Pond Creek, and Spewmarrow Creek, as well as smaller bodies, all of which occur in the south-central part of the map area (Boydton, Clarksville South, and Tungsten 7.5′ quadrangles; see quadrangle index on map sheet).

The pluton at Eastland Creek consists of medium-gray to dark-gray, medium- to coarse-grained hornblende-labradorite gabbro and local clinopyroxene-rich hornblende gabbro. Both rock types contain secondary epidote, sericite, and chlorite. Locally cut by bodies of melanocratic medium-grained hornblende quartz diorite and dikes of leucocratic hornblende quartz diorite. Contains numerous greenstone inclusions.

The pluton at Beaver Pond Creek consists of dark-gray, very coarse to coarse-grained hornblende gabbro and hornblende-clinopyroxene gabbro. Both rock types contain deuteric epidote, sericite, and chlorite. Cut by dikes of medium-gray, medium-grained hornblende diorite and light-gray leucocratic hornblende quartz diorite; has inclusions of fissile felsite, phyllite, and quartz porphyry. Hadley (1973, 1974) described augite, minor olivine, and brown hornblende replacing diopsidic pyroxene.

The pluton at Spewmarrow Creek consists of dark-gray to black, medium- to coarse-grained hornblende-clinopyroxene-calcic-plagioclase gabbro. Locally contains minor olivine and brown hornblende replacing diopsidic pyroxene. Igneous hornblendes from the Beaver Pond Creek and Spewmarrow Creek gabbro bodies in the Clarksville South 7.5′ quadrangle (Peper and others, 1996) have complex $^{40}Ar/^{39}Ar$ age spectra that show maximum ages of cooling through closure of about 600 Ma and 586 Ma, respectively (Kunk and others, 1995).

Smaller gabbro bodies in the Boydton 7.5′ quadrangle (0.5 km north of Skipwith and 0.4 km north of Liberty Church) are mostly dark-gray to black, coarse- to medium-grained clinopyroxene-hornblende-calcic-plagioclase gabbro to melanocratic hornblende quartz diorite

Vance pluton (Neoproterozoic)—This pluton, also called the Vance County pluton (Casadevall and Rye, 1980), consists of metamorphosed granitoid units Zvh, Zvto, Zvb, and Zvbm

Zvbm Mylonitic biotite granodiorite to quartz monzonite—Very-light-gray to medium-gray, medium- to coarse-grained, well-foliated, mylonitic granodiorite, leucogranite, and quartz monzonite. Mylonitic equivalent of Zvb in Nutbush Creek mylonite zone

Zvb Metamorphosed biotite granodiorite to leucogranite and quartz monzonite—Very-light-gray to medium-gray, light-gray to tan weathering, medium- to coarse-grained, strongly to weakly foliated, undifferentiated granitoids including biotite granodiorite, leucogranite, and quartz monzonite. Biotite content is typically 3–7 percent. Commonly equigranular to subporphyritic, but locally pegmatitic. Calcic plagioclase has relict zoning and is altered to albite, epidote, and sericite. Similar rock crosscuts hornblende metagranodiorite (Zvh) as dikes 0.5–3.0 m thick. A U-Pb TIMS zircon age is 571±17 Ma (LeHuray, 1989). Includes biotite metagranodiorite to quartz monzonite (€Zbm) of Peper and others (1996) and porphyritic granite (€Zvpg) of Blake and others (2010)

Zvto Metamorphosed biotite-hornblende tonalite—Very-light-gray, medium-grained metatonalite composed mainly of plagioclase, quartz, hornblende, and biotite. Occurs as relatively small bodies distinguished from surrounding granitoids, especially within metamorphosed hornblende granodiorite (Zvh)

Zvh Metamorphosed hornblende granodiorite to quartz diorite to quartz monzonite—Light-gray to brown weathering, very coarse to coarse-grained, locally pegmatitic, equigranular to subporphyritic metagranitoids. Contains hornblende (5–10 percent) and biotite (3–7 percent) in clots and patches 6 mm to 1 cm in length. Also contains gray quartz crystals 4–6 mm in length. Relict concentric zoning is visible in altered calcic plagioclase (albite, epidote, and sericite). Outcrops have a spotted appearance due to patchy clusters of mafic minerals as well as small rounded inclusions of fine-grained biotite-rich quartz diorite (1 cm to as much as 1 m in length). Mica-rich palimpsests of phyllite, folded inclusions of felsite and greenstone, and pods (autoliths?) of hornblende diorite are common. Described as albite granodiorite by Parker (1963), who reported as much as 20 percent potassium feldspar in matrix. Also corresponds to hornblende metagranodiorite to quartz monzonite (€Zhm) of Peper and others (1996) and tonalite (€Zvt) of Blake and others (2010)

Zbg **Metagranite of Orgainsville (Neoproterozoic)**—Light-gray to white-weathering, medium- to fine-grained, mostly strongly foliated muscovite-biotite monzogranite, ranging to granodiorite, quartz monzonite, and tonalite. Equigranular to subporphyritic. Consists of approximately equal amounts of flattened gray quartz grains 1–2 mm in length and altered, rounded, anhedral plagioclase and potassium feldspar grains 2–3 mm in length. Biotite content is 3–5 percent and muscovite content is 0–3 percent. Includes septa, lenses, and lobes in contact with Buffalo granite (Db). Contains round inclusions of foliated biotite quartz diorite (Zd) (Peper and Wygant, 1997). Foliation that is locally at high angles to the regional foliation but subparallel to the pluton margins may be magmatic flow structure. Preliminary U-Pb TIMS zircon age is 602±9 Ma (Horton and others, 1999). Here informally named for exposures in vicinity of Orgainsville, Mecklenburg County, Va. (Clarksville North 7.5′ quadrangle; see quadrangle index on map sheet). Equivalent to biotite granite (PzZbg) of Peper and others (1996), unit Zbg of Peper and Wygant (1997), and foliated biotite granodiorite near Clarksville of Horton and others (2016)

Zd **Foliated biotite quartz diorite (Neoproterozoic)**—Medium- to light-gray, medium-grained, mostly strongly foliated, biotite quartz diorite. Leucocratic and composed mainly of cloudy plagioclase (altered to albite, sericite, epidote, and carbonate), quartz (5–15 percent), and streaks of brown biotite (5–7 percent). Plagioclase crystals appear rounded and average about 4 mm in length; quartz is fine grained. Unit includes minor amounts of weakly foliated, equigranular, medium grained, weakly altered melanocratic oligoclase-quartz-biotite-hornblende diorite. The foliated biotite quartz diorite occurs as inclusions within, and is also cut by, dikes of the metagranite of Orgainsville (Zbg), which are too small to show at this map scale (Peper and Wygant, 1997). It also occurs as a body within and as dikes cutting Abbeyville metagabbro (Zm). Equivalent to unit Zdi of Peper and Olinger (1998)

Zm **Abbeyville metagabbro (Neoproterozoic)**—Dark-greenish-gray, melanocratic, coarse-grained, weakly foliated hornblende metagabbro. Stubby, rectangular 1- to 2-cm-long aggregates of green hornblende and chlorite are set in a matrix of epidote-sericite-carbonate-albite altered from relict calcic-plagioclase grains. Commonly has relict texture of a coarse-grained plutonic rock. Locally includes strongly foliated hornblende-chlorite-albite schist composed mainly of green hornblende (about 75 percent) plus chlorite and trace amounts of sulfide minerals. Abbeyville metagabbro forms inclusions within and is cut by dikes of younger Buffalo granite (Db). Metagabbro bodies occur within and near margins of Buffalo granite along Bluestone Creek, Little Bluestone Creek, and Buffalo Creek. Westernmost body was informally named Abbeyville gabbro by Laney (1917, p. 37–38), who described relict broad-band twinning in the altered plagioclase matrix and sparse relict pyroxene; Laney (1917) referred to some schistose varieties of metagabbro as impure soapstone. Equivalent to Abbeyville gabbro as used on Geologic Map of Virginia (Virginia Division of Mineral Resources, 1993)

Zto **Biotite tonalite (Neoproterozoic?)**—Gray- to orange-gray-weathering, massive, medium- to fine-grained white biotite tonalite. Contains subequal amounts of plagioclase (An_{25}) and quartz, 10–15 percent biotite, and minor potassium feldspar, sericite, chlorite, epidote, sphene, and oxide. Equivalent to unit to of Burton (1995b)

Zqd **Hornblende-biotite quartz diorite or tonalite (Neoproterozoic?)**—Gray-weathering, medium-grained, massive quartz diorite or tonalite. Composed mainly of plagioclase (An_{35}), quartz (up to 30 percent), biotite, and hornblende. Hornblende and biotite are commonly partially altered to chlorite. Distinguished from biotite tonalite (Zto) by presence of hornblende and from hornblende diorite and gabbro (Zdg) by abundant quartz. May be facies of biotite tonalite (Zto). Equivalent to unit ht of Burton (1995b)

Zdg **Hornblende diorite and gabbro (Neoproterozoic?)**—Dark-gray, medium- to coarse-grained, weakly foliated to massive hornblende diorite, hornblende quartz diorite, and minor hornblende±clinopyroxene-labradorite gabbro. In diorite, original mineralogy is now partially altered to blue-green amphibole, chlorite, epidote, and sericite, with quartz content typically 5–10 percent and biotite content 0–10 percent. In gabbro, pyroxene (which originally composed about 50 percent of rock) is now completely altered to amphibole. At Hughs Lake near Chase City, exposures are typically cut by one or more Paleozoic dikes (1–3 m wide) of leucocratic hornblende-biotite quartz diorite and rare bodies of very-light-gray to white, fine-grained biotite tonalite with epidotized borders. A U-Pb TIMS zircon age is 583±3 Ma (Horton and others, 1995). Previously mapped and described as unit dg by Burton (1995b)

Zmt **Tonalite at Mayo Reservoir (Neoproterozoic?)**—Very-light-gray to light-gray, fine- to medium-grained, weakly to strongly foliated, metamorphosed tonalite, quartz diorite, and trondhjemite. Composed of plagioclase, quartz, and variable minor amounts of biotite, muscovite, and microcline; accessory minerals include epidote, chlorite, magnetite, titanite, zircon, and minor carbonate (Kreisa, 1980). Intrudes lower part of the Hyco Formation. Here informally named for exposures on northwest side of Mayo Reservoir in Person County, N.C. Previously mapped and described as quartz diorite by Kreisa (1980), who reported an SiO_2 content of 68–72 percent based on three chemical analyses

Zgnv **Granite of North View pluton (Neoproterozoic)**—White- to light-gray, fine- to medium-grained, weakly foliated, metamorphosed alkali-feldspar biotite granite, riebeckite granite, and leucogranite. Composed mostly of perthitic to non-perthitic microcline, albite, and quartz. Biotite granite, the most abundant type, consists mainly of subhedral perthitic microcline in a fine- to medium-grained albite-quartz matrix; minor and accessory minerals include biotite, magnetite, titanite, garnet, zircon, epidote (secondary), and chlorite (secondary); mafic minerals form clusters which define a weak foliation. Riebeckite granite also consists mainly of subhedral perthitic microcline in fine- to medium-grained albite-quartz matrix but is distinguished by minor riebeckite (a blue-green metamorphic amphibole) and accessory minerals including aegirine and fluorite in addition to biotite, magnetite, allanite, and zircon; mafic minerals form clusters which define weak foliation. In leucogranite, mafic minerals are sparse and typically not in clusters; accessory and trace minerals include biotite, magnetite, chlorite, titanite, garnet, epidote, muscovite, and calcite. This unit was first described by Farrar and Givan (1988) and was studied in greater detail by Bentley (1992). A U-Pb TIMS zircon age of granite is 571±5 Ma (Horton and others, 1999). Map shows inclusions (interpreted as xenoliths) of fine-grained felsite (Zf) possibly correlative with the Hyco Formation

Layered and Stratified Rocks

[Lithofacies are independent of stratigraphic order within the Hyco, Aaron, and Virgilina Formations]

The Virgilina, Va., area near the Virginia-North Carolina border contains the type areas of the Hyco, Aaron, and Virgilina Formations (in ascending stratigraphic order) following Laney (1917), Kreisa (1980), and Harris and Glover (1988). Nomenclature for these formations follows Harris and Glover (1988) as commonly used in other publications (for example, Virginia Division of Mineral Resources, 1993; Hackley and others, 2007; Horton and others, 2016).

Virgilina Formation (Neoproterozoic)—Metavolcanic and tuffaceous rocks that overlie metasedimentary rocks of the Aaron Formation; includes Zvgs, Zvg, and Zvs

Zvs Metasedimentary upper unit—Predominantly light- to medium-gray, thin and evenly bedded, locally phyllitic, locally graded or cross-laminated slaty metasiltstone and metamudstone. Much lesser interleaved greenish-gray, fine-grained volcanic metasandstone, schistose or massive greenstone, and light-tan-weathering slaty felsic metatuff. Occurs in Virgilina synclinorium and Dryburg syncline

Zvg Greenstone lower unit—Predominantly light-greenish-gray, dark-reddish-brown-weathering, blocky to locally schistose greenstone. Composed mainly of chlorite, epidote, albite, sericite, and carbonate. Interlayered with lesser amounts of gray, slaty, locally phyllitic metamudstone and only minor felsic volcaniclastic rock. Massive, medium-grained flow rock with relict basaltic and amygdaloidal texture is prominent in cliffs along lower reach of Hyco River near Hyco Landing. Relict epidotized pillow structures are prominent in cliff exposures along eastern side of a big bend in the Roanoke River, 6 km southwest of Red Oak. Subordinate lenses of tan- to yellowish-weathering, schistose felsic metatuff are 1–3 m thick

Zvgs Greenstone and chlorite-sericite phyllite—Heterogeneous unit that includes massive greenstone, phyllitic and fissile mafic metatuff, chlorite-muscovite phyllite (foliated metaclastite), amygdaloidal metabasalt, and mafic crystal metatuff with chlorite-epidote matrix. Rocks weather dark reddish-brown. Amygdaloidal metabasalt flows (1–2 m thick) locally make up 5 percent of unit. Relict bedding (as much as 10 cm thick) commonly visible in mafic metatuff. Includes a few subordinate lenses (1–3 m thick) of schistose, fissile, tan- to yellow-tan-weathering, felsic metatuff. Bodies of Zvgs in Boydton-Tungsten area resemble the greenstone lower unit of the Virgilina Formation (Zvg) and are interpreted as equivalent in stratigraphic and structural position. Alternatively, Zvgs can be interpreted as facies of the Aaron Formation (Peper and others, 1996; Peper and Wygant, 1997)

Aaron Formation (Neoproterozoic)—Sequence of metasedimentary rocks interpreted to have been deposited by turbidity currents in a deep, submarine fan setting (Harris, 1984; Harris and Glover, 1988); includes Zaps, Zasg, Zag, Zapv, Zab, Zas, Zac, Zap, and Za

Za Metamudstone—Light-gray, blocky to thin-bedded, slaty to phyllitic, metamudstone and metasiltstone. Unit also contains lesser amounts of light-gray to white, thin-bedded, fine- to medium-grained quartz metasandstone, and lesser amounts of light- to dark-green, blocky to thin-bedded chlorite- and epidote-rich mafic volcaniclastic rocks having sparse felsic volcaniclastic layers

Zap Phyllitic metasiltstone—Light-brownish-gray to medium-gray to very-light-gray, fine-grained phyllite. Composed mainly of quartz, sericitic white mica, and commonly plagioclase; chlorite is a common accessory. Locally contains minor interlayers of phyllitic metasandstone, phyllitic felsic metatuff, greenstone, and chloritic metatuff. Sparse graded bedding described by Peper and others (1996) and Peper and Wygant (1997). Interpreted to unconformably overlie Hyco Formation based on truncation of Zhf and Zhc at western contact. Zap is a probable eastern equivalent of Za

Zac Metaconglomerate and metasandstone—Clast-supported metaconglomerate, and metaconglomerate having phyllitic matrix; interbedded with slate or phyllite and pebbly to granular quartz metasandstone. The clast-supported metaconglomerate is poorly sorted and predominantly consists of white subrounded quartz pebbles and smaller light and dark pebbles of volcaniclastic rock in pale green sandy to phyllitic matrix. South of the Red Oak pluton, this distinctive marker unit within the Aaron Formation is continuous along the western limb of the Dryburg syncline and discontinuous along the eastern limb. Northeast of the Red Oak pluton, it occurs as subparallel lenses that suggest folding or faulting. Less extensive lenses of interlayered metaconglomerate and quartzite in phyllite are present in other parts of the Aaron Formation

Zas Metasandstone—White- to light-tan-weathering, fine- to medium-grained, thinly laminated, sericitic quartzite and variably feldspathic metasandstone; locally grades into pebbly metasandstone

Zab Volcanic metabreccia and metaconglomerate—Occurs as two thin lenses within and at margin of phyllitic metasiltstone unit (Zap) mapped 1.3 km southwest of the Island Creek Public Use Area on the western limb of the Island Creek syncline near the Virginia-North Carolina border. Western lens is gray, thickly layered lithic metatuff containing angular fragments of metafelsite. Eastern lens is brown-weathering, medium-bedded pebble metaconglomerate intercalated with thick layers of amygdaloidal metabasalt, fissile felsic crystal metatuff, and brown chloritic phyllite

Zapv Felsic lithic and crystal-lithic metatuff—Light-bluish-gray, very fine grained, phyllitic volcaniclastic rock having flattened pumice and other lithic volcanic clasts (lapilli) up to 5 cm in length. Composed of very fine grained quartz, plagioclase, sericitic white mica, and minor chlorite; commonly contains plagioclase phenocrysts. Occurs as layers in phyllitic metasiltstone (Zap)

Zag Mafic metatuff—Green-weathering, thin-bedded to blocky, chloritic and epidotitic mafic metatuff interbedded with slaty metamudstone and light-green volcanic metasandstone

Zasg Chlorite schist and greenstone—Heterogeneous unit of interlayered epidote-albite-chlorite-quartz-carbonate greenstone, chlorite schist, and minor thick-layered mafic feldspar-crystal metatuff having a chlorite-epidote matrix. Occurs at base of phyllitic metasiltstone (Zap) and includes rare amygdaloidal metabasalt in flows (1–3 m thick) west of Boydton, Va.

Zaps Phyllonitic metasiltstone—Variably phyllonitic and mylonitic metasiltstone and associated metasedimentary rocks. White-mica “button” fabric, undulatory schistosity, shear bands, quartz ribbons, and secondary folds are common in Clover shear zone. Zaps is coincident with an aeromagnetic high anomaly (U.S. Geological Survey, 1978a), and iron oxide pellets are common in overlying residual soil. Deformed equivalent of metamudstone (Za); gradational into less deformed rocks

Hyco Formation (Neoproterozoic)—Predominantly felsic to intermediate metavolcanic rocks; includes Zhpm, Zhm, Zhg, Zhb, Zhqz, Zhph, Zhl, Zhd, Zhmm, Zhcs, Zhv, Zhst, Zhs, Zhar, Zhq, Zhc, Zhf, Zhvb, Zhfa, and Zhfm. Horton and others (1999) reported overlapping Neoproterozoic U-Pb TIMS zircon ages of 621±8 Ma and 616±4 Ma from two localities near the top of the Hyco Formation (see Zhc description below). Subsequent U-Pb TIMS zircon ages from the Hyco Formation are similar and include 615+3.7/-1.9 Ma for a dacitic metatuff (Wortman and others, 2000), 619.9+4.5/-3 Ma for a felsic gneiss (Wortman and others, 2000), and 616.5±1.2 Ma for felsic metatuff near the top of the formation (Bowman and others, 2013)

Zhfm Felsic mylonite—Light-gray, very fine grained, thinly laminated felsic mylonite and ultramylonite in Clover shear zone. This map unit is the mylonitic equivalent of unit Zhf and the contact with Zhf is gradational

Zhfa Fine-grained felsic gneiss and amphibolite—Very-light-gray, fine-grained felsic gneiss and lesser amounts of interlayered dark-greenish-gray, fine-grained amphibolite; variably mylonitic to non-mylonitic, well foliated, and layered on centimeter to meter scales. Composition and layering (transposed bedding?) indicate metavolcanic origin. Probable epidote-amphibolite to amphibolite facies. Zhfa includes rocks interpreted by Kreisa (1980) as the westernmost part of Hyco Formation. It borders units of the Country Line complex (Zcc, Zcm) along the eastern flank of Hyco shear zone (Hibbard and others, 1998; Hibbard and Bradley, 2017)

Zhvb Felsic metavolcanic breccia and tuffaceous greenstone—Light-gray, fine- to coarse-grained felsic metavolcanic breccia containing flattened lithic clasts up to 5 cm in length interlayered with light-gray, finer grained felsic metatuff, and light-greenish-gray tuffaceous greenstone containing fine-grained amphibole. Uppermost unit of Hyco Formation south of Dan River on the western limb of Virgilina synclinorium. Described as a "marker zone" and mapped as vb by Kreisa (1980)

Zhf Fissile felsic metatuff—Very-light-gray to white to yellowish-gray, fine-grained, fissile to phyllitic metatuff. Composed of fine-grained feldspar, quartz, and minor sericitic white mica. Common accessory minerals include biotite, magnetite as tiny octahedra, and secondary epidote and chlorite. Laminated to thickly bedded, locally has flattened lithic clasts and sparse phenocrysts of quartz or plagioclase. Contains minor interlayers of crystal metatuff, feldspathic metasandstone, feldspar metaporphyry, quartz dacite metaporphyry, mafic metatuff, and amygdaloidal metabasalt. This unit occurs at different stratigraphic levels throughout the Hyco Formation. Same as unit p€h of Kreisa (1980), Zfm of Peper and others (1996), and Zf of Peper and Wygant (1997) and Burton (1995b). Lens south of Buffalo granite (Db) was mapped as Goshen schist by Laney (1917)

Zhc Felsic crystal metatuff—Light-gray to yellowish-gray, grayish-orange to moderate-brown weathering, fine- to medium-grained, weakly to moderately foliated, felsic crystal metatuff. Matrix of very fine grained quartz, feldspar, and sericitic white mica contains quartz and plagioclase phenocrysts 2–5 mm in length. Contains minor intercalated beds of fissile to massive, fine-grained felsic metatuff and volcanic metasandstone. This lithofacies occurs at different stratigraphic horizons in the Hyco Formation. Two occurrences of felsic crystal metatuff are stratigraphically just below the Aaron Formation. One is in the Buffalo Springs 7.5′ quadrangle 0.5 km southeast of Aarons Creek, and the other is in the Baskerville 7.5′ quadrangle (see quadrangle index on map sheet) 0.2 km northeast of Allen Creek and 4.9 km north-northeast of Boydton, Va. These two Zhc occurrences have overlapping U-Pb TIMS zircon ages of 621±8 Ma and 616±4 Ma, respectively (Horton and others, 1999)

Zhq Quartz metaporphyry—Light-gray to white, medium-grained, massive to weakly foliated, partly schistose and fissile, muscovite-quartz-feldspar metaporphyry. Contains relict subhedral phenocrysts of gray quartz averaging about 4 mm in diameter. A small pod of hypabyssal rock 3 km southwest of Finchley, Va., in the southeastern part of Clarksville North 7.5′ quadrangle (see quadrangle index on map sheet) has apophyses, dikes, and sills extending into bedded lithic-crystal metatuff of the coarse-grained felsic metatuff unit (Zhl). Larger lenses south of Buffalo granite (Db) are entirely extrusive rock. Lenses 2.3 km southeast of Buffalo Junction, Va., and along U.S. Highway 15 at southern border of map area are light-gray to white, medium-grained, massive to weakly layered, partly schistose and fissile, quartz-feldspar muscovite metaporphyry containing rounded relict subhedral phenocrysts of gray quartz averaging 4 mm in length. A folded lens east of U.S. Highway 15 and south of the Grassy Creek fault is light-gray, medium-grained, medium-bedded, quartz metaporphyry interleaved with pebbly felsic metatuff and thin-bedded felsic crystal metatuff. Same as unit Zqm of Peper and others (1996) and unit Zq of Peper and Wygant (1997)

Zhar Zone of advanced argillic alteration—Patchy, white-weathering, massive kaolin and sericite in which local masses of siliceous rock enclose smaller masses of high-alumina minerals, especially pyrophyllite. Formed by variably intense hydrothermal alteration of fissile felsic metatuff and quartz metaporphyry

Zhs Phyllite and phyllitic metasandstone—Light-gray to white-weathering, fine-grained, fissile phyllite and thinly layered, fine-grained micaceous metasandstone. Same as unit Zs of Peper and Wygant (1997)

Zhst Layered metasiltstone and metatuff—Buff- to dark-gray-weathering, fine-grained, finely bedded to well-layered metasiltstone and metatuff. Primary structures include faint, fine-bedding laminae and cross beds in metasiltstone and conspicuous, light and dark, millimeter- to centimeter-scale compositional layering in metatuff. Minerals include, in varying abundances, quartz, albite, sericite, biotite, chlorite, and epidote; compositional layering is caused by changing abundances of quartzofeldspathic versus ferromagnesian minerals. Same as unit Zvl of Burton (1995b)

Zhv Phyllitic volcaniclastic rock and mudflow breccia—Bluish-gray-weathering, fine-grained, quartz-albite-sericite-chlorite-epidote phyllite with relict plagioclase phenocrysts and flattened pumice clasts 1–5 mm in length; includes minor, gray-weathering, non-foliated mudflow breccia consisting of poorly sorted, matrix-supported, angular to subrounded clasts as much as 5 cm in length of felsic to intermediate chlorite-biotite-sericite-epidote-albite metavolcanic rock. Same as unit Zpv of Burton (1993, 1995b)

Zhcs Lithic-crystal metatuff and volcanic metasandstone—Occurs as two lenses in vicinity of John H. Kerr Reservoir east of Occoneechee State Park. Western lens consists of light-gray to tan, felsic crystal metatuff, welded metatuff, metarhyodacite, chert-pebble metaconglomerate, and cross-bedded volcanic metasandstone that crosses John H. Kerr Reservoir and Panhandle Creek. Eastern lens consists of light-gray, medium-grained, thick-bedded to massive felsic metatuff and white, cross-laminated volcanic metasandstone that crosses Peckerwood Branch. Both lenses are in northern part of Clarksville South 7.5′ quadrangle (see quadrangle index on map sheet). Same as unit Zcms of Peper and others (1996)

Zhmm Pebbly metamudstone and crystal-lithic metatuff—Very coarse grained pebbly metamudstone with brown matrix and cobbles of metabasalt and metafelsite as much as 10 cm in diameter. Metamudstone is interlayered with light-tan-weathering, blocky, felsic crystal-lithic metatuff containing pebbles of metabasalt. Same as unit Zmm of Peper and others (1996)

Zhd Fine-grained quartz dacite—Greenish-gray, tan-weathering, very fine to fine-grained, mostly massive quartz dacite and quartz-dacite porphyry; probably hypabyssal. Occurs as lensoid pods within fissile felsic metatuff (Zhf) in the Boydton and Clarksville South 7.5′ quadrangles (see quadrangle index on map sheet). Equivalent to unit Zd of Peper and others (1996)

Zhl Coarse-grained felsic metatuff—Heterogeneous unit composed mainly of very coarse to coarse-grained felsic metavolcaniclastic crystal and crystal-lithic metatuff (~50 percent), but contains some fine-grained felsic metatuff (~25 percent) and lesser extrusive and hypabyssal metarhyodacite (~15 percent). Mafic extrusive rocks, dikes, and volcaniclastic rocks are less abundant (~10 percent), but mafic clasts are present in most exposures of felsic volcaniclastic rock. Crystal-lithic metatuff is very coarse grained and contains sub-angular to rounded clasts of fine-grained felsite porphyry, crystal-lithic tuff, fine-grained quartz (metachert?), rhyodacite, and mafic metamudstone as well as broken, subhedral to rounded crystals of quartz and plagioclase.

Metamudstone interbeds have angular to subrounded metabasalt blocks 1 m in diameter. Intercalated yellow-tan to deep-red and reddish-orange weathering, fine-grained schistose quartz dacite and quartz dacite porphyry. These intercalated rocks mainly contain quartz and plagioclase as well as a few percent sericite, quartz (gray subhedral grains in augen with tails about 4 mm in length), and tiny magnetite octahedra (1–2 mm in length). Maximum clast size observed in outcrop generally decreases northeastward along the strike of the unit from boulder- to cobble-sized clasts south of Finchley, Va. (just north of the John H. Kerr Reservoir), to pebble-sized clasts north of Finchley. Mafic metatuffs typically compose about 10 percent of exposures southwest of Finchley and less than 3 percent of exposures northeast of Finchley.

Eruptive sequences of metarhyodacite lava flows (100–150 m thick) are overlain by coarse-grained crystal-lithic metatuff grading upward into airfall tuff; both are visible in shore exposures in Longwood Public Use Area on Grassy Creek. Combined thickness of metarhyodacite flows is as much as 120 m in cliffs along John H. Kerr Reservoir southeast of Clarksville, Va. Mafic lava flows, dikes, and metatuffs are most abundant south and east of Spewmarrow Creek where they make up 25 percent of exposures. Includes unit Zft of Peper and others (1996) and unit Zl of Peper and Wygant (1997)

Zhph Phyllitic volcanic metasiltstone and metatuff—White- to light-tan-weathering, fine- to medium-grained phyllitic volcanic metasiltstone and metatuff consisting of intercalated beds that vary in abundance of feldspar and quartz. Composed mainly of quartz, albite, sericitic white mica, and chlorite. Thin bedded to laminated to bedded on a scale of meters. Interpreted to consist of intercalated volcanically derived metasandstones and metasiltstones and felsic metatuffs reworked by sedimentary processes. Minor interlayers include light-gray- to tan-weathering quartz and feldspar crystal metatuff, fine-grained fissile felsite, massive fine-grained metarhyodacite(?) lava, fine-grained cross-laminated volcanic metasandstone, and metamafic lavas. Interfingers with coarse-grained felsic metatuff (Zhl) on its southernmost extent. Includes mixed phyllite (Zph) of Burton (1995b) and felsic phyllite (Zfp) of Peper and Wygant (1997)

Zhqz Micaceous quartzite—Very-light-gray, fine-grained, foliated micaceous quartzite. Composed mainly of quartz with lesser amounts of white mica. Interpreted to be metasandstone. Occurs as sparse, thin, lenticular bodies within the Hyco Formation; includes lens within fissile felsic metatuff (Zhf) 0.8 km west-northwest of Kenbridge, Va.

Zhb Metabasalt—Heterogeneous unit mapped as lenses in coarse-grained felsic metatuff (Zhl) and as elongate and irregular inclusions in Buffalo granite (Db). Includes dark-gray to greenish-gray to dark-greenish-gray metabasalt in lava flows (in part porphyritic or amygdaloidal), metabasalt in dikes, chlorite schist, chloritic epidote-quartz-albite-sericite metatuff and rare felsic metatuff. Also includes dark-gray, medium-grained amphibolite at contact with Buffalo granite. Same as unit Zmb of Peper and others (1996) and unit Zb of Peper and Wygant (1997)

Zhg Greenstone—Dark-green, fine-grained, massive to weakly foliated, locally amydaloidal, albite-epidote-chlorite greenstone interpreted as metabasalt and dark-green, well-foliated albite-epidote-chlorite phyllite interpreted as basaltic metatuff within the Hyco Formation. Same as unit Zm of Burton (1993, 1995b)

Zhm Chloritic metatuff—Greenish-gray, fine-grained, thinly layered to laminated, schistose metatuff containing chlorite, albite, quartz, sericite, and epidote. Mapped as unit Zm by Peper and others (1996) in Clarksville South 7.5′ quadrangle (see quadrangle index on map sheet)

Zhpm Fine-grained porphyritic metabasalt—Dark-gray, very fine grained, massive, porphyritic metabasalt. Contains abundant, concentrically zoned phenocrysts of calcic plagioclase having epidote-sericite altered cores averaging 4 mm in length in fine-grained chlorite-epidote-sericite matrix. Hypabyssal intrusive rock having apophyses into coarse-grained felsic metatuff (Zhl). Mapped as Zpm by Peper and others (1996) in Clarksville South 7.5′ quadrangle (see quadrangle index on map sheet)

Vicinity of Nutbush Creek Mylonite Zone

[Neoproterozoic ages are inferred for units similar to nearby Hyco and Aaron Formations. Stratigraphic order undetermined]

PzZq **Quartz rock (Paleozoic or Neoproterozoic?)**—White, fine-grained, sugary-textured vein quartz or possible quartzite, and lesser coarsely crystalline vein quartz. Locally contains rounded to angular cm-scale quartz lumps or clasts and thin, phyllitic stringers or interlayers consisting of fine-grained sericite (Burton, 1993). Occurs as elongate, tabular, foliation-parallel layer that crosses the Meherrin River within the granite of North View pluton (Zgnv)

Zg **Greenstone and chloritic phyllite (Neoproterozoic)**—Greenish-gray, fine- to medium-grained, phyllitic to blocky greenstone and chloritic phyllite. Interpreted to be predominantly metatuff of mafic to intermediate composition containing epidote and chlorite. The main marker layer (which extends from Vance pluton to the northern edge of the map, east of Victoria) gently truncates units of Hyco and Aaron Formations, suggesting an unconformity or fault. This layer includes Stith Mine copper deposit on Mines Creek. Minor mafic metavolcanic layers and lenses east of marker layer are also designated Zg

Zp **Phyllitic metasiltstone (Neoproterozoic)**—White, fine-grained, albite-quartz-sericite phyllitic metasiltstone and bluish-green, fine-grained, epidote-albite-sericite-chlorite phyllitic metasiltstone, interlayered on a scale of meters. Unit includes minor interlayers of greenstone

Zms **Muscovite-quartz schist (Neoproterozoic)**—Very-light-gray, fine- to medium-grained, muscovite-quartz schist having locally abundant veins of granular quartz in plane of schistosity. Composed mostly of muscovite and quartz. Dextral shear bands and subhorizontal quartz elongation lineation are common but not ubiquitous. Similar in composition and possibly related to finer-grained, more phyllitic unit Zp and more highly deformed unit PMps. Occurs along Nutbush Creek mylonite zone about 4 km west-northwest of Kenbridge, Va.

Zcl **Felsic lithic and crystal-lithic metatuff (Neoproterozoic)**—Light-bluish-gray, very fine grained, phyllitic volcaniclastic rock having flattened pumice and other lithic volcanic clasts (lapilli) up to 5 cm in length. Composed of quartz, plagioclase, sericitic white mica, and minor chlorite; commonly contains plagioclase phenocrysts. Occurs as layers in phyllitic metasiltstone unit (Zp) and resembles unit Zapv of Aaron Formation

Zf **Fine-grained felsite (Neoproterozoic)**—White- to very-light-gray, fine-grained, fissile to phyllitic felsite. Composed of fine-grained feldspar, quartz, and sericitic white mica. Physically similar and possibly equivalent to unit Zhf of Hyco Formation

Zmyv **Mylonitic metavolcanic and metasedimentary rocks (Neoproterozoic)**—Interlayered mylonitic and phyllonitic, felsic to mafic metavolcanic rocks and phyllonitic metasiltstones. Interpreted to be broadly equivalent to Carolina slate belt metavolcanic and metasedimentary rocks of similar compositions

Zkg **Gneiss of Kenbridge (Neoproterozoic?)**—Thin- to thick-layered, mostly fine-grained, locally very fine to medium grained hornblende-biotite-quartz-plagioclase gneiss having mafic to intermediate and felsic interlayers. Mafic to intermediate layers consist mainly of plagioclase, quartz, hornblende, and biotite in varied amounts; accessory chlorite, epidote, and pyrite are concentrated in strongly foliated or lineated zones. Felsic layers consist of plagioclase, quartz, lesser amounts of biotite, and sporadic accessory minerals including white mica, potassium-feldspar augen, garnet, and disseminated mafic minerals in rusty-weathering layers. Includes minor layers and boudins of amphibolite, concordant and discordant injections of foliated granite and pegmatite, and sparse phyllonitic white-mica schist. Variably mylonitic and lineated near eastern contact and, to a lesser extent, near the western contact. Very fine grained, laminated ultramylonite and mylonitic gneisses have concordant quartz ribbons and veins, spaced white-mica partings, shear bands, and sparse mica fish. Quartz, feldspar, and hornblende-elongation lineations and parallel quartz rods are subhorizontal. Asymmetric, tight to isoclinal folds typically have steep plunge and Z shape in horizontal exposure. Geophysical maps (U.S. Geological Survey, 1978a, b) show coincident magnetic high and gamma-ray low anomalies. Unit may be an epidote-amphibolite-facies equivalent of the Hyco Formation in the Carolina terrane, may be part of the Raleigh terrane, or may be a transpressive slice of different rocks bounded by fault strands within the Lake Gordon mylonite zone

Western Flank of Carolina Terrane (Mainly Epidote-Amphibolite Facies to Amphibolite Facies)

Intrusive Rocks

PzZgn **Mica gneiss and metagranite, undivided (Paleozoic to Neoproterozoic?)**—Mica gneiss (interpreted as paragneiss) injected by equally abundant sheets and lenses of metagranite. The metagranite includes gneissic leucogranite and gneissic muscovite-biotite granite identical to metagranite of Saxe (PMgn) and concordant to foliation and gneissic layering. The mica gneiss consists mainly of muscovite-biotite-quartz-feldspar paragneiss which is fine to coarse grained and thin to thick layered. It has medium dark-gray biotite-rich layers, very-light-gray to pinkish-gray, leucocratic felsic layers, and minor discontinuous layers of augen gneiss rich in feldspar porphyroblasts, muscovite-biotite schist, hornblende gneiss, and thin amphibolite layers. Locally includes migmatite; mylonitic gneiss having anastomosing foliation, asymmetric boudinage, or dextral shear bands; and fine-grained, thinly laminated, felsic mylonite having pink feldspar and thin muscovite partings. Included in the granitic gneiss unit of Baird (1991)

PzZgp **Megacrystic biotite-quartz-feldspar orthogneiss (Paleozoic or Neoproterozoic?)**—Brownish-gray to grayish-black, fine- to medium-grained biotite-quartz-feldspar orthogneiss (metagranodiorite) containing medium- to coarse-grained, euhedral microcline megacrysts. Composed of microcline, plagioclase, quartz, biotite, and minor muscovite. Euhedral allanite rimmed by epidote is a common accessory mineral. Bodies within biotite-hornblende gneiss of Cluster Springs (Zcc) are interpreted as deformed, metamorphosed intrusive rocks. Previously mapped and interpreted by Bradley (1996) as Milton terrane biotite gneiss

PzZgb **Metagabbro or metadiorite (Paleozoic or Neoproterozoic?)**—Dark-gray to dark-greenish-gray, medium- to coarse-grained, granoblastic, amphibolitic metagabbro to metadiorite in the vicinity of South Boston, Va., and Cluster Springs, Va. Composed mainly of hornblende (partly replacing pyroxene) and plagioclase; accessory minerals include titanite, ilmenite, and biotite. Mapped by Kreisa (1980) who reported relict subophitic texture and 1.5-cm-long hornblende crystals

Layered and Stratified Rocks

[Stratigraphic order undetermined]

PzZks **Kyanite-mica schist (Paleozoic or Neoproterozoic?)**—Medium-light-gray, medium-grained, aluminous biotite-muscovite schist and schistose mica gneiss containing minor kyanite and accessory garnet. Occurs as a lenticular body within mica gneiss and metagranite (PzZgn) at Jones Creek, 2.8 km west of Saxe, Va. Age and affinity are undetermined

Country Line complex (Neoproterozoic)—Informal name of Hibbard and others (1998) for gneisses in hanging wall rocks of the Hyco shear zone on western flank of the Carolina terrane. Includes rocks informally described below as layered gneiss of South Boston (Zclg), biotite-hornblende gneiss of Cluster Springs (Zcc), and mylonitic biotite-hornblende gneiss of Cluster Springs (Zcm). The Country Line complex was initially called the Country Line Creek complex (informal name of Shell [1996]) to the southwest in North Carolina

Zcm Mylonitic biotite-hornblende gneiss of Cluster Springs—Dark-gray to greenish-black, fine-grained, thinly layered, variably mylonitic biotite-hornblende gneiss. Mylonitic equivalent of unit Zcc. Extends southwest from Scottsburg basin as a narrow, fault-bounded unit along Clover shear zone; borders westernmost Hyco Formation units Zhf and Zhfa

Zcc Biotite-hornblende gneiss of Cluster Springs—Dark-gray to greenish-black, fine- to medium-grained biotite-hornblende gneiss with hornblende gneiss interlayers. Layering is typically defined by mafic layers (1–100 cm thick) with discontinuous quartz and feldspar segregations (2–10 mm thick). Typical minerals are plagioclase, quartz, hornblende, epidote, biotite, and local chlorite. The unit also contains lesser amounts of felsic gneiss, amphibolite, and granite layers. Here informally named for exposures in vicinity of Cluster Springs, Halifax County, Va. (Cluster Springs 7.5′ quadrangle; see quadrangle index on map sheet). Largely equivalent to hornblende-biotite gneiss (hbgn) of Kreisa (1980)

Zclg Layered gneiss of South Boston—Layered gneiss composed of dark-gray to greenish-black mafic hornblende-biotite gneiss, hornblende gneiss, and amphibolite containing white to pinkish-gray, fine- to medium-grained granitic interlayers on a centimeter to meter scale. Wortman and others (1998) interpret this gneiss to be a metavolcanic rock and report U-Pb TIMS zircon ages of 613.9±9.3 Ma for the concordia upper intercept (interpreted as a crystallization age) and 322.5±2.7 Ma for the lower intercept (interpreted as the age of metamorphism and deformation). These ages are consistent with an $^{40}Ar/^{39}Ar$ age of 322.9±7.8 Ma for hornblende also reported by Wortman and others (1998), which is interpreted to represent cooling through about 500 °C following the thermal peak of metamorphism. Here informally named for exposures in the vicinity of South Boston, Halifax County, Va. Excellent exposures at the South Boston quarry (Salem Stone Corporation) consist of hornblende-biotite gneiss and hornblende gneiss with felsic gneiss interlayers. Previously described informally as amphibole gneiss (Goodwin and others, 1986, stop 7A), layered gneiss (Bradley, 1996), South Boston hornblende gneiss (Wortman and others, 1998), and as part of the Country Line complex (Hibbard and others, 1998); this unit includes rocks interpreted differently by Baird (1989) as St. Matthews Church amphibolite member (informal name) of Hyco Formation

Milton Terrane

Intrusive Rocks

Pzbg **Foliated biotite granite (Paleozoic?)**—Medium-gray, fine- to medium-grained, foliated biotite granite. Composed mainly of plagioclase, microcline, quartz, and biotite; accessory minerals include chlorite, epidote, and magnetite

Osgr **Metagranite and mica gneiss of Shelton Formation (Ordovician)**—Subequal mixture of undivided intrusive metagranite and mica gneiss, generally separable at outcrop scale but not at this map scale. Metagranite is light-gray to medium-gray, fine- to medium-grained, variably well foliated, and composed mainly of plagioclase, microcline, quartz, biotite (less than 10 percent), and muscovite. Locally has feldspar porphyroblasts, mineral-elongation lineation, and gneissic segregation into alternating very-light-gray feldspar-quartz layers and dark-gray biotite-rich layers. Metagranite has Ordovician U-Pb TIMS zircon age of 463±14 Ma (Hund, 1987). The mica gneiss contains minor mica schist layers and sparse layers and lenses of amphibolite and hornblende gneiss. Metagranite sheets and lenses are generally concordant to foliation and gneissic layering. The Shelton Formation of Henika and Thayer (1977) and Henika (1980) was mapped as part of Shelton Igneous Suite (Ofgn) in adjacent Danville 30′ × 60′ quadrangle (Henika, 2002)

Omi **Amphibolitic metagabbro (Ordovician?)**—Dark-gray to dark-greenish-gray to grayish-black, medium- to coarse-grained, granoblastic, amphibolitic metagabbro or metadiorite composed mainly of plagioclase and hornblende. Plutons locally contain small masses of altered ultramafic rock (Omu). Same as hornblende-biotite gneiss unit (hbgn) of Kreisa (1980) in South Boston 7.5′ quadrangle (see quadrangle index on map sheet); equivalent to metamorphosed mafic igneous complex unit (Omi) of Henika (2002) in adjacent Danville 30′ × 60′ quadrangle

Omu **Altered ultramafic rock (Ordovician?)**—Dark-greenish-gray, fine- to coarse-grained, altered ultramafic rocks. Locally contains actinolite, chlorite, epidote, and euhedral pyroxene, and in some exposures is composed mostly of actinolite (Kreisa, 1980). Small, isolated lenses occur throughout Milton terrane; those within amphibolitic metagabbro (Omi) may be cumulates. Labeled small circular polygons on the map indicate masses too small to show at this map scale

Layered and Stratified Rocks

[Stratigraphic order undetermined]

Cunningham complex (Ordovician)—The Cunningham complex (informal name of Shell, [1996]) was extended from North Carolina into Virginia by Hibbard and others (1998). Includes biotite gneiss of Halifax (Omc) and biotite gneiss and schist of Cedar Grove (Omm) as informally named below. Ordovician ages are inferred for the Cunningham complex and other undated Milton terrane gneisses based on a U-Pb TIMS zircon age of 458.5+3.8/-1.0 Ma (Coler and others, 2000) from felsic gneiss (metarhyolite) west of the map area near Danville, Va. Interpreted as footwall rocks of Hyco shear zone (Hibbard and others, 1998)

Omm Biotite gneiss and schist of Cedar Grove—Interlayered light-gray, fine- to medium-grained, biotite-quartz-feldspar paragneiss and muscovite-biotite schist containing accessory garnet and sillimanite. Rocks are variably migmatitic and gneissic layering is thin to thick. More micaceous and schistose than the biotite gneiss of Halifax (Omc). Composition indicates a clastic metasedimentary protolith. Here informally named for exposures in the vicinity of Cedar Grove, Halifax County, Va. (Cluster Springs 7.5′ quadrangle; see quadrangle index on map sheet). Equivalent to biotite gneiss unit (bgn) of Kreisa (1980) and grouped into garnetiferous biotite gneiss unit (€Obg) in adjacent Danville 30′ × 60′ quadrangle (Henika, 2002)

Omc Biotite gneiss of Halifax—Light-gray to dark-gray, fine- to coarse-grained, thin- to thick-layered, heterogeneous biotite gneiss, muscovite-biotite gneiss, and minor mica schist. Contains quartz, plagioclase (oligoclase), biotite, and variable lesser amounts of muscovite, hornblende, microcline, and epidote. Ranges from porphyroblastic gneiss (composed of dark-gray, medium-grained, biotite-rich matrix and white, coarse-grained, feldspar-quartz porphyroblasts) to light-gray, fine- to medium-grained, homogeneous gneiss (composed of plagioclase, potassium feldspar, quartz, and biotite). Garnet occurs locally as porphyroblasts up to 2 cm in diameter; sillimanite is locally present. Interlayers include muscovite-biotite gneiss, muscovite-biotite schist, biotite schist, and foliated metagranite as well as thin layers and pods of amphibolite and sparse calc-silicate rock. Composition indicates clastic metasedimentary origin. Here informally named for exposures in the vicinity of Halifax, Va. (Halifax 7.5′ quadrangle; see quadrangle index on map sheet). Equivalent to Milton terrane biotite gneiss of Bradley (1996) and part of hornblende-biotite gneiss, hornblende gneiss, schist, and amphibolite unit (€Omg) in adjacent Danville 30′ × 60′ quadrangle (Henika, 2002)

Omg **Biotite metagranite and fine-grained felsic gneiss (Ordovician)**—Subequal mixture of light-gray to medium-gray, mostly medium-grained, foliated biotite metagranite and very-light-gray, fine- to very fine grained, foliated, commonly leucocratic felsic gneiss. Generally separable in well-exposed outcrops, but not at this map scale. Generally lacks mica gneiss and schist interlayers. Metagranite is variably well foliated. The fine-grained felsic gneiss is identical to and gradational into fine-grained felsic gneiss (Oml). This unit is possibly related to metagranite of the Shelton Formation in unit Osgr, which has a U-Pb TIMS zircon age of 463±14 Ma (Hund, 1987)

Oml **Fine-grained felsic gneiss (Ordovician)**—Very light gray, fine- to very fine grained, granoblastic, commonly leucocratic, felsic biotite-quartz-feldspar gneiss. Composed of quartz, feldspar, minor biotite, and accessory muscovite. Lighter gray and less biotite rich than biotite felsic gneiss of Turnip Creek (Omb). Contains minor amounts of fine- to medium-grained foliated metagranite and sparse foliated metadiorite, hornblende metagranite, biotite and muscovite schists, biotite gneiss, and amphibolite. White to yellowish-gray, sandy soil and saprolite are characteristic and distinct from darker, clayey soil and saprolite of nearby units. Composition and grain size suggest metavolcanic origin, possibly as felsic metatuff. Similar felsic gneiss described as metarhyolite near Danville, Va., has a U-Pb TIMS zircon age of 458.5+3.8/-1.0 Ma (Coler and others, 2000). Unit includes rocks mapped and described by Baird (1991) as lower felsic gneiss and muscovite quartz schist. Mapped as part of Shelton Igneous Suite unit (Ofgn) in adjacent Danville 30′ × 60′ quadrangle (Henika, 2002), where it has an Ordovician U-Pb TIMS zircon age of 463±14 Ma (Hund, 1987)

Omf **Gneiss of Conner Lake (Ordovician?)**—Medium-gray, fine- to medium-grained, layered biotite-quartz-feldspar gneiss that is variably interlayered with very-light-gray, mostly medium-grained, biotite granite gneiss. The biotite-quartz-feldspar gneiss has layer-parallel foliation, minor interlayers of micaceous gneiss and schist, and isolated pods of altered ultramafic rock (Omu). Here informally named for exposures in vicinity of Conner Lake, Halifax County, Va. (Conner Lake 7.5′ quadrangle; see quadrangle index on map sheet). Equivalent to unit grf of Nelson and Nelson (1997); corresponds to part of garnetiferous biotite gneiss unit (€Obg) in adjacent Danville 30′ × 60′ quadrangle (Henika, 2002)

Omp **Biotite-quartz-feldspar gneiss (Ordovician?)**—Medium-gray, fine-grained, thin- to thick-layered, granoblastic to lepidoblastic paragneiss. Composed mainly of plagioclase (oligoclase, An_{12}, and andesine, An_{36}), quartz, and biotite, and contains minor garnet, epidote, muscovite, and magnetite. Thin amphibolite layers are common; other mica gneiss and schist layers are sparse. Composition suggests clastic metasedimentary origin, probably as metagraywacke. Corresponds to part of hornblende-biotite gneiss, hornblende gneiss, schist, and amphibolite unit (€Omg) in adjacent Danville 30′ × 60′ quadrangle (Henika, 2002)

Omb **Biotite felsic gneiss of Turnip Creek (Ordovician?)**—Medium-light-gray, fine-grained, thin- to thick-layered biotite-quartz-feldspar gneiss; darker, more biotite-rich (typically greater than 10 percent), and more aluminous than Oml. Contains thin amphibolite layers, thin quartz schist layers, minor granite gneiss, and minor biotite schist layers; thin quartz schist layers are 5–18 cm thick, sparse, and irregularly distributed. Composition suggests a protolith of metatuff or volcanically derived clastic metasediments. Relation, if any, to Shelton Formation is undetermined. Here informally named for exposures in vicinity of Turnip Creek north of Roanoke River in Conner Lake 7.5′ quadrangle; equivalent to biotite felsic gneiss unit (fm) of Nelson and Nelson (1997)

Omh **Biotite-hornblende gneiss of Ellis Creek (Ordovician?)**—Medium-gray to dark-gray, mostly medium-grained, granoblastic, biotite-hornblende gneiss. Contains highly variable amounts of hornblende (10–90 percent), biotite, plagioclase (oligoclase to andesine), and quartz; local accessory minerals include magnetite, epidote, and chlorite. Hornblende typically more abundant than biotite; some hornblende is chloritized. Alternating dark-gray, hornblende-rich bands are gradational into light-gray, felsic hornblende-poor bands. Minor interlayers and lenses include fine-grained biotite-quartz-plagioclase-microcline gneiss, biotite schist, fine-grained amphibolite, sparse muscovite schist, biotite-quartz-feldspar gneiss, granite gneiss, and rare pyroxene-rich ultramafic pods (Omu). Here informally named for exposures in vicinity of Ellis Creek south of Roanoke River in Halifax County, Va. (Conner Lake 7.5′ quadrangle, see quadrangle index on map sheet). Equivalent to hornblende-biotite gneiss unit (hbf) of Nelson and Nelson (1997). Includes rocks previously described and interpreted differently as Catawba Creek amphibolite member of Hyco Formation, Blackwater Creek gneiss, and Ellis Creek gneiss (informal names of Baird [1989]) and as mafic gneiss, fine-grained hornblende-bearing felsic gneiss, and medium-grained hornblende-bearing felsic gneiss (Baird, 1991)

References Cited

Achtermann, R.D., 1985, Geology of the Meherrin, Virginia area—Tracing formations across the staurolite isograd from the Carolina slate belt into the Charlotte belt: Blacksburg, Va., Virginia Polytechnic Institute and State University, M.S. thesis, 34 p., accessed October 14, 2021, at https://vtechworks.lib.vt.edu/bitstream/handle/10919/52078/LD5655.V855_1989.A258.pdf?sequence=1&isAllowed=y.

Bailey, C.M., and Owens, B.E., 2012, Traversing suspect terranes in the central Virginia Piedmont—From Proterozoic anorthosites to modern earthquakes, *in* Eppes, M.C., and Bartholomew, M.J., eds., From the Blue Ridge to the Coastal Plain—Field excursions in the Southeastern United States: Boulder, Colo., Geological Society of America Field Guide 29, p. 327–344, accessed October 14, 2021, at https://doi.org/10.1130/2012.0029(10).

Baird, R.A., 1988, Shear zone geometry in previously foliated rocks—An example from the Clover shear zone, south central VA [abs.]: Geological Society of America Abstracts with Programs, v. 20, no. 4, p. 253.

Baird, R.A., 1989, Tectonic and geologic development of the Charlotte belt, south central Virginia Piedmont: Blacksburg, Va., Virginia Polytechnic Institute and State University, Ph.D. dissertation, 187 p., accessed October 14, 2021, at https://vtechworks.lib.vt.edu/bitstream/handle/10919/54766/LD5655.V856_1989.B357.pdf?sequence=1.

Baird, R.A., 1991, Stratigraphy of the northern Charlotte metamorphic belt—Application to the Charlotte belt/Milton belt problem: Southeastern Geology, v. 32, no. 2, p. 61–82.

Baird, R.A., and Glover, L., III, 1997, Tectonics of the west flank of Carolina terrane in south-central Virginia—Fold nappe emplacement followed by Carboniferous orogen-parallel ductile shear, *in* Glover, L., III, and Gates, A.E., eds., Central and southern Appalachian sutures—Results of the EDGE Project and related studies: Geological Society of America Special Paper 314, p. 25–48.

Bentley, M.G., 1992, A petrographic study of the peralkaline North View pluton, located in the south-central Virginia Piedmont: Richmond, Ky., Eastern Kentucky University, unpublished M.S. thesis, 125 p.

Berquist, C.R., Jr., Drake, A.A., Evans, N.H., Farrar, S.S., Henika, W.S., Horton, J.W., Jr., Lyttle, P.T., Marr, J.D., Jr., Pavlides, L., and Rankin, D.W., 1993, Blue Ridge and Piedmont, *in* Rader, E.K., and Evans, N.H., eds., Geologic map of Virginia—Expanded explanation: Charlottesville, Va., Virginia Division of Mineral Resources, p. 25–59.

Blackburn, T.J., Olsen, P.E., Bowring, S.A., McLean, N.M., Kent, D.V., Puffer, J., McHone, G., Rasbury, E.T., and Et-Touhami, M., 2013, Zircon U-Pb geochronology links the end-Triassic extinction with the Central Atlantic magmatic province: Science, v. 340, no. 6135, p. 941–945, accessed October 14, 2021, at https://doi.org/10.1126/science.1234204.

Blake, D.E., Buford, C.L., Schronce, A.G., and Hill, D.T., 2010, Geologic map of the North Carolina portion of the John H. Kerr Dam 7.5-minute quadrangle, Warren and Vance Counties, North Carolina: North Carolina Geological Survey Open-File Report 2010–01, 1 sheet, scale 1:24,000, accessed October 14, 2021, at https://deq.nc.gov/about/divisions/energy-mineral-land-resources/north-carolina-geological-survey/ncgs-maps/open-file-reports-maps.

Blake, D.E., Finnerty, P.C., Rice, A.K., and Nolan, J.T., 2018, Geologic map of the eastern half of the Warrenton 7.5-minute Quadrangle, Warren County, North Carolina: North Carolina Geological Survey Open-File Report 2018–09, 1 sheet, scale 1:24,000. [Superseded by North Carolina Geological Survey Open-File Report 2020–03.]

Blake, D.E., Rice, A.K., Finnerty, P.C., and Nolan, J.T., 2020, Bedrock geologic map of the Warrenton 7.5-minute Quadrangle, Warren County, North Carolina: North Carolina Geological Survey Open-File Report 2020–03, 1 sheet, scale 1:24,000, accessed October 14, 2021, at https://deq.nc.gov/about/divisions/energy-mineral-land-resources/north-carolina-geological-survey/ncgs-maps/open-file-reports-maps. [Supersedes North Carolina Geological Survey Open-File Report 2018–09.]

Blake, D.E., Stoddard, E.F., and Bradley, P.J., 2011, Transition between the Raleigh and Carolina terranes in north-central North Carolina: Geological Society of America Field Trip Guidebook for the 60th Annual Meeting of the Southeastern Section, Field Trip 403, 44 p.

Blake, D.E., Stoddard, E.F., Bradley, P.J., and Clark, T.W., 2012, Neoproterozoic to Mesozoic petrologic and ductile-brittle structural relationships along the Alleghanian Nutbush Creek fault zone and Deep River Triassic basin in North Carolina, *in* Eppes, M.C., and Bartholomew, M.J., eds., From the Blue Ridge to the Coastal Plain—Field excursions in the Southeastern United States: Boulder, Colo., Geological Society of America Field Guide 29, p. 219–261, accessed October 14, 2021, at https://doi.org/10.1130/2012.0029(07).

Bowman, J.D., 2010, The Aaron Formation—Evidence for a new lithotectonic unit in Carolinia, north central North Carolina: Raleigh, N.C., North Carolina State University, M.S. thesis, 111 p.

Bowman, J.D., and Hibbard, J.P., 2010, The Aaron sequence—A new lithotectonic unit in Carolinia, north central North Carolina [abs.]: Geological Society of America Abstracts with Programs, v. 42, no. 1, p. 164.

Bowman, J.D., Hibbard, J.P., and Miller, B.V., 2013, The Virgilina Sequence redefined, north central North Carolina, *in* Hibbard, J., and Pollock, J., eds., One arc, two arcs, old arc, new arc—The Carolina terrane in central North Carolina—Carolina Geological Society Annual Meeting and Field Trip, November 8–10, 2013, Salisbury, North Carolina, [Guidebook]: [Salisbury, N.C.], Carolina Geological Society, p. 127–138, accessed October 14, 2021, at https://carolinageologicalsociety.org/2010s_files/gb%202013.pdf.

Bradley, P., Cattanach, B., Henika, W., Hibbard, J., Ozdogan, M., Robbins, E., and Thayer, P., 2006, Geology in the Southside Virginia Piedmont: Martinsville, Va., Virginia Museum of Natural History, Scientific publication series, Guidebook no. 6, 28 p. [Edited by W.S. Henika, J. Hibbard, and J. Beard.]

Bradley, P.J., 1996, The structural relationship between the Hyco shear zone and the Milton Terrane in the South Boston, Virginia area: Raleigh, N.C., North Carolina State University, unpublished M.S. thesis, 86 p.

Brown, W.R., 1953, Structural framework and mineral resources of the Virginia Piedmont, *in* McGrain, P., ed., Proceedings of the Southeastern Mineral Symposium, 1950: Kentucky Geological Survey Special Publication, 9th series, no. 1, p. 88–111.

Burton, W.C., 1993, Preliminary bedrock geologic map of the Wightman 7.5′ quadrangle, Virginia: U.S. Geological Survey Open-File Report 93–614, 1 sheet, scale 1:24,000.

Burton, W.C., 1995a, Evidence for pre-cleavage deformation and post-cleavage intrusion in the northern Carolina slate belt, Virginia [abs.]: Geological Society of America Abstracts with Programs, v. 27, no. 2, p. 39.

Burton, W.C., 1995b, Preliminary geologic map of the Lunenburg and Fort Mitchell 7.5′ quadrangles, Virginia: U.S. Geological Survey Open-File Report 95–4, 1 pl., scale 1:24,000, 14-p. pamphlet.

Burton, W.C., and Armstrong, T.R., 1997, Structural and thermobaric history of the western margin of the Goochland terrane in Virginia [abs.]: Geological Society of America Abstracts with Programs, v. 29, no. 3, p. 7–8.

Burton, W.C., Kunk, M.J., and Marr, J.D., Jr., 2000, $^{40}Ar/^{39}Ar$ age constraints on the timing of Alleghanian metamorphism in the central and southern Virginia Piedmont [abs.]: Geological Society of America Abstracts with Programs, v. 32, no. 2, p. A-8.

Butler, J.R., 1980, Review of potential host rocks for radioactive waste disposal in the Piedmont province of North Carolina: U.S. Department of Energy technical report DP–1562/UC—70, prepared by E.I. du Pont de Nemours & Co., Savannah River Laboratory, Aiken, S.C., under contract no. DE–AC09–76SR00001, 47 p., accessed October 14, 2021, at https://www.osti.gov/servlets/purl/6679857/.

Casadevall, T., 1977, The Nutbush Creek dislocation, Vance County, North Carolina, and Mecklenburg County, Virginia—A probable fault of regional significance [abs.]: Geological Society of America Abstracts with Programs, v. 9, no. 2, p. 127–128.

Casadevall, T., and Rye, R.O., 1980, The Tungsten Queen deposit, Hamme district, Vance County, North Carolina—A stable isotope study of a metamorphosed quartz-huebnerite vein: Economic Geology, v. 75, no. 4, p. 523–537.

Chaumba, J.B., Reid, J.C., and Parker, J.C., 2015, Hamme (Tungsten Queen) Mine tailings, Vance County, North Carolina—Mineral chemistry of potentially recoverable huebernite-wolframite and sulfide minerals: Southeastern Geology, v. 51, no. 1, p. 33–49.

Cheek, L.C., and Owens, B.E., 2007, Geochemistry of the Raleigh gneiss in the Piedmont Province of southeastern Virginia—Implications for the nature of the protolith [abs.]: Geological Society of America Abstracts with Programs, v. 39, no. 2, p. 27.

Coler, D.G., Wortman, G.L., Samson, S.D., Hibbard, J.P., and Stern, R., 2000, U-Pb geochronologic, Nd isotopic, and geochemical evidence for the correlation of the Chopawamsic and Milton terranes, Piedmont zone, southern Appalachian orogen: Journal of Geology, v. 108, no. 4, p. 363–381.

Cummins, L.E., 1987, Geochemistry, mineralogy, and origin of Mesozoic diabase dikes of Virginia: Tallahassee, Fla., Florida State University, Ph.D. dissertation, 454 p.

Druhan, R.M., Butler, J.R., Horton, J.W., Jr., and Stoddard, E.F., [1994], The Nutbush Creek fault zone, eastern Piedmont of North Carolina and Virginia, *in* Stoddard, E.F., and Blake, D.E., eds., Geology and field trip guide, western flank of the Raleigh metamorphic belt, North Carolina—Carolina Geological Society field trip guidebook 1994, November 5–6, 1994, Raleigh, North Carolina: Raleigh, N.C., Carolina Geological Society, p. 47–56. [Also available at https://carolinageologicalsociety.org/1990s_files/gb%201994.pdf.]

Druhan, R.M., and Rollins, F.O., 1984, The Nutbush Creek fault zone in the eastern Piedmont of North Carolina [abs.]: Geological Society of America Abstracts with Programs, v. 16, no. 3, p. 135.

Duval, J.S., Jr., Cook, B., and Adams, J.A.S., 1971, Circle of investigation of an air-borne gamma-ray spectrometer: Journal of Geophysical Research, v. 76, no. 35, p. 8466–8470, accessed October 14, 2021, at https://doi.org/10.1029/JB076i035p08466.

Edwards, L.E., Weems, R.E., Carter, M.W., Spears, D.B., and Powars, D.S., 2018, The significance of dinoflagellates in the Miocene Choptank Formation beneath the Midlothian gravels in the southeastern Virginia Piedmont: Stratigraphy, v. 15, no. 3, p. 179–195, accessed October 14, 2021, at https://www.micropress.org/microaccess/stratigraphy/issue-342/article-2076.

Espenshade, G.H., 1947, Tungsten deposits of Vance County, North Carolina, and Mecklenburg County, Virginia: U.S. Geological Survey Bulletin 948–A, 17 p., 5 pls.

Farrar, S.S., 1984, The Goochland granulite terrane—Remobilized Grenville basement in the eastern Virginia Piedmont, *in* Bartholomew, M.J., ed., The Grenville event in the Appalachians and related topics: Boulder, Colo., Geological Society of America Special Paper 194, p. 215–227.

Farrar, S.S., 1985a, Stratigraphy of the northeastern North Carolina Piedmont: Southeastern Geology, v. 25, no. 3, p. 159–183.

Farrar, S.S., 1985b, Tectonic evolution of the easternmost Piedmont, North Carolina: Geological Society of America Bulletin, v. 96, no. 3, p. 362–380.

Farrar, S.S., and Givan, M.J., 1988, Alkaline-peralkaline (A-type) granites of the eastern Piedmont, North Carolina and Virginia [abs.]: Geological Society of America Abstracts with Programs, v. 20, no. 4, p. 263.

Farrar, S.S., and Owens, B.E., 2001, A north-south transect of the Goochland terrane and associated A-type granites, Virginia–North Carolina, *in* Hoffman, C.W., ed., Field trip guidebook, 50th Annual Meeting, Southeastern Section, Geological Society of America, April 2001, Raleigh, North Carolina: Boulder, Colo., Geological Society of America, p. 75–92.

Finnerty, P.C., 2020, A lithotectonic evaluation of the eastern Raleigh terrane in the northern Macon Quadrangle, North Carolina eastern Piedmont: Wilmington, N.C., University of North Carolina at Wilmington, M.S. thesis, 180 p., 2 pls.

Finnerty, P., Nolan, J.T., Rice, A.K., Peach, B.T., Blake, D.E., LaMaskin, T.A., and Barbeau, D.L., Jr., 2019, Status of geologic mapping and LA-ICP-MS U-Pb zircon geochronology from the Raleigh terrane in the North Carolina eastern Piedmont [abs.]: Geological Society of America Abstracts with Programs. v. 51, no. 3, accessed October 15, 2021, at https://doi.org/10.1130/abs/2019SE-327097.

Foose, M.P., Slack, J.F., and Casadevall, T.J., 1980, Textural and structural evidence for a predeformational hydrothermal origin of the Tungsten Queen deposit, Hamme district, North Carolina: Economic Geology, v. 75, no. 4, p. 515–522.

Foose, M.P., Slack, J.F., and Casadevall, T.J., 1981, Textural and structural evidence for a predeformational hydrothermal origin of the Tungsten Queen deposit, Hamme district, North Carolina—A reply: Economic Geology, v. 76, no. 4, p. 980–982.

Gair, J.E., 1977, Map and diagrams showing structural control of the Hamme tungsten deposit, Vance County, North Carolina: U.S. Geological Survey Miscellaneous Investigations Series, Map I–1009, 1 pl., accessed October 15, 2021, at https://doi.org/10.3133/i1009.

Gair, J.E., 1981, Textural and structural evidence for a predeformational hydrothermal origin of the Tungsten Queen deposit, Hamme district, North Carolina, and the Tungsten Queen deposit, Hamme district, Vance County, North Carolina—A stable isotope study of a metamorphosed quartz-huebnerite vein—A discussion: Economic Geology, v. 76, no. 4, p. 978–979.

Gair, J.E., and Windolph, J.F., Jr., 1975, Geochemical soil sampling traverses, Hamme tungsten district, North Carolina—Traverses 289–299, 301–323: U.S. Geological Survey Open-File Report 75–71, 1 pl., scale 1:24,000.

Ganguli, P.M., Kunk, M.J., Wintsch, R.P., Dorais, M.J., and Sacks, P.E., 1995, High precision sanidine $^{40}Ar/^{39}Ar$ results from Mesozoic rhyolite dikes near Lake Gaston, N.C. and VA [abs.]: Geological Society of America Abstracts with Programs, v. 27, no. 1, p. 45.

Glover, L., III, and Sinha, A.K., 1973, The Virgilina deformation, a Late Precambrian to Early Cambrian(?) orogenic event in the central Piedmont of Virginia and North Carolina: American Journal of Science, Special issue, v. 273–A (The Cooper Volume), p. 234–251. ["A special volume of the American Journal of Science in memory of Byron Nelson Cooper, 1912–1971."]

Glover, L., III, Speer, A., Russell, G.S., and Farrar, S.S., 1983, Ages of regional metamorphism and ductile deformation in the central and southern Appalachians: Lithos, v. 16, no. 3, p. 223–245.

Goldberg, S.A., [1994], U-Pb geochronology of volcanogenic terranes of the eastern North Carolina Piedmont—Preliminary results, *in* Stoddard, E.F., and Blake, D.E., eds., Geology and field trip guide, western flank of the Raleigh metamorphic belt, North Carolina—Carolina Geological Society field trip guidebook 1994, November 5–6, 1994, Raleigh, North Carolina: Raleigh, N.C., Carolina Geological Society, p. 13–17.

Goodwin, B.K., Ramsey, K.W., and Wilkes, G.P., [1986], Guidebook to the geology of the Richmond, Farmville, Briery Creek, and Roanoke Creek basins, Virginia—18th Annual Meeting of the Virginia Geological Field Conference, October 18–19, 1986: [Richmond, Va.], Virginia Geological Field Conference, 75 p.

Hack, J.T., 1982, Physiographic divisions and differential uplift in the Piedmont and Blue Ridge: U.S. Geological Survey Professional Paper 1265, 49 p.

Hackley, P.C., and Peper, J.D., 1998, Reconnaissance bedrock geologic map of the Keysville 7.5-minute quadrangle, Prince Edward, Charlotte, and Lunenburg Counties, Virginia: U.S. Geological Survey Open-File Report 98–764, 1 pl., scale 1:24,000, 14-p. pamphlet, accessed May 6, 2016, at http://pubs.usgs.gov/of/1998/0764/.

Hackley, P.C., Peper, J.D., Burton, W.C., and Horton, J.W., Jr., 2007, Northward extension of Carolina slate belt stratigraphy and structure, south-central Virginia—Results from geologic mapping: American Journal of Science, v. 307, no. 4, p. 749–771.

Hadley, J.B., 1973, Igneous rocks of the Oxford area, Granville County, North Carolina: American Journal of Science, Special issue, v. 273–A (The Cooper Volume), p. 217–233. [“A special volume of the American Journal of Science in memory of Byron Nelson Cooper, 1912–1971.”]

Hadley, J.B., 1974, Geologic map of the Oxford quadrangle, Granville and Vance Counties, North Carolina: U.S. Geological Survey Miscellaneous Field Studies Map MF–608, 1 sheet, scale 1:62,500. [Also available at https://ngmdb.usgs.gov/Prodesc/proddesc_3724.htm.]

Hardison, R.B., and Long, D.D., 1910, Soil survey of Granville County, North Carolina: Washington, D.C., U.S. Soil Conservation Service, p. 341–380, scale 1:62,500. [Text file available at https://www.nrcs.usda.gov/Internet/FSE_MANUSCRIPTS/north_carolina/granvilleNC1910/granvilleNC1910.pdf.]

Harris, C.W., 1984, Coarse-grained submarine-fan deposits of magmatic arc affinity in the Late Precambrian Aaron Formation, North Carolina, U.S.A.: Precambrian Research, v. 26, no. 3–4, p. 285–306.

Harris, C.W., and Glover, L., III, [1985], The Virgilina deformation—Implications of stratigraphic correlation in the Carolina slate belt—Field trip guide, Carolina Geological Society, Durham, North Carolina, November 16–17, 1985: [Durham, N.C.], Carolina Geological Society, 35 p. [Also available at https://carolinageologicalsociety.org/1980s_files/gb%201985.pdf.]

Harris, C.W., and Glover, L., III, 1988, The regional extent of the ca. 600 Ma Virgilina deformation—Implications for stratigraphic correlation in the Carolina terrane: Geological Society of America Bulletin, v. 100, no. 2, p. 200–217.

Hatcher, R.D., Jr., 1987, Tectonics of the southern and central Appalachian internides: Annual Reviews of Earth and Planetary Sciences, v. 15, p. 337–362.

Hatcher, R.D., Jr., Howell, D.E., and Talwani, P., 1977, Eastern Piedmont fault system—Speculation on its extent: Geology, v. 5, no. 10, p. 636–640.

Hatcher, R.D., Jr., and Merschat, A.J., 2006, The Appalachian Inner Piedmont—An exhumed strike-parallel, tectonically forced orogenic channel, *in* Law, R.D., Searle, M.P., and Godin, L., eds., Channel flow, ductile extrusion and exhumation in continental collision zones: Geological Society of London Special Publication 268, p. 517–541.

Henika, W.S., 1980, Metamorphic and structural evidence of an intrusive origin for the Shelton Formation, *in* Price, V., Jr., Thayer, P.A., and Ranson, W.A., eds., Geological investigations of Piedmont and Triassic rocks, central North Carolina and Virginia: Carolina Geological Society field trip guidebook, October 11–12, 1980, p. V1–V17. [Also available with different pagination (p. 23–31) at https://carolinageologicalsociety.org/1980s_files/gb%201980.pdf.]

Henika, W.S., 2002, Geologic map of the Virginia portion of the Danville 30 × 60 quadrangle: Virginia Division of Mineral Resources Publication 166, 1 sheet, scale 1:100,000. [Also available at https://www.dmme.virginia.gov/commerce/ProductDetails.aspx?ProductID=1445.]

Henika, W.S., and Thayer, P.A., 1977, Geology of the Blairs, Mount Hermon, Danville, and Ringgold quadrangles, Virginia: Virginia Division of Mineral Resources Publication 2, 45 p., 2 pls., scale 1:24,000.

Henry, E.F., Sinclair, A.W., Perry, H.H., Simmons, C.S., Leighty, R.V., Satterfield, H.R., and Pfeiffer, N.H., 1956, Soil survey of Mecklenburg County, Virginia: Washington, D.C., U.S. Soil Conservation Service, 116 p., 8 soil maps, scale 1:24,000.

Hibbard, J., Bradley, P., and Shell, G., 2017, Ramping through the Piedmont—An overview of the geology of the Hyco shear zone, north-central North Carolina, *in* Hibbard, J., Bradley, P., and Owens, B., Ramping through the Piedmont—Geology of the Hyco shear zone and associated hanging wall rocks in north-central North Carolina—Carolina Geological Society 78th Annual Meeting, November 3–5, 2017, Roxboro, North Carolina: [Raleigh, N.C.], Carolina Geological Society, 24 p.

Hibbard, J.P., 2017, Compiled geologic map of the Hyco shear zone and adjacent portions of the Cluster Springs and Roxboro 7.5-minute quadrangles, Person County, North Carolina: North Carolina Geological Survey Open-File Report 2017–16, 1 sheet, scale 1:24,000, accessed October 14, 2021, at https://deq.nc.gov/about/divisions/energy-mineral-land-resources/north-carolina-geological-survey/ncgs-maps/open-file-reports-maps.

Hibbard, J.P., Beard, J.S., Henika, W.S., and Horton, J.W., Jr., 2016, Geology of the western Piedmont in Virginia, *in* Bailey, C.M., Sherwood, W.C., Eaton, L.S., and Powars, D.S., eds., The geology of Virginia: Martinsville, Va., Virginia Museum of Natural History Special Publication 18, p. 87–124.

Hibbard, J.P., and Bradley, P.J., comps., 2017, Geology of the Hyco shear zone in North Carolina and Virginia: North Carolina Geological Survey Open-File Report 2017–06, 1 sheet, scale 1:80,000, accessed October 14, 2021, at https://deq.nc.gov/about/divisions/energy-mineral-land-resources/north-carolina-geological-survey/ncgs-maps/open-file-reports-maps.

Hibbard, J.P., Miller, B.V., Tracy, R.J., and Carter, B.T., 2005, The Appalachian peri-Gondwanan realm—A palaeogeographical perspective from the south, *in* Vaughan, A.P.M., Leat, P.T., and Pankhurst, R.J., eds., Terrane processes at the margins of Gondwana: Geological Society of London Special Publication, v. 246, p. 97–111.

Hibbard, J.P., and Pollock, J.C., eds., 2013, One arc, two arcs, old arc, new arc—The Carolina terrane in central North Carolina—Carolina Geological Society Annual Meeting and Field Trip, November 8–10, 2013, Salisbury, North Carolina, [Guidebook]: [Salisbury, N.C.], Carolina Geological Society, 265 p., accessed October 14, 2021, at https://carolinageologicalsociety.org/2010s_files/gb%202013.pdf.

Hibbard, J.P., Shell, G.S., Bradley, P.J., Samson, S.D., and Wortman, G.L., 1998, The Hyco shear zone in North Carolina and southern Virginia—Implications for the Piedmont zone-Carolina zone boundary in the southern Appalachians: American Journal of Science, v. 298, no. 2, p. 85–107.

Hibbard, J.P., Stewart, K.G., and Henika, W.S., 2001, Framing the Piedmont zone in North Carolina and southern Virginia, *in* Hoffman, C.W., ed., Field trip guidebook, 50th Annual Meeting, Southeastern Section, Geological Society of America, April 2001, Raleigh, North Carolina: Boulder, Colo., Geological Society of America, p. 1–26.

Hibbard, J.P., Stoddard, E.F., Secor, D.T., and Dennis, A.J., 2002, The Carolina Zone—Overview of Neoproterozoic to early Paleozoic peri-Gondwanan terranes along the eastern flank of the southern Appalachians: Earth Science Reviews, v. 57, nos. 3–4, p. 299–339.

Hibbard, J.P., van Staal, C.R., and Rankin, D.W., 2007, A comparative analysis of pre-Silurian crustal building blocks of the northern and the southern Appalachian orogen: American Journal of Science, v. 307, no. 1, p. 23–45.

Horton, J.W., Jr., Aleinikoff, J.N., and Burton, W.C., 1995, Mesoproterozoic and Neoproterozoic terranes in the eastern Piedmont of Virginia, implications of coordinated field studies and U-Pb geochronology [abs.]: Geological Society of America Abstracts with Programs, v. 27, no. 6, p. A-397.

Horton, J.W., Jr., Aleinikoff, J.N., Burton, W.C., Peper, J.D., and Hackley, P.C., 1999, Geologic framework of the Carolina slate belt in southern Virginia—Insights from geologic mapping and U-Pb geochronology [abs.]: Geological Society of America Abstracts with Programs, v. 31, no. 7, p. A-476.

Horton, J.W., Jr., Berquist, C.R., Jr., Marr, J.D., Jr., Druhan, R.M., Sacks, P.E., and Butler, J.R., 1993a, The Lake Gordon mylonite zone—A link between the Nutbush Creek and Hylas zones of the Eastern Piedmont fault system [abs.]: Geological Society of America Abstracts with Programs, v. 25, no. 4, p. 23.

Horton, J.W., Jr., and Daniels, D.L., 1999, Applications of aerial gamma-ray spectrometric and magnetic surveys in geologic mapping—A case study in southern Virginia and northern North Carolina, *in* Sacks, P.E., ed., Geology of the Fall Zone region along the North Carolina-Virginia State line—Guidebook for the 1999 meeting of the Carolina Geological Society, Emporia, Virginia, November 6–7, 1999: [Emporia, Va.], Carolina Geological Society, p. 29–36.

Horton, J.W., Jr., Drake, A.A., Jr., and Rankin, D.W., 1989, Tectonostratigraphic terranes and their Paleozoic boundaries in the central and southern Appalachians, *in* Dallmeyer, R.D., ed., Terranes in the circum-Atlantic Paleozoic orogens: Boulder, Colo., Geological Society of America Special Paper 230, p. 213–245.

Horton, J.W., Jr., Drake, A.A., Jr., and Rankin, D.W., 1994, Terranes and overlap sequences in the central and southern Appalachians, an expanded explanation for part of the circum-Atlantic terrane map: U.S. Geological Survey Open-File Report 94–682, 40 p.

Horton, J.W., Jr., Drake, A.A., Jr., Rankin, D.W., and Dallmeyer, R.D., 1991, Preliminary tectonostratigraphic terrane map of the Central and Southern Appalachians: U.S. Geological Survey Miscellaneous Investigations Series Map I–2163, 1 pl., scale 1:2,000,000, 15-p. pamphlet.

Horton, J.W., Jr., Owens, B.E., Hackley, P.C., Burton, W.C., Sacks, P.E., and Hibbard, J.P., 2016, Geology of the eastern Piedmont in Virginia, *in* Bailey, C.M., Sherwood, W.C., Eaton, L.S., and Powars, D.S., eds., The geology of Virginia: Martinsville, Va., Virginia Museum of Natural History Special Publication 18, p. 125–158.

Horton, J.W., Jr., Peper, J.D., Burton, W.C., Weems, R.E., and Sacks, P.E., 2001, Geologic map of the South Boston 30X60-minute quadrangle, Virginia and North Carolina [abs.]: Geological Society of America Abstracts with Programs, v. 33, no. 2, p. A-23.

Horton, J.W., Jr., Peper, J.D., Burton, W.C., Weems, R.E., Sacks, P.E., and Crider, E.A., Jr., 2022, Database for the geologic map of the South Boston 30′ × 60′ quadrangle, Virginia and North Carolina: U.S. Geological Survey data release, https://doi.org/10.5066/P98AQDR7.

Horton, J.W., Jr., Peper, J.D., Marr, J.D., Jr., Burton, W.C., and Sacks, P.E., 1993b, Preliminary geologic map of the South Boston 30 X 60 minute quadrangle, Virginia and North Carolina: U.S. Geological Survey Open-File Report 93–244, 1 pl., scale 1:100,000, 20-p. pamphlet. [Also available at https://doi.org/10.3133/ofr93244.]

Horton, J.W., Jr., and Stern, T.W., 1994, Tectonic significance of preliminary uranium-lead ages from the eastern Piedmont of North Carolina [abs.]: Geological Society of America Abstracts with Programs, v. 26, p. 21.

Huber, P.H., and LeTourneau, P.M., 2006, Revised lithostratigraphy of the Norian-Hettangian Pomperaug rift basin, western Connecticut—Resolving a century-old conflict in geologic interpretation: New Mexico Museum of Natural History and Science Bulletin 37, p. 43–61.

Hund, E., 1987, U-Pb dating of granites from the Charlotte belt of the southern Appalachians: Blacksburg, Va., Virginia Polytechnic Institute and State University, unpublished M.S. thesis, 73 p.

Ingle, S., Mueller, P.A., Heatherington, A.L., and Kozuch, M., 2003, Isotopic evidence for the magmatic and tectonic histories of the Carolina terrane—Implications for stratigraphy and terrane affiliation: Tectonophysics, v. 371, nos. 1–4, p. 187–211.

Johnson, S.S., Wilkes, G.P., and Zeiler, T.L., 1985, Simple Bouguer gravity anomaly map of the Farmville, Briery Creek, Roanoke Creek, Randolph, and Scottsburg basins and vicinity, Virginia: Virginia Division of Mineral Resources Publication 47, 1 sheet, scale 1:125,000.

Jourdan, F., Marzoli, A., Bertrand, H., Cirilli, S., Tanner, L.H., Kontak, D.J., McHone, G., Renne, P.R., and Bellieni, 2009, $^{40}Ar/^{39}Ar$ ages of CAMP in North America—Implications for the Triassic-Jurassic boundary and the ^{40}K decay constant bias: Lithos, v. 110, p. 167–180, accessed October 15, 2021, at https://doi.org/10.1016/j.lithos.2008.12.011.

Kish, S.A., and Fullagar, P.D., 1978, Summary of geochronological data for Late Paleozoic plutons from high grade metamorphic belts of the eastern Piedmont of North Carolina, South Carolina, and Virginia, *in* Snoke, A.W., ed., Geological investigations of the eastern Piedmont, southern Appalachians—Carolina Geological Society field trip guidebook 1978, October 7–8, 1978, West Columbia, South Carolina: [West Columbia], S.C., Carolina Geological Society, p. 61–64.

Kish, S.A., and Stein, H.J., 1989, Post-Acadian metasomatic origin for copper-bearing vein deposits of the Virgilina district, North Carolina and Virginia: Economic Geology, v. 84, no. 7, p. 1903–1920.

Kozur, H.W., and Weems, R.E., 2007, Upper Triassic conchostracan biostratigraphy of the continental rift basins of eastern North America—Its importance for correlating Newark Supergroup events with the Germanic Basin and the international geologic time scale, *in* Lucas, S.G., and Spielmann, J.A., eds., The global Triassic: New Mexico Museum of Natural History and Science Bulletin, v. 41, p. 137–188.

Kozur, H.W., and Weems, R.E., 2010, The biostratigraphic importance of conchostracans in the continental Triassic of the northern hemisphere, *in* Lucas, S.G., ed., The Triassic timescale: Geological Society of London Special Publication 334, p. 315–417.

Kreisa, R.D., 1980, Geology of the Omega, South Boston, Cluster Springs, and Virgilina quadrangles, Virginia: Charlottesville, Va., Virginia Division of Mineral Resources Publication 5, 22 p., 2 pls., scale 1:24,000.

Kunk, M.J., Horton, J.W., Jr., and Peper, J.D., 1995, Preliminary $^{40}Ar/^{39}Ar$ mineral ages from the Raleigh metamorphic belt, Carolina slate belt, and Milton belt in the South Boston, VA-NC, 30×60 minute quadrangle [abs.]: Geological Society of America Abstracts with Programs, v. 27, no. 2, p. 67.

Laney, F.B., 1917, The geology and ore deposits of the Virgilina district of Virginia and North Carolina: Virginia Geological Survey Bulletin 14, 176 p., folded map in pocket. [Prepared jointly by the Virginia geological survey and the North Carolina geological and economic survey. Also published as North Carolina Geological and Economic Survey Bulletin 26.]

LeGrand, H.E., 1960, Geology and ground-water resources of Pittsylvania and Halifax Counties: Charlottesville, Va., Virginia Division of Mineral Resources Bulletin 75, 86 p., 1 pl., folded map in pocket. [Also available at https://energy.virginia.gov/commercedocs/BUL_75.pdf.]

LeHuray, A.P., 1989, U-Pb and Th-Pb whole rock studies in the southern Appalachian Piedmont: Southeastern Geology, v. 30, no. 2, p. 77–94.

Lesure, F.G., 1993, Reconnaissance geochemistry in the southern part of the Virgilina district, North Carolina and Virginia: U.S. Geological Survey Miscellaneous Field Studies Map MF–2203, 1 sheet, scale 1:48,000. [Also available at https://ngmdb.usgs.gov/Prodesc/proddesc_5835.htm.]

Lesure, F.G., Mosier, E.L., Watts, K.C., Jr., and Frisken, J.G., 1992, Analyses and descriptions of some rock samples, Virgilina district and vicinity, North Carolina and Virginia: U.S. Geological Survey Open-File Report 92–314, 19 p. [Also available at https://pubs.usgs.gov/of/1992/0314/report.pdf.]

Marzoli, A., Jourdan, F., Puffer, J.H., Cuppone, T., Tanner, L.H., Weems, R.E., Bertrand, H., Cirilli, S., Bellieni, G., and De Min, A., 2011, Timing and duration of the Central Atlantic magmatic province in the Newark and Culpeper basins, eastern U.S.A.: Lithos, v. 122, nos. 3–4, p. 175–188, accessed October 15, 2021, at https://www.sciencedirect.com/science/article/pii/S0024493710003567.

McCartan, L., Peper, J.D., Bachman, L.J., and Horton, J.W., Jr., 1998, Application of geologic map information to water quality issues in the southern part of the Chesapeake Bay watershed, Maryland and Virginia, eastern United States: Journal of Geochemical Exploration, v. 64, nos. 1–3, p. 355–376, accessed October 15, 2021, at https://doi.org/10.1016/S0375-6742(98)00043-0.

McHone, J.G., 2000, Non-plume magmatism and rifting during the opening of the central Atlantic Ocean: Tectonophysics, v. 316, nos. 3–4, p. 287–296.

Meador, J.P., 1949, The geography and petrography of eastern Lunenburg County, Virginia: Charlottesville, Va., University of Virginia, unpublished M.A. thesis, 56 p.

Miller, B.A., and Juilleret, J., 2020, The colluvium and alluvium problem—Historical review and current state of definitions: Earth Science Reviews, v. 209, 22 p., accessed October 16, 2021, at https://doi.org/10.1016/j.earscirev.2020.103316.

Morrow, R.H., IV, 2015, The Macon fault zone—A folded dextral shear strand of the eastern Piedmont fault system in North Carolina: Wilmington, N.C., University of North Carolina at Wilmington, M.S. thesis, 117 p., 2 pls, accessed October 14, 2021, at http://dl.uncw.edu/Etd/2015-1/r1/morrowr/robertmorrow.pdf.

Morrow, R.H., IV, Stoddard, E.F., and Blake, D.E., 2016, Geologic map of the Inez 1:24,000 quadrangle, Warren County, North Carolina (revised December 19, 2017): North Carolina Geological Survey Open-File Report 2016–12, 1 sheet, scale 1:24,000 accessed October 14, 2021, at https://deq.nc.gov/about/divisions/energy-mineral-land-resources/north-carolina-geological-survey/ncgs-maps/open-file-reports-maps.

Muller, I.P., and Owens, B.E., 2020, Further investigations of the Union Mill gneiss in the Raleigh terrane, Piedmont province, Virginia [abs.]: Geological Society of America Abstracts with Programs v. 52, no. 2, accessed October 16, 2021, at https://doi.org/10.1130/abs/2020SE-344872.

Nelms, D.L., Harlow, G.E., Jr., and Bruce, T.S., 2016, Hydrogeology of Virginia, *in* Bailey, C.M., Sherwood, W.C., Eaton, L.S., and Powars, D.S., eds., The geology of Virginia: Martinsville, Va., Virginia Museum of Natural History Special Publication 18, p. 315–340.

Nelson, A.E., and Nelson, F.J., 1997, Reconnaissance geologic map of the Halifax, Scottsburg, Nathalie, and Conner Lake 7.5-minute quadrangles, Halifax and Charlotte Counties, Virginia: U.S. Geological Survey Open-File Report 97–707, 1 pl., scale 1:48,000, 16-p. pamphlet, accessed October 16, 2021, at https://doi.org/10.3133/ofr97707.

Nolan, J.T., 2020, Evaluating petrologic, structural, and geochronologic relationships of the eastern Raleigh terrane in the western Afton Quadrangle, North Carolina: Wilmington, N.C., University of North Carolina at Wilmington, M.S. thesis, 185 p., 2 pls.

Nolan, J.T., Finnerty, P., Blake, D.E., LaMaskin, T.H., and Barbeau, D.L., Jr., 2020, Pushing up daisies—Domainal analysis of the transpressional eastern Raleigh terrane using combined lithologic, structural, and geochronologic data [abs.]: Geological Society of America Abstracts with Programs, v. 52, no. 2, accessed October 16, 2021, at https://doi.org/10.1130/abs/2020SE-345264.

Olsen, P.E., 1997, Stratigraphic record of the early Mesozoic breakup of Pangea in the Laurasia-Gondwana rift system: Annual Review of Earth and Planetary Sciences, v. 25, p. 337–401.

Olsen, P.E., McCune, A.R., and Thomson, K.S., 1982, Correlation of the early Mesozoic Newark Supergroup by vertebrates, principally fishes: American Journal of Science, v. 282, p. 1–44.

Owens, B.E., and Bailey, C.M., [2018], Geology of the Southside Piedmont, Virginia—2018 Virginia Geological Field Conference: [Williamsburg, Va.], College of William & Mary, 34 p., accessed September 3, 2020, at https://wm1693.app.box.com/s/pjc0y83boidu8h0sliui0j3eo0sd6cmi.

Owens, B.E., and Buchwaldt, R., 2009, The taste of crow—A revised age for a metaigneous variety of the Raleigh gneiss, southeastern Virginia Piedmont [abs.]: Geological Society of America Abstracts with Programs, v. 41, no. 1, p. 47.

Ozdogan, M., Cattanach, B.L., Bradley, P.J., and Hibbard, J.P., 1997, Preliminary results of detailed mapping in the Milton terrane, south-central Virginia [abs.]: Geological Society of America Abstracts with Programs, v. 29, p. 62.

Parker, J.M., III, 1963, Geologic setting of the Hamme tungsten district, North Carolina and Virginia: U.S. Geological Survey Bulletin 1122–G, 69 p., 2 pls., scales 1:48,000 and 1:125,000.

Pavich, M.J., Leo, G.W., Obermeier, S.F., and Estabrook, J.R., 1989, Investigations of the characteristics, origin, and residence time of the upland residual mantle of the Piedmont of Fairfax County, Virginia: U.S. Geological Survey Professional Paper 1352, 58 p., 3 pls., scale 1:100,000, accessed October 16, 2021, at http://pubs.er.usgs.gov/publication/pp1352.

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.

Peach, B.T., 2018, Lithodemic, geochronologic, and structural evaluation of the Raleigh terrane in the North Carolina eastern Piedmont: Wilmington, N.C., University of North Carolina at Wilmington, M.S. thesis, 183 p., 2 pls.

Peach, B.T., Blake, D.E., and LaMaskin, T.A., 2017, Zircon geochronology of the Raleigh terrane in the North Carolina eastern Piedmont [abs.]: Geological Society of America Abstracts with Programs, v. 49, accessed October 16, 2021, at https://doi.org/10.1130/abs/2017SE-289947.

Peper, J.D., Clark, T.W., and Kanahele, K.A., 1996, Geologic map of the Clarksville South and Tungsten 7.5-minute quadrangles, Virginia and North Carolina: U.S. Geological Survey Miscellaneous Geologic Investigations Series Map I–2471, 1 sheet, scale 1:24,000. [Also available at https://doi.org/10.3133/i2471.]

Peper, J.D., Grosz, A.E., Kress, T.H., Collins, T.K., Kappesser, G.B., Huber, C.M., and Webb, J.R., 1995, Acid deposition sensitivity map of the Southern Appalachian Assessment Area; Virginia, North Carolina, South Carolina, Tennessee, Georgia, and Alabama: U.S. Geological Survey Open-File Report 95–810, scale 1:1,000,000, accessed October 16, 2021, at https://pubs.er.usgs.gov/publication/ofr95810.

Peper, J.D., and Hackley, P.C., 1999, Geologic map of the Green Bay 7.5-minute quadrangle, Prince Edward County, Virginia: U.S. Geological Survey Open-File Report 99–423, 2 pls., scale 1:24,000, 25-p. pamphlet, accessed October 16, 2021, at http://pubs.usgs.gov/of/1999/0423/.

Peper, J.D., McCartan, L.B., Horton, J.W., Jr., and Reddy, J.E., 2001, Preliminary lithogeochemical map showing near-surface rock types in the Chesapeake Bay watershed, Virginia and Maryland: U.S. Geological Survey Open-File Report 01–187, 1 pl., scale 1:500,000, 26-p. pamphlet, accessed October 13, 2021, at http://pubs.usgs.gov/of/2001/of01-187.

Peper, J.D., and Olinger, K.I., 1998, Reconnaissance geologic map of the Buffalo Springs and Nelson 7.5-minute quadrangles, Virginia and North Carolina: U.S. Geological Survey Open-File Report 98–775, 28 p., 1 pl., scale 1:24,000.

Peper, J.D., and Wygant, A.W., 1997, Reconnaissance geologic map of the Clarksville North and Boydton 7.5-minute quadrangles, Mecklenburg and Charlotte Counties, Virginia: U.S. Geological Survey Open-File Report 97–524, 25 p., 1 pl., scale 1:48,000. [Also available at https://doi.org/10.3133/ofr97524.]

Pindell, J., and Dewey, J.F., 1982, Permo-Triassic reconstruction of western Pangea and the evolution of the Gulf of Mexico/Caribbean region: Tectonics, v. 1, no. 2, p. 179–211.

Pollock, J.C., 2007, The Neoproterozoic-early Paleozoic tectonic evolution of the peri-Gondwanan margin of the Appalachian orogen—An integrated geochronological, geochemical and isotopic study from North Carolina and Newfoundland: Raleigh, N.C., North Carolina State University, Ph.D. dissertation, 194 p., accessed October 14, 2021, at https://repository.lib.ncsu.edu/handle/1840.16/5435.

Pollock, J.C., Hibbard, J.P., and Sylvester, P.J., 2010, Depositional and tectonic setting of the Neoproterozoic–early Paleozoic rocks of the Virgilina sequence and Albemarle Group, North Carolina, *in* Tollo, R.P., Bartholomew, M.J., Hibbard, J.P., and Karabinos, P.M., eds., From Rodinia to Pangea—The lithotectonic record of the Appalachian region: Boulder, Colo., Geological Society of America Memoir 206, p. 739–772.

Ragland, P.C., Cummins, L.E., and Arthur, J.D., 1992, Compositional patterns for early Mesozoic diabases from South Carolina to central Virginia, *in* Puffer, J.H., and Ragland, P.C., eds., Eastern North American Mesozoic magmatism: Boulder, Colo., Geological Society of America Special Paper 268, p. 309–331.

Ramsey, K.W., 1982, Depositional environments and provenance of sedimentary rocks in the Roanoke Creek basin (Triassic), Virginia: Nashville, Tenn., Vanderbilt University, unpublished M.S. thesis, 116 p.

Rice, A.K., 2021, Lithodemic, lithologic and structural analysis of the eastern Raleigh terrane in the southern Macon Quadrangle, North Carolina: Wilmington, N.C., University of North Carolina at Wilmington, M.S. thesis, 139 p., 2 pl.

Rice, A.K., Stoddard, E.F., Blake, D.E., and Bradley, P.J., 2020, Compiled data for the Henderson and western Roanoke Rapids 1:100K sheets—Utilizing GIS to unravel structural geology problems [abs.]: Geological Society of America Abstracts with Programs, v. 52, no. 2, accessed October 16, 2021, at https://doi.org/10.1130/abs/2020SE-344955.

Robbins, E.I., 1985, Palynostratigraphy of coal-bearing sequences in early Mesozoic basins of the eastern United States, *in* Robinson, G.R., Jr., and Froelich, A.J., eds., Proceedings of the second U.S. Geological Survey workshop on the early Mesozoic basins of the eastern United States: United States Geological Survey Circular 946, p. 27–29.

Rogers, J.J.W., and Coleman, D.S., 2010, Evolution of the slate belt in North Carolina: Southeastern Geology, v. 47, no. 1, p. 1–14.

Russell, G.S., Russell, C.W., and Farrar, S.S., 1985, Alleghanian deformation and metamorphism in the eastern North Carolina Piedmont: Geological Society of America Bulletin, v. 96, no. 3, p. 381–387.

Sacks, P.E., 1996a, Geologic map of the Bracey 7.5-minute quadrangle, Mecklenburg County, Virginia, and Warren County, North Carolina: U.S. Geological Survey Miscellaneous Field Studies Map MF–2285, 1 sheet, scale 1:24,000. [Also available at https://doi.org/10.3133/mf2285.]

Sacks, P.E., 1996b, Geologic map of the South Hill SE 7.5-minute quadrangle, Mecklenburg and Brunswick Counties, Virginia, and Warren County, North Carolina: U.S. Geological Survey Miscellaneous Field Studies Map MF–2286, 1 sheet, scale 1:24,000. [Also available at https://doi.org/10.3133/mf2286.]

Sacks, P.E., 1996c, Geologic map of the Gasburg 7.5-minute quadrangle, Brunswick County, Virginia, and Warren, Northampton, and Halifax Counties, North Carolina: U.S. Geological Survey Miscellaneous Field Studies Map MF–2287, 1 sheet, scale 1:24,000.

Sacks, P.E., 1999, Geologic overview of the eastern Appalachian Piedmont along Lake Gaston, North Carolina and Virginia, *in* Sacks, P.E., ed., Geology of the Fall Zone region along the North Carolina-Virginia State line—Guidebook for the 1999 meeting of the Carolina Geological Society, Emporia, Virginia, November 6–7, 1999: [Emporia, Va.], Carolina Geological Society, p. 1–15.

Sacks, P.E., and Horton, J.W., Jr., 1993, Structural and lithologic relationships in the Raleigh metamorphic belt near Lake Gaston, Virginia and North Carolina [abs.]: Geological Society of America Abstracts with Programs, v. 25, no. 4, p. 66.

Sacks, P.E., Boltin, W.R., and Stoddard, E.F., 2011, Bedrock geologic map of the Hollister 7.5-minute Quadrangle, Warren and Halifax Counties, North Carolina: North Carolina Geological Survey Open-File Report 2011–03, 1 sheet, scale 1:24,000. [Also available at https://deq.nc.gov/about/divisions/energy-mineral-land-resources/north-carolina-geological-survey/ncgs-maps/open-file-reports-maps.]

Samson, S., Palmer, A.R., Robison, R.A., and Secor, D.T., Jr., 1990, Biogeographical significance of Cambrian trilobites from the Carolina slate belt: Geological Society of America Bulletin, v. 102, p. 1459–1470.

Samson, S.D., Coler, D.G., and Speer, J.A., 1995a, Geochemical and Nd–Sr–Pb isotopic composition of Alleghanian granites of the southern Appalachians—Origin, tectonic setting, and source characterization: Earth and Planetary Science Letters, v. 134, nos. 3–4, p. 359–376.

Samson, S.D., Hibbard, J.P., and Wortman, G.L., 1995b, Nd isotopic evidence for juvenile crust in the Carolina terrane, southern Appalachians: Contributions to Mineralogy and Petrology, v. 121, no. 2, p. 171–184.

Samson, S.D., Secor, D.T., and Hamilton, M.A., 2001, Wandering Carolina—Tracking exotic terranes with detrital zircons [abs.]: Geological Society of America Abstracts with Programs, v. 33, no. 6, p. 1558.

Schaeffer, B., and McDonald, N.G., 1978, Redfieldiid fishes from the Triassic-Liassic Newark Supergroup of eastern North America: Bulletin of the American Museum of Natural History, v. 159, no. 4, p. 131–173, accessed October 26, 2021, at https://digitallibrary.amnh.org/handle/2246/561.

Secor, D.T., Jr., Samson, S.L., Snoke, A.W., and Palmer, A.R., 1983, Confirmation of the Carolina slate belt as an exotic terrane: Science, v. 221, no. 4611, p. 649–651.

Shell, G.S., Jr., 1996, Nature of the Carolina slate belt-Milton belt boundary near Yanceyville, North Carolina: Raleigh, N.C., North Carolina State University, unpublished M.S. thesis, 96 p.

Shervais, J.W., Shelley, S.A., and Secor, D.T., Jr., 1996, Geochemistry of volcanic rocks of the Carolina and Augusta terranes in central South Carolina—An exotic rifted volcanic arc?, *in* Nance, R.D., and Thompson, M.D., eds., Avalonian and related peri-Gondwanan terranes of the Circum-North Atlantic: Boulder, Colo., Geological Society of America Special Paper 304, p. 219–236.

Sinha, A.K., Hund, E.A., and Hogan, J.P., 1989, Paleozoic accretionary history of the North American plate margin (central and southern Appalachians)—Constraints from the age, origin, and distribution of granitic rocks, *in* Hillhouse, J.W., ed., Deep structure and past kinematics of accreted terranes: Washington, D.C., American Geophysical Union Monograph Series, v. 50, p. 219–238.

Sinha, A.K, and Zietz, I., 1982, Geophysical and geochemical evidence for a Hercynian magmatic arc, Maryland to Georgia: Geology, v. 10, no. 11, p. 593–596.

Smoot, J.P., 1991, Sedimentary facies and depositional environments of early Mesozoic Newark Supergroup basins, eastern North America: Palaeogeography, Palaeoclimatology, Palaeoecology, v. 84, nos. 1–4, p. 369–423.

Smoot, J.P., 2016, Early Mesozoic geology in Virginia, *in* Bailey, C.M., Sherwood, W.C., Eaton, L.S., and Powars, D.S., eds., The geology of Virginia: Martinsville, Va., Virginia Museum of Natural History Special Publication 18, p. 159–192.

Speer, J.A., McSween, H.Y., Jr., and Gates, A.E., 1994, Generation, segregation, ascent, and emplacement of Alleghanian plutons in the southern Appalachians: Journal of Geology, v. 102, no. 3, p. 249–267.

Stimpson, J.V., Mathis, R.L., Jr., Shope, W.I., Cawthorn, J.W., and Clapp, D., 1980, Soil survey of Vance County, North Carolina: Washington, D.C., U.S. Soil Conservation Service, 94 p., 17 soil maps, scale 1:20,000.

Stoddard, E.F., 1992, A new suite of post-orogenic dikes in the eastern North Carolina Piedmont; Part II, mineralogy and geochemistry: Southeastern Geology, v. 32, no. 3, p. 119–142.

Stoddard, E.F., and Bechtel, R., 2020, Bedrock geologic map of the Vicksboro 7.5-minute Quadrangle, Warren, Vance, and Franklin Counties, North Carolina: North Carolina Geological Survey Open-File Report 2020–02, 1 sheet, scale 1:24,000, accessed October 14, 2021, at https://deq.nc.gov/about/divisions/energy-mineral-land-resources/north-carolina-geological-survey/ncgs-maps/open-file-reports-maps. [Supersedes North Carolina Geological Survey Open-File Report 2018–11.]

Stoddard, E.F., and Blake, D.E., 2020, Geology of the Vicksboro quadrangle, NC—Implications for eastern Piedmont plutons, fault zones, and terranes [abs.]: Geological Society of America Abstracts with Programs, v. 52, no. 2, accessed October 16, 2021, at https://doi.org/10.1130/abs/2020SE-344923.

Stoddard, E.F., Blake, D.E., and Buford, C.L., 2016, Bedrock geologic map of the Middleburg 7.5-minute quadrangle, Vance and Warren Counties, North Carolina: North Carolina Geological Survey Open-File Report 2016–04, 1 sheet, scale 1:24,000, accessed October 14, 2021, at https://deq.nc.gov/about/divisions/energy-mineral-land-resources/north-carolina-geological-survey/ncgs-maps/open-file-reports-maps.

Stoddard, E.F., Delorey, C.M., McDaniel, R.D., Dooley, R.E., Ressetar, R., and Fullagar, P.D., 1986, A new suite of post-orogenic dikes in the eastern North Carolina Piedmont; Part I, occurrence, petrography, paleomagnetics, and Rb/Sr geochronology: Southeastern Geology, v. 27, no. 1, p. 1–12.

Stoddard, E.F., Farrar, S.S., Horton, J.W., Jr., Butler, J.R., and Druhan, R.M., 1991, The eastern Piedmont in North Carolina, chap. 5 *of* Horton, J.W., Jr., and Zullo, V.A., eds., The geology of the Carolinas—Carolina Geological Society fiftieth anniversary volume (1st ed.): Knoxville, Tenn., University of Tennessee Press, p. 79–92.

Stoddard, E.F., Farrar, S.S., Huntsman, J.R., Horton, J.W., Jr., and Boltin, W.R., 1987, Metamorphism and tectonic framework of the northeastern Piedmont of North Carolina, *in* Whittecar, G.R., ed., Geological excursions in Virginia and North Carolina—Geological Society of America—Southeastern Section, 36th Annual Meeting, March 25–27, 1987, Norfolk, Virginia, Guidebook: Norfolk, Va., Old Dominion University, Department of geological sciences, p. 43–86.

Stoddard, E.F., Sacks, P.E., Clark, T.W., and Bechtel, R., 2011, Bedrock geologic map of the Littleton 7.5-minute quadrangle, Warren and Halifax Counties, North Carolina: North Carolina Geological Survey Open-File Report 2011–02, 1 sheet, scale 1:24,000, accessed October 14, 2021, at https://deq.nc.gov/about/divisions/energy-mineral-land-resources/north-carolina-geological-survey/ncgs-maps/open-file-reports-maps.

Streckeisen, A.L., 1973, Plutonic rocks—Classification and nomenclature recommended by the IUGS subcommission on the systematics of igneous rocks: Geotimes, v. 18, no. 10, p. 26–30.

Sues, H.-D., and Olsen, P.E., 2015, Stratigraphic and temporal context and faunal diversity of Permian-Jurassic continental tetrapod assemblages from the Fundy rift basin, eastern Canada: Atlantic Geology, v. 51, p. 139–205.

Sweet, P.C., 1976, Abandoned copper mines and prospects in the Virgilina District, Virginia: Virginia Minerals, v. 22, no. 3, p. 25–34.

Tobisch, O.T., 1972, Geologic map of the Milton quadrangle, Virginia-North Carolina and adjacent areas of Virginia: U.S. Geological Survey Miscellaneous Geologic Investigations Map I–638, scale 1:62,500.

Tobisch, O.T., and Glover, L., III, 1969, Metamorphic changes across part of the Carolina slate belt-Charlotte belt boundary, North Carolina and Virginia, *in* Geological Survey research 1969: U.S. Geological Survey Professional Paper 650–C, p. C1–C7. [Also available at https://doi.org/10.3133/pp650C.]

Tobisch, O.T., and Glover, L., III, 1971, Nappe formation in part of the central and southern Appalachian Piedmont: Geological Society of America Bulletin, v. 82, p. 2209–2230.

U.S. Geological Survey, 1971, Aeromagnetic map of the South Boston quadrangle, Halifax County, Virginia, and Person and Granville Counties, North Carolina: U.S. Geological Survey Geophysical Investigations Map GP–747, scale 1:62,500. [Also available at https://ngmdb.usgs.gov/Prodesc/proddesc_6102.htm.]

U.S. Geological Survey, 1978a, Aeromagnetic map of parts of Prince Edward, Lunenburg, and Mecklenburg Counties, Virginia: U.S. Geological Survey Open-File Report 78–599, 1 pl., scale 1:250,000, accessed August 9, 2018, at https://pubs.er.usgs.gov/publication/ofr78599.

U.S. Geological Survey, 1978b, Aeroradioactivity map of parts of Prince Edward, Lunenburg, and Mecklenburg Counties, Virginia: U.S. Geological Survey Open-File Report 78–598, 1 pl., scale 1:250,000, accessed August 17, 2018, at https://pubs.er.usgs.gov/publication/ofr78598.

U.S. Geological Survey, 1994a, Aeroradiometric maps of parts of the South Boston and Emporia 30′ X 60′ quadrangles, Virginia and North Carolina: U.S. Geological Survey Open-File Report 94–253, 8 sheets, scale 1:100,000, accessed September 18, 2019, at https://pubs.er.usgs.gov/publication/ofr94253.

U.S. Geological Survey, 1994b, Residual aeromagnetic map of the Danville area, Virginia and North Carolina: U.S. Geological Survey Open-File Report 94–219, 2 sheets, scale 1:100,000, accessed September 18, 2019, at https://pubs.er.usgs.gov/publication/ofr94219.

Vines, J., Hibbard, J., and Shell, G., 1998, Structural geology of the High Rock granite—Implications for displacement along the Hyco shear zone, North Carolina: Southeastern Geology, v. 37, p. 163–176.

Virginia Division of Mineral Resources, 1993, Geologic map of Virginia: Charlottesville, Va., Virginia Division of Mineral Resources, scale 1:500,000. [Also available at https://ngmdb.usgs.gov/Prodesc/proddesc_34878.htm.]

Weems, R.E., 1998, Newly recognized en echelon fall lines in the Piedmont and Blue Ridge provinces of North Carolina and Virginia, with a discussion of their possible ages and origins: U.S. Geological Survey Open-File Report 98–374, 28 p., 12 figs.

Weems, R.E., and Edwards, L.E., 2007, Post-middle Miocene origin of modern landforms in the eastern Piedmont of Virginia: Stratigraphy, v. 4, no. 1, p. 35–48.

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, no. 2, p. 195–209.

Weems, R.E., Schindler, J.S., and Lewis, W.C., 2010, Detailed sections from auger holes in the Emporia 1:100,000-scale quadrangle, North Carolina and Virginia: U.S. Geological Survey Open-File Report 2010–1121, 288 p., accessed October 16, 2021, at https://pubs.usgs.gov/of/2010/1121.

Weems, R.E., Tanner, L.H., and Lucas, S.G., 2016, Synthesis and revision of the lithostratigraphic groups and formations in the Upper Permian?–Lower Jurassic Newark Supergroup of eastern North America: Stratigraphy, v. 13, no. 2, p. 111–153.

Wortman, G.L., Samson, S.D., and Hibbard, J.P., 1996, Discrimination of the Milton belt and the Carolina terrane in the southern Appalachians—A Nd isotopic approach: Journal of Geology, v. 104, no. 2, p. 239–247.

Wortman, G.L., Samson, S.D., and Hibbard, J.P., 1998, Precise timing constraints on the kinematic development of the Hyco shear zone—Implications for the central Piedmont shear zone, southern Appalachian orogen: American Journal of Science, v. 298, no. 2, p. 108–130.

Wortman, G.L., Samson, S.D., and Hibbard, J.P., 2000, Precise U-Pb zircon constraints on the earliest magmatic history of the Carolina terrane: Journal of Geology, v. 108, no. 3, p. 321–338, accessed October 16, 2021, at https://doi.org/10.1086/314401.

Zietz, I., Calver, J.L., Johnson, S.S., and Kirby, J.R., 1977a, Aeromagnetic map of Virginia: U.S. Geological Survey Geophysical Investigations Map GP–915, scale 1:500,000.

Zietz, I., Calver, J.L., Johnson, S.S., and Kirby, J.R., 1977b, Aeromagnetic map of Virginia—In color: U.S. Geological Survey Geophysical Investigations Map GP–916, scale 1:1,000,000.

Horton and others—**Geologic Map of the South Boston 30′ × 60′ Quadrangle, Virginia and North Carolina**—Scientific Investigations Map 3483

ISSN 2329-132X (online)
https://doi.org/10.3133/sim3483
Supersedes USGS Open-File Report 93-244