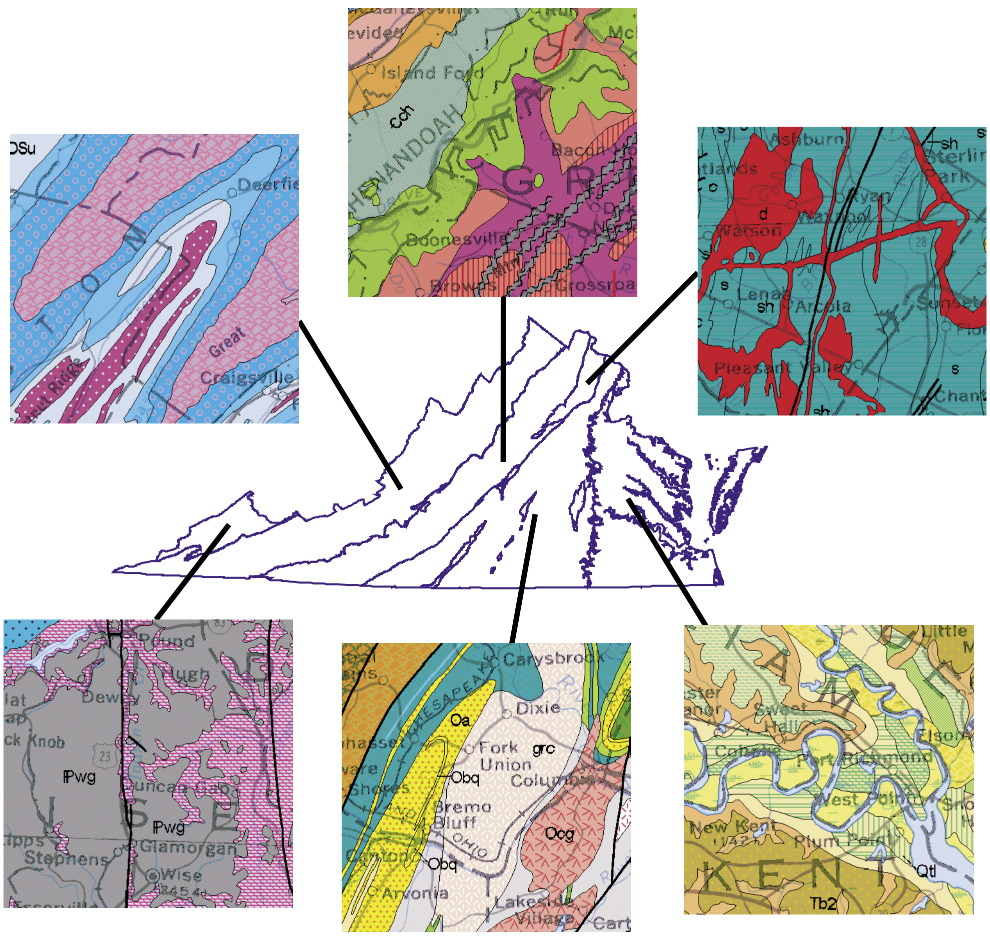
COMMONWEALTH OF VIRGINIA
DEPARTMENT OF MINES, MINERALS AND ENERGY

DIVISION OF MINERAL RESOURCES
PUBLICATION 174

DIGITAL REPRESENTATION OF THE 1993 GEOLOGIC MAP OF VIRGINIA — EXPANDED EXPLANATION



COMMONWEALTH OF VIRGINIA
DEPARTMENT OF MINES, MINERALS, AND ENERGY
DIVISION OF MINERAL RESOURCES
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2003

PREFACE

This expanded explanation for the 1993 Geologic Map of Virginia is intended to bridge the gap between the explanation printed on the map and detailed geologic reports and maps published by the Division of Mineral Resources, the U.S. Geological Survey, and elsewhere. The expanded explanation presents a physical description of each rock unit, along with pertinent references to guide the user in seeking more information. Contributions to the expanded explanation are presented as submitted by individual contributors, with limited editorial modification to provide consistency of format. For many units, a discussion of stratigraphic framework, tectonic setting, and regional correlations is included. Interpretations reflect current thinking on the part of the contributors, and may change with future research. For a few units, rock descriptions are cursory or lacking; these too are obvious targets for future research.

Selection of unique color/pattern combinations for a map with over three hundred units was a daunting task. Unit colors in the Appalachian Plateaus, Valley and Ridge, Mesozoic basins, and Coastal Plain convey age, in conformance with maps previously published by the Division of Mineral Resources. Colors for units in the Piedmont and Blue Ridge have been assigned according to rock-type and, to a limited extent, age. Rock-types and corresponding color groupings for Piedmont and Blue Ridge map units are outlined below.

ROCK UNITS	COLOR
mafic volcanic rocks	light greens
felsic volcanic rocks	light blues
mixed mafic and felsic volcanic rocks	blue-greens
granitic plutonic rocks	reds to pinks; older units have deeper colors
mafic plutonic rocks	dark greens
clastic metasedimentary rocks; pelitic schists	light browns, yellows, oranges
carbonate rocks	dark blue
paragneisses	dark browns
orthogneisses	purples to violets; older units have deeper colors

The Division of Mineral Resources extends appreciation to the following individuals for their reviews of this manuscript: from the U.S. Geological Survey — W.C. Burton, A.A. Drake, Jr., J.W. Horton, Jr., P.T. Lyttle, L. Pavlides, J.S. Schindler, and C.S. Southworth; from Eastern Kentucky University — S.S. Farrar; and from the Division of Mineral Resources — J.F. Conley, S.S. Johnson, and J.D. Marr, Jr., and Gerald P. Wilkes.

Some of the text and most of the figures in this expanded explanation for the Geologic Map of Virginia have been updated from the original "hard copy" printing of 1993. An index to the names used on the geologic map has also been added as "Index II" in the back of the expanded explanation. The Division also recognizes the efforts of Karen K. Hostettler and Michael L. Upchurch for their work in making this digital representation of the Geologic Map of Virginia possible.

CONTENTS

ILLUSTRATIONS

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DIGITAL REPRESENTATION OF THE 1993 GEOLOGIC MAP OF VIRGINIA — EXPANDED EXPLANATION

MAPPED UNITS OF THE APPALACHIAN PLATEAUS AND VALLEY AND RIDGE

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E. K. Rader,
A. R. Taylor,
W. W. Whitlock
G. P. Wilkes

p, b *Igneous rocks*. **p - Peridotite** (Warren County, Rader and Biggs, 1976), chlorite, phlogopite, hydrobiotite pseudomorphs after olivine and pyroxene, pyrite, perovskite partly altered to leucoxene, apatite, dolomite, ilmenite, magnetite, epidote, and garnet. **Kimberlite** (Rockbridge County, Sears and Gilbert, 1973; Spencer, 1968), altered matrix montmorillonite, vermiculite, and chlorite; separated crystals Cr-rich spinel, clinopyroxene, garnet, ilmenite, rutile, anatase, zircon, and amphibole. **b - Basalt** (Mole Hill, Rockingham County, Brent, 1960), labradorite, augite, olivine, magnetite, serpentine, chlorite, dolomite, epidote(?). Radiometric age: 47± 1 Ma (Eocene, Wampler and Dooley, 1975).

Dikes in Highland and adjacent counties are of three types: Mafic rocks, felsic rocks, and breccia. Mafic rocks are dark gray to black and range from aphanitic to porphyritic in texture. Phenocrysts include plagioclase, clinopyroxene and, occasionally, olivine and biotite. Amygdules may be present, and xenoliths of country rock are common. Felsic rocks are mineralogically variable and texturally complex.They are light- to medium-gray when fresh and are generally porphyritic with phenocrysts of plagioclase, biotite, hornblende, orthopyroxene, and orthoclase. Breccia (or "diatreme") contain abundant xenoliths of older igneous rock, sedimentary county rock, and xenocrysts of various minerals. Radiometric dates for some of the intrusive rocks are Eocene in age (Fuller and Bottino, 1969). Field relationships of other bodies suggest Mesozoic emplacement.

Alkalic intrusive rocks, including nepheline-syenite, teschenite-syenite, and teschenite-picrite occur in Augusta County (Rader, 1967).

Diabase dikes occur in several counties and are shown in red on the map.

Ph *Harlan Sandstone* (Campbell, 1893) (Figure 1) Sandstone, siltstone, shale, and coal. **Sandstone**, feldspathic, moderately quartzose, argillaceous, medium-gray, fine- to coarse-grained, thin- to thick-bedded, cross-bedded; quartzose sandstone is pebbly, moderately resistant, cliff-forming, and in lenticular bodies at base of formation where it fills channels (Miller, 1969; Miller and Roen, 1973). Sandstone comprises as much as 48 percent of formation. **Siltstone and shale**, medium- to dark-gray and brown, locally reddish-brown; contains 22 discontinuous coal beds. Miller (1969) changed the name from Harlan Sandstone (Campbell, 1893) to Harlan Formation because of the heterogeneous lithology and defined the base as the top of the High Splint coal bed. It is as much as 650 feet thick in northern Lee and western Wise counties, adjacent to Kentucky; upper part removed by erosion in Virginia (Miller and Roen, 1973; Nolde, Henderson, and Miller, 1988; Nolde, Whitlock, and Lovett, 1988a)

Pw, Pwg *Wise Formation and Gladeville Sandstone.*

Wise Formation (Campbell, 1893) . Sandstone, siltstone, shale, limestone, coal, and underclay. **Sandstone**, lithic, feldspathic, micaceous, argillaceous, carbonaceous locally, light- to medium-gray to moderate- and pale-yellow-brown, fine- to coarse-grained, locally pebbly, thin- to thick-bedded, cross-bedded to even-bedded, locally massive, well-cemented; contains fragments of shale, siltstone, and carbonized plant fossils locally. **Siltstone and shale**, light-olive-gray, medium- to dark-gray and grayish-black, contains siderite ironstone in very-thin beds and nodules, carbonized plant fossils; invertebrate fossils in dark-gray to black shale and micrograined limestone in the upper part of formation (Miller, 1969; Miller and Roen, 1973; Nolde, Henderson, and Miller,1988; Nolde, Whitlock, and Lovett, 1988a). **Limestone**, medium- to dark-gray, micrograined, in very-thin lenses and beds in shale and siltstone in two to three zones in lower part of formation (Taylor, 1989; Whitlock, Lovett, and Diffenbach, 1988). **Coal** interbedded with shale, siltstone, and sandstone. **Underclay**, light-gray, root casts, beneath coal; as much as 5 feet thick under the Williamson coal bed in Buchanan County (Henika, 1989b). A dark-gray to brownish-gray, int clay in the Phillips (Fire Clay; No.7) coal bed in northern Lee County (Miller and Roen, 1973) and western Wise County is a volcanic ash deposit (Seiders, 1965) that covers parts of Kentucky, Tennessee, Virginia and West Virginia; it has been dated at an age of 311 - 312 million years (Lyons and others, 1992; Rice and others, 1990). Base of formation at bottom of Dorchester coal bed. Thickness 2150 to 2268 feet.

Gladeville Sandstone (Campbell, 1893). **Quartzarenite and sublitharenite**, silica cemented, locally feldspathic and micaceous, conglomeratic, white to medium-gray to pale-yellowish-orange, weathers yellowish-gray, fine- to medium-grained, thin- to very-thick-bedded, thin- to thick- planar and trough cross-beds, slabby to blocky, contains fragments of dark-gray shale, coal, and fossil plants and quartz-pebble conglomerate near base. Underlies Wise Formation in northeastern Lee, southern Wise, and western Dickenson counties and pinches out in northern Wise and eastern Dickenson counties. A sandstone in the underlying Norton Formation below the Norton coal bed, as much as 100 feet below the stratigraphic position of the Gladeville, was misidentified as Gladeville in Lee County, and parts of Wise, Dickenson, and in Buchanan counties prior to the 1980s (Henika, 1989a; Miller and Roen, 1973; Nolde, Whitlock, and Lovett, 1988b; Whitlock,1987). Because of this, coal beds in the upper Norton and lower Wise Formations were miscorrelated where the Gladeville was absent. Thickness 0 to 65 feet.

Pz *Norton, New River, Lee, and Pocahontas undivided.* Refer to individual units for descriptions.

Pn *Norton Formation* (Campbell, 1893). Siltstone, shale, sandstone, conglomerate, limestone, and coal. **Siltstone and shale**, light- to medium-gray, with siderite and claystone concretions, fossiliferous; interbedded with and grades into sandstone. **Sandstone**, feldspathic, micaceous, argillaceous, light- to medium-gray, very-fine- to coarse-grained, thin- to

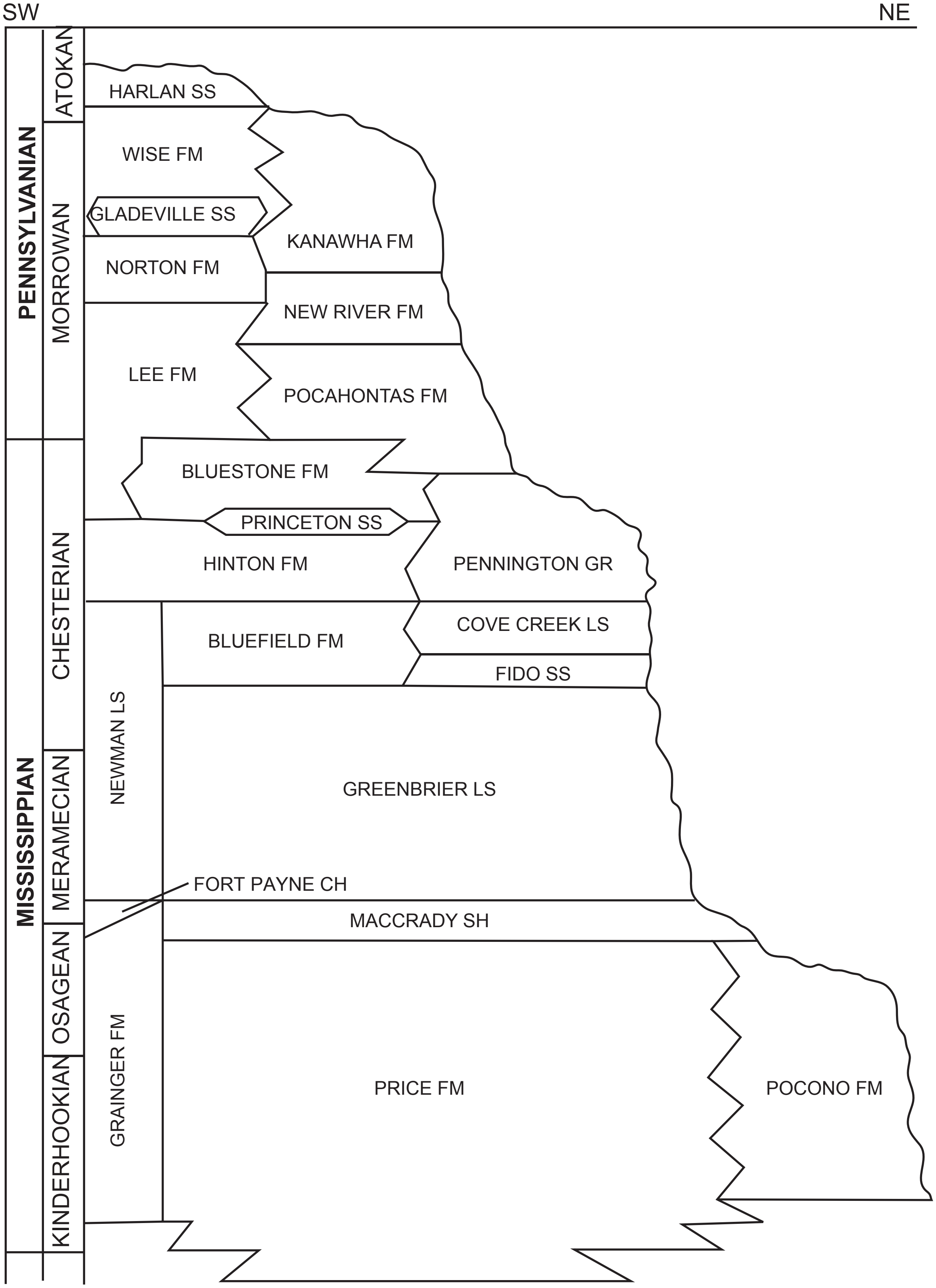

Figure 1. Correlation of Pennsylvanian and Mississippian units.

very-thick-bedded, cross-bedded, locally massive, well-cemented. **Conglomerate** in thin zones in McClure Sandstone Member (lateral equivalent to part of Bee Rock Sandstone Member of the Lee Formation). **Limestone**, medium-gray, micrograined, locally in lenses in two zones above the McClure Sandstone Member (Taylor, 1989; Whitlock, 1989). Coal in several beds and zones. A **volcanic ash** parting is in the Upper Banner coal bed locally (Diffenbach, 1988, 1989; Evans and Troensegaard, 1991; Henika, 1989a). The base of the Norton is defined as the top of the uppermost quartzarenite of the Lee Formation. On the western side of the coalfield the base of the Norton is at the top of the Bee Rock Sandstone Member of the underlying Lee Formation. However, the Bee Rock grades eastward into feldspathic, conglomeratic sandstone of the McClure Sandstone Member of the Norton. Several underlying Lee quartzarenites successively tongue out or grade into finer grained clastic rocks to the southeast stratigraphically lowering the base of the Norton. This accounts for the great range in thickness of 500 to 2480 feet for the Norton Formation.

PMl/ Pl *Lee Formation* (Campbell, 1893). Quartzarenite, conglomerate, sandstone, shale, siltstone, and coal. **Quartzarenite**, white, very-light- to light-gray, fine- to coarse-grained, locally conglomeratic, quartz-pebble conglomerate lenses, cross-bedded, channel-fill deposits. **Sandstone**, feldspathic, micaceous, light-gray, fine- to medium-grained. **Shale and siltstone**, medium-dark-gray to dark-gray, interbedded; **coal** in several beds and zones.

The quartzarenites terminate eastward by intertonguing and grading into finer grained and less quartzose rocks (Englund and DeLaney, 1966). Miller and Roen (1973) believe the lower three quartzarenites are Mississippian and intertongue with the Pennington Group. These die out northeastward from southwestern Lee County (Miller, 1969).

The quartzarenites in the upper part of the Lee tongue out or grade into finer clastic rocks of the Norton and Pocahontas Formations successively from highest to lowest southeastward (Englund, 1979; Miller, 1974). These quartzarenites consist of five tongues in northern Buchanan County (Lovett and others, 1992); but to the east only the lowest tongue exists (Whitlock, 1989; Nolde, 1989), and that grades eastward into sandstone in the New River Formation in eastern Buchanan, northeastern Russell, and western Tazewell counties.

Formerly rocks east of the quartzarenites were considered Lee (Harnsberger, 1919; Virginia Division of Mineral Resources, 1963), but now are designated New River Formation (Englund, 1981) and correlative to the lower part of the Norton Formation.

The Lee Formation thickens and truncates progressively older rocks northwestward (Miller, 1974). The intertonguing and unconformable relationship accounts for the great range in thickness for the Lee Formation. It ranges in thickness from 0 in southern Buchanan County (Meissner and Miller, 1981), to 1680 feet in Lee County (Miller and Roen, 1973).

Pk *Kanawha Formation* (Campbell and Mendenhall, 1896). Sandstone, siltstone, shale, coal, and underclay. **Sandstone**, feldspathic, micaceous, with dark mineral grains, light- to medium-gray, fine- to coarse-grained, upper beds locally conglomeratic, lenticular, thick-bedded to massive, cross-bedded. **Siltstone and shale**, medium- to dark-gray, even-bedded, interbedded with sandstone, coal, and medium-gray underclay. Base of formation conformable, placed at the bottom of Kennedy coal bed overlying McClure Sandstone Member of New River Formation (Englund, 1981; Meissner and Miller, 1981; Windolph, 1987). Equivalent to the Wise Formation and upper part of the Norton Formation. Thickness: 550 + feet (J. E. Nolde, personal communications, 1993); top part eroded.

Pnr *New River Formation* (Fontaine, 1874; redefined by Read and Mamay, 1964). Sandstone, siltstone, shale, coal, underclay, and limestone. **Sandstone**, feldspathic, micaceous, disseminated dark mineral grains, light- to medium-light-gray, very-fine- to coarse-grained, locally conglomeratic with quartz pebbles as much as 3 inches in diameter, thin- to thick-bedded, locally massive, ripple-bedded, cross-bedded; contains carbonaceous fragments. **Siltstone**, medium-light- to medium-gray, even-bedded, ripple-bedded, deformed locally. **Shale**, medium-gray to black, evenly to indistinctly bedded, with few very fissile carbonaceous beds, plant fossils, ironstone laminations and concretions. **Coal**, finely cleated, impure coal partings in several beds, locally grades into black carbonaceous shale. **Underclay**, medium-gray, clayey to silty, contains root casts. **Limestone**, medium-gray, argillaceous, in thin discontinuous beds and ellipsoidal concretions locally occurs near base and middle part of formation. Marine invertebrate fossils locally in basal bed. Base is conformable with Pocahontas Formation and placed at bottom of Pocahontas No. 8 coal bed in most outcrop areas (Englund and Thomas, 1990). Northwest of outcrop belt, base is unconformable with the underlying Pocahontas Formation. The New River is thickest in western Tazewell and eastern Buchanan counties (Englund, 1981); it ranges from 1380 to 1925 feet in thickness.

Pp *Pocahontas Formation* (Campbell, 1896; also mapped with **Pz** and **Pl**). Sandstone, siltstone, shale, underclay, and coal. **Sandstone**, feldspathic, micaceous, dark and light lithic fragments, pale-orange, light-brownish-gray, and medium- to dark-gray, very-fine- to medium-grained, fine- to coarse-grained in northern outcrop area, thin- to thick-bedded and massive, sparsely cross-bedded, ripple-marked, with local shale interbeds and dark laminations; contains well-rounded quartz pebbles as much as 1 inch in diameter, locally in channel-fill deposits and basal beds; thin-bedded sandstone contains shale interbeds, shale fragments, ironstone nodules, coal debris, and sparse plant fossils. Few quartzose sandstones commonly interbedded with thin, dark-gray shales and siltstones in subsurface in Buchanan, Dickenson, and Wise counties (Miller, 1974). Sandstone comprises 70 percent of formation (Englund, 1979). **Siltstone and shale**, medium- to dark-gray, laminated, even- to irregulary bedded, fissile to aggy, fossiliferous with fresh and brackish water animal and plant fossils (Englund, 1979). **Coal**, finely cleated. **Underclay**, medium-gray, clayey to silty, contains root casts. Basal part gradational to intertonguing with underlying Bluestone Formation of the Pennington Group; base placed at top of red, green, or gray calcareous, marine shales of the underlying Bluestone Formation (Miller, 1974). The Pocahontas wedges out in the subsurface in the northwestern parts of Lee, Wise, Dickenson, and Buchanan

Counties (Englund, 1979; Miller, 1974) and is thickest in western and northern Tazewell County. It ranges from 0 to 970 feet in thickness.

Mz *Mississippian formations undivided*: Pennington Group, Bluefield Formation, Greenbrier Limestone, Maccrady Shale, and Price Formation; includes Newman Limestone, Fort Payne Chert, and Grainger Formation in western Lee County. Refer to individual units for descriptions.

Mp *Pennington Group* (Campbell, 1893). Bluestone Formation, Princeton Sandstone, and Hinton Formation. Raised to Group rank by Harris and Miller (1958). The group consists of shale, sandstone, mudstone, conglomerate, siltstone, minor limestone, and coal locally. The **shale, siltstone, and mudstone** are gray to black and shades of red, and mottled red and gray. The **sandstone** is locally quartzose and conglomeratic, and ranges from shades of gray to brown, and only locally mottled within red shales; many sandstones pinch out southwestward in the Tazewell County area, but two persist farther west and southwest. The **limestone** is gray to brown, generally near the middle of the group, and is the most widespread marine unit. The Bluestone and Hinton Formations thin to the west-southwest in southwestern Virginia; the widespread sandstone and limestone members nearly converge southwestward to within 80 feet of each other from about 600 feet of separation in northern Tazewell County. The Princeton Sandstone wedges out in Tazewell County.

The top of the Pennington Group is intertonguing to unconformable with the overlying Lee Formation in the western part of the Southwest Virginia coalfield; basal contact is conformable. The Group thins westward; variation in thickness partly due to intertonguing and the unconformity. The Pennington Group ranges from 235 feet in thickness without the Pinacle Overlook Member of the Lee (as interpreted from Vanover and others, 1989) in the southwest to 2355 feet (Trent and Spencer, 1990) in Tazewell County and 1335 feet in in a partial section in Washington County (Bartlett and Webb, 1971), where it is mapped as the Pennington Formation.

Bluestone Formation (Campbell, 1896). Sandstone, siltstone, shale, mudstone, minor limestone, coal, and underclay. **Sandstone**, argillaceous, micaceous, locally quartzose, very-light to dark-gray, light-olive- to greenish-gray, yellowish-orange to dark-yellowish-brown, moderate-red, very-fine- to medium-grained, thin- to very-thick-bedded, cross-bedded, locally ripple-bedded, interbedded with shale and siltstone; forms ledges and cliffs. Sandstone in middle of formation in Scott and Russell counties is conglomeratic with quartzite pebbles and other rock clasts (Evans and Troensegarrd, 1991; Nolde and Diffenbach, 1988). Upper part intertongued with Lee in northern Lee County (Miller and Roen, 1973). **Siltstone, shale, and mudstone**, partly calcareous, greenish-gray, dark-gray to grayish-black, pale- to moderate-red and mottled red and greenish-gray; siderite nodules in variegated shales and siltstones; fossils in dark-gray shale (Englund, 1968). **Limestone**, argillaceous, medium-gray, thin, lenticular, fossiliferous, in middle of formation, and in thin discontinuous beds at the base of the formation in the subsurface in western Tazewell and eastern Buchanan Counties (Englund, 1981). Thin coal bed in upper part of formation in northern Lee County (Miller and Roen, 1973); coal and impure coal in thin discontinuous beds in middle of formation in northern Tazewell County; underlain by underclay, locally as much as three feet thick, with root casts (Englund, 1968). Top unconformable with the overlying Lee Formation in northwestern Wise and Dickenson counties and extreme northwestern Buchanan County but is intertonguing to the southeast (Miller, 1974) and southwest in northern Lee County (Miller and Roen, 1973). Base conformable with the underlying Princeton Sandstone in northern Tazewell County, but is disconformable to the southwest because the Princeton wedges out southwestward in Tazewell County and the Bluestone lies on the Hinton Formation (Englund and Thomas, 1990). Bluestone thins northwestward and ranges in thickness from 40 feet in southwestern Lee County (Englund, Landis, and Smith, 1963) to as much as 850 feet to the northeast in Tazewell County (Englund and Thomas, 1990).

Princeton Sandstone (Campbell and Mendenhall, 1896). **Sandstone**, light-gray to light-greenish-gray, weathered locally to pale-reddish-brown, fine- to coarse-grained, thin- to very-thick-bedded, locally cross-bedded, calcite cemented, becomes friable upon weathering, contains conglomerate lenses as much as two feet thick with well-rounded to angular pebbles of quartz, shale, siltstone, limestone, chert, and ironstone; fossils in limestone clasts (Englund, 1968, 1979; Trent and Spencer, 1990). Wedges out southwestward in west-central Tazewell County (Englund, 1979). The Princeton as mapped in Lee County and southwestern Scott County (Harris and Miller, 1958; Miller and Roen, 1973) is a different sandstone. The Princeton ranges from 0 to 60 feet in thickness.

Hinton Formation (Campbell and Mendenhall, 1896). Shale, siltstone, mudstone, sandstone, limestone, minor coal, underclay. **Shale, siltstone, and mudstone**, partly calcareous, grayish-red, medium-gray, and greenish-gray, fossiliferous. **Sandstone**, quartzose, feldspathic, very-light- to medium-light-gray, greenish-gray, yellowish-brown, pale- to moderate-red, locally mottled, very-fine- to medium-grained, thin- to very-thick-bedded, contains quartz-pebble conglomerate, tree trunk impressions, and coal fragments; cobbles in lowest member locally; interbedded with dark-gray to grayish-black shale. A widespread conglomeratic sandstone in the upper part of the formation has been misidentified as the stratigraphically higher Princeton Sandstone (Englund, 1979). **Limestone**, argillaceous, light-grayish-brown, medium-gray, thin-bedded, nodular, very fossiliferous, contains marine fossils of Chesterian age and is most widespread marine unit (Little Stone Gap Member) in the Hinton (Englund, 1979). Base conformable. The formation ranges from 164 feet in thickness in southwestern Lee County to 1320 feet in northern Tazewell County (Englund, 1968, 1979).

Mbf *Bluefield Formation* (Campbell, 1896). Shale, siltstone, and limestone, with minor sandstone, coal, and underclay. **Shale and siltstone**, calcareous in part, medium- to medium-dark-gray, light-greenish- to greenish-gray, grayish-red; interbedded with limestone,thin sandstone and a few thin beds of black carbonaceous shale. **Limestone**, argillaceous, lower part dolomitic, light-olive-gray to medium-gray, light-bluish-gray and brownish-gray, micrograined to medium-grained, thin-bedded, very fossiliferous; black chert nodules in lower part; interbedded with fossiliferous light-greenish-gray shale. **Sandstone**, quartzose to feldspathic, light-gray to greenish-gray, very-fine- to medium-grained, thin- to thick-bedded, ripple-bedded, contains root casts in upper part, pyrite nodules, and shale and siltstone interbeds. Coal, locally impure in upper half of formation (Englund, 1968; Windolph, 1987). **Underclay**, medium-gray, clayey to silty, contains root casts. The Bluefield probably is equivalent to upper part of the Newman Limestone (Englund, 1979) and is a transition zone between carbonates of the underlying Greenbrier Limestone and clastics of the overlying Pennington Group. It is conformable and gradational with underlying formation. Formation thins westward; it ranges in thickness from 150 feet near Kentucky-Virginia boundary (Miller, 1974, p. 25) to 1250 feet in Tazewell County (Cooper, 1944, p. 169).

Mccf *Cove Creek Limestone and Fido Sandstone.*

Cove Creek Limestone (Butts, 1927). **Limestone**, argillaceous, light-gray to greenish-gray, thin- to thick-bedded, sparsely fossiliferous, with thin, brownish laminae; thin beds and zones of medium- to coarse-grained, calcareous sandstone locally present. The Cove Creek Limestone ranges from 1010 to 1220 feet in thickness (Averitt, 1941; Bartlett and Webb, 1971).

Fido Sandstone (Butts, 1927). **Sandstone**, calcareous, reddish-brown to dark-brown, fine- to coarse-grained, thick-bedded, cross-bedded, and ripple-marked, fossiliferous, with one or more beds of argillaceous limestone. The Fido Sandstone ranges from 35 to 75 feet in thickness (Averitt, 1941; Bartlett and Biggs, 1980).

Mg *Greenbrier Limestone* (Rogers, in Macfarlane, 1879). Limestone, dolomite, and minor shale. **Limestone**, very-light-olive- to olive-gray and brownish-gray, and medium- to dark-gray, micrograined to coarse-grained, thin- to thick- bedded, thinner bedded in upper part, even- to cross-bedded; few shaly beds in upper part; oolitic in upper part and in cross-laminated beds near base; black chert near middle of formation, gray to pale-red near base; very fossiliferous. Pale-brown **dolomite** near upper chert zone, minor dolomite locally in lower part. Few interbeds of greenish-gray and grayish-red, calcareous, silty **shale**. Limestone is petroliferous locally in upper part (Henika, 1988). Base locally unconformable with underlying Maccrady Shale. Formation thickens to east, ranging from 200 feet in western Wise County to 3500 feet in Washington and Scott counties..

The Greenbrier is equivalent to (descending): Gasper Limestone, Ste. Genevieve Limestone, St. Louis Limestone (Hillsdale Limestone), and Little Valley Limestone (Warsaw equivalent), and to lower part of the Newman Limestone (Butts, 1940; LeVan and Rader, 1983).

Newman Limestone (Campbell, 1893). Limestone and shale. **Limestone**, light-olive-gray in lower half, medium-gray to olive-gray in upper half, aphanic to fine-grained, partly oolitic, partly argillaceous, with basal beds of dark-gray chert nodules and local dolomite. **Shale**, medium-gray to medium-dark-gray, partly calcareous, interbedded with limestone in upper half of unit. The Newman Limestone ranges from 550 to 600 feet in thickness and is equivalent to the Bluefield Formation and Greenbrier Limestone.

Fort Payne Chert. (Smith, *in* Squire, 1890). Greenish-gray **chert** in thin beds (2 - 6 inches thick); with shale partings. The Fort Payne Chert ranges from 0 to 20 feet in thickness and pinches out to the northeast.

Grainger Formation (Campbell, 1893). **Shale**, pale-olive- or greenish-gray to dark-greenish-gray, locally grayish-red in lower half and at top; with some interbedded pale-olive-gray **siltstone** and very-fine-grained **sandstone**, locally abundant siderite nodules near base. The Grainger Formation ranges from 250 to 325 feet in thickness and is the lateral equivalent of the Maccrady Shale and Price Formation.

Mmpr *Maccrady Shale and Price Formation*. Refer to individual units for descriptions.

Mm *Maccrady Shale* (Stose, 1913). Shale, siltstone, minor limestone, and sandstone. **Shale and siltstone**, light-grayish-red, few light-greenish-gray beds, silty, very-thin- to medium-bedded, indistinctly bedded, interbedded. Collapse breccia in middle of formation, with anhydrite (?) locally in western Tazewell County (Windolph, 1987). **Limestone**, dolomitic, light-yellowish-brown and bluish-gray in Washington and Tazewell counties. **Sandstone**, light- to medium-gray, fine- to coarse-grained, locally cross-bedded. Maccrady sparsely fossiliferous including a fish-bone bed (Bartlett, 1974, p. 101). Contains **salt, anhydrite**, and economic deposits of **gypsum** where the formation is thickest and folded and faulted in Smyth County (Sharpe, 1984; Stose, 1913). Basal beds locally interfinger with and are gradational with underlying Price Formation and lie on progressively older units of the Price west of a line from northeastern Tazewell County through central Washington County (Bartlett, 1974, p. 99). Maccrady thins northwestward, but locally thins southwestward (Warne, 1990). It wedges out at the southwest corner of Virginia (Englund, 1979); in northern and western Washington and northwestern Smyth counties the Maccrady is less than 50 feet thick (Averitt, 1941; Warne, 1990), but it is as much as 2000 feet thick to the northeast in Smyth County (Sharpe, 1984), and at least 1000 feet thick in a partial section in Montgomery County (Bartholomew and Lowry, 1979).

Mpr *Price Formation* (Campbell, 1894). Sandstone, quartzarenite, conglomerate, siltstone, shale, limestone, and coal. **Sandstone**, feldspathic, slightly micaceous, light-gray to medium-gray, weathers olive-gray to greenish-gray, few grayish-red beds, very-fine- to medium-grained, thin- to thick-bedded, cross-laminated in upper part of formation, locally conglomeratic with quartz pebbles and granules. The lowest part of the Price contains quartz pebble conglomerate and quartzarenite, with marine fossils in basal beds. Formation becomes finer grained to the southwest. Sandstone is dominant in the upper half of formation. **Siltstone and silty shale**, partly calcareous, locally pyritic and glauconitic, greenish-gray, medium-dark-gray to light-olive-gray, locally black and carbonaceous, laminated to medium-bedded, hard, hackly, fissile to platy, fossiliferous; interbedded with sandstone. **Limestone**, rare, argillaceous, arenaceous, very- thin beds, as much as six inches thick, in interbedded siltstones and shales (Bartlett, 1974, p. 83-84). Coal in upper part of formation (Bartholomew and Brown, 1992; Bartlett, 1974; Cooper, 1944).

The Price is a westward thinning clastic wedge (Bartlett, 1974, p. 170) that is equivalent to part of the Grainger Formation in the southwesternmost part of Virginia. It overlies the Chemung Formation from southwestern Washington County to the northeast and the Brallier Formation or the Chattanooga Shale to the southwest. Base is conformable, placed at the base of a conglomerate northeast of Lee County (Bartlett, 1974). Thickness is variable; it is 250 feet thick in Lee County, 185 feet thick (Henika, 1988) in Scott County and as much as 1800 feet thick (Campbell and others, 1925) in Montgomery County.

Mpo *Pocono Formation* (Lesley, 1876). Quartzitic **sandstone**, light-gray or tan, medium- to coarse-grained, locally conglomeratic, thick-bedded, resistant, interbedded with thin, gray, organic shale and a few very-thin coal beds. Conformable with underlying Hampshire Formation; formation present northeast of Alleghany and Roanoke Counties. Thickness may exceed 750 feet. It is laterally equivalent to the Price Formation to the southwest.

MDcw *Chattanooga Shale and Wildcat Valley Sandstone.*

Chattanooga Shale (Hayes, 1891). Shale, siltstone, and sandstone. **Shale**, carbonaceous, grayish-black to black, fissile to platy, thin- to thick-laminated, locally fossiliferous and pyritic, locally contains phosphatic nodules in the upper part, locally has strong petroliferous odor (Henika, 1988); with beds and zones of medium-gray to greenish-gray, locally silty shale. **Siltstone**, light-gray to grayish-black, laminated to thick-bedded, locally wavy- and ripple-bedded. **Sandstone**, light-gray, very-fine-grained. Grayish-black to black, carbonaceous shale comprises 100 percent of the formation in western Lee County and is predominant in the formation throughout southwest Virginia. The Chattanooga Shale uncomformably overlies the Silurian Hancock Formation throughout most of Lee County and the lower Devonian Wildcat Valley Sandstone to the northeast. The Chattanooga Shale ranges in thickness from 200 feet in western Lee County (Englund, 1964) to 1870 feet in northwestern Russell County (Meissner and Miller, 1981). Roen and others (1964) and Kepferle and others (1981) discussed divisions of the Chattanooga Shale and correlation with other units.

*Wildcat Valley Sandston*e (Miller, Harris, and Roen, 1964). Sandstone, limestone, and shale. **Sandstone**, locally calcareous, locally quartzose, light-gray, grayish-orange, and dark-yellowish-brown, very-fine- to coarse-grained, thin- to massive-bedded, fossiliferous, friable, locally glauconitic; with chert nodules and beds. Locally dark-reddish-brown ironstone replaces sandstone. **Limestone**, gray, pinkish-gray, and light-brownish-gray, coarse-grained, thick- to massive-bedded, sandy, locally present. **Shale**, yellowish-green to gray, locally present. Where the Wildcat Valley Sandstone is present it uncomformably overlies the Silurian Hancock Formation. The Wildcat Valley Sandstone is absent throughout most of Lee County (Englund, 1964; Harris, 1965; Miller and Roen, 1973) but reaches a maximum of 60 feet in thickness to the northeast (Lower Devonian sandstone of Harris and Miller, 1963).

Dhs *Hampshire Formation* (Darton, 1892) (Figure 2) **Sandstone and interbedded mudstone**, grayish-red or greenish-or brownish-gray; fine-grained, locally conglomeratic sandstone, planar cross-bedded to massive sandstone beds with coaly plant material; intertongues with underlying Chemung Formation. It thickens northeastward from 200 feet in Botetourt County to 2000 feet in Frederick County and is time equivalent to part of the upper Chattanooga Shale in southwestern Virginia. It is not present southwest of Botetourt and Alleghany counties.

Dch *Chemung Formation* (Hall, 1839). *Redefined as the Foreknobs Formation* (Dennison, 1970). **Sandstone and shale**, dark-gray and greenish-gray, fine-grained, thin- to thick-bedded, lithic sandstone and interbedded greenish-gray, fissile, clay shale. Minor quartz-pebble conglomerate, thin red sandstone, and locally, fossil shell beds. Very thin or absent in southwestern Virginia; thickens to about 2500 feet northeastward in Frederick County. Gradational contact with underlying Brallier Formation and equivalent to part of the Chattanooga Shale to the southwest. Redefined and described as part of the Greenland Gap Group by Dennison (1970).

Db *Brallier Formation* (Butts, 1918). Shale, sandstone, and siltstone. **Shale**, partly silty, micaceous, greenish-gray, grayish-brown and medium- to dark-gray, black, weathers light-olive-gray with light-yellow, brown and purple tints; black shale in thin beds and laminae, sparsely fossiliferous. **Sandstone**, micaceous, medium-light-gray, very-fine- to fine-grained, thin- to thick-bedded, and light-brown siltstone interbedded with shale. Locally **siltstone** is in very-thin, nodular, ferruginous lenses (Bartlett, 1974). Lower contact transitional; base at lowest siltstone bed above relatively non-silty dark-gray shale. Equivalent to part of the Chattanooga Shale. Formation thins southwestward; it ranges from 940 feet in thickness in southwestern Washington County (Bartlett and Webb, 1971) to more than 2200 feet in Augusta County (Rader, 1967).

Dma *Mahantango Formation* (Willard, 1935). Shale, siltstone, and sandstone. **Shale**, gray, pale-green, and black, weathers silvery gray, silty with minor interbedded siltstones; lower contact gradational with underlying Marcellus Shale. **Silt-**

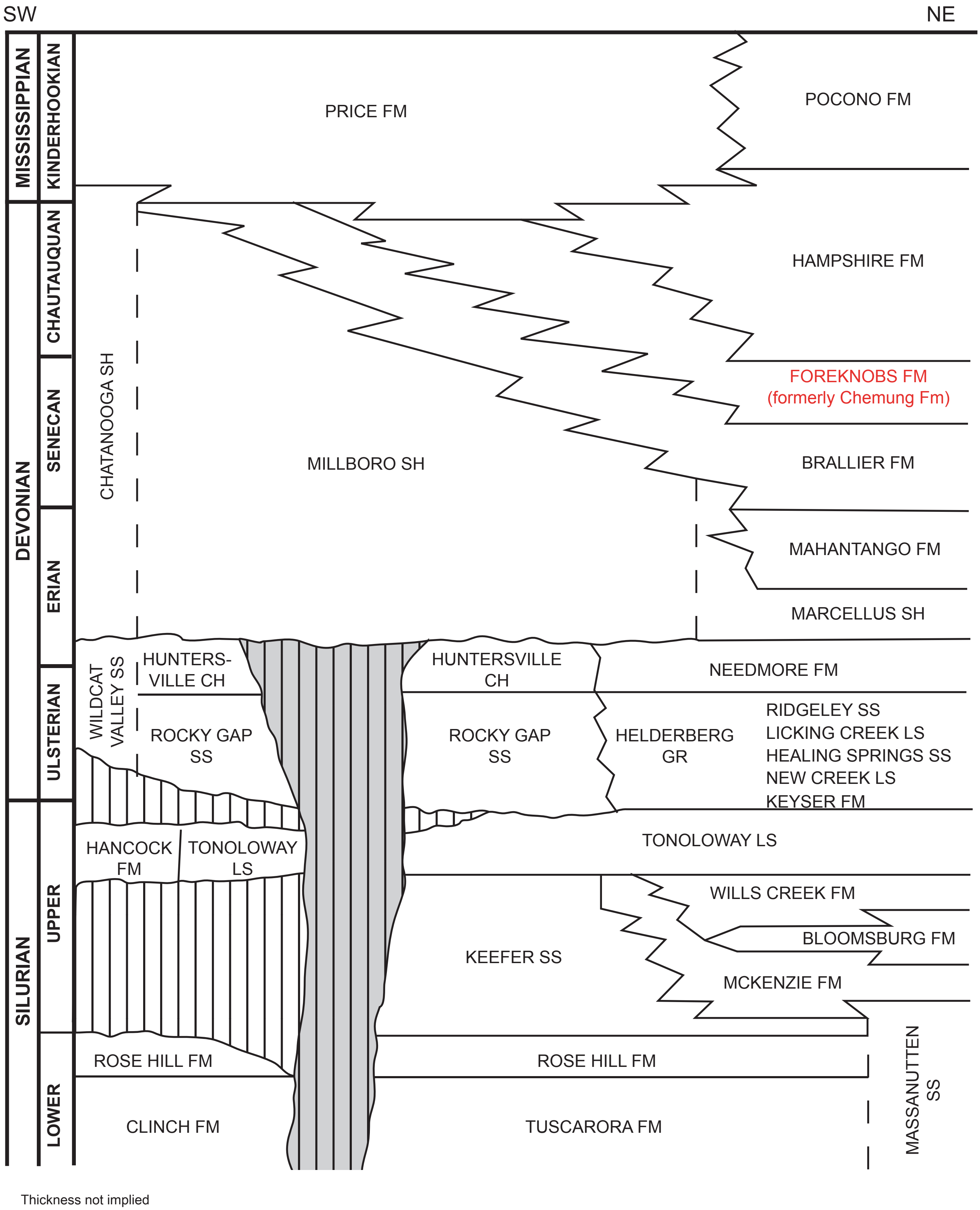

Figure 2. Correlation of Devonian and Silurian units.

stone, greenish-gray with interbedded shale. **Sandstone**, greenish-gray to grayish-brown, fine-grained, fossiliferous. Spheroidal weathering common in all lithologies. Thickness ranges from 0 in southwestern Shenandoah County (Butts, 1940) to approximately 1100 feet in Frederick County (Butts and Edmundson, 1966).

Southwest of Shenandoah County the Mahantango Formation is indistinguishable from the underlying Marcellus Shale. They are combined and mapped as a single unit, the Millboro Shale, from southern Shenandoah County to Southwest Virginia (Rader, 1982).

Dmrn *Marcellus Shale and Needmore Formation*.

Marcellus Shale (Hall, 1839; Butts and Edmundson, 1966). **Shale**, dark-gray to black, more or less fissile, pyritic. Thickness estimated to be 500 feet in Frederick County and 350 to 400 feet in the Massanutten synclinorium (Rader and Biggs, 1976).

Needmore Formation (Willard, 1939). **Shale**, dark or greenish gray, with thin beds or nodules of black, argillaceous limestone and the Tioga metabentonite beds (Dennison and Textoris, 1970), generally present with the Millboro or Marcellus Shale and is disconformable with the underlying Ridgeley Sandstone. Thickness ranges from 0 to 160 feet and is replaced to the southwest by the Huntersville Chert.

Dmn *Millboro Shale and Needmore Formation*.

Millboro Shale (Cooper, 1939; Butts, 1940). **Shale**, black, fissile, pyritic, with septarian concretions locally, gradational with underlying Needmore Shale; present southwest of Shenandoah County except in southwesternmost Virginia; thickness is as much as 1000 feet in north-central western Virginia. Laterally equivalent to the Marcellus Shale and Mahantango Formation to the northeast and the lower part of the Chattanooga Shale to the southwest. It is gradational with the underlying Needmore Formation.

Needmore Formation. Refer to description under **Dmrn**.

Dx *Millboro Shale, Huntersville Chert, and Rocky Gap Sandstone.*

Millboro Shale. Refer to previous description under **Dmn**.

Huntersville Chert (Price, 1929). **Chert**, white, thin-bedded, iron-stained, blocky, fossiliferous with cherty, glauconitic sandstone and greenish-gray shale. The Huntersville Chert ranges from 10 to 60 feet in thickness (Bartlett and Webb, 1971). Butts (1940, p. 303) states, "The Onondaga [Huntersville Chert] persists to Mendota, Washington County, but 10 miles farther southwest.... it is absent in a fully exposed section". The Huntersville correlates with the Needmore Formation to the northeast and the upper part of the Wildcat Valley Sandstone in Lee County.

Rocky Gap Sandstone (Swartz, 1929). **Sandstone**, medium- to light-gray, weathers dark-yellowish-orange, coarse-grained, scattered, thin, quartz-pebble conglomerate beds, arenaceous chert in upper ten feet, calcite cement, friable when weathered. Thickness ranges from 0 near McCall Gap, Washington County to about 85 feet in Bland and Giles counties.

Equivalent in part to the Wildcat Valley Sandstone of Lee County and the Ridgeley (Oriskany) Sandstone and Helderberg Group north of Craig County. The lower contact is disconformable. The upper contact with the Huntersville Chert appears to be conformable.

Lower Devonian* and Upper Silurian Age Formations (includes rock units below the Needmore Formation and above the Keefer or Massanutten Sandstones).

* Stratigraphic studies of the sequence of Lower Devonian limestone rock units indicate a more complex interrelationship of rock types than suggested by this text.

DSz *LowerDevonian and Silurian formations undivided*

Landslides with intact stratigraphic units.

DSOz *Lower Devonian, Silurian, and Upper Ordovician formations undivided.*

Landslides with intact stratigraphic units.

DSu *Ridgeley Sandstone and Helderberg and Cayuga Groups.*

Ridgeley Sandstone (Swartz, 1913). **Sandstone**, gray, fine-to coarse-grained, locally conglomeratic, weathers yellowish- to dark-yellowish-brown, friable, calcareous, and fossiliferous. Thickness ranges up to 150 feet but is highly variable locally; occurs in western Virginia north of Craig County. Same as the Oriskany Sandstone of Butts (1933), and is continuous with the Rocky Gap Sandstone to the southwest. It grades downward into the Licking Creek Limestone and has been extensively mined for iron ore (Lesure, 1957).

Helderberg Group.

Licking Creek Limestone (Swartz, 1929). Upper member is light-gray, coarse-grained, arenaceous **limestone**; lower member is medium-to dark-gray, fine-grained, chert bearing **limestone**. Thickness ranges from 0 to150 feet and is present northeastward from Craig County; same as the Becraft (upper member) and New Scotland (lower member) of Butts (1940). It conformably overlies the Healing Springs Sandstone where the sandstone is present. It was extensively mined for iron with the Ridgeley Sandstone.

Healing Springs Sandstone (Swartz, 1929). **Sandstone**, light-gray, medium- to coarse-grained, cross-laminated, and calcareous with local lenses of chert. Present in Alleghany, Bath, and Augusta Counties where it is generally less than 20 feet thick and conformably overlies the New Creek Limestone. It appears to be a northeast extending tongue of Rocky Gap Sandstone.

New Creek Limestone (Bowen, 1967; Coeymans Limestone of earlier reports). **Limestone**, light- to-medium-gray with pink calcite crystals, very-coarse-grained, crinoidal, with lenses of quartz sandstone locally in the lower part. Occurs as local reefoidal buildups northeast of Alleghany County.

Keyser Formation (Swartz, 1913). Limestone, sandstone, and shale. **Limestone** (upper), medium- to dark-gray, fine- to medium-grained, nodular, scattered, small chert nodules, biohermal, fossiliferous. **Limestone** (lower), medium- to dark-gray, fine- to coarse-grained, medium- to thick-bedded, very nodular, shaly, with thin (1- to 3-inch thick) crinoidal layers. **Sandstone**, medium-light-gray, medium-grained, calcareous, cross-bedded. **Shale**, medium-gray, calcareous. Upper and lower boundaries are conformable north of Clifton Forge. Thickness ranges from 250 feet in Highland County to 50 feet in Augusta County.

In Highland and Bath counties the upper and lower limestones are separated by a calcareous shale unit (Big Mountain Shale Member). To the south and southeast the shale is replaced by sandstone (Clifton Forge Sandstone Member). From Craig County southwestward, the Keyser becomes all sandstone and is equivalent to the lower portion of the Rocky Gap Sandstone. Southwest of Newcastle the lower contact is disconformable.

For mapping purposes the Keyser is considered to be part of the Helderberg Group.

Cayuga Group.

Tonoloway Limestone (Ulrich, 1911). **Limestone**, very-dark-gray, fine-grained, thin-bedded to laminated, with some arenaceous beds; celestite locally occurs in vugs and as veins. Thickness ranges from a few feet in southwestern Virginia to more than 500 feet in Highland County. It is conformable with the underlying Wills Creek Formation and equivalent to the Hancock Formation of Southwest Virginia.

Wills Creek Formation (Uhler, 1905). **Limestone**, medium-to dark-gray, fine-grained, arenaceous, thin-bedded, with calcareous shale and mudstone, and thin, quartzose sandstone beds. Occurs only in western Virginia where the thickness ranges from 0 to more than 400 feet. It conformably overlies the Bloomsburg Formation and is laterally equivalent to the upper part of the Keefer Sandstone to the east and southwest of Craig County where the typical Wills Creek lithology is absent.

Bloomsburg Formation (White, 1893). **Sandstone**, reddish-gray, fine-grained, thick-bedded with red mudstone interbeds. Thickness ranges from 35 to 400 feet between Frederick County and the northern Massanutten Mountains respectively. It grades into the Wills Creek Formation to the southwest, and is probably equivalent, in part, to the Keefer Sandstone southwest of Craig and Botetourt counties.

McKenzie Formation (Stose and Swartz, 1912). **Shale**, medium-gray, yellowish weathering and interbedded sandstone, medium-gray, medium-grained, friable, thin-bedded and calcareous. Thickens northeastward from a few feet in Bath County to about 200 feet in Frederick County. It is probably equivalent in part to the Keefer Sandstone to the southwest and southeast and appears to be conformable with the Keefer Sandstone in northwestern Virginia.

Skrt *Keefer Sandstone, and Rose Hill and Tuscarora Formations.*

Keefer Sandstone (Ulrich, 1911). **Sandstone**, light-gray, fine-grained, cross-laminated, medium-bedded, very resistant. Thins northward and southwestward from a maximum of over 300 feet in Craig and western Botetourt counties. To the north it appears to interfinger with the Wills Creek and McKenzie Formations. The Keefer is equivalent to the upper portion of the Massanutten Sandstone. (The Keefer Sandstone, as used in this report, includes all of the quartzarenites with minor *Skolithus*-bearing red sandstone and minor calcite cemented quartzarenite in the interval above the Rose Hill Formation and below the Tonoloway Limestone in Botetourt, Rockbridge, and Augusta counties between Eagle Rock and Augusta Springs (Lampiris, 1976).

Rose Hill Formation (Swartz, 1923). **Sandstone**, dark grayish-red, fine- to coarse-grained, poorly-sorted, argillaceous; hematite cemented, quartz sandstone interbedded with red or yellowish-green clay shale and greenish-gray, fine-grained sandstone. It is largely siltstone and shale with minor sandstone and thin limonitic iron ore beds in Southwest Virginia. Conformable with the underlying Tuscarora Formation, the Rose Hill Formation ranges up to 500 feet in thickness in northern and western Virginia but pinches-out in southwestern Botetourt and Roanoke counties where the Keefer and Tuscarora Formations merge. It is present with other Silurian rocks everywhere except in the Massanutten Mountains or where an unconformity exists in exposures east of Walker Mountain.

Tuscarora Formation (Darton and Taff, 1896). Quartzite, quartzarenite, and minor shale. **Quartzite**, light-gray with few nearly white, porcelaneous beds, fine- to medium-grained, with quartz-pebble conglomerate locally near base, quartz cemented, thick-bedded, and cross-bedded, resistant, cliff- and ledge-former, generally not more than 75 feet thick, comprises entire unit in many areas or is upper member where unconformably overlying a lower quartzarenite and shale member. **Quartzarenite**, light-yellowish-brown or medium-gray, fine-grained, thin-bedded, ranges in thickness from 0 to 175 feet. **Shale**, light- to medium-brownish-gray, arenaceous, thin interbeds in quartzarenite. Conformably overlies the Juniata Formation in central western Virginia. Where lower member is absent the upper member unconformably overlies the Juniata, Oswego, Martinsburg, or Reedsville Formations or may be conformable with the Juniata Formation in northern Virginia. In southwestern Virginia grayish-red, fine-grained, ferruginous sandstone with lenses of coarse-grained, quartz sandstone and quartz-pebble conglomerate are included in the upper part of the formation. The Tuscarora is equivalent to the Clinch Formation and to the lower part of the Massanutten Sandstone.

Sm *Massanutten Sandstone* (Geiger and Keith, 1891).

Quartzite and sandstone, very-light-gray, fine-grained, well-sorted, locally conglomeratic, thick-bedded and cross-bedded, very resistant with minor shale partings in upper part. Thickness ranges from 600 to nearly 1200 feet. Present only in the Massanutten Mountains, the sandstone unconformably overlies the Martinsburg Formation and is a lateral equivalent to the Tuscarora, and Rose Hill Formations, and Keefer Sandstone (Perry, 1977).

Shrc *Hancock, Rose Hill, and Clinch Formations*.

Hancock Formation (Keith, 1896). Dolomite, limestone, and sandstone. **Dolomite**, locally calcareous, locally siliceous, light-olive-gray and light-to dark-gray, aphanic to fine-grained, finely-laminated to massive-bedded, locally stromatolitic and vuggy. **Limestone**, medium- to dark-gray and bluish-gray, aphanic to fine-grained, laminated to thick-bedded, ribbon-banded, mottled, locally emits petroliferous odor when broken. **Sandstone**, locally calcareous, generally quartzose, medium-grained to pebbly and conglomeratic locally at base of formation; and fine- to medium-grained sandstone locally interbedded with limestone. The formation grades from dolomite with minor limestone and a basal sandstone in southwestern Lee County (Cayuga Dolomite of Miller and Fuller, 1954) to limestone with an underlying or interbedded dolomite with sandstone partings, and a basal sandstone to the northeast and east (Harris and Miller, 1958; Miller and Roen, 1971). The Hancock Formation ranges from 75 to 225 feet in thickness and correlates with the Tonoloway Limestone.

Rose Hill Formation . Refer to description under **Skrt**.

Clinch Formation (Safford, 1856). Quartzarenite and shale. **Quartzarenite**, very-light gray, olive-gray, and brownish-gray with local grayish-red beds, very-fine-grained to very-coarse-grained with local conglomeratic zones, thin- to thick-bedded with thin, greenish-gray and dark-gray shale beds and partings in upper part. **Shale**, light-olive-gray to grayish-green; with thin, very fine- to fine-grained sandstone interbeds in the lower one-third to one-quarter of the unit. Erosional unconformity at base of unit identified in northern Lee County (Miller and Roen, 1973). The Clinch Formation ranges from 220 to 330 feet in thickness.

The Division of Mineral Resources uses the name Clinch Formation for exposures in Lee, Wise, and Scott counties where the lower Silurian rocks include the lower Hagan Shale Member and the upper Poor Valley Ridge Sandstone Member. The name Tuscarora Formation is used for the lower Silurian quartzitic sandstone unit in all areas northward in the Valley and Ridge of Virginia, including the Clinch Mountain area where the name Clinch Formation was first used, because of similarity between the Tuscarora and the rocks on Clinch Mountain. In the past many geologists used the name Clinch Sandstone in the southern part of the Valley and Ridge of Virginia and the name Tuscarora Formation in the northern part of the Valley and Ridge of Virginia (Butts, 1940) for essentially the same group of quartzitic sandstones. Dennison and Boucot (1974) and Miller (1976) described the facies change of the lower Silurian Clinch Sandstone of Southwest Virginia from quartzitic sandstones in the Clinch Mountain belt in Scott and Wise Counties to sandstones and shales in the Lee, southwestern Wise, and western Scott counties area.

Sz *Silurian formations undivided*

Landslides with intact stratigraphic units.

SOz *Silurian and Upper Ordovician formations undivided.*

Ou *Sequatchie Formation, Reedsville Shale, Trenton Limestone, and Eggleston Formation* (Figure 3) .

Sequatchie Formation (Ulrich, 1913). Siltstone, limestone, and shale. **Siltstone**, calcareous, medium-gray to grayish-red, maroon, and green, even and wavy thin-beds. **Limestone**, argillaceous, gray, greenish-gray, and grayish-red to dusky-red, nodular, in 1-inch to 3-feet thick planar beds. **Shale**, grayish-red. Percentage of each lithotype varies throughout the lateral and vertical extent of the formation. The Sequatchie Formation ranges from 250 to 440 feet in thickness. Laterally equivalent to the Juniata Formation.

Reedsville Shale (Ulrich, 1911). Shale, siltstone, and minor limestone. **Shale**, locally silty, calcareous, yellowish-gray, grayish-olive, greenish-gray, and medium-gray. **Siltstone**, calcareous, greenish-gray to olive-gray, in 1- to 2-inch thick planar beds. **Limestone**, medium- to dark-gray, fine- to coarse-grained, fossiliferous, in 6-inch thick beds; and silty to argillaceous, medium-light-gray to medium-dark-gray and olive-gray, micrograined to medium-grained limestone, generally in 1- to 2-inch thick planar beds. A few very-fine-grained sandstone beds are present within the unit. The shales are predominant throughout most of southwestern Virginia (Miller and Brosgé, 1954; Miller and Fuller, 1954). Siltstones and limestones are subordinate to and interbedded with the shales. The Reedsville Shale ranges from 275 feet in Lee County to approximately 1000 feet in Frederick County. It is equivalent to the upper Martinsburg of previous reports in western Virginia and is conformable with the underlying Trenton Limestone and Dolly Ridge Formation.

Trenton Limestone (Vanuxem, 1838). **Limestone**, medium-light-gray to dark-gray and brownish-gray, micrograined to medium-grained, fossiliferous, thin- to medium-bedded, wavy- to platy-bedded with grayish-yellow and dark-gray shale partings, minor olive-black chert nodules; and one bentonite bed noted in western Scott County (Harris and Miller, 1958). (See Eggleston Formation description for additional discussion of the bentonite beds). Locally some of the dark-colored beds emit a petroliferous odor when broken. The Trenton Limestone ranges from 300 to 600 feet in thickness.

Eggleston Formation (Matthews, 1934). Mudstone, siltstone, limestone, and bentonite. **Mudstone and siltstone**, light-gray, greenish-gray and yellowish-gray, locally contains gray and white mottled calcite patches and stringers. **Limestone**, light-olive-gray to olive-gray and light-brown, aphanic to medium-grained, thin-bedded; with argillaceous, yellowish-gray, micrograined to medium-grained limestone. Two thick (1-3 feet), greenish-gray, bentonite beds in upper part of unit. Olive-black chert nodules are locally present. **Mudstone** is dominant in lower and locally in upper part; light-olive-gray to olive-gray **limestone** is dominant in middle part of unit. The Eggleston Formation ranges from 125 to 180 feet in thickness.

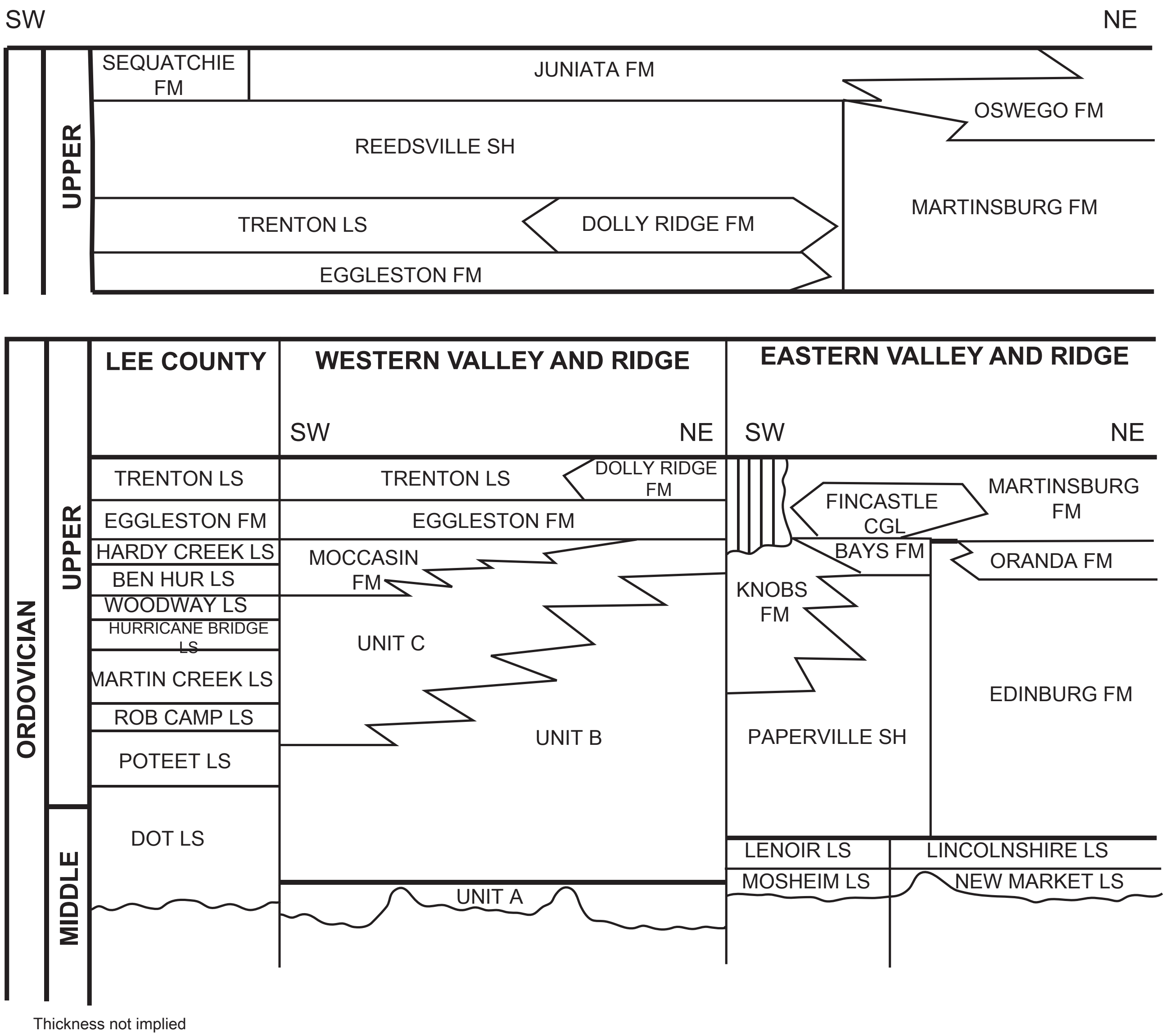

Figure 3. Correlation of Upper and Middle Ordovician units.

Haynes (1992) reported on three K-bentonite beds in the Trenton and Eggleston Limestones and the Moccasin Formation in the Valley and Ridge Province of southwest Virginia. The uppermost K-bentonite bed has not been correlated regionally and is known locally as the V-7. The lower two K-bentonite beds have been identified from regional correlations as the Deicke K-bentonite overlain by the Millbrig K-bentonite.

Ous *Juniata Formation, Reedsville Shale, Trenton Limestone, and Eggleston Formation.*

Juniata Formation (Darton and Taff, 1896). Siltstone, shale, sandstone, and limestone. **Siltstone, shale, and sandstone**, locally calcareous, grayish-red, locally fossiliferous; with some interbeds of greenish-gray shale, quartzarenite, and argillaceous limestone. Cycles consisting of a basal, cross-bedded quartzarenite with a channeled lower contact; a middle unit of interbedded mudstone and burrowed sandstone; and an upper bioturbated mudstone are commonly present north of New River (Diecchio, 1985). The Juniata Formation ranges from less than 200 to more than 800 feet in thickness.

In southwestern Virginia the red, unfossiliferous, and argillaceous Juniata Formation is present in the southeastern belts. It is equivalent to the gray, fossiliferous, and limy Sequatchie Formation of western belts (Thompson, 1970; Dennison and Boucot, 1974). Even though the beds along Clinch Mountain, in Scott County, contain minor amounts of carbonate rock (Harris and Miller, 1958) the majority is grayish-red siltstone, which is typical of the Juniata Formation.

Reedsville Shale. Refer to description under **Ou**.

Trenton Limestone. Refer to description under **Ou**.

Eggleston Formation. Refer to description under **Ou**.

Oun *Juniata, Oswego, Martinsburg (Reedsville and Dolly Ridge), and Eggleston Formation*s.

Juniata Formation. Refer to description under **Ous**.

Oswego Formation (Prosser, 1890). **Sandstone**, greenish-gray, fine- to coarse-grained, conglomeratic with chert, quartz, and lithic pebbles. Minor interbeds of olive-gray shale with thin sandstone layers. Conformable with underlying Reedsville Shale. Present northeast of Bath and Augusta counties but thins in all directions from a maximum thickness of 500 feet in western Rockingham County (Diecchio, 1985).

Reedsville Shale . Refer to description under **Ou**.

Dolly Ridge Formation (Perry, 1972). **Limestone**, medium-gray, fine-grained, thin-bedded, argillaceous, with interbedded olive-gray, calcareous claystone, silty argillaceous limestone, gray shale and thin K-bentonite beds. Thickness about 400 feet in Bath and Highland counties; laterally equivalent to the Trenton Limestone and part of the lower Martinsburg Formation of previous reports in western Virginia. It is gradational with the underlying Eggleston Formation.

Eggleston Formation. Refer to description under **Ou**.

Martinsburg Formation. Refer to **Om** (Martinsburg and Oranda Formations) for description. The Martinsburg is only present with this map unit (**Oun**) in northern Rockingham County where it occupies the Reedsville Shale - Dolly Ridge Formation interval.

Om *Martinsburg and Oranda Formations*.

Martinsburg Formation (Geiger and Keith, 1891). Three lithologic packages are recognized in the Martinsburg (in ascending order): black shale and limestone; sandstone and shale; and sandstone (Rader and Biggs, 1976). The lower unit consists of 200 to 250 feet of black calcareous shale, black aphanic, argillaceous limestone; and thin, light-brown K-bentonites. The bulk of the formation, more than 2800 feet, is composed of olive-green to gray, fine- to medium-grained, lithic sandstone and greenish-gray shale and siltstone. These lithologies occur in base-truncated Bouma cycles. Graded bedding, ute casts, and load casts are common. The upper unit, about 170 feet thick, is brownish-gray, medium- to coarse-grained, quartz sandstone. The lower two-thirds of this sandstone contains near-shore, marine fossils.

Oranda Formation (Cooper and Cooper, 1946). Limestone and siltstone. **Limestone**, medium- to dark-gray, fine-grained, very argillaceous. **Siltstone**, black to dark-gray; both lithologies silicified where in contact with a K-bentonite. Five K-bentonites identified in the type section (Rader and Read, 1989).

Okpl *Knobs formation, Fincastle Conglomerate Member of the Martinsburg Formation, Paperville Shale, and Lenoir and Mosheim Limestones.*

Knobs formation (Cooper, 1961). Shale, siltstone, sandstone, and conglomerate. **Shale and siltstone**, brown. **Sandstone**, lithic, greenish-brown, fine- to coarse-grained. **Conglomerate**, polymictic (rounded to subrounded clasts of limestone, dolomite, sandstone, quartzite, vein quartz, shale, chert, and feldspar in calcareous matrix). Some interbeds of calcareous siltstone and sandstone. The Knobs formation ranges from 800 to 3400+ feet in thickness (the upper part of the unit is eroded) (Bartlett and Biggs, 1980). The Knobs formation corresponds to the upper member of the Athens Shale of Butts (1933) as described by Bartlett and Biggs (1980).

Fincastle Conglomerate Member of the Martinsburg Formation. Conglomerate, sandstone, shale, and siltstone (Rader and Gathright, 1986). **Conglomerate (type 1)**, poorly sorted, clast-supported, pebble to boulder clasts of limestone, dolomite, quartzite, sandstone, chert, vein quartz, granite gneiss, quartz-pebble conglomerate, greenstone, and shale, subangular to subrounded. **Conglomerate (type 2)**, poorly-sorted, matrix supported clasts of quartzite, vein quartz, limestone, and chert, subrounded to well-rounded. Matrix framework grains in both types are sand-size quartz, limestone, and dolomite with minor chlorite and sericite. The cement is calcite. The conglomerate fines upward from a scoured base to sandstone. **Sandstone**, lithic, medium- to very-coarse-grained, brownish-gray, cross stratification rare. **Shale and siltstone**, gray, convolute bedding common.

This member is restricted to the Fincastle area of Botetourt County.

Paperville Shale (Cooper, 1956). **Shale**, olive-gray to dark-gray, fissile, thin-bedded; with minor gray, argillaceous siltstone, fossiliferous in lower part. The Paperville Shale ranges from 200 to 2300 feet in thickness (Bartlett and Biggs, 1980). The Paperville Shale corresponds to the lower member of the Athens Shale of Butts (1933) as described by Bartlett and Biggs (1980).

Lenoir Limestone (Safford and Killibrew, 1876). **Limestone**, argillaceous, gray to dark-gray, fine-grained, medium-bedded, silty laminations, fossiliferous. Lower contact is unconformable. The Lenoir Limestone ranges from 0 to 70 feet in thickness (Bartlett and Biggs, 1980).

Mosheim Limestone (Ulrich, 1911). **Limestone**, aphanic, medium-bedded with calcite crystal clusters, sparsely fossiliferous; limestone-dolomite-chert clasts in aphanic limestone matrix common at base of unit; rare thin interbedded dolomite. Unconformable with underlying unit. The Mosheim Limestone ranges from 0 to 150 feet in thickness (Bartlett and Biggs, 1980).

The Lenoir and Mosheim Limestones have a combined thickness up to 270 feet in southwestern Washington County (Bartlett and Webb, 1971).

In the Fincastle Valley the nomenclature Lincolnshire and New Market Limestones replaces Lenoir and Mosheim Limestones of older reports.

Ols *Moccasin Formation, Bays Formation, Unit C, Unit B, and Unit A.*

Moccasin Formation (Campbell, 1894). Mudstone, shale, limestone, and sandstone. **Mudstone and shale**, dusky-red to dark-reddish-brown, calcareous, ripple-marks, and mud cracks common. **Limestone**, light-olive-gray, weathers very-light-gray, aphanic with "birds-eyes", locally fossiliferous. The limestone generally is the middle member of the Moccasin southwest of Giles County. In eastern Giles County and northeastward a thin medium-grained, gray sandstone occurs near the base of the Moccasin. The thickness ranges from 0 in northern Alleghany County to about 600 feet in Scott County.

Bays Formation (Keith, 1895). Siltstone, sandstone, mudstone, and limestone. **Siltstone**, grayish-red, olive- to light-olive-gray, locally calcareous, sandy in part. **Sandstone**, light-gray to yellowish-gray, fine- to very-coarse-grained, locally conglomeratic, calcareous. **Mudstone**, grayish-red, olive- to light-olive-gray, mudcracks common. **Limestone**, grayish-red to light-olive-gray, aphanic. Five distinct K-bentonites reported by Hergenroder (1966). Contacts are conformable except perhaps in Botetourt, Roanoke, and Montgomery counties. Thickness ranges from 105 feet north of Wytheville to 890 feet near Daleville in Botetourt County.

From Scott and Washington counties to Highland County and northwest of the Pulaski and North Mountain faults a multitude of stratigraphic names have been applied to the rocks between the Bays or Moccasin (above) and the Beekmantown or Knox (below). The lack of detailed geologic mapping, except in Scott and Giles counties, the restricted area of the two major stratigraphic studies (Cooper and Prouty, 1943; Kay, 1956), and the general disagreement as to mappability and correlation of units makes it impossible to apply specific stratigraphic nomenclature at this time. Therefore, the rocks are described as three packages of lithologies (from youngest to oldest): Unit C, Unit B, and Unit A.

Unit C. **Limestone**, medium- to dark-gray, aphanic to fine-grained with thin, medium- to coarse-grained beds, argillaceous, nodular to planar-bedded, locally very fossiliferous. The following names have been applied to Unit C: Witten, Bowen, Wardell, Gratton, Benbolt, Chatham Hill, Wassum, Rich Valley, Athens, Ottesee, Liberty Hall, Fetzer, and Giesler.

Unit B. **Limestone**, light- to dark-gray, aphanic to coarse-grained, black and gray chert nodules, carbonate mound build-ups. This unit is characterized by grainstone with interbedded micrite and chert. The overlying Unit C is very argillaceous and lacks chert. The following names have been applied to Unit B: Wardell, Gratton, Benbolt, Lincolnshire, Big Valley, McGlone, McGraw, Five Oaks, Peery, Ward Cove, Rockdell, Rye Cove, Effna, Whitesburg, Holston, Pearisburg, and Tumbez.

Unit A. **Dolostone**, light- to medium-gray, fine-grained, locally conglomeratic, cherty. **Limestone**, medium- to dark-gray, fine-grained, locally cherty. **Shale**, light-gray to dusky-red. A basal chert-dolomite **conglomerate** with clasts as much as cobble size is locally present on the unconformity surface. The following names have been applied to Unit A: Blackford, Elway, Tumbez, Lurich (lower part), and "basal clastics".

Oml *Hardy Creek, Ben Hur, Woodway, Hurricane Bridge, Martin Creek, Rob Camp, Poteet, and Dot Limestones* (Lee County).

Hardy Creek Limestone (Miller and Fuller, 1947). **Limestone**, light-olive-gray to olive-gray, light- to medium-gray, and brown, micrograined, 1- to 2-inch-thick beds, even-bedded; with interbedded yellowish-gray, argillaceous, limestone; and light-olive-gray, aphanic limestone. Olive-black chert nodules locally abundant. The Hardy Creek Limestone ranges from 75 to 150 feet in thickness.

Ben Hur Limestone (Miller and Brosgé, 1950). **Limestone**, argillaceous, yellowish-gray, light-olive-gray, light-brown, and light-gray, micrograined, thin-bedded; some beds composed of fossil detritus in middle of unit; and some beds of coarse-grained limestone. The Ben Hur Limestone ranges from 95 to 165 feet in thickness.

Woodway Limestone (Miller and Brosgé, 1950). **Limestone**, light-olive-gray to olive-gray and light-brownish-gray to brownish-gray, micrograined, thin-bedded, even-bedded; interbedded with olive-gray to olive-black, medium-grained, wavy-bedded limestone; and sparse zones of argillaceous limestone. Thin limestone beds composed of fossils locally abundant at base of unit. Locally abundant olive-black chert nodules. The Woodway Limestone ranges from 240 to 400 feet in thickness.

Hurricane Bridge Limestone (Miller and Brosgé, 1950). **Limestone**, light-gray and light-olive-gray to olive-gray, thin-bedded, micrograined, yellowish-gray; with intervals of interbedded grayish-red, argillaceous, micrograined limestone; and light-olive-gray, thick-bedded, micrograined limestone. Dark-gray chert zones locally present. The Hurricane Bridge Limestone ranges from 200 to 370 feet in thickness.

Martin Creek Limestone (Miller and Brosgé, 1950). **Limestone**, light-olive-gray to dark-olive-gray, locally with abundant fossil fragments, medium-grained; and light-olive-gray to dark-olive-gray, micrograined limestone; with locally abundant olive-black chert nodules. A fine- to coarse-grained limestone that is a maximum 35 feet thick is locally present. Locally the dark colored, medium-grained limestone emits a petroliferous odor when broken. The Martin Creek Limestone ranges from 40 to 180 feet in thickness.

Rob Camp Limestone (Miller and Brosgé, 1950). **Limestone**, light-olive-gray, thin- to massive-bedded, micrograined, with patches of white calcite ("birds-eyes") and very sparse chert nodules. The Rob Camp Limestone ranges from discontinuous (where cut out by post-depositional erosion) to a maximum 150 feet in thickness (Miller and Brosgé, 1954).

Poteet Limestone (Miller and Brosgé, 1950). **Limestone**, grades from light-olive-gray and medium-gray, micrograined

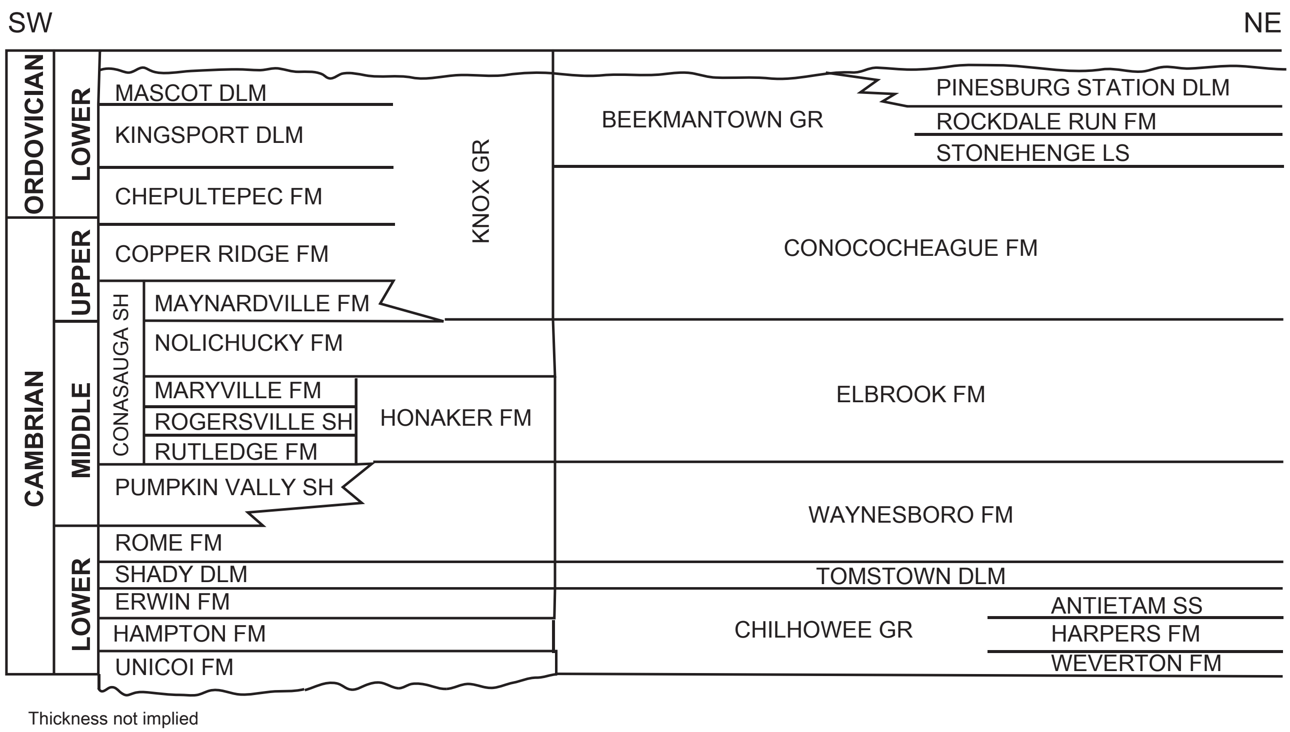

Figure 4. Correlation of Lower Ordovician and Cambrian units.

limestone; interbedded with argillaceous, yellowish-gray, micrograined limestone in the southwest; to dark-gray, medium-grained limestone; overlain by interbedded light-olive-gray, micrograined limestone, and argillaceous limestone in the northeast. Locally abundant olive-black chert nodules. Generally thin- to medium-bedded. The Poteet Limestone ranges from 45 to 110 feet in thickness.

Dot Limestone (Miller and Brosgé, 1950). Limestone, dolomite, and shale. **Limestone**, light-olive-gray, micrograined, thin- to medium-bedded, locally dolomitic. **Dolostone**, argillaceous, conglomeratic (pebbles and cobbles derived from underlying dolomite and chert), grayish-red, yellowish-gray, and very-light- to medium-gray, micro-grained, grades into overlying limestone. **Shale**, dolomitic to calcareous, very-light- to light-gray, interbedded with limestone and dolomite beds. One or more chert zones may be locally present near top of unit. Generally lower contact is represented by an unconformity overlain by the conglomeratic dolomites. The Dot Limestone ranges from 70 to 220 feet in thickness.

Oeln *Edinburg Formation, and Lincolnshire and New Market Limestones* (northeast of Roanoke County).

Edinburg Formation (Cooper and Cooper, 1946). Limestone and shale. **Limestone**, dark-gray to black, aphanic, thin-bedded with thin, black shale partings, locally contorted limestone beds, intraformational limestone breccias, and olistoliths interstratified with typical planar bedded limestone (Liberty Hall lithofacies). **Limestone**, medium- to light-gray, fine- to coarse-grained, nodular with very thin, black shale partings (Lantz Mills lithofacies). **Limestone**, light-gray, medium- to coarse-grained, thick-bedded (St Luke Limestone Member). **Shale**, black, graptolites common, basal unit in Augusta, eastern Rockingham, and southern Page counties. Thickness ranges from 400 feet at Strasburg to approximately 100 feet west of Lexington with a maximum of nearly 1500 feet near Harrisonburg.

Lincolnshire Limestone (Cooper and Prouty, 1943). **Limestone**, light- to dark-gray, fine- to coarse-grained, with black chert nodules. Light-gray, coarse-grained limestone probably represents carbonate mounds *(Murat limestone)*. Upper contact is gradational; the lower contact is disconformable. Thickness ranges from 25 feet west of Front Royal to 280 feet northwest of Lexington (Cooper and Cooper, 1946).

New Market Limestone (Cooper and Cooper, 1946). **Limestone**, medium- to dark-gray, aphanic to fine-grained. The upper portion of the New Market, the major quarry rock of northern Virginia, is massive micrite that weathers to uted ledges. The lower portion is dolomitic with scattered lenticular, black, pyritic limestone, locally conglomeratic at the base. Upper contact is disconformable and the lower contact is a locally angular unconformity. The thickness ranges from 0 near Staunton to 250 feet west of Edinburg.

O€k *Knox Group* (Safford, 1869). Dolostone, limestone, and sandstone. **Dolostone**, light- to medium-gray, very-fine- to fine-grained, locally with pink streaks in the upper part; and very-light-gray to dark-gray and brownish-gray, medium- to coarse-grained, locally argillaceous dolostone near the base of the unit; greenish-gray shale partings locally present; chert is abundant in some parts of the unit. **Limestone**, blue-gray to dark-blue-gray, very-fine- to coarse-grained, locally sandy. **Sandstone**, gray to brown, fine- to medium-grained. Limestone is dominant in the eastern thrust belts. The Knox Group ranges from 2000 feet in Southwest Virginia to 3560 feet in thickness to the east in Washington County (Bartlett and Webb, 1971).

The Knox includes the Mascot, Kingsport, Chepultepec, and Copper Ridge Dolomites and the Maynardville Formation.

Omk *Mascot and Kingsport Dolomites* (Figure 4).

Mascot Dolomite (Rodgers, 1943). Dolostone and limestone. **Dolostone**, nearly white or very-light- to medium-gray with red- to pink-streaks, very-fine- to fine-grained; with subordinate medium- to coarse-grained dolostone; thin green shale partings; sandstone lenses to 1-foot thick; and grayish-red and dark-gray dolostones; all locally present. Dense, gray **limestone** is in the lower half and chert is present locally. Unconformable (locally angular) upper contact. The Mascot Dolomite ranges from 330 to 640 feet in thickness.

Kingsport Dolomite (Rodgers, 1943). Dolostone and limestone. **Dolostone**, very-light-gray to dark-gray and light- to dark-brown, fine- to coarse-grained; with white chert; thin green shale partings; sandstone lenses; and scattered sand grains. Fine-grained **limestone** is locally present. The Kingsport Dolostone ranges from 100 to 350 feet in thickness. The Longview Limestone of previous reports is included in the Kingsport (Harris, 1969).

O€cc *Chepultepec, Copper Ridge, and Maynardville Formations.*

Chepultepec Formation (Ulrich, 1911). **Dolostone**, argillaceous, sandy, light-gray, light-olive-gray, and grayish-brown, very-fine- to coarse-grained. Contains white to light-gray chert nodules and beds; sandstone and dolomitic sandstone lenses and beds; scattered sand grains; minor intraformational conglomerate beds; greenish-gray clay shale partings; and dark-gray, petroliferous dolostone. The Chepultepec ranges from 300 to 850 feet in thickness (Brent, 1963).

Copper Ridge Formation (Ulrich, 1911). **Dolostone**, generally divisible into a lower olive-brownish-gray to dark-gray, medium- to coarse-grained, thick- to massive-bedded dolostone, some of which emits a petroliferous odor on freshly broken surfaces ("stinkstone"); and an upper olive-brownish-gray to light-gray, very-fine- to medium-grained dolostone with minor silty and sandy zones. Olive-black, oolitic chert beds and light-gray to white, chalcedonic chert nodules are present. Similar divisions were described by several geologists including Miller and Brosgé (1954), Miller and Fuller (1954), and Bridge (1956). The Copper Ridge ranges from 415 to 850 feet in thickness.

Maynardville Formation (Oder, 1934). Limestone and dolostone. **Limestone**, locally dolomitic, locally argillaceous, medium- to dark-gray, very-fine- to fine-grained, medium- to thick-bedded, mottled; with argillaceous to dolomitic bands and partings which give the rock a ribbon-banded or straticulate appearance. **Dolostone**, very-light-gray to dark-gray, light-olive-gray to olive-gray and locally yellowish-gray or dark-bluish-gray, very-fine- to coarse-grained, finely laminated to thick-bedded (thin-bedded near top of unit distinguishes it from overlying Copper Ridge Formation); with black chert; minor lenses and beds of fine- to medium-grained, locally dolomitic sandstone; very-fine-grained, yellowish-gray, argillaceous sandstone; and rounded-pebble conglomerate; all locally present. Generally the limestone is in the lower one-third to one-half of the unit and the dolostone is in the upper two-thirds to one-half of the unit, with a transition zone from one to the other. The Maynardville Formation ranges from 60 to 300 feet in thickness, thinning to the east-northeast from Lee County. Thickness variations may be due in part to grouping of the limestone with the underlying Nolichucky Formation or the dolostone with the overlying Copper Ridge, as noted by Derby (1965).

O€z *Lower Ordovician and Upper Cambrian Formations undivided; includes Pinesburg Station Dolomite, Rockdale Run Formation, Beekmantown Formation, Stonehenge Limestone, and Conococheague Formation*. Refer to descriptions under **Ob** and **O€co/€co**.

Ob *Beekmantown Group*. Includes the Pinesburg Station Dolomite, the Rockdale Run Formation, and the Stonehenge Limestone (northern Virginia only) or the Beekmantown Formation and Stonehenge Limestone (central and southwestern Virginia).

Pinesburg Station Dolomite (Sando, 1956). **Dolostone**, dark- to light-gray, fine- to medium-grained, medium- to thick-bedded with minor nodular white chert. It ranges from 0 to 400 feet in thickness and is equivalent to beds in the upper Beekmantown Formation. Present only in Clarke and Frederick counties and is conformable with the underlying Rockdale Run Formation and unconformable with the overlying New Market or Lincolnshire Limestones.

Rockdale Run Formation (Sando, 1958). Dominantly limestone and dolomitic limestone, lesser dolostone with minor chert throughout. **Limestone**, light- to medium-gray, fine-grained generally, but coarse, bioclastic limestone locally, medium- to thick-bedded. **Dolostone**, light-gray, fine- to medium-grained, thick-bedded with "butcher block" weathering and minor nodular or bedded chert in both limestone and dolostone. Unconformably overlain by the New Market Limestone where the Pinesburg Station Dolomite is absent. It is laterally equivalent to the Beekmantown Formation and conformably overlies the Stonehenge Limestone. The formation is about 2700 feet thick.

Beekmantown Formation (Clarke and Schuchert, 1899). Dominantly dolostone and chert-bearing dolostone with lesser limestone. **Dolostone**, light- to very-dark-gray, fine- to coarse-grained, mottled light- and dark-gray, with crystalline beds locally contains nodular, dark-brown or black chert and thick, hill forming, lenticular chert beds in lower part. **Limestone**, very-light- to medium-gray, fine-grained, medium- to thick-bedded, locally dolomitic and locally fossiliferous. The formation is present from Page and Shenandoah counties southwestward in the easternmost exposures of the Lower Ordovician rocks. It and the underlying Stonehenge Limestone, are equivalent to the Mascot and Kingsport Dolomites of the upper part of the Knox Group. It is unconformably overlain by Middle Ordovician limestones and conformably overlies the Stonehenge Limestone.

Erosion, related to the unconformity at the top of the Beekmantown Group and Knox Group, has produced erosional breccias, local topographic relief, and paleokarst topography as well as significant regional thinning of the rock units. The Beekmantown Group thins from about 3000 feet in Page County to less than 700 feet in Washington County, largely because of post-Beekmantown erosion.

Stonehenge Limestone (Sando, 1956). Limestone with interbedded dolostone in northwestern Virginia. **Limestone**, dark-gray, fine-grained, laminated to massive, with black nodular chert. **Dolostone**, light-gray, fine-to very-coarse-grained, as thin- to medium-interbeds or as coarse- grained, massive, reefoidal bodies. Reefoidal bodies are restricted to the middle portion of the formation. The formation conformably overlies the Conococheague Formation and thins northwestward from 400 or 500 feet in the southeasternmost exposures (Page County) to a few tens of feet in the northwestern exposures (western Rockingham County) and is not recognizable or included in the lower Beekmantown or upper Conococheague in much of southwestern or western Virginia. It is equivalent to the lower part of the Kingsport Dolomite.

Oz *Ordovician formations undivided.*

O€co/€co *Conococheague Formation* (Stose, 1908). Dominantly limestone with significant dolostone and sandstone beds in lower part and locally in upper part. **Limestone**, medium- to very-dark-gray, fine-grained, thin-bedded with wavy siliceous partings that weather out in relief. Vertically repetitious primary sedimentary features such as sharpstone conglomerate, laminated bedding, and algal structures indicate cyclic sedimentation. **Dolostone**, medium-gray, fine- to medium-grained, laminated to massive-bedded with primary features similar to those in the limestones. **Sandstone**, medium-gray, brown weathering, cross-laminated, medium- to thin-bedded, forms linear ridges, largely associated with dolostone beds but quartz sand common in most lithologies. Formation is present throughout the Valley of Virginia southeast of the Pulaski and North Mountain faults. It ranges in thickness from about 2200 feet in northern Virginia to 1,700 feet near Abingdon. The Conococheague is approximately equivalent to the Copper Ridge and Chepultepec Formations and conformably overlies the Elbrook Formation.

€c *Conasauga Shale* (Hayes, 1891). **Shale**, sericitic to micaceous, dark-greenish-gray, with local zones of red shale; thin interbeds of limestone, and thin-bedded, fine-grained sandstone. The lower contact with the Rome Formation is not exposed in Lee County. The Conasauga Shale is approximately 560 feet thick in western Lee County (Miller and Fuller, 1954).

€nmrr *Nolichucky and Maryville Formations, Rogersville Shale, and Rutledge Formation.*

Nolichucky Formation (Campbell, 1894). Shale, siltstone, and limestone. **Shale**, locally calcareous, light-olive-gray and bluish-gray, fissile, with minor sandstone and dolomite. **Siltstone**, locally calcareous, yellowish-brown and grayish-orange, thin-bedded. **Limestone**, argillaceous to glauconitic, medium-light-gray to dark-gray and bluish-gray, fine- to coarse-grained; contains oolitic- and at-pebble conglomerate beds, locally stromatolitic. Shale and siltstone make up 20 to 50 percent of the formation (Derby, 1965). A limestone unit up to 165 feet in thickness is present approximately 100 feet above the base of the Nolichucky in northern Russell County (Miller and Meissner, 1977). The Nolichucky Shale ranges from 440 to 690 feet in thickness in Southwest Virginia but pinches out to the northeast in Giles County.

Maryville Formation (Keith, 1895). **Limestone**, locally dolomitic, silty, medium- to dark-gray and bluish-gray, locally ribbon-banded, generally thick-bedded; with thin shale interbeds and sparse dolostone beds. May be as much as 60 percent oolitic limestone in some areas (Harris and Miller, 1958). The Maryville ranges from 500 to 700 feet in thickness.

Rogersville Shale (Campbell, 1894). **Shale**, silty in part, dark-bluish-gray and dark-greenish-gray, fissile, with minor siltstone, limestone, dolostone, and sandstone. The Rogersville Shale ranges from 60 to 110 feet in thickness.

Rutledge Formation (Campbell, 1894). Limestone and dolostone. **Limestone**, locally dolomitic, silty partings, medium-dark-gray to bluish-gray, thick-bedded, mottled, ribbon-banded, with minor chert. **Dolostone**, light-olive-gray and dark-gray, fine- to medium-grained, present in the upper part of the formation in eastern Scott County. The formation forms prominent bluffs on the south-side of Clinch River and Copper Creek in Scott and Russell counties. The Rutledge ranges from 215 to 375 feet in thickness.

The Maryville Formation, Rogersville Shale, and Rutledge Formation grade from predominantly limestone with subordinate dolostone and shale in southeastern Lee County and southwestern Scott County to limestone with a middle dolostone and thin shale near the Scott County-Russell County line. Northeast of this area the laterally equivalent rocks are predominantly dolostone with subordinate limestone at the top and bottom and are called the Honaker Formation (Evans and Troensegaard, 1991).

€nhk *Nolichucky and Honaker Formations.*

Nolichucky Formation. Refer to description under **€nmrr**.

Honaker Formation (Campbell, 1897). Dolostone, limestone, and shale. **Dolostone**, light- to dark-gray to dark-bluish-gray, aphanic to coarse-grained, thin- to massive-bedded, "butcher-block" weathering; with sparse interbeds of argillaceous limestone, and minor dark-gray chert. **Limestone**, argillaceous, ribbon-banded in part, light- to medium-gray, very-fine-grained, thick-bedded. **Shale**, greenish-gray, laminated to thin-bedded. The Honaker Formation is predominantly dolostone with subordinate limestone. The dolostone becomes more dominant in the northeastern part of outcrop belt (Evans and Troensegaard, 1991). Shale is locally present as a 20- to 60-feet-thick unit in the middle of the formation and as thin interbeds with the dolostone and limestone throughout the area. The Honaker Formation ranges from about 1000 to 1100 feet in thickness. It is laterally equivalent to the lower Elbrook to the east.

Ꞓe *Elbrook Formation* (Stose, 1906). Dolostone and limestone with lesser shale and siltstone. **Dolostone**, medium-to dark-gray, fine- to medium-grained, laminated to thick-bedded. **Limestone**, dark-gray, fine-grained, thin- to medium-bedded, with algal structures and sharpstone conglomerate. **Shale and siltstone**, light- to dark-gray, dolomitic, platy weathering, with minor grayish-red or olive-green shales. Interbedded limestone and dolostone dominate the upper part of the formation; dolomitic siltstone and shale and thin- bedded argillaceous limestone dominate the lower part. The formation ranges between 1500 and 2900 feet in thickness in the southeasternmost exposures but is incomplete elsewhere due to faulting. The Elbrook of northern Virginia is transitional with the Nolichucky and Honaker Formations (locally the limestone facies of the Nolichucky has been differentiated from the Elbrook by Bartlett and Biggs (1980). It is also approximately equivalent to the rock sequence comprised of the Nolichucky and Maryville Formations, the Rogersville Shale, and the Rutledge Formation. Farther southwest the Conasauga Shale is the Elbrook equivalent. The Elbrook appears to be conformable and gradational with the underlying Waynesboro or Rome Formations.

From Washington County to Augusta County much of the Elbrook Formation adjacent to the Pulaski and Staunton faults is a breccia of the "Max Meadows tecontic breccia type" (Cooper and Haff, 1940). These breccias are composed of crushed rock clasts that range from sand size to blocks many feet long, derived almost entirely from the lower part of the Elbrook Formation. The breccia commonly forms lowlands characterized by karst features.

Ꞓr *Pumpkin Valley Shale and Rome Formation*.

Pumpkin Valley Shale (Bridge, 1945). **Shale**, light-greenish-gray to dark-greenish-gray, grayish-brown, and maroon; a few beds of similar colored siltstone; sparse beds of limestone and dolostone. The Pumpkin Valley Shale conformably overlies the Rome Formation. The formation is approximately 350 feet thick.

Harris (1964) identified the Pumpkin Valley Shale of Southwest Virginia as a formation within the Conasauga Group; however, because of similar lithologies it is often indistinguishable from the Rome Formation and the two formations commonly are mapped together.

Rome Formation (Hayes, 1891). Siltstone, shale, sandstone, dolostone, and limestone. **Siltstone and shale**, greenish-gray and grayish-red, laminated to thin-bedded. **Sandstone**, micaceous, locally glauconitic, greenish-gray and reddish-gray, very-fine- to medium-grained, thin-bedded. **Dolostone**, light- to dark-gray, aphanic to medium-grained, thin-to massive-bedded, with ripple marks and mudcracks. **Limestone**, argillaceous, very-light-gray to dark-gray, thin- to medium- bedded. Carbonate rocks range from sparse 1- to 2-feet-thick beds in western Scott County to discontinuous units as much as 50 feet thick which comprise 30 to 40 percent of the formation in western Russell and Washington counties (Evans and Troensegaard, 1991; Bartlett and Webb, 1971). Maximum recorded thickness is 1500 feet in the Clinchport area (Brent, 1963); although this may have included the Pumpkin Valley Shale. A complete thickness has not been determined because the lowermost part of the Rome Formation is normally absent due to faulting.

Ꞓwb *Waynesboro Formation* (Stose, 1906). Largely dolostone and limestone with distinctive upper and lower sequences of interbedded red mudrock, red sandstone, and dolostone. **Dolostone**, light- and dark-gray, mottled, fine- to coarse-grained, thick-bedded, calcareous. **Limestone**, medium-gray, fine-grained, thick-bedded, locally with black chert nodules. **Mudrock**, grayish-red, locally fissile, interbedded with dolostone and sandstone. **Sandstone**, dark- grayish-red, fine- to medium-grained, medium- to thin-bedded, forms low ridges and hills. The Waynesboro Formation is laterally equivalent to the Rome Formation and is only present northeast of Roanoke. It is well exposed in Botetourt County (Haynes, 1991) and in Clarke County (Gathright and Nystrom, 1974) where lower shale beds of the Elbrook Formation were incorrectly included in the Waynesboro as an upper member. It is conformable with the underlying Tomstown Dolomite and is between 1100 and 1200 feet thick.

Ꞓt *Tomstown Dolomite* (Stose, 1906). Dolostone, limestone and minor chert. **Dolostone** (upper member), light- to dark-gray, fine- to coarse-grained, medium- to thick-bedded, locally laminated with white chert nodules in uppermost beds; about 600 feet thick. **Dolostone** (high magnesian member), very-light-gray to yellowish-white, medium- to coarse-grained, very-thick-bedded, locally dark-gray, fine-grained and with white, coarse-grained, lenticular dolostone mottling; about 200 feet thick. Limestone, very-dark-gray, very-fine-grained, thin-bedded, partly dolomitic, with shaly partings; about 325 feet thick. The Tomstown is lithologically similar to, but thinner than the Shady Dolomite of southwestern Virginia and conformably overlies the Antietam Formation.

Ꞓs *Shady Dolomite* (Keith, 1903). Dolostone with minor limestone and shale divided into three members: Ivanhoe (upper) Member; Austinville (middle) Member, and Patterson (lower) Member. **Ivanhoe Member**, dark-gray, fine-grained limestone and minor interbedded black shale; 100 to 500 feet thick. **Austinville Member**, very-light-gray to cream colored, fine- to medium-grained, crystalline or saccharoidal, massive-bedded dolostone with several sequences of interbedded limestone, very-dark-gray dolostone or mottled dolostone and shale; 1000 feet thick. **Patterson Member**, medium- to dark-gray, fine-grained, thin-bedded dolostone or limestone with silicious partings and intraformational breccia beds; 800 feet thick. The Shady Dolomite is gradational with the underlying Erwin Formation and the upper two members grade southeastward into shaly dolostone with biohermal mounds, intraformational limestone or dolostone breccias, oolitic limestone, and arenaceous limestone and dolostone. This upper, southeastern facies, is in part equivalent to beds in the lower Rome Formation (Pfiel and Read, 1980). The Shady is very poorly exposed except near New River in Wythe and Smyth counties where it is at least 2100 feet thick and where major lead and zinc deposits were mined from the upper members (Currier, 1935).

Ꞓch *Chilhowee Group* (Keith, 1903). The Chilhowee Group includes the Antietam, Harpers, and Weverton Formations in the northeastern portion of the Blue Ridge Province and the Erwin, Hampton, and Unicoi Formations in the southwestern portion of the Blue Ridge Province.

Antietam Formation (Williams and Clark, 1893). **Quartzite**, medium-gray to pale-yellowish-white, fine- to medium-grained, locally with very minor quartz-pebble conglomerate, cross-laminated, medium- to very-thick-bedded, very resistant, forms prominent cliffs and ledges, contains a few thin interbeds of light-gray phyllite, has calcareous quartz sandstone at the top that is transitional with the overlying Tomstown Dolomite, and many beds contain *Skolithos linearras*. It is laterally equivalent to the Erwin Formation to the southwest. The formation interfingers with the underlying Harpers Formation and ranges in thickness from less than 500 feet in Clarke County to nearly 1000 feet in Rockingham County (Gathright and Nystrom, 1974; Gathright, 1976).

Harpers Formation (Keith, 1894). Metasandstone, metasiltstone, and phyllite. **Metasandstone**, dark-greenish-gray to brownish-gray, fine-grained, sericitic, thin- to medium-planar bedded, locally bioturbated, *Skolithos*-bearing litharenite; dark-gray, fine-grained, cross-laminated, thick-bedded, laterally extensive bodies of quartzite; and very-dark-gray, medium- to coarse-grained, thick-bedded, ferruginous, very resistant, quartzitic sandstone. These beds were extensively mined for iron ore north of Roanoke (Henika, 1981). **Metasiltstone**, dark-greenish-gray, thin, even bedded, sericitic, and locally bioturbated. **Phyllite**, medium- to light-greenish-gray, bronze weathering, laminated, sericitic. The Harpers is laterally equivalent to the Hampton Formation to the southwest and they are so similar that the names have been used interchaneably in the northern Blue Ridge (Gathright, 1976; Brown and Spencer, 1981). The Harpers conformably overlies the Weverton or Unicoi Formations, thickens northeastward from about 1500 feet north of Roanoke to about 2500 feet in Clarke County. The thicker sections are dominated by phyllite and metasiltstone and the thinner sections by metasandstone and quartzite.

Weverton Formation (Williams and Clark, 1893). Quartzite, metasandstone, and phyllite. **Quartzite**, medium- to very-dark-gray, weathers light-gray, fine- to coarse-grained, well-rounded quartz-pebble conglomerate beds locally, medium- to thick-bedded, cross-bedded, very resistant, with interbedded **metasandstone**, dark-greenish- gray, feldspathic, thick-bedded, with ferruginous cement in some beds. **Phyllite**, light- to dark-greenish-gray or dark-reddish-gray, laminated, sericitic, with coarse sand grains and quartz-pebble conglomerate in a few thin beds, generally in lower part. Formation ranges in thickness from more than 600 feet in Clarke County to less than 200 feet in Augusta County (Gathright and Nystrom, 1974; Gathright and others, 1977). The Weverton is lithologically very similar to strata in the upper portion of the Unicoi Formation to the south to which it may be equivalent. The Weverton appears to unconformably overlie the Catoctin and Swift Run Formations and the Blue Ridge basement complex and is present northeast of Augusta County.

Ꞓeh *Erwin and Hampton Formations.*

Erwin Formation (Keith, 1903,1907). Quartzite, sandstone, and shale. **Quartzite**, light-gray to white, medium- to fine-grained, thick-bedded, cross-laminated, quartz cemented, and very resistant. **Sandstone**, ferruginous, dark-gray to bluish-black, medium- to coarse-grained, locally conglomeratic, and with various amounts of hematite cement, in medium- to thick-beds. **Shale**, silty and sandy, drab-greenish-gray, thin- to medium-bedded, non-resistant, comprises much of the formation but is poorly exposed. The Erwin is less than 1000 feet thick and is equivalent to the Antietam Formation and possibly the upper part of the Harpers Formation in northern Virginia.

Hampton Formation (Keith, 1903). Shale, sandstone, and quartzite. **Shale**, dark-gray or dark-greenish-gray, fissile, very argillaceous, silty laminae common, with interbeds of siltstone and fine-grained, lithic sandstone. **Sandstone**, feldspathic, greenish-gray, vitreous, medium- to coarse-grained, pebbly, cross-laminated. **Quartzite**, white to light-brown, vitreous, fine-grained, medium- to thin-bedded, resistant, restricted to the upper part of the formation. The Hampton is largely equivalent to the Harpers Formation to the northeast and ranges in thickness from more than 1500 feet to about 1200 feet with the thinner sequence in the northwesternmost exposures.

Ꞓu *Unicoi Formation* (Keith, 1903,1907). Sandstone and quartzite with phyllite, tuffaceous phyllite, conglomerate, and minor basalt. **Sandstone**, lithic or feldspathic, pinkish-gray to dark-greenish-gray, fine- to coarse-grained, angular, poorly sorted, locally conglomeratic. **Quartzite**, largely in upper part of the unit, white, pale-green, or gray, vitreous, medium- to coarse-grained, locally feldspathic, medium- to very-thick-bedded, very resistant to weathering and erosion. **Phyllite**, reddish-, purplish-, or greenish-gray, as thin, sparse interbeds throughout, with purple tuffaceous phyllites in lower part. **Conglomerate**, fine- to coarse-polymictic-pebble conglomerate, medium- to thick-bedded, with lithic clasts and quartz pebbles. **Basalt**, very-dark-grayish-green, aphanitic, locally amygdaloidal; in one to three beds a few feet thick in the lower part only. Upper part has more quartzite and contains phyllite beds similar to the overlying Hampton Formation. Lower part is very feldspathic, contains most of the conglomerate beds and all of the volcanic rocks. The Unicoi is present from Augusta County to Tennessee and is laterally equivalent, at least in part, to the Weverton Formation to the northeast (King and Ferguson, 1960; Brown and Spencer, 1981; Rankin, 1993). The formation unconformably overlies the rocks of the Blue Ridge basement complex and possibly the Catoctin Formation in western Amherst County and is disconformable with the underlying Konnarock Formation in Grayson County. The upper unit is generally 600 to 1000 feet thick and the lower unit ranges from less than 100 feet to more than 1500 feet.

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BLUE RIDGE AND PIEDMONT

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my *mylonite*. Includes protomylonite, mylonite, ultramylonite, and cataclastic rocks. Lithology highly variable, depending on the nature of the parent rock, and on intensive parameters and history of deformation. In most mapped belts of mylonite and cataclastic rock (**my**), tectonized rocks anastomose around lenses of less-deformed or undeformed rock. In the Blue Ridge, some of these lenses are large enough to show at 1:500,000 scale. In many places mylonitic and cataclastic rocks are gradational into less deformed or undeformed adjacent rocks, and location of contacts between tectonized rocks (my) and adjacent units is approximate or arbitrary. These boundaries are indicated on the map by color-color joins with superimposed shear pattern.

Most mapped belts of mylonite represent fault zones with multiple movement histories. In the Blue Ridge, Paleozoic-age contractional deformation fabrics are superimposed on Late Precambrian extensional fabrics (Simpson and Kalaghan, 1989; Bailey and Simpson, 1993). Many Piedmont mylonite zones contain dextral-transpressional kinematic indicators that formed during Late Paleozoic collisional tectonics (Bobyarchick and Glover, 1979; Gates and others, 1986). Paleozoic and older faults were reactivated in many places to form extensional faults during the Mesozoic (Bobyarchick and Glover, 1979).

BLUE RIDGE ANTICLINORIUM

STRATIFIED ROCKS OF THE BLUE RIDGE ANTICLINORIUM

Ꞓch *Chilhowee Group, undivided*. Quartz pebble conglomerate, quartzite, metasiltstone, and phyllite.

Ꞓf *Frederick Limestone*. Medium-gray to medium-bluish-gray laminated, thinly-bedded limestone.

Ꞓt *Tomstown Dolomite*. Very-pale-orange, purplish-gray, bluish-white, or medium-bluish-gray, fine- to medium-grained massive dolomite.

Ꞓev *Everona Limestone* (Jonas, 1927). Thinly-laminated medium-bluish-gray limestone with graded, graphitic silty partings; includes calcareous graphitic phyllite, and pyrite-bearing graphitic slate.

Mineralogy: calcite + quartz + muscovite ± graphite ± chlorite ± albite ± pyrite + tourmaline.

The Everona occurs dominantly as lenticular bodies immediately northwest of or within the Mountain Run fault zone (Evans, 1984; Conley, 1989; Rossman, 1991). In most outcrops primary laminations are complexly folded due to strain accommodation associated with the Mountain Run fault. Unit thickness and degree of lateral continuity are structurally controlled in many places. Mack (1965) reports thicknesses ranging from about 20 to 1100 feet.

Jonas (1927) reports retrieving trilobite fragments from sandy beds adjacent to the Everona, but these were so poorly preserved that E.O. Ulrich could not identify them, even with respect to genus. Recent attempts to extract conodonts from the Everona have so far proven fruitless. The Everona is interpreted to be in stratigraphic continuity with phyllites and metasiltstones that are conformable above the Catoctin Formation (Evans, 1984; Rossman, 1991), and is likely Early Paleozoic in age.

Candler Formation (Ꞓca, ls, Ꞓcas)

Ꞓca *phyllite and schist*. Medium- to dark-gray and greenish-gray mica phyllite and sandy laminated schist. Lenses and pods of feldspathic quartzite, metamorphosed quartzarenite, dolomitic marble, and dark-gray to medium-bluish-gray, laminated marble are common in the upper part.

Mineralogy: quartz + albite + muscovite + chlorite + magnetite-ilmenite + epidote ± biotite ± chloritoid ± calcite. Chloritoid and magnetite porphyroblasts are common near the Bowens Creek fault.

Geophysical signature: Low amplitude, linear magnetic highs are superimposed on a pronounced southeast-sloping magnetic gradient between Alligator Back units northwest of the Candler and a persistant linear magnetic trough localized along the trend of the Bowens Creek fault zone.

Microstructural elements in the upper Candler indicate dextral transpression along a continuous shear zone (Bowens Creek fault zone) within the Candler outcrop belt from the Virginia-North Carolina boundary in Patrick County northeastward to at least the north end of Buffalo Ridge on the Amherst-Campbell County line. Conley and Henika (1970) and Gates (1986) hypothesized that the Bowens Creek fault is part of a major strike slip (wrench) system that is part or a continuation of the Brevard fault zone to the southwest .

Northeast of the Scottsville Mesozoic basin, the Candler includes laminated metasiltstone (Ꞓcas), ferruginous metatuff, dolomitic marble, and phyllite that are conformable above Catoctin metabasalt (Evans, 1984; Conley, 1989; Rossman, 1991); in Orange County, the Candler includes the True Blue formation of Pavlides (1989, 1990).

ls *limestone*. Medium-bluish-gray, thinly-laminated limestone and laminated calcareous mudstone; resembles Everona Limestone.

Ꞓcas *laminated metasiltstone*. Grayish-green, fine- to very-fine-grained, laminated schistose and phyllitic metasiltstone; relict detrital quartz and albite define graded laminations on the order of 0.5 to 1 cm thick. Mineralogy: quartz + chlorite + muscovite + albite + epidote + magnetite + tourmaline + zircon.

Laminated metasiltstone occurs in stratigraphic conformity above the Catoctin Formation; in southeastern Albemarle County, the unit contains discontinuous interbeds of ferruginous metatuff. Laterally discontinuous beds of feldspathic metasandstone, micaceous quartzite, and coarse-grained to pebbly metagraywacke occur within the metasiltstone outcrop belt, and are interbedded with phyllites somewhat higher in the section (Evans, 1984).

Єzmq *micaceous quartzite*. Coarse-grained micaceous quartzite and feldspathic metasandstone with interbedded metasiltstone and phyllite; occurs above Catoctin greenstone **(ЄZc)** in an outlier surrounded by Mesozoic rocks east of Culpeper. These rocks are lithologically similar to, and probably correlative with micaceous quartzites in the True Blue formation of Pavlides (1989, 1990), and with feldspathic metasandstone lenses in the Candler Formation.

Catoctin Formation (ЄZc, ЄZcb, ЄZct, ЄZcs, ЄZcr, ЄZhb, ЄZlb)

ЄZc *metabasalt*. Grayish-green to dark-yellowish-green, fine-grained, schistose chlorite- and actinolite-bearing metabasalt, commonly associated with epidosite segregations.

Mineralogy: chlorite + actinolite + albite + epidote + titanite ± quartz + magnetite. Relict clinopyroxene is common; biotite porphyroblasts occur locally in southeastern outcrop belts.

Geophysical signature: The Catoctin as a whole has a strong positive magnetic signature. However, between Warrenton and Culpeper the lowest part of the Catoctin, which consists of low-titanium metabasalt and low-titanium metabasalt breccia, is non-magnetic, and displays a strong negative anomaly.

Metabasalt **(ЄZc)** is by far the most widespread unit comprising 3000 feet or more of section (Gathright and others, 1977). Primary volcanic features are well preserved in many places. In the northwestern outcrop belt, these include vesicles and amygdules, sedimentary dikes, ow-top breccia, and columnar joints (Reed, 1955; Gathright, 1976; Bartholomew, 1977); relict pillow structures have been reported in Catoctin greenstones east of Buena Vista (Spencer and others, 1989). In the southeastern outcrop belt, amygdaloidal metabasalts are common, as are volcanoclastic rocks interbedded with basaltic ows (Rossman, 1991). Fragment-al zones occur locally between individual lava ows; map-scale hyaloclastite pillow breccias occur at three stratigraphic levels within the southeastern outcrop belt **(ЄZcb, ЄZhb, ЄZlb**; Espenshade, 1986; Kline and others, 1990).

ЄZcb *hyaloclastite pillow breccia* (Kline and others, 1990). Poorly-sorted assemblages of ellipsoidal to angular clasts of metabasalt in a finer-grained matrix; clasts range in size from 1 cm to greater than 1 m across, but generally are on the order of 2 to 15 cm. Mineralogy and textural features in clasts are identical to those in Catoctin metabasalt (ЄZb). Matrix consists of coarse- to fine-grained material of similar mineralogy to clasts, in a mesostasis that may constitute up to 30 percent of the matrix. Breccias are generally matrix supported. Pillows and pillow breccias are locally delineated by concentrations of epidote + quartz on rims and in interstices; pillows are attened and ellipsoidal, and range up to about 3 m in maximum dimension (Kline and others, 1990). Thickness is on the order of 300 m.

ЄZct *purple tuffaceous phyllite*. Purple- and green-mottled hematite-cemented chlorite-sericite phyllite and slate; relict pumice, lithic fragments, and devitrified glass shards are visible in thin section. Occurs as interbeds generally less than 10 meters thick within metabasalt in northwest and southeast outcrop belts; in most places, lateral continuity cannot be demonstrated because of limited outcrop.

ЄZcs *metasedimentary rocks*. Quartzite, feldspathic metasandstone, metasiltstone, and phyllite; occurs in discontinuous beds that are generally less than 50 feet thick, interbedded with Catoctin metabasalt (ЄZc).

ЄZcr *metarhyolite*. Includes light-gray to medium-light-gray, aphanitic to fine-grained metarhyolite containing grayish-yellow potassium feldspar phenocrysts; and, medium-gray to medium-dark-gray tuffaceous metarhyolite containing potassium feldspar phenocrysts and quartz-filled amygdules. Metarhyolite occurs as dikes up to 50 m thick, cutting Grenville basement and the Swift Run Formation (Southworth, 1991); also as cream-colored rhyolitic metatuff which is interbedded with metabasalt (ЄZc) stratigraphically near the base of that unit in Loudoun and northwestern Fauquier Counties (Nickelsen, 1956; Gathright and Nystrom, 1974). Metarhyolite at two localities in Loudoun County has been dated at 564 ± 9 Ma and 572 ± 5 Ma (U-Pb zircon; Aleinikoff and others, 1991).

ЄZhb *metabasalt breccia* (high-titanium) (Espenshade, 1986). Dark-green, amygdular ellipsoids ranging from about 5 to 40 cm in length in a matrix of dark-green, dense angular fragments about 0.5 to 5 cm across; epidote is commonly abundant in the matrix; ellipsoidal amygdules contain quartz and epidote. Titanite constitutes several percent of the mode. This unit, where present, may be as thick as 2800 feet, and occurs stratigraphically above the low-titanium breccia **(ЄZlb)**.

ЄZlb *metabasalt breccia* (low-titanium) (Espenshade, 1986). Blocky or angular fragments of grayish-green, fine-grained rock in a fine-grained, generally schistose matrix. Breccia fragments range from 1 to 20 cm long, and form rough, knobby surfaces on weathered outcrops. Where present, this breccia occurs at or near the base of Catoctin metabasalt **(ЄZc)** on the southeast limb of the Blue Ridge anticlinorium; the unit is as much as 3000 feet thick. Furcron (1939) mapped both high- and low-titanium breccias as Warrenton agglomerate; R.L. Smith (personal communication in Espenshade, 1986) interpreted the breccias as subareal agglutinates. Kline and others (1990) presented evidence that the breccias are hyaloclastite pillow breccias, erupted in a subaqueous environment.

Reed (1955) recognized a mappable stratigraphy within the Catoctin, and made the interpretation that the greenstones were metamorphosed tholeiitic ood basalts that originated in a “nonorogenic” setting. Rankin (1975) considered the Catoctin to have originated during continental volcanism associated with the opening of a proto-Atlantic Iapetus ocean in Latest Precambrian time, and included the Catoctin in the Crossnore volcanic-plutonic group.

Badger and Sinha (1988) studied chemical stratigraphy within individual ows and dated Catoctin metabasalts at 570 ± 36 Ma using Rb-Sr systematics on samples showing little

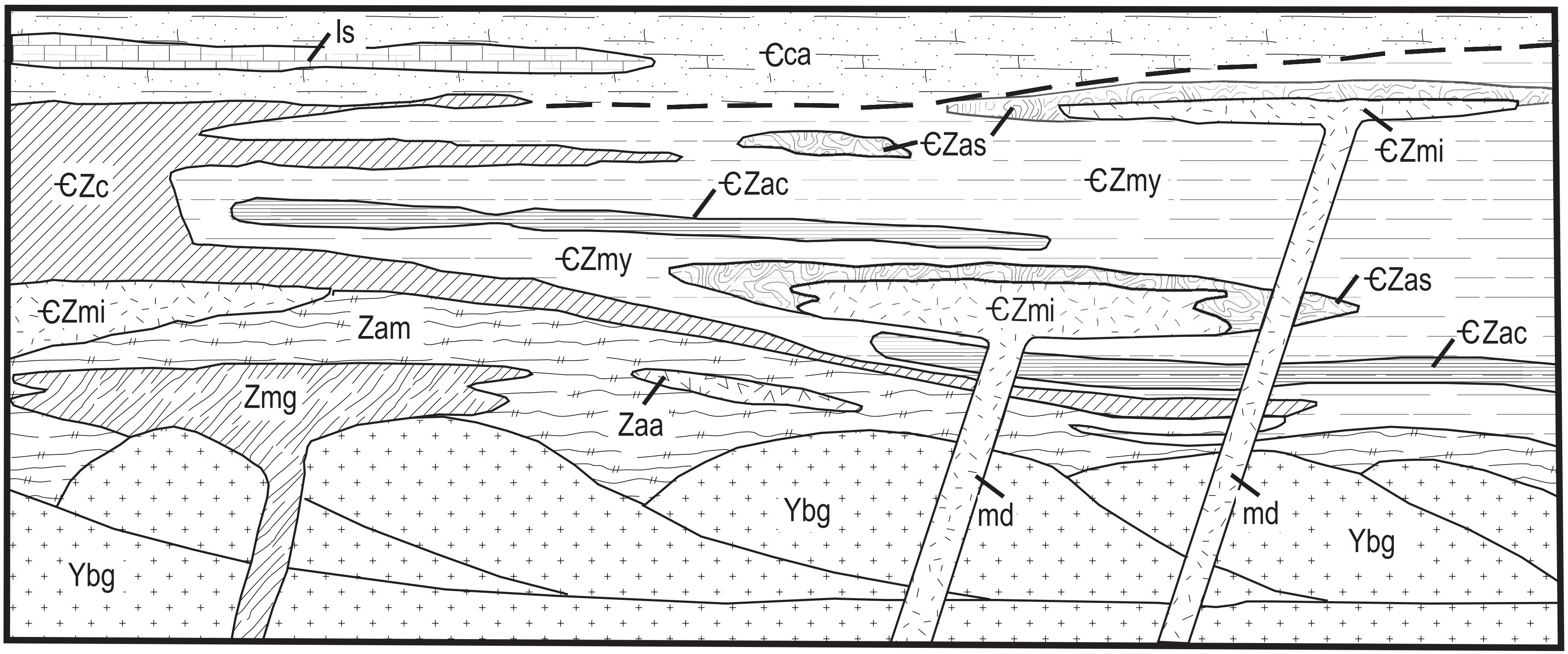

Figure 5. Complex relationships between lithofacies of the Catoctin Formation **(CZc)** and units in the Lynchburg Group of southwestern Virginia, including the Ashe Formation **(Zaa, Zam)**, the Moneta Gneiss **(Zmg)**, Mafic Igneous Complexes **(CZmi)**, the Alligator Back Formation **(CZmy, CZac, CZas)**, and the Candler Formation **(Cca, ls)**. The Alligator Back and Candler lithofacies were formerly considered part of the Evington Group in southwestern Virginia.

evidence of elemental mobility during metamorphism. This date is consistent with radiometric age data from Catoctin metarhyolite, discussed above, and with the occurrence of Early Cambrian-age *Rusophycus* stratigraphically above the Catoctin near the base of the Chilhowee Group (Simpson and Sundberg, 1987). These constraints suggest that some portion of the Catoctin may be as young as Cambrian in age.

Regional mapping suggests that metabasalts and amphibole gneisses within the Ashe **(Zaa)**, Alligator Back **(ЄZas),** and Bassett Formations **(ЄZba)** are volcanogenic rocks that are correlative with the Catoctin in a lithostratigraphic sense and in terms of tectonic setting, but not necessarily in a strict time sense. Catoctin volcanism likely spanned a considerable time period; correlative units to the southwest were probably time-transgressive to a degree (Figure 5).

ЄZmd *metagabbro*. Dusky-green to black, medium- to coarse-grained, massive to vaguely-foliated amphibolite.

Mineralogy: (1) actinolite + chlorite + albite + epidote + quartz + magnetite ± titanite; (2) hornblende + plagioclase + epidote + magnetite + quartz ± titanite.

Geophysical signature: strong positive magnetic anomaly. Metagabbro occurs as dikes that cut Grenville basement and the Lynchburg Group, and as sills occurring primarily in the Charlottesville and Alligator Back Formations in association with ultramafic rocks. Crosscutting relations imply that these rocks are related to the Catoctin in time. Reed and Morgan (1971) demonstrated on the basis of geochemistry that metadiabase dikes cutting Grenville basement in northern Virginia are feeders to the Catoctin. Metagabbroic dikes in the central Virginia Blue Ridge could represent a deeper level of Catoctin feeder system, although that hypothesis has not been substantiated by field or geochemical study.

ЄZmi *mafic igneous complex*. Metamorphosed stratiform mafic and ultramafic rocks include: greenish-gray, locally layered, coarse-grained metagabbro; dark-greenish-black schistose metabasalt; and, gray to grayish-green talc-chlorite-tremolite schist.

Mineralogy: (1) chlorite + epidote + plagioclase + quartz + titanite + ilmenite; (2) chlorite + actinolite + biotite + epidote + titanite + plagioclase + quartz; (3) chlorite + actinolite + talc + dolomite + magnetite-ilmenite; (4) tremolite + chlorite + magnetite-ilmenite; (5) serpentine + talc + chlorite + actinolite ± olivine ± augite.

Geophysical signature: strike-elongate positive magnetic anomaly.

Metamorphosed mafic and ultramafic complexes are generally sheet-like bodies, concordant near the base of the Alligator Back and Charlottesville Formations. In Nelson County, these rocks are cut by metagabbroic dikes **(ЄZmd)** that are likely related to the Catoctin.

Hess (1933) reports a stratified association of ultramafic, mafic, and minor silicic lithologies at Schuyler which he attributes to in situ differentiation of a sheet-like concordant intrusion. Glover and others (1989) report a non-tectonized intrusive contact between Charlottesville Formation metasiltstone and ultramafic schist at Schulyer. In contrast, Conley (1985) presents evidence that ultramafic-mafic complexes in Franklin County are tectonicly-emplaced slices of oceanic crust (ophiolites). Tectonic setting and mode of emplacement for these rock assemblages remain enigmatic; correlation of complexes in the southwestern Piedmont with those in the central Blue Ridge may ultimately prove invalid.

ЄZum *ultramafic rocks*. Grayish-green to light-gray talc-chlorite-actinolite or talc-tremolite schist.

Mineralogy: (1) chlorite + actinolite + talc + dolomite + ilmenite + magnetite; (2) serpentine (antigorite) + talc + chlorite ± olivine ± augite; (3) tremolite + cummingtonite + chlorite + talc + magnetite-ilmenite ± quartz.

Geophysical signature: elongate positive magnetic anomaly.

Elongate, lenticular bodies generally trend parallel to schistosity of enclosing rocks and are concordant at variable stratigraphic levels within the Lynchburg Group.

Zsr *Swift Run Formation* (Jonas and Stose, 1939; King, 1950; Gathright, 1976). Heterogeneous assemblage includes: pebbly to cobbly quartzite and feldspathic metaconglomerate; gray, grayish-pink, or grayish-green, feldspathic quartzite and metasandstone, locally crossbedded; greenish-gray, silvery quartz-sericite-chlorite sandy schist; and, greenish-gray to grayish-red-purple chlorite-sericite tuffaceous phyllite and slate. In Loudoun County, contains pinkish-gray and yellowish-gray to light brownish-gray, fine-grained dolomitic marble (Southworth, 1991). Individual lithologies are laterally discontinuous; formation ranges up to 350 feet in total thickness, but is locally very thin or absent (Gathright, 1976).

The Swift Run was originally defined on the northwest limb of the Blue Ridge anticlinorium (Stose and Stose, 1946), where the unit rests unconformably on Grenville-age rocks, and is overlain conformably by the Catoctin Formation; the upper contact is mapped at the bottom of the lowest massive metabasalt. In places Swift Run lithologies are interbedded with Catoctin metabasalts, and the contact between the two units is gradational (Gathright, 1976). Swift Run metasedimentary rocks on the northwest limb have been interpreted as deposited in alluvial fan, oodplain, and lacustrine environments (Schwab, 1986); these are interbedded with metamorphosed tuffaceous and volcanoclastic units (Gathright, 1976; Bartholomew, 1977).

Although the Swift Run has been interpreted as a thin western equivalent of the Lynchburg Group in the southeastern Blue Ridge (Stose and Stose, 1946; Brown, 1970), some workers have correlated the Swift Run with discontinuous lenses of feldspathic sandstone interbedded with felsic metatuff that occur immediately below the Catoctin on the southeast limb of the anticlinorium (Nelson, 1962; Conley, 1978; 1989; Wehr, 1985). On the Geologic Map of Virginia (1993), the Swift Run is terminated along an east-west-trending normal fault just west of Leesburg, and is not mapped farther southwest on the southeast limb of the Blue Ridge anticlinorium.

Zm *marble*. Includes white and light-gray to grayish-blue, fine-grained dolomitic marble and siliceous marble, dolomitic meta-arkose, dolomitic quartz-muscovite schist, and calcitic marble; may contain quartz, feldspar, muscovite, phlogopite, and tremolite.

Marble is poorly exposed in discontinuous lenses either just below the top of the Fauquier Formation laminated metasiltstone **(Z)** or just above the base of the Catoctin **(ЄZc)**; a lense of dolomitic marble occurs within the Swift Run Formation in Loudoun County. Along the Hazel River, a marble clast conglomerate with a biotite-rich feldspathic matrix occurs just below the base of the Catoctin Formation.

Fauquier Formation (Z , Zfs, Zfa, Zfc; Furcron, 1939; Espenshade, 1986)

Z *laminated metasiltstone and phyllite.* Medium- to dark-gray (fresh), very-pale-orange (weathered), very-fine-grained, laminated metasiltstone, composed of alternating silty and micaceous layers on the order of a millimeter to several millimeters thick, and phyllite without discernable layers; major minerals are silt-size quartz and sericite; chlorite, biotite, and magnetite occur locally.

Thiesmeyer (1939) described these rocks as "varved slates" interpreted as lacustrine deposits. Espenshade (1986) called this unit metarhythmite. The unit is on strike with, and in part equivalent to the Monumental Mills Formation of Wehr (1985), interpreted as deposited in a delta front-slope environment.

Zfs *meta-arkose and metasiltstone*. Alternating beds of dark-gray, very-fine-grained meta-arkose and metasiltstone; composed dominantly of angular quartz grains, with lesser plagioclase and potassium feldspar, and minor biotite. Cross-bedding and graded bedding are present; thickness ranges from 300 to 500 meters.

Zfa *arkosic metasandstone*. Dark-gray, medium- to coarse-grained metasandstone contains quartz, plagioclase, perthitic potassium feldspar, and sericite, with minor biotite and epidote; thin beds of pebble conglomerate occur with coarse-grained metasandstone; commonly cross-bedded. Unit comprises the lowest part of the Fauquier; thickness is extremely variable. In the vicinity of Castleton, fine-grained volcanogenic rocks geochemically indistinguishable from nearby Battle Mountain Felsite (Zrbf) are interbedded with the basal Fauquier (Hutson, 1990).

Zfc *metaconglomerate*. Pebbles, cobbles, and occasional boulders of quartz, several varieties of granite, and feldspar, in a meta-arkosic matrix. Discontinuous lenses occur at or near the base of the Fauquier.

Meta-arkose, metasiltstone, and metaconglomerate of the Fauquier **(Zfs, Zfa, Zfc)** are interpreted as non-marine, uvial sediments, deposited unconformably on Grenville-age basement (Espenshade, 1986). These units have been mapped on a lithologic basis in metasedimentary outliers west of the principal Fauquier strike-belt, and include some rocks previously mapped as Mechums River Formation (Gooch, 1958).

Stratigraphic and facies relations between Fauquier lithologic units and laterally equivalent Monumental Mills and other Lynchburg Group units are discussed by Wehr (1985), Wehr and Glover (1985), Conley (1989), and Kasselas (1993).

Lynchburg Group (Zmm, Zch, Zls, Zlq, Zlg, Zlm, Zlc, Zlf; includes Alligator Back and Ashe Formations, and Moneta Gneiss)

Zmm *Monumental Mills Formation* (Wehr, 1985). Light-gray, fine- to very-fine-grained metasandstone characterized by thin planar beds separated by biotite-rich silty partings; and dark-gray laminated siltstone and mudstone containing abundant synsedimentary deformation features including folds, faults, convolute bedding, and erosional-depositional discordances.

Mineralogy: quartz + albite + muscovite + biotite + epidote + calcite + chlorite + titanite + magnetite ± garnet ± pyrite; porphyroblastic garnet and biotite are common.

The Monumental Mills has been interpreted to represent deposition in a delta front-slope environment (Wehr, 1985).

Zch *Charlottesville Formation* (Nelson, 1962). Coarse-grained to pebbly quartzose metasandstone and quartzite interbedded with laminated micaceous metasiltstone and graphitic phyllite and slate. Sandstone beds are typically amalgamated and massive; grading, horizontal stratification, and complete Bouma sequences are preserved locally (Wehr, 1985; Conley, 1989). The formation includes cross-bedded quartzite, feldspathic metasandstone, and muscovite schist in the upper portion (Conley, 1989; mapped as Swift Run Formation by Nelson, 1962); in the Culpeper area, includes in part the Ball Mountain Formation of Wehr (1985) and Kasselas (1993). The unit contains numerous apparently concordant mafic and ultramafic sills in the lower portion. Southwest of Nelson County, rocks equivalent to the Charlottesville Formation have been mapped as Alligator Back Formation. Outcrop belt is as much as 3.7 miles wide.

Zls *metasandstone*. Medium- to coarse-grained, locally pebbly, feldspathic micaceous metasandstone; cross-bedded. Laterally continuous unit occurs in the upper portion of the Charlottesville Formation.

Zlq *quartzite*.

Zlg *graphitic phyllite and metasiltstone*. Black graphite- and pyrite-bearing phyllite and slate, with thin interbeds of sericite phyllite, metasiltstone and quartzite. The unit includes the Johnson Mill graphite slate formation of Nelson (1962); thickness is on the order of 100 m.

Zlm *metagraywacke*. Metagraywacke, quartzose schist, and conglomerate. Graded bedding, cut-and-fill structures, and incomplete Bouma cycles are characteristic; conglomeratic lenses occur throughout the unit.

Geophysical signature: Positive magnetic and positive radiometric anomalies.

Metagraywacke is interpreted to have been deposited in a series of coalescing submarine fans, with conglomerate deposited in submarine distributary channels developed on the fans (Conley, 1989). The unit as mapped includes in part the Rockfish conglomerate formation, and the Lynchburg gneiss formation (restricted) of Nelson (1962), and is equivalent to Ashe Formation metagraywacke **(Zam)**, on strike to the southwest. The unit has been mapped on a lithologic basis in outliers to the west of the main strike-belt, including parts of the Mechums River formation strike-belt of Gooch (1958) and Nelson (1962).

Zlc *conglomerate and metagraywacke*.

Zlf *fanglomerate*. Matrix-supported, poorly-sorted pebbly to cobbly lithic conglomerate occurs at the base of the Lynchburg Group; includes in part the Rockfish conglomerate formation of Nelson (1962).

Alligator Back Formation (€Zas, €Zac, €Zmy; Rankin, and others,1973).

€Zas *actinolite schist*. Dark-grayish-green chlorite-actinolite schist metabasalt.

Mineralogy: actinolite + epidote + chlorite ± biotite + albite + quartz + magnetite-ilmenite.

Geophysical signature: linear, positive magnetic anomaly.

Schist commonly contains recognizable ow structures, deformed and mineralized pillow basalts, pyroclastic breccia, pink and white marble, and laminated metatuff. Massive to thin beds are interlayered with metamorphosed sedimentary and mafic to ultramafic rocks. This unit was previously mapped as the Catoctin Formation or the Slippery Creek Greenstone in the Lynchburg quadrangle (Brown 1958).

€Zac *banded marble*. Light- and dark-gray, laminated fine- to medium-grained marble, calcareous gneiss, and schist.

Mineralogy: calcite + quartz + biotite + muscovite + plagioclase + pyrite + magnetite-ilmenite.

Thick to thin beds of marble are interlayered with graphitic phyllite and mica schist; the lithology grades from impure marble to calcareous metagraywacke depending on percentage of detrital calcite present. The unit includes the Arch Marble of Brown (1958) and the Archer Creek Formation of Espenshade (1954).

€Zmy *feldspathic metagraywacke*. Heterogeneous assemblage of rock-types includes medium- to light-gray, laminated quartzofeldspathic to calcareous gneiss with thin mica schist partings; white and gray, fine- to coarse-grained, generally laminated marble; gray to greenish-gray fine-grained graphitic mica schist and quartzite; light-gray, medium- to fine-grained mica schist; massive quartzite and micaceous blue quartz granule metasandstone; and, dark-greenish-black actinolite schist.

Mineralogy: (1) quartz + potassium feldspar + plagioclase + biotite + muscovite + calcite + epidote + titanite + magnetite-ilmenite; (2) quartz + muscovite + chlorite + graphite + titanite + ilmenite; (3) quartz + albite + muscovite + biotite + titanite + ilmenite; (4) quartz + muscovite + garnet + kyanite; (5) chlorite + tremolite + magnetite-ilmenite; (6) chlorite + actinolite-tremolite + talc + dolomite + magnetite-ilmenite; (7) quartz + albite + actinolite + biotite + epidote + magnetite.

Units here mapped as Alligator Back Formation were previously mapped as the Evington Group (Espenshade, 1954; Brown, 1958; Redden, 1963; Gates, 1986; Patterson, 1987) and considered to be younger than the Lynchburg Group. Regional mapping by Henika (1991) and Scheible (1975) indicates that rocks assigned to Alligator Back Formation by Rankin and others (1973) are continuous with the upper part of the Lynchburg Group in the type section along the James River at Lynchburg (Jonas, 1927) and that the Alligator Back consistently dips southeast beneath the overlying Candler Formation from the Virginia-North Carolina border to the James River at Lynchburg. Sedimentary and structural facing criteria indicate that rock units immediately southeast of the Candler Formation in an outcrop belt from Stapleton on the James River, southwest to Leesville Dam on the Roanoke River, are older than the Candler (Henika, 1992). Although previously mapped as upper Evington Group (Espenshade, 1954; Brown, 1958; Redden, 1963; Patterson, 1987), these rocks are herein correlated with the Alligator Back Formation (upper Lynchburg Group), having been uplifted against the Candler Formation to the northwest along the Bowens Creek fault (Henika, 1992). Rocks in the same outcrop belt along strike to the southwest of the Leesville Reservoir were previously correlated with the Alligator Back Formation by Conley (1985).

Espenshade (1954)	Brown (1951,1958)	Henika (1992)
Younger Greenstone	Slippery Creek Greenstone	Alligator Back actinolite schist unit
Mount Athos Fm.	Mount Athos Fm. Pelier Schist	Alligator Back metagraywacke unit
Archer Creek Fm.	Arch Marble Joshua Schist	Alligator Back marble and calcareous metagraywacke unit
---------------------------BOWENS CREEK FAULT------------------------------		
Candler Fm.	Candler Fm.	Candler Fm.

Table. Units southeast of the Candler Formation along the James River.

The sequence of lithologic units within the Alligator Back Formation southeast of the Bowens Creek fault is the same as that proposed by Brown (1951; 1958), and Espenshade (1954) for the formations in the Evington Group, that are structurally above the Candler Formation. The sequence is based on the detailed structural and stratigraphic relationships first established by Brown (1958) in the Lynchburg 15-minute quadrangle. The sequence is summarized in the table on the following page.

Ashe Formation (Zaa, Zas, Zam, Zmg)

Zaa *amphibolite*. Dark-greenish-gray to black, coarse- to fine-grained amphibolite, hornblende gneiss, and schist, with interlayered biotite-muscovite gneiss and mica schist. Coarse garnetiferous amphibolite, pink and white marble, and pyrite-chalcopyrite-calcite veins are common near the top of the Ashe.

Mineralogy: (1) quartz + actinolite + epidote + chlorite; (2) quartz + hornblende + plagioclase + epidote + garnet + magnetite.

Geophysical signature: amphibolite, and hornblende gneiss and schist give positive linear magnetic anomalies.

Relict amygdaloidal textures and hyaloclastic (pillow) structures indicate massive to thick-bedded amphibolite and hornblende gneiss were derived from basaltic ows or shallow sills. Some thin-bedded hornblende gneiss and schist units that commonly contain interbedded micaceous and feldspathic layers may be derived from volcaniclastic sedimentary rocks.

Zas *mica schist or phyllite*. Medium- to dark-gray, medium- to fine-grained mica schist, phyllite, and slate.

Mineralogy: (1) quartz + muscovite + magnetite; (2) quartz + muscovite + chlorite + stilpnomelane; (3) quartz + plagioclase + biotite + garnet + magnetite; (4) quartz + biotite + staurolite + garnet + magnetite; (5) quartz + biotite + kyanite + garnet + staurolite; chlorite occurs as a secondary mineral.

Geophysical signature: isolated magnetic peaks resulting from concentrations of magnetite in the wider belts of mica schist.

Although these rocks have been grouped as a single unit following Espenshade and others (1975), mapping in Floyd County (Dietrich, 1959) suggests that the unit includes rocks stratigraphically at the base of the Ashe as well as rocks stratigraphically above the Ashe, coeval in part with the Alligator Back Formation.

Zam *biotite gneiss*. Medium- to light-gray, massive, conglomeratic biotite schist and gneiss, with feldspar, quartz, and granitic clasts; grades upwards into medium- to fine-grained, salt-and-pepper-textured two-mica plagioclase gneiss with very-light-gray mica schist interbeds. Quartzite, impure marble, calcareous gneiss and amphibolite occur locally. Some dark-gray to black, pyrite-bearing mica schist occurs at tops of thick, fining-upwards graded sequences.

Mineralogy: (1) quartz + plagioclase + potassium feldspar + biotite + muscovite + chlorite + epidote + ilmenite; (2) quartz + plagioclase + biotite + muscovite + epidote-allanite + garnet + titanite + ilmenite; (3) quartz + calcite + plagioclase + biotite + muscovite + epidote + ilmenite + titanite; chlorite occurs as a secondary mineral.

Unit is unconformable on Grenville basement and cut by Late Precambrian mafic and felsic dikes.

Zmg *Moneta Gneiss*. Moderate-olive-brown to dusky-yellowish-green to black-and-white-banded, medium- to fine-grained biotite-hornblende gneiss, with interlayers of light gray, fine-grained quartz-feldspar gneiss, amphibolite, and mica schist. Felsitic crystal tuff breccia, feldspathic conglomerate, and mafic and felsic dikes and sills are recognized within the Moneta, especially along the James River west of Lynchburg. Wang and Glover (1991) recognized two kinds of mafic metavolcanic rocks in this unit, lavas and tuffs. The lavas have well-preserved hyaloclastic textures; metatuffs commonly contain delicate mineral segregation lamination.

Mineralogy: (1) quartz + plagioclase + microcline + biotite + muscovite + garnet + magnetite-ilmenite; (2) hornblende + plagioclase + biotite + quartz + magnetite-ilmenite + titanite; (3) hornblende + plagioclase + garnet + biotite + magnetite-ilmenite.

Geophysical signature: broad, elongate, positive magnetic anomaly.

Numerous pegmatite dikes and sills concentrated within the hornblende biotite gneiss were mined for feldspar in the area between Moneta and Forest where the unit was first described by Pegau (1932). In the Lynchburg area the Moneta was mapped as Reusens Migmatite by Brown (1958). It was interpreted to be a Late Precambrian volcanic-sedimentary complex by Conley and Henika (1970) and Wang and Glover (1991). The Moneta is here assigned to the Lynchburg Group because it has an intertonguing relationship with basal conglomeratic Lynchburg rocks and with similar rocks in the base of the Ashe Formation southwest of Lynchburg.

Zkr *Konnarock Formation* (Rankin, 1993). Mostly moderate-red glaciogenic sedimentary rocks include massive diamictite (tillite), bedded diamictite, varve-like laminite locally containing dropstones, massive mudstone, pink arkose, and minor conglomerate. Clasts in the diamictite and laminite are dominantly granitoid, but include rhyolite and greenstone of the Mount Rogers Formation. Thickness is as much as 3275 feet; diamictite is most common toward the top of the section.

Mount Rogers Formation (Zmp, Zmr, Zml, Zgs, Zmf; Rankin and others, 1972; Rankin, 1993)

Zmp *porphyritic rhyolite* (Wilburn Rhyolite Member, Mt. Rogers volcanic center). Very-dusky-purple, high-silica rhyolitic welded tuff containing about 30 percent quartz and mesoperthite phenocrysts. This unit constitutes a chemically- and mineralogically-zoned ash- ow sheet at least 760 m thick, in which the main body is metaluminous and the basal phenocryst-poor 30 m were initially peralkaline.

Zmr *phenocryst-poor rhyolite* (Whitetop Rhyolite Member and Buzzard Rock Member, Mt. Rogers volcanic center).

Whitetop Rhyolite Member, phenocryst-poor, very dusky purple, high-silica, metaluminous rhyolite lava ows and minor tuff containing 0 to 10 percent phenocrysts of quartz and mesoperthite.

Buzzard Rock Member, blackish-red, low-silica, metaluminous rhyolite lava ows containing 5 to 20 percent prominant phenocrysts of mesoperthite and plagioclase; includes minor interbedded volcaniclastic sedimentary rocks. The Buzzard Rock is a thin unit that occurs beneath the Whitetop Rhyolite Member.

Zml *Graywacke conglomerate, graywacke, tuffaceous sandstone, laminated siltstone, shale, and minor greenstone and rhyolite.* Most of the sedimentary rocks are volcanigenic but contain a significant detrital contribution from the underlying crystalline rocks of the Grenville-age basement.

Zgs *Greenstone and interbedded metasedimentary rocks*. Relict plagioclase phenocrysts are prominent in some greenstone.

Zmf *Porphyritic felsite*. Includes coarsely porphyritic felsite from the Pond Mountain volcanic center that could be a hypabyssal intrusive, and porphyritic rhyolite from the Razor Ridge volcanic center that is extrusive, as well as the Fees Rhyolite Member near the base of the formation.

BLUE RIDGE BASEMENT COMPLEX

LATE PROTEROZOIC IGNEOUS ROCKS

Zav *felsic volcanic and volcaniclastic rocks*. Dark-gray to black, biotite- and pyrite-rich volcaniclastic rock interbedded with medium-gray, fine-grained rocks with numerous quartz-filled vesicles; upper part of the unit consists of medium-dark-gray, fine-grained felsic rock with numerous clasts of fine-grained, white-weathering, vesiculated felsite interlayered with fine-grained, clast-free felsic rock. Dikes of clast-free felsic rock cut nearby Middle Proterozoic granitic gneiss **(Ybp)**; conformably overlain by feldspathic metasandstones of the Fauquier Formation.

Zgd *biotite granodiorite or biotite granite*. Leucocratic to mesocratic, medium-grained, equigranular, vaguely foliated, epidote-, garnet-, uorite- and/or allanite-bearing, two-feldspar muscovite-biotite granodiorite to granite; salt-and-pepper appearance is characteristic; associated aplite and pegmatite dikes common.

Geophysical signature: weak positive radiometric anomaly.

The plutons of this suite are widespread in the southeastern portion of the basement complex, and are correlated with Rockfish River, Mobley Mountain, Striped Rock plutons, and with Robertson River Igneous Suite.

Zgdr *Rockfish River pluton* (Sinha and Bartholomew, 1984). Medium-gray, equigranular medium-grained, vaguely-foliated, uorite-, epidote-, and garnet-bearing muscovite-biotite granodiorite; aplite and pegmatite dikes cut pluton and surrounding country rock. The pluton has been dated at 730 Ma (U-Pb zircon; Sinha and Bartholomew, 1984, recalculated from Davis, 1974); and 573±50 Ma (Rb-Sr whole-rock; Smith and others, 1981).

Zgdm *Mobley Mountain granite* (Brock and others, 1987; Herz and Force, 1987). Leucocratic to mesocratic, medium-grained, equigranular, epidote-, orencite-, garnet-, and uorite-bearing muscovite-biotite granite; faintly foliated. Salt-and-pepper appearance is characteristic; aplite and pegmatite dikes cut the pluton and surrounding country rock. Dated at 652±22 Ma (Rb-Sr whole rock; Brock and others, 1987).

Zgds *Striped Rock granite* (Stose and Stose, 1957). Fine- to medium-grained equigranular, uorite-, epidote-, and allanite-bearing hornblende-biotite granite and granite gneiss; faintly foliated to mylonitic (Simpson and Kalaghan, 1989). The Striped Rock has been dated at 695 Ma (U-Pb zircon; Odom and Fullagar, 1984).

Robertson River Igneous Suite (Zrbf, Zrbg, Zra, Zrh, Zrc, Zrw, Zrl, Zram, Zrr; Tollo and Lowe, 1993)

Zrbf, Zrbg *Battle Mountain Alkali Feldspar Granite.*

Zrbf *felsite*. Light-gray to gray, fine-grained to aphanitic, equigranular to sparsely porphyritic (mesoperthite phenocrysts) felsite composed of alkali feldspar, quartz, and rare plagioclase with minor biotite, aegirine, uorite, and basnäsite; locally displays ow banding, miarolitic cavities containing quartz, and probable lithophysae; intrudes associated alkali feldspar granite; dated at 704±4 Ma (U-Pb zircon; Tollo and Aleinikoff, in press).

Zrbg *granitoid*. Light-gray to gray, medium-grained, inequigranular alkali feldspar granite composed of alkali feldspar mesoperthite, albite, and quartz with minor biotite, aegirine, zircon, uorite, and basnäsite; locally displays miarolitic cavities containing quartz; dated at 705±2 Ma (U-Pb zircon; Tollo and Aleinikoff, in press).

Zra *Amissville Alkali Feldspar Granite*. Light- to dark-gray, medium-grained, inequigranular to porphyritic (quartz phenocrysts) alkali feldspar granite composed of microcline mesoperthite, quartz, and plagioclase, with aegirine, riebeckite, biotite, zircon, uorite, and stilpnomelane. Euhedral quartz phenocrysts are diagnostic; locally displays miarolitic cavities containing quartz; intruded by fine-grained dikes of identical mineralogic composition. Field relations indicate the Amissville is older than Battle Mountain granitoid; geochemistry indicates these units are comagmatic.

Zrh *Hitt Mountain Alkali Feldspar Syenite*. Light-gray, coarse-grained to locally pegmatitic, inequigranular alkali feldspar syenite composed of microcline mesoperthite, quartz, and saussuritized plagioclase, with lesser hastingsitic amphibole, biotite, allanite, zircon, stilpnomelane, apatite, and rare garnet; locally displays cumulate and pseudocumulate texture. The syenite has been dated at 706± 2 Ma (U-Pb zircon; Tollo and Aleinikoff, in press).

Zrc *Cobbler Mountain Alkali Feldspar Quartz Syenite*. Light- to dark-gray, medium- to coarse-grained, porphyritic (mesoperthite phenocrysts) to seriate-equigranular alkali feldspar-quartz syenite composed of microcline mesoperthite, quartz, and plagioclase, with hastingsitic amphibole, biotite, stilpnomelane, zircon, allanite, uorite, and rare aegirine-augite. Euhedral to subhedral feldspar phenocrysts are diagnostic. Syenite locally displays miarolitic cavities containing quartz. The rock has been dated at 722± 3 Ma (U-Pb zircon; Tollo and Aleinikoff, in press).

Zrw *White Oak Alkali Feldspar Granite*. Light-gray to gray, coarse-grained, inequigranular alkali feldspar granite composed of microcline microperthite, quartz, and plagioclase, with hastingsitic amphibole, allanite, uorite, stilpnomelane, zircon, chlorite, and calcite. Unaltered surfaces display pronounced vitreous luster. Granite typically occurs intermixed with light-gray, fine-grained, mineralogically identical alkali feldspar granite that is locally younger. The unit has been dated at 725± 8 Ma (U-Pb zircon; Tollo and Aleinikoff, in press).

Zrl *Laurel Mills Granite*. Gray, coarse-grained, inequigranular granite composed of alkali feldspar mesoperthite, quartz, and plagioclase, with hastingsitic amphibole, biotite, stilpnomelane, zircon, apatite, ilmenite, magnetite, and titanite. Amphiboles typically are entirely to partially replaced by fine-grained intergrowths of quartz, biotite, stilpnomelane, magnetite, and titanite. Pale blue color of the quartz is locally diagnostic. The granite typically displays numerous, anastomosing, mesoscopic zones of deformation. The unit has been dated at 728±2 Ma (U-Pb zircon; Tollo and Aleinikoff, in press).

Zram *Arrington Mountain Alkali Feldspar Granite*. Light-gray, medium-grained, equigranular alkali feldspar granite composed of microcline microperthite, quartz, and plagioclase, with hastingsitic amphibole, biotite, stilpnomelane, allanite, uorite, zircon, epidote, apatite, rare garnet, and muscovite. The granite is locally intruded by light-gray, fine-grained dikes of mineralogically identical alkali feldspar granite. The unit has been dated at 730± 4 Ma (U-Pb zircon; Tollo and Aleinikoff, in press).

Zrr *Rivanna Granite*. White, medium-grained, biotite-, allanite-, uorite-, and stilpnomelane-bearing granite to alkali feldspar granite; color index less than 5; locally displays miarolitic cavities containing quartz and pyrite. The granite has been dated at 735± 4 Ma (U-Pb zircon; Tollo and Aleinikoff, in press).

MIDDLE PROTEROZOIC (GRENVILLE-AGE) PLUTONIC ROCKS

Yal *alkali-feldspar leucogranite*. Leucocratic, coarse-grained to megacrystic, equigranular to porphyritic granite contains white alkali feldspar phenocrysts and interstitial blue quartz, with accessory biotite, pyroxene, and garnet; primary ow-banding is locally delineated by aligned feld-spar phenocrysts.

Geophysical signature: positive radiometric anomaly.

This lithology occurs as dikes and discrete plutons, comprises migmatitic leucosomes within early or pre-Grenville-age layered gneisses, and occurs as xenoliths within some Grenville-age plutonic rocks. This is a lithologic unit that likely includes rocks spanning a range of ages.

Yor *Old Rag granite* (Furcron, 1934). Leucocratic, coarse-grained, foliated, alkali feldspar-blue quartz granite contains accessory biotite, muscovite, garnet, magnetite, and zircon; dated at 1115 Ma (U-Pb zircon; Lukert, 1982).

Geophysical signature: positive radiometric anomaly.

Ycz *Crozet granite* (Nelson, 1962). Leucocratic, coarse-grained, porphyritic alkali feldspar granite.

Ysh *Schaeffer Hollow granite* (Herz and Force, 1987). Leucocratic, coarse-grained, porphyritic, alkali feldspar-blue quartz granite; may contain as much as 10 percent biotite (after hornblende or pyroxene?); accessories include ilmenite, apatite, and zircon; gradational into mylonitic aser gneiss; contains granulite xenoliths.

Ygt *garnetiferous leucocratic metagranite*. Leucocratic, medium- to fine-grained, equigranular to granoblastic monzogranite contains very-light-gray to light-gray feldspar, medium-gray quartz as much as 0.5 cm in diameter, and dusky-red euhedral to anhedral almandine garnet as much as 1 cm in diameter. Mineralogy includes quartz, microperthite, microcline, myrmekite, plagioclase, symplectitc biotite and minor chlorite, ilmenite, zircon, titanite, epidote, leucoxene, and clinozoisite. Modal composition ranges from 28 to 29 percent quartz, 35 to 40 percent potassium feldspar, 28 to 32 percent plagioclase feldspar, 2 to 5 percent almandine garnet. U-Pb zircon data suggest a crystallization age of approximately 1070 Ma (Aleinikoff and others, 1993). In northern Virginia there are numerous localities where dikes of this unit cut porphyroblastic granite gneiss **(Ybp)**.

Yg *leucocratic metagranite*. White to light-olive-gray, to pink, fine- to medium-grained, massive monzogranite composed of 22 to 38 percent quartz (white, clear, or blue), 33 to 34 percent orthoclase, microcline, and rod and bleb microperthite, and 38 to 44 percent oligoclase and albite, and minor biotite. Locally, potassium feldspar porphyroblasts are 1 to 2 cm in diameter. In Loudoun County this unit becomes coarser-grained and richer in biotite from west to east across the outcrop belt. U-Pb zircon data from two localities in Loudoun County indicate crystallization ages of 1058±3 Ma and 1060±2 Ma (Aleinikoff and others, 1993).

Yblg biotite-muscovite leucogranite gneiss: Leucocratic, coarse- to very-coarse-grained granite gneiss contains subhedral to euhedral Potassium feldspar megacrysts, and interstitial quartz and plagioclase; muscovite, biotite, epidote, titanite, and magnetite-ilmenite make up 5 to 15 percent of the mode; hornblende and garnet are locally present. Plagioclase is largely replaced by felty masses of epidote, muscovite, and titanite; clusters of green-brown, biotite laths contain subhedral to euhedral epidote prisms; magnetite-ilmenite is rimmed by anhedral masses of titanite. The rock contains a penetrative schistosty defined by biotite and muscovite.

Ygbt *biotite granite*. Leucocratic, medium- to coarse-grained, gneissic granite; dominantly perthitic Potassium feldspar, plagioclase, and quartz, with minor biotite, muscovite, and ilmenite; accessories include apatite and zircon. Feldspars show alteration to epidote and sericite; gneissic fabric is defined by atten quartz and feldspars.

Ygr *biotite granite gneiss*:. Pink to gray, medium-grained, well-foliated or lineated biotite-plagioclase-quartz-microcline gneiss.

Yra *Roseland anorthosite* (Ross, 1941; Herz and Force, 1987). White alkalic anorthosite contains andesine antiperthite megacrysts, blue quartz, and lesser orthopyroxene and rutile; cataclastic fabric is pervasive; dated at 1045 Ma (Sm-Nd whole-rock; Pettingill and others, 1984).

Yt metatrondhjemite. White, medium- to fine-grained, weakly to moderately well-foliated biotite-quartz-plagioclase gneiss; potassium feldspar is rare or absent.

Marshall Metagranite (Ymc, Ymm; Espenshade, 1986)

Ymc *coarse-grained metagranite*. Medium-gray to brownish-gray, medium- to coarse-grained monzogranite composed of 30 percent quartz (clear or blue), 28 percent rod and bleb perthite, microcline, and orthoclase, and 42 percent saussuritized oligoclase. Sheared rock commonly has as much as 20 percent biotite. Porphyroblastic augen, commonly 1 to 2 cm in length, consist of aggregates of potassium feldspar, plagioclase, and quartz. U-Pb zircon data indicate a crystallization age of 1127±7 Ma (Aleinikoff and others, 1993).

Ymm *medium-grained biotite metagranite*. Medium- to dark-gray, fine- to medium-grained, mostly equigranular, but rarely inequigranular granite. Principal minerals are bluish-gray quartz, oligoclase, microcline, and biotite, with lesser amounts of muscovite, opaque minerals, epidote, chlorite, and rare garnet. Gneissic layering, commonly absent, is well developed locally. This unit commonly occurs as dikes intruding porphyroblastic granite gneiss **(Ybp)**, and contains xenoliths of **Ybp**. U-Pb zircon data indicate crystallization ages of 1110±4 Ma and 1112±3 Ma (Aleinikoff and others, 1993). Single crystals of monazite give an age of 1051±3 Ma, interpreted to be a metamorphic age related to intrusion of adjacent granites that yield ages ranging from 1055 to 1070 Ma **(Yg, Ygt, Ybg)**.

Yl *leucocharnockite*. Leucocratic, coarse-grained to megacrystic pyroxene-bearing granite, porphyritic in part with euhedral potassium feldspar phenocrysts, interstitial plagioclase and quartz; ferromagnesian minerals include orthopyroxene, clinopyroxene, magnetite-ilmenite; hornblende, red-brown biotite, and garnet may be present. Accessory minerals include zircon, monozite, and apatite. Pyroxene is thoroughly uralitized.

Ypc *porphyritic leucocharnockite*. Leucocratic, very-coarse-grained, porphyritic pyroxene-bearing granite with euhedral Potassium feldspar megacrysts, interstitial plagioclase and blue quartz; clinopyroxene and/or orthopyroxene are thoroughly uralitized; hornblende, titaniferous biotite, and garnet may be present; accessory minerals include magnetite-ilmenite, apatite, and zircon.

Rocks within this map unit were dated at 1075 Ma (U-Pb zircon; Sinha and Bartholomew, 1984), and 1021±36 Ma (Sm-Nd whole rock; Pettingill and others, 1984).

Yc *charnockite.* Includes dusky-green, mesocratic, coarse- to very-coarse-grained, equigranular to porphyritic, massive to vaguely foliated pyroxene-bearing granite to granodiorite; contains clinopyroxene and orthopyroxene, intermediate-composition plagioclase, potassium feldspar, and blue quartz. Reddish-brown biotite, hornblende, and poikilitic garnet are present locally; accessory minerals include apatite, magnetite-ilmenite, rutile, and zircon.

Geophysical signature: charnockite pods in the southeastern Blue Ridge produce a moderate positive magnetic anomaly relative to adjacent biotite gneisses, resulting in spotty magnetic highs.

This unit includes a host of plutons that are grouped on the basis of lithology, but are not necessarily consanguineous. These include Pedlar charnockite, dated at 1075 Ma (U-Pb zircon, Sinha and Bartholomew, 1984) and Roses Mill charnockite (Herz and Force, 1987), dated at 1027±101 Ma (Sm-Nd, Pettingill and others, 1984).

Ycm *charnockite gneiss*. Leucocratic to mesocratic, coarse-grained, porphyritic, pyroxene-bearing granite gneiss; well-developed shear foliation is superimposed on segregation layering defined by quartz-feldspar and mafic-rich domains; includes mylonitic augen gneiss.

Yhg *megacrystic charnockite*. Porphyritic, foliated pyroxene-hornblende granite contains potassium feldspar megacrysts up to 4 cm across; hornblende and magnetite-ilmenite are the dominant ferromagnesian minerals; color index is about 15. Pyroxene is thoroughly uralitized; plagioclase contains abundant small epidote prisms. Adjacent to contacts with overlying Cambrian clastic rocks, charnockite grades into unakite; includes Vesuvius megaporphyry of Bartholomew and Lewis (1984).

Elk Park Plutonic Group (Yep, Yec; Rankin and others, 1972; 1973)

Includes augen gneiss and porphyritic gneiss **(Yep)**, and equigranular quartz monzonite, quartz monzonite aser gneiss, and quartz monzonite gneiss **(Yec)**. Rocks range in composition from diorite to quartz monzonite; most are quartz monzonite in which the primary dark mineral is biotite, with or without hornblende; epidote and titanite are common accessory minerals. Porphyritic rocks contain microcline phenocrysts. Augen gneiss was probably derived from porphyritic plutonic rocks by shearing.

This unit includes in part the Little River Gneiss of Dietrich (1959) and Cranberry Gneiss (Rankin and others, 1972; 1973). U-Pb zircon data from the Cranberry has been interpreted to signify ages of 1050 Ma (Davis and others, 1962) and 1080 Ma (Rankin and others, 1969).

Ymg *two-mica granite* (Conley, 1989). Coarse-grained, inequigranular muscovite-biotite two-feldspar granite gneiss contains 2-cm clots of biotite and relict orthopyroxene; accessory minerals are epidote, rutile, actinolite, hornblende, and zircon. Unit is considered intrusive into biotite augen gneiss.

Ybp *porphyroblastic granite gneiss*: Dark-yellowish-brown to moderate-yellowish-brown, medium-grained, granoblastic to megacrystic, mafic-rich monzogranite composed of 27 to 38 percent quartz, 28 to 39 percent orthoclase, rod and bleb perthite, microcline, and myrmekite, and 33 to 40 percent oligoclase and andesine. Porphyroblasts of potassium feldspar range from 1 to 10 cm while plagioclase and quartz are generally 2 cm or less in maximum dimension. Mafic minerals, including almandine, biotite, chlorite, hornblende, and opaque minerals, are, in places, concentrated in layers. Almandine (up to 1 cm in diameter) makes up as much as 3 percent of the mode, while hornblende, commonly 0.5 to 0.75 cm in length, constitutes less than 1 percent. The rock breaks along cleavage surfaces that are commonly rich in chlorite, giving the whole rock a light green color.

A U-Pb zircon age from this rock is 1144±2 Ma; two different populations of monazite give ages of 1106±1 Ma and 1063±1 Ma, respectively (Aleinikoff and others, 1993). This unit is the oldest dated granitic rock in the northern Virginia Blue Ridge, and is very commonly intruded by dikes of the Marshall Metagranite **(Ym)** and garnetiferous leucocratic metagranite **(Ygt)**, and less commonly by leucocratic metagranite **(Yg)**. These field relations suggest that the monazite ages are not cooling ages but represent the times of metamorphic growth during subsequent intrusive events.

Ybg *porphyroblastic biotite-plagioclase augen gneiss*. Mesocratic, medium- to coarse-grained, biotite-rich quartzofeldspathic gneiss contains prominent subhedral to euhedral monocrystalline feldspar augen. The ratio plagioclase: potassium feldspar may be as high as 10:1; color index ranges from 30 to 50. Apatite, epidote, muscovite, ilmenite, and titanite are ubiquitous accessories. Plagioclase contains abundant prismatic epidote and white mica; ilmenite is rimmed with masses of anhedral titanite; subhedral hornblende and subhedral to euhedral almandine-grossular garnet occur locally. In the vicinity of adjacent charnockite, anhedral actinolitic amphibole pseudomorphs after pyroxene or rims thoroughly uralitized relict pyroxene. Rock fabric is gradational from granofels to mylonite gneiss.

Geophysical signature: negative magnetic signature relative to adjacent charnockite.

In northern Virginia, this unit strongly resembles prophyroblastic granite gneiss **(Ybp)**; however, the augen in **Ybp** are more commonly polycrystalline aggregates rather than single-crystal porphyroblasts. This unit is widespread in the central and southeastern Blue Ridge, encompassing a number of lithologically similar metaplutonic entities: the "biotitic facies" of the Roses Mill and Turkey Mountain ferrodiorites of Herz and Force (1987), the Archer Mountain quartz monzonite of Bartholomew and others (1981), biotite granofels and augen gneiss of Evans (1984, 1991), biotite augen gneiss of Conley (1989), and augen-bearing gneiss of Lukert and Halladay (1980), and Lukert and Nuckols (1976). Historically, most workers have interpreted these rocks as Grenville-age plutons in which the present-day biotite-rich mineral assemblage is a primary igneous assemblage that crystallized from a melt (for example, Bartholomew and others, 1981). Herz and Force (1987) and Evans (1991) presented evidence that these biotite gneisses were derived from charnockite plutons by retrograde hydration reactions.

Pettingill and others (1984) reported ages of 1009±26 Ma (Rb-Sr whole-rock) and 1004±36 Ma (Sm-Nd whole-rock) for ferrodiorite to quartzmonzonite in the Roseland district. Where this unit has been mapped in the Upperville quadrangle (A.E. Nelson, unpublished data), U-Pb zircon data suggest a crystallization age of 1055±2 Ma (Aleinikoff and others, 1993).

Yhd *biotite-hornblende granodiorite*. Mesocratic, medium- to coarse-grained, equigranular, massive to vaguely foliated granodiorite contains poikilitic green-brown hornblende, subhedral in part; lesser reddish-brown biotite, and accessory apatite, magnetite-ilmenite, and zircon; color index 30 to 40.

Yn *metanorite and metadiorite*. Gray-weathering, medium- to coarse-grained, massive to weakly foliated hornblende-orthopyroxene-plagioclase metanorite and medium- to fine-grained biotite-hornblende-plagioclase metadiorite. Occurs as lenses and thin belts, commonly in proximity to garnet graphite paragneiss **(Yp)**.

Yum *metaperidotite, hornblende metagabbro, and metapyroxenite*. Metaperidotite, greenish-black, dark-yellowish-brown weathering, medium-grained, massive; consists of serpentine, amphibole, dark chlorite, and magnetite; serpentine replaces subhedral olivine; non-pleochroic amphibole occurs as single crystals, presumably pseudomorphic after subhedral to anhedral pyroxene; some amphibole occurs as large poikilitic crystals.

Hornblende metagabbro, greenish-black, medium-grained, speckled-white-weathering, massive, with a weak foliation and well-preserved primary igneous fabric; subhedral plagioclase is replaced by clinozoisite and albite; anhedral pyroxene is replaced by fibrous tremolite; brown hornblende occurs as subhedral single crystals.

Metapyroxenite, dark-greenish-gray to greenish-black, light-greenish-gray weathering, medium-grained, weakly-foliated actinolite-rich rock contains lesser chlorite; amphibole is pseudomorphic after pyroxene.

MIDDLE PROTEROZOIC GNEISSES

Ygn *leucocratic granulite and gneiss*. Leucocratic, fine- to medium-grained layered gneiss contains predominantly alkali feldspar and blue quartz; ferromagnesian minerals including pyroxene, ilmenite, hornblende, reddish-brown biotite, or garnet constitute less than one percent of the mode. Quartz and feldspar are granoblastic; gneissic fabric is defined by discontinuous quartz-rich domains.

Ygg *layered leucocratic granite gneiss*. Pale-red, pinkish-gray to light-gray leucocratic syenogranite with medium-light-gray to greenish-gray melanocratic layers (0.25 to 1 cm thick) that are commonly migmatitic. Mineralogy consists of 26 to 39 percent quartz, 49 to 51 percent rod and bleb perthite, microcline, and orthoclase, 12 to 23 percent oligoclase, and minor garnet and biotite. Layering consists of 0.5- to 2-cm-thick segregations of alkali feldspar, plagioclase, and quartz. Garnet and biotite are commonly restricted to melanocratic layers containing plagioclase and quartz.

Isotopic data from multigrain fractions and single zircons are scattered, with Pb-Pb ages ranging from 1092 to 1139 Ma (Aleinikoff and others, 1993). Field relations are complex and suggest that the protolith for this unit may have been a composite of **Ybp** and younger granite(s) that was highly tectonized and homogenized during the Grenville orogeny.

Ypg *layered pyroxene granulite*. Medium- to dark-greenish-gray, fine- to medium-grained, segregation-layered quartzofeldspathic granulite. Major minerals are quartz, plagioclase, potassium feldspar (includes assemblages with one alkali feldspar), orthopyroxene and clinopyroxene, and magnetite-ilmenite; garnet, hornblende, and reddish-brown biotite are widespread minor constituents. Apatite and zircon are accessory minerals. Color index ranges from 15 to 35. Quartz and feldspars are granoblastic; ferromagnesian minerals define dark layers on the order of 1 to 3 mm thick, giving the rock a characteristic pinstriped appearance. Migmatitic leucosomes locally cut segregation layering.

Geophysical signature: positive magnetic anomalies relative to adjacent biotite granulite and layered gneiss **(Ygb)**.

This unit pre-dates charnockite, alkali feldspar leucogranite, and other plutonic rocks on basis of cross-cutting relations, and is generally considered pre-Grenville-age country rock that was metamorphosed under granulite-facies metamorphic conditions and intruded by plutonic rocks during the Grenville orogeny. The unit includes Lady Slipper granulite gneiss (1130 Ma, U-Pb zircon, Sinha and Bartholomew, 1984), and Nellysford and Hills Mountain granulite gneisses of Bartholomew and others (1981).

Ypp *layered porphyroblastic pyroxene granulite*. Leucocratic to mesocratic, segregation-layered quartzofeld-spathic granulite contains prominent potassium feldspar por-phyroblasts; major mineralogy, quartz, plagioclase, K- feldspar, orthopyroxene or clinopyroxene, and magnetite-ilmenite; hornblende, reddish-brown biotite, and garnet are widespread minor constituents. Accessory minerals include apatite and zircon. Segregation layering is defined by millimeter- to centimeter-scale quartz-feldspar- and pyroxene-rich domains; migmatitic leucosomes of alkali feldspar and blue quartz are common. This rock-type is considered to be pre-Grenville-age country rock, although no radiometric data is available.

Ygh *hornblende gneiss*. Gray-weathering, medium- to fine-grained, massive to strongly-foliated hornblende-quartz-microcline-plagioclase gneiss with rare biotite and orthopyroxene. This lithology is very similar to layered pyroxene granulite (Ypg), and is considered equivalent.

Yfh *Flint Hill Gneiss* (Lukert and others, 1977). Segregation-layered quartzofeldspathic biotite gneiss contains quartz, plagioclase, microcline, green biotite, ilmenite, and titanite; accessories include epidote, apatite, and zircon. Segregation layering is defined by quartz-feldspar- and biotite-rich domains on the order of a few millimeters thick; migmatitic leucosomes of quartz and alkali feldspar cut segregation layering in places; veins of blue quartz are common.

This unit is considered correlative with layered biotite granulite and gneiss **(Ygb)**; the Flint Hill has been dated at 1081 Ma (U-Pb zircon; Lukert and others, 1977).

Ygb *layered biotite granulite and gneiss*. Leucocratic to mesocratic, segregation-layered quartzofeldspathic granulite and gneiss contain quartz, plagioclase (albite), microcline (includes assemblages with one alkali feldspar), biotite, ilmenite, and titanite; garnet and hornblende are commonly present. Accessory minerals include apatite and zircon. Epidote and white mica are ubiquitous secondary minerals. Relict pyroxene, largely replaced by actinolitic amphibole, occurs locally. Segregation layering is defined by alternating quartzofeldspathic and biotite-rich domains on the order of a few millimeters to centimeters thick. Quartz and feldspar are granoblastic; biotite defines a penetrative schistosity that crosscuts segregation layering. Migmatitic leucosomes composed of alkali feldspar and blue quartz cut segregation layering, and locally define attenuated isoclinal folds.

This unit surrounds pods of layered pyroxene granulite **(Ypg)**, and is cut by Grenville-age metaplutonic rocks including porphyroblastic biotite-plagioclase augen gneiss **(Ybg)** and alkali feldspar granite **(Yal)**. The unit has been correlated with Flint Hill Gneiss **(Yfh)** (Evans, 1991), and may correlate with Stage Road layered gneiss of Sinha and Bartholomew (1984). These gneisses have been interpreted as derived from layered pyroxene granulite **(Ypg)** by retrograde hydration reactions (Evans, 1991).

Yma *layered quartzofeldspathic augen gneiss and flaser gneiss*. Leucocratic to mesocratic, mesoscopically-layered coarse-grained quartzofeldspathic biotite gneiss contains prominent polycrystalline quartz-feldspar augen within an anastomosing, mica-rich, schistose matrix. Major mineralogy includes quartz, plagioclase, microcline, muscovite, biotite, epidote, titanite, and ilmenite; apatite and zircon are accessory minerals.

This unit is gradational into biotite granulite and gneiss **(Ygb)**, and is at least in part derived from that unit by superimposition of cataclastic to mylonitic fabric. Includes in part Stage Road layered gneiss (Sinha and Bartholomew, 1984; U-Pb discordia from 915 Ma to 1860 Ma).

Ybr *border gneiss* (Hillhouse, 1960). Pyroxene- and locally graphite-, sulfide-, and garnet-bearing quartzofeldspathic granulite and gneiss; includes platy leucocratic charnockite and charnockite gneiss; surrounds and is intruded by Roseland Anorthosite. Border gneiss is equivalent to banded granulite of Herz and Force (1987), and has been interpreted as in part a paragneiss derived from pre-Grenville-age sedimentary-volcanic rocks (Bartholomew and Lewis, 1984; Herz and Force, 1987).

Yp *garnet graphite gneiss*. Light-brown-weathering, medium- to fine-grained graphite-biotite-garnet-plagioclase-quartz paragneiss; includes quartz-chlorite-magnetite schist and carbonaceous phyllonite; graphite makes up 10 percent of the rock in places and garnet, up to 25 percent locally. The protolith of this unit is intepreted to be metasedimentary country rock that Grenville-age plutonic rocks intruded. The rock is similar in appearance to parts of the border gneiss (Ybr).

Yq *quartzite and quartz-sericite tectonite*. Light-gray to white, fine- to medium-grained, massive; contains rounded zircons, thin lenses of graphite, and pods of paragneiss (Yp); unit is considered part of a metasedimentary suite.

STRATIFIED ROCKS OF THE WESTERN PIEDMONT

ЄZab *Alligator Back Formation* (Sauratown Mountains; Conley, 1985). Light-gray, medium- to coarse-grained porphyroblastic garnet-mica schist; contains interbeds of dark-gray graphitic mica schist, calc-gneiss, mica gneiss, feldspathic quartzite with blue quartz granule beds, and garnet-hornblende schist.

Mineralogy: (1) quartz + muscovite + garnet + staurolite + biotite + magnetite; (2) quartz + muscovite + biotite + garnet + kyanite + staurolite + magnetite; (3) quartz + biotite + muscovite + garnet + chlorite + epidote + rutile + titanite + magnetite-ilmenite (retrograde assemblage locallized in sheared rocks along the Ridgeway fault). Garnet, kyanite, and staurolite porphyroblasts are generally pristine.

Zau *Ashe Formation* (Sauratown Mountains; Conley, 1985). Light-gray, medium-grained muscovite and muscovite-biotite gneiss with thick interbeds of muscovite schist and pebbly feldspathic quartzite. Thick lenses of garnet- hornblende schist locally mark the basal and upper contacts with the underlying basement gneiss and the overlying metapelites respectively. The unit is cut by dikes, sills and thick sheets of pegmatite and alaskite, especially concentrated along the zone of transitional contact with Alligator Back mica schist units.

Mineralogy: (1) quartz + plagioclase + Potassium feldspar + muscovite + biotite + tourmaline + epidote + titanite + magnetite-ilmenite; (2) quartz + plagioclase + muscovite + biotite + graphite + magnetite-ilmenite; (3) hornblende + plagioclase + quartz + garnet; (4) hornblende + plagioclase + quartz + epidote + chlorite + magnetite-ilmenite.

Geophysical signature: Low-amplitude, elongate, positive magnetic anomalies are associated with garnet-mica and hornblende schist outcrop belts; elongate magnetic lows coincide with areas underlain by gneiss units.

Ysc *Stuart Creek Gneiss* (Conley, 1985). Light-gray to black and white, massive to irregularly-layered augen and aser gneiss with anastamosing layers of mylonitic biotite schist, hornblende schist and foliated leucogranite. Augen gneiss is composed of microcline, plagioclase, and perthite porphyroclasts up to 4 cm across in a matrix of plagioclase, quartz, and biotite, with accessory titanite, epidote, hornblende, and opaque minerals.

This rock was correlated with the Elk Park Group of the southwestern Blue Ridge by Espenshade and others (1975). Rankin and others (1971) obtained a lead-lead zircon age of 1192 Ma from a layered biotite gneiss unit in a similar stratigraphic position as the Stuart Creek but exposed in a quarry at Pilot Mountain, North Carolina, about 25 miles southwest of the Virginia-North Carolina boundary.

ЄZfm *Fork Mountain Formation* (Conley and Henika, 1973; Conley, 1985). Light- to medium-gray, fine- to medium-grained, polydeformed and polymetamorphosed porphyroblastic aluminosilicate-mica schist, interlayered with medium-gray irregularly-layered garnetiferous biotite gneiss, migmatitic in part; calcsilicate granofels; amphibolite; rare white marble; and, coarse calc-quartzite lenses.

Complex schistosity, multiple crenulation cleavages, and partly-retrograded, polymetamorphic aluminosilicate and garnet porphyroblasts are diagnostic of Fork Mountain schists. Primary sedimentary structures rarely are preserved. A spectacular polymictic breccia bed that can be traced along strike for several miles within the Fork Mountain near Stuart is a notable exception. Medium- to coarse-granular, blue-quartz lenses, angular to rounded inclusions of boudinaged fine-grained, color-laminated, calc-silicate rock, and thick beds of coarse, clast-supported, epidotized lithic breccia are typical of the Fork Mountain biotite gneiss.

Prograde regional metamorphic mineral assemblages: (1) quartz + muscovite + biotite + garnet + staurolite + magnetite-ilmenite + rutile; (2) quartz + muscovite + paragonite + plagioclase + garnet + staurolite + sillimanite + magnetite-ilmenite + rutile; (3) quartz + biotite + sillimanite + potassium feldspar + plagioclase + garnet + magnetite-ilmenite; (4) quartz + plagioclase + biotite + muscovite + sillimanite + garnet + tourmaline; (5) quartz + plagioclase + potassium feldspar + biotite + hornblende + epidote + ilmenite; (6) quartz + plagioclase + potassium feldspar + muscovite + biotite + sillimanite + magnetite-ilmenite + garnet + kyanite.

Retrograde metamorphic mineral assemblages: (1) quartz + muscovite + chlorite; (2) quartz + muscovite + chloritoid + chlorite; (3) quartz + muscovite + staurolite + chloritoid; (4) quartz + muscovite + kyanite.

Contact metamorphic mineral assemblages: (1) andalusite + sillimanite + kyanite + corundum; (2) corundum + spinel + magnetite + kyanite.

Geophysical signature: The Fork Mountain has a characteristic "curly maple" pattern on magnetic contour maps. This pattern is the result of isolated concentrations of highly magnetic minerals that produce rounded, high-intensity, positive and negative anomalies.

The aluminosilicate-mica schist is the upper part of the Fork Mountain Formation and forms a series of northeastward-trending ridges along the northwest side of the Smith River allochthon. The garnetiferous biotite gneiss is at a lower structural level of the Fork Mountain Formation near Martinsville where lower strata have been intruded by the Martinsville igneous complex, and the remaining metasedimentary rocks contain extensive thermal metamorphic zones locallized along the intrusive contacts (Conley and Henika, 1973). Biotite gneiss in the Fork Mountain Formation has been interpreted to be a highly metamorphosed diamictite (Rankin, 1975; Conley, 1985; and Pavlides, 1989).

At the northeastern limit of the Fork Mountain outcrop belt, in Appomattox and Buckingham counties, the dominant lithologies are polydeformed yellowish-gray chloritoid-chlorite-muscovite quartzose phyllite and quartz-rich mica schist. Tightly-folded, transposed pinstriped segregation layering at a high angle to the penetrative schistosity defined by phyllosilicate minerals is characteristic; polycrystalline quartz-rich boudins are abundant. These rocks are lithologically indistinguishable from those along the highly-tectonized western margin of the metagraywacke, quartzose schist, and melange **(CZpm)** outcrop belt; current interpretation is that the Fork Mountain is correlative to some degree with **CZpm**.

Bassett Formation (ЄZba, Zbg; Conley and Henika, 1973)

ЄZba *amphibolite*. Dark-greenish-gray to black-and-white, medium- to coarse-grained, layered to massive hornblende schist, hornblende gneiss, amphibolite, garnet-pyroxene granofels, and coarse uralitic hornblende metagabbro. Mafic rocks are interlayered with white to light-gray, medium- to coarse-grained quartz-feldspar granofels, and cut by alaskite and pegmatite dikes and sills. Ovoid masses of quartz, plagioclase, epidote and quartz that resemble attened amygdules, and features that resemble graded bedding and cut-and-fill structures suggest a mixed volcanic-volcaniclastic protolith (Conley and Henika, 1970).

Mineral assemblages: (1) hornblende + plagioclase + quartz + pyroxene + garnet + epidote + magnetite + titanite; (2) diopside + grossular + plagioclase + magnetite + quartz + epidote; (3) hornblende + plagioclase + potassium feldspar + quartz + epidote.

Geophysical signature: Narrow, positive magnetic anomolies closely parallel amphibolite outcrops belts.

Zbg *biotite gneiss*. Light-gray to black-and-white, fine- to medium-grained, leucocratic biotite gneiss that is mostly segregation-layered, but locally is a medium-grained quartz-feldspar granofels. Contains interlayers of muscovite-biotite schist, quartz schist, and epidote quartzite.

Mineral assemblages: (1) quartz + plagioclase + potassium feldspar + biotite + muscovite + magnetite-ilmenite + tourmaline ± kyanite ± epidote ± titanite ± hornblende ± garnet; (2) quartz + plagioclase + epidote + pyroxene.

Porphyroclasts of zoned plagioclase in an equigranular, polygonal quartz-potassium feldspar groundmass and medium to thick bedding suggest a volcaniclastic protolith (Conley, 1985). Gneisses are migmatitic and cut by numerous granite dikes and sills near the contacts with the Martinsville igneous complex.

Geophysical signature: potassium feldspar-bearing gneisses have positive radiometric, and generally at magnetic signatures relative to adjacent amphibolite units.

In the core of the Sherwill anticline (Campbell and Appomattox counties), the dominant rock-type is graded salt-and-pepper metagraywacke, interbedded with lesser mica schist and graphite schist. This association bears lithologic affinity to the Lynchburg Group, which occupies the cores of structural domes to the west; this correlation has been made by several workers (Brown, 1958; Kaldy, 1977; Gates, 1987).

Mine Run complex (OZI, OZII, OZIII; Pavlides, 1989; 1990)

OZI *melange zone I* (Pavlides, 1989). Fine-grained schist and phyllite matrix encloses coarse-grained metasandstone beds locally; contains exotic blocks of mafic and felsic metavolcanic rocks **(vo)** similar to metavolcanic rocks of the Chopawamsic Formation **(Ccv)**. Blocks of blastomylonitic tonalite and granodiorite gneiss **(gn)** are present locally.

OZII *melange zone II* (Pavlides, 1989). Schist and phyllite matrix is more complexly deformed than the matrix of melange zone I; contains metavolcanic blocks **(vo)** similar to Chopawamsic Formation rocks **(Ccv)**, in addition to granitoid blocks of altered tonalite and granodiorite **(gr)**; intruded by the Ellisville biotite granodiorite **(SOe)**.

OZIII *melange zone III* (Pavlides, 1989). Phyllite and schist matrix contains abundant euhedral magnetite; many matrix rocks are highly deformed on a mesoscopic and microscopic scale. Mafic exotic blocks **(mf)** include amphibolite, ultramafic rocks, serpentinite, and talc; many mafic and ultramafic blocks are composite. Biotite gneiss blocks **(gn)** are also present. Metavolcanic olistoliths **(vo)** are rare.

Geophysical signature: Strong positive magnetic anomaly.

This unit is intruded by the Ellisville biotite granodiorite **(SOe)**.

ЄZpm *metagraywacke, quartzose schist, and melange*. Metagraywackes are quartzose chlorite or biotite schists containing very fine to coarse granules of blue quartz; primary graded laminations have been transposed by shearing into elongate lozenges that give the rock a distinctive pin-striped appearance in weathered surfaces perpendicular to schistosity. A mylonitic fabric is superimposed in varying degrees, as are late-stage chevron-style folds. In Buckingham, Appomattox, and Campbell Counties, rocks in this unit are progressively more tectonized from east to west across the outcrop belt; in the western portion, the dominant lithology is a polydeformed, mylonitic mica schist with abundant quartz-rich boudins; transposed pinstriped lamination or segregation layering at a high angle to mylonitic schistosity is characteristic. Metagabbroic blocks ranging in size from 5 cm to 3 m across and larger have been identified at widely scattered locations throughout the outcrop belt.

Mineralogy: quartz + albite + epidote + chlorite + muscovite + magnetite ± chloritoid ± calcite; biotite- and staurolite-bearing assemblages occur in Appomattox and Campbell Counties. Detrital minerals identified in thin section include plagioclase, perthite, epidote, magnetite, tourmaline, and titanite. Lithic fragments include dacite tuff, gabbro, and monocrystalline quartz with zircon and biotite inclusions (Evans, 1984).

The northern portion of the outcrop belt includes melange zone IV of the Mine Run complex of Pavlides (1989; 1990). In Albemarle and Fluvanna counties, **ЄZpm** includes the lower chlorite-muscovite unit of Smith and others (1964) and Hardware metagraywacke of Evans (1984). In Appomattox and Buckingham Counties, polydeformed quartzose mica schists in the western portion of the outcrop belt are lithologically indistinguishable from schists mapped as Fork Mountain Formation in structural blocks that occur to the west; these units are considered to be at least in part correlative. In Campbell County, polydeformed metagraywacke and mica schist is intruded by the Cambrian-age Melrose Granite **(Єm)**.

vl *metavolcanic and metavolcanic clastic phyllite* (Pavlides, 1990). Chlorite- and chlorite-epidote phyllite with variable amounts of silt-size quartz and plagioclase; in part metafelsite or metatuff. Euhedral magnetite is locally abundant. Unit grades westward into metasandstone and metasiltstone **(mss)**.

mss *metasandstone and metasiltstone* (Pavlides, 1990).

Quartz- and plagioclase-bearing metasandstone and metasiltstone are interbedded with chlorite- and muscovite-rich laminae; unit grades into phyllonite and mylonite in the Mountain Run fault zone.

Interlayered felsic and mafic metavolcanic and metasedimentary rocks (Єfvs, Єmvs)

Єfvs *felsic metatuff, mica schist, and gneiss*. Includes light-gray to grayish-pink, very-fine-grained to aphanitic, thin-bedded dacitic metatuff, locally containing subhedral to euhedral plagioclase phenocrysts; very-light-gray pinstriped quartz-rich, muscovite and biotite-muscovite schist; and, medium-gray fine-grained salt-and-pepper biotite-muscovite gneiss.

Mineralogy: quartz + plagioclase + muscovite ± biotite + epidote + magnetite.

These lithologies are interlayered with subordinate amounts of greenstone metabasalt and amphibole gneiss.

Єmvs *greenstone or amphibole gneiss*. Includes dark- to dusky-green, schistose actinolite-chlorite metabasalt with epidote-quartz segregations; and, layered hornblende-plagioclase gneiss. These lithologies are interlayered with subordinate amounts of dacitic metatuff, quartz-muscovite schist, and fine-grained salt-and-pepper biotite-muscovite gneiss.

Popes Head Formation (OЄps, OЄpo; Drake and Lyttle, 1981)

OЄps *Station Hills Phyllite*. Light-greenish-gray, dusky-yellow-weathering phyllite and lesser amounts of very-fine-grained metasiltstone. Beds are 2 to 12 cm thick; many have thin basal intervals of graded siltstone.

Mineralogy: muscovite + quartz + biotite + chlorite + plagioclase + magnetite + epidote.

The top of the unit is nowhere exposed; maximum known thickness is 300 m. Some chlorite-rich phyllite is probably mafic metatuff; unit grades down into Old Mill Branch Metasiltstone.

OЄpo *Old Mill Branch Metasiltstone*. Light-greenish-gray, pale-greenish-yellow- or yellowish-gray-weathering, medium- to fine-grained graded micaceous metasiltstone and lesser fine-grained micaceous metasandstone; fine-grained beds are phyllite and micaceous metasiltstone. Graded beds are 2 to 24 cm thick.

Mineralogy: quartz + muscovite + biotite + plagioclase + chlorite + magnetite + epidote.

The unit contains felsic metatuff (mineral assemblage quartz + plagioclase + epidote + muscovite + biotite + chlorite + green amphibole + magnetite) and mafic metatuff (mineral assemblage blue-green amphibole + plagioclase + titanite) layers up to 180 cm thick. Maximum thickness of unit is about 2300 feet; unit overlies with apparent unconformity the Mather Gorge, Sykesville, and Yorkshire Formations, the Annandale Group, and the Piney Branch Complex (Drake and Lyttle, 1981). The unit is intruded by Occoquan Granite.

ЄZpb *Piney Branch Complex* (Drake and Morgan, 1981). Heterogeneous assemblage of metamorphosed peridotite, pyroxenite, and gabbro; dominant rock-types include serpentinite, soapstone, and actinolite schist. The unit contains dikes and sheets of plagiogranite.

Єy *Yorkshire Formation* (Drake and Morgan, 1981). Polygenetic melange consisting of a dark quartz-plagioclase-chlorite matrix that contains chips, fragments, and small blocks of quartz, ultramafic rock, metagabbro, plagiogranite, mafic volcanic rock, and other exotic blocks. Characterized by abundant light-colored feldspar grains that contrast with the dark-colored phyllosilicate component. The Yorkshire forms thin, discontinuous lenses at the base of the Piney Branch Complex.

Mather Gorge Formation (ЄZms, ЄZmg; Drake and Froelich, in press)

ЄZms *schist*, greenish-gray to gray, reddish-brown-weathering, fine- to coarse-grained, lustrous, quartz-rich; and much lesser mica gneiss; contains interbedded metagraywacke and some calc-silicate rock; also contains abundant mafic and ultramafic rock debris.

Typical mineral assemblages from west to east and from low to high metamorphic grade are: (1) quartz + muscovite + chlorite + plagioclase + epidote + magnetite-hematite; (2) quartz + muscovite + biotite + garnet + staurolite + plagioclase + magnetite ± andalusite; (3) quartz + muscovite + garnet + kyanite + plagioclase + staurolite + magnetite; and (4) quartz + biotite + plagioclase + sillimanite ± microcline + magnetite. Higher-grade schists are migmatitic, and in many places show effects of a retrograde metamorphic overprint.

ЄZmg *metagraywacke*, light- to medium-gray, yellowish- to reddish-brown-weathering, fine- to medium-grained, generally well-bedded, and lesser semi-pelitic schist; contains interbedded quartzose schist and some calc-silicate rock; mineral assemblages as in schist **(ЄZms)**. Beds range from about 3 cm to 3 m, averaging about 20 cm; graded bedding, sole marks, and slump features are abundant. Mather Gorge is unconformable beneath Popes Head Formation, which is intruded by Occoquan Granite; includes rocks previously mapped in northern Virginia as Peters Creek Schist.

Єsv *Sykesville Formation* (Hopson, 1964; Drake, 1985). Light- to medium-gray, medium-grained metasedimentary melange consisting of a quartzofeldspathic matrix that contains quartz "eyes" and a heterogeneous suite of pebble- to boulder- and larger-size olistoliths. These include: Mather Gorge Formation migmatite, phyllonite, and metagraywacke; also, ultramafic, metagabbroic, and felsic and mafic metavolcanic rocks, plagiogranite, and quartzite. The Sykesville is intruded by Occoquan Granite.

Annandale Group (ЄZl, ЄZa; Drake, 1985)

ЄZl *Lake Barcroft Metasandstone* (Drake and Lyttle, 1981). Light-greenish-gray to light-gray, medium-grained meta-arenite; and, very-light-gray, fine- to medium-grained metagraywacke. Meta-arenite beds are massive, up to 2 m thick, and probably result from sedimentary amalgamation;

metagraywacke beds are regular, sharp, and at based, containing graded and parallel-laminated intervals; thickness ranges from 10 to 15 cm.

Mineralogy: (meta-arenite), quartz + epidote + plagioclase + chlorite + muscovite + magnetite; (metagraywacke), quartz + biotite + muscovite + plagioclase + garnet + epidote + magnetite.

Unit is about 1200 feet thick; grades downward into Accotick schist.

ЄZa *Accotink Schist* (Drake and Lyttle, 1981). Light-gray, yellowish-gray to moderate-brown to very-pale-orange-weathering schist and interbedded with micaceous metagraywacke. Locally, schist contains randomly scattered, discontinuous beds of meta-arenite. Schist intervals are 20 to 210 cm thick, but individual sedimentation units average about 1 cm.

Mineralogy: quartz + muscovite + biotite + chlorite + plagioclase; accessory minerals include garnet, magnetite, epidote, apatite, zircon, and pyrite.

Micaceous metagraywacke appears to be a more quartzofeldspathic element of a pelitic sedimentary sequence. Unit thickness is unknown because the base is nowhere exposed; the Accotink is intruded by Occoquan Granite.

Єi *Indian Run Formation* (Drake, 1985). Poorly- to well-foliated metasedimentary melange consisting of a medium-grained quartz-plagioclase-muscovite-biotite-chlorite-garnet matrix containing quartz "eyes" and a heterogeneous suite of olistoliths. These include: foliated Accotink Schist and Lake Barcroft Metasandstone, and foliated ultramafic, metagabbroic, and felsic and mafic metavolcanic rocks. The Indian Run pre-dates Occoquan Granite.

OЄu *metasedimentary rocks, undivided* (Pavlides, 1990). Gray to green phyllite, gray to white metasiltstone and fine-grained quartzite, fine-grained mica schist, green slate and phyllite, and sparse granule quartzite and graywacke; may be coeval in part with Old Mill Branch Metasiltstone Member of the Popes Head Formation (OЄpo).

OЄp *phyllite* (Pavlides, 1990): Mostly gray-to-green phyllite with lesser metasiltstone. Mylonitic rocks composed commonly of schist or phyllite with elongate granules of quartz, occur in the southern part of the outcrop belt. These are interpreted as highly tectonized parts of this formation. Alternatively, these rocks may be part of a separate terrane.

Єl *Lunga Reservoir Formation* (Pavlides, 1989; 1990). Metadiamictite, characterized by a nonstratified, micaceous quartzofeldspathic matrix resembling a granitoid, containing rounded to subrounded silt- to sand-sized quartz and plagioclase grains, fine-grained and porphyroblastic muscovite, green porphyroblastic biotite, garnet and magnetite. Granule-, pebble-, and cobble-sized lumps of milky quartz are ubiquitous; mica schist and gneiss clasts are common; calc-silicate clasts are rare. Pebble-, cobble-, and boulder-sized fragments of mafic and ultramafic rock are sparsely distributed in the southern part of the outcrop belt, but are locally abundant in the north. Locally along the contact with the Chopawamsic Formation, the Lunga Resevoir contains exotic fragments similar to lithologies found in the Chopawamsic. The Lunga Resevoir is intruded by Occoquan Granite.

Єp *Purcell Branch Formation* (Pavlides, 1989; 1990). Metadiamictite, characterized by a dark-gray, micaceous quartzofeldspathic matrix with a pervasive, anastomosing foliation.

Mineralogy: quartz + plagioclase + muscovite + biotite (commonly retrograded to chlorite) + epidote + magnetite.

Lumps of milky quartz, sparsely distributed, have undergone tectonic attening and recrystallization; phyllitic rock chips are sparse. Exotic blocks on the order of several meters to several hundreds of meters in length include felsite, greenstone and greenschist, mafic rocks, and amphibolite; these are interpreted as derived from the Chopawamsic Formation (Pavlides, 1989).

SOe *Ellisville biotite granodiorite* (Pavlides, 1990). Mesocratic, coarse- to medium-grained, equigranular to porphyritic, massive to strongly foliated granodiorite.

Mineralogy: quartz + plagioclase + potassium feldspar + biotite; accessories include epidote, allanite, titanite, and apatite. Porphyritic rocks contain potassium feldspar megacrysts up to 1.5 cm across; myrmekite commonly occurs adjacent to potassium feldspar. Brownish-green, strongly pleochroic biotite is associated with, and in places poikilitically encloses epidote, allanite, titanite, and apatite. Subhedral epidote locally encloses euhedral titanite. Pleochroic green amphibole and muscovite are minor constituents locally.

The Ellisville has been dated at 440±8 Ma (Rb-Sr whole-rock; Pavlides and others, 1982).

IGNEOUS ROCKS OF THE WESTERN PIEDMONT

Єlw *Leatherwood Granite* (Jonas, 1928; Pegeau, 1932; Conley, 1985). Light-gray, medium- to coarse-grained, porphyritic biotite granite generally shows rapakivi texture.

Mineralogy: quartz + potassium feldspar + plagioclase + biotite + muscovite + epidote + apatite + titanite + zircon + magnetite.

Geophysical signature: positive radiometric, negative magnetic.

The major part of the Leatherwood occurs as sheets at the top of the Martinsville igneous complex. Leatherwood Granite and associated Rich Acres gabbro are cut by dikes of dark-gray, coarse-grained, porphyritic olivine norite. The Leatherwood was dated at 450 Ma (U-Pb zircon; Rankin, 1975); 464±20 Ma (Rb-Sr whole-rock, Odom and Russell, 1975); and 516 Ma (U-Pb zircon; Sinha and others, 1989).

Єra *Rich Acres Formation* (Conley and Henika, 1973; Conley, 1985). Dikes, sills, and irregularly-shaped plutons of dark-greenish-gray, medium-grained, locally porphryitic, biotite-hornblende gabbro.

Mineralogy: plagioclase + clinopyroxene + orthopyroxene + hornblende + biotite + magnetite + quartz + rutile + apatite + zircon + epidote + calcite + pyrite + titanite; plagioclase is altered to epidote; pyroxenes are altered to uralite. Outer parts of some plutons are injected with thin veins composed of hornblende + plagioclase, and hornblende + pyroxene + plagiocase, and with quartz-microcline-oligoclase pegmatite.

The unit includes small, irregularly-shaped plutons of porphyritic norite composed of 1- to 4-cm orthopyroxene and clinopyroxene and 1-cm plagioclase laths in ophitic texture, hornblende, biotite, and olivine. The Rich Acres is part of the Martinsville igneous complex of Ragland (1974).

Ꞓm *Melrose granite*. Light-greenish-gray to pink-banded, massive, medium- to coarse-grained biotite granite; ranges in composition from quartz monzonite to quartz diorite. Fabric shows a southeastward progression from protomylonite to mylonite to ultramylonite where the unit is cut by the Brookneal shear zone (Gates and others, 1986).

Mineralogy: quartz + plagioclase + potassium feldspar + biotite + muscovite + chlorite + epidote + titanite + garnet + magnetite-ilmenite + calcite + zircon (Gates, 1981).

Geophysical signature: positive radiometric, negative magnetic.

The Melrose has been dated at 515 Ma (U-Pb zircon; Sinha and others, 1989).

PzZdm *Diana Mills complex* (Brown, 1969). Principally hornblende metadiorite and hornblende-quartz metadiorite; includes hornblendite, amphibolite, metaperidotite, orbicular serpentinite, pegmatite, and aplite.

Metamorphosed hornblende diorite and hornblende-quartz diorite are dark-grayish-green, medium-grained porphyritic, and massive to crudely-foliated. Phenocrysts are 1 to 10 mm anhedral to subhedral plagioclase of intermediate composition; matrix minerals include hornblende and plagioclase, with variable amounts of biotite and quartz. Accessory minerals include: apatite, zircon, muscovite, magnetite, ilmenite, and pyrrhotite. Epidote, chlorite, and titanite are common secondary minerals.

Hornblendites are dark-green, medium- to coarse-grained rocks consisting dominantly of blocky euhedral to subhedral hornblende, with minor interstitial highly altered feldspar, and apatite.

Amphibolite and metaperidotite are dark-green coarse-grained rocks composed of anhedral pale-green uralitic hornblende which in places contains relict clinopyroxene and orthopyroxene, and rounded blebs of serpentine with cores of acicular tremolite, apparently after olivine.

Orbicular serpentinite is dark-gray serpentinite composed of variable amounts of talc, amphibole, and chlorite, with fragmentary remnant pyroxene; the rock contains rounded orbicules from about 2 to 20 cm in diameter. These are composed predominantly of fibrous antigorite, oriented in concentric bands around the periphery, and contain cracks filled with magnetite, chlorite, and talc.

Pegmatite and aplite are composed of plagioclase, epidote, clinozoisite, muscovite, and quartz; hornblende megacrysts are present in some pegmatite.

The complex is generally concordant with the foliation in the enclosing metagraywacke **(Ꞓzpm)**, which shows enlarged micas and mica porphryoblasts adjacent to the contact. Structural setting and rock assemblage are suggestive of a layered intrusive sill (Brown, 1969). More recently the Diana Mills has been interpreted as an exotic block, emplaced within the enclosing unit by gravity sliding, or by other tectonic means (Brown and Pavlides, 1981; W. R. Brown, personal communication to Nick Evans, 1993).

Green Springs pluton (PzZgq, PzZgs; Hopkins, 1960; Rossman, 1991)

PzZgq *quartz diorite and granite*. Light-gray, medium- to coarse-grained, massive to indistinctly-foliated.

Mineralogy: quartz + plagioclase (intermediate composition) + potassium feldspar + biotite + muscovite.

PzZgs *diorite and hornblendite*. Diorite, light- to dark-gray, fine- to coarse-grained. Hornblendite and amphibolite occur as dikes associated with diorite; these are coarse-grained, with blocky hornblende and plagioclase; epidote-rich alteration zones are common.

Mineralogy: hornblende + plagioclase (intermediate composition); accessory minerals include apatite, titanite, zircon, garnet, pyrite, and magnetite. Augite, diopside, quartz, and potassium feldspar are locally present. Hornblende is largely replaced by chlorite or biotite; plagioclase contains abundant epidote inclusions. Late biotite porphyroblasts are common; these are commonly hydrated to form vermiculite.

Rossman (1991) interprets the Green Springs to be a at-topped intrusive body with its upper surface approximately coincident with the present land surface. He notes that the pluton contains metasedimentary xenoliths that resemble the enclosing metagraywacke, and has a thermal aureole that is manifested by garnet and biotite porphryoblasts in the surrounding country rocks. Conley and Johnson (1975) concluded that the pluton was rootless at depth on the basis of a gravity study.

Vermiculite is being extracted commercially from a deposit near the northeast margin of the pluton.

Buckingham complex (PzZbq. PzZbk; Henika, 1969)

PzZbq *quartz diorite*. Light-gray, medium- to coarse-grained, biotite-quartz diorite; migmatitic zones, kyanite, and sillimanite occur adjacent to contacts in country rocks.

Mineralogy: quartz + plagioclase + potassium feldspar + biotite + epidote + allanite + muscovite + magnetite.

This lithology cuts across older units in the Buckingham complex.

PzZbk *metamorphosed mafic and ultramafic rocks*. Dark-greenish-gray, massive to layered, coarse-grained metagabbro, with metapyroxenite and metaperidotite layers. Early layered units are cut by late-stage aplitic granodiorite veins and dikes. Screens of metasedimentary country rocks separate differentiated metaperidotite-metagabbro sills. Younger quartz diorite pluton **(PzZbq)** partially brecciates older mafic rocks.

Mineralogy (secondary minerals in parentheses): metaperidotite, orthopyroxene + clinopyroxene + olivine + magnetite (+ tremolite-actinolite + chlorite + serpentine + talc + epidote + magnetite + calcite); metapyroxenite, orthopyroxene

+ clinopyroxene + hornblende + magnetite (+ chlorite + talc + plagioclase + epidote + quartz + magnetite); metagabbro, hornblende + clinopyroxene + orthopyroxene + biotite + plagioclase + magnetite (+ biotite + chlorite + epidote + muscovite + quartz + garnet).

Geophysical signature: Positive magnetic anomalies are associated with mafic and ultramafic sills.

Obi *Bear Island Granodiorite* (Cloos and Cooke, 1953; Drake and Lee, 1989). Leucocratic, fine-grained, muscovite-biotite granodiorite and related quartz-albite-microcline pegmatite. Unit comprises small- to moderate-sized sheets and crosscutting bodies. Muscovite from pegmatite dated at 469±20 Ma, interpreted as time of cooling below 500^0 C (Rb-Sr; Muth and others, 1979).

Ol *Lake Jackson pluton* (Pavlides, 1990). Mesocratic, fine- to medium-grained, strongly-foliated and locally lineated micaceous metatonalite. Plagioclase shows alteration to fine-grained white mica and granular epidote; quartz has commonly been recrystallized into granoblastic- to mosaic-textured aggregates; attened quartz blebs along with dimensionally-aligned feldspar impart a mineral lineation locally. Biotite, epidote, chlorite, and muscovite define a discontinuous sinuous foliation. Allanite is an accessory mineral that is locally rimmed by epidote.

Ot *metatonalite* (Pavlides, 1990). Leucocratic, fine-grained, hypidiomorphic-granular, massive metatonalite-metaplagiogranite composed predominantly of sodic plagioclase and quartz, with minor potassium feldspar; plagioclase is variably altered to epidote and white mica. Thin cataclastic seams of quartz with white mica locally cut the rock.

Lahore Complex (Ola, Olp, Olm; Pavlides, 1982; 1990)
Ola *amphibole monzonite*. Mesocratic, medium-grained, amphibole monzonite and amphibole-quartz monzonite have a foliation defined by alignment of tabular feldspar crystals. Mineralogy includes microcline or orthoclase, intermediate-composition plagioclase, and quartz; mafic minerals are amphibole ranging from common hornblende to edenite, locally rimming pyroxene, subordinate biotite, and magnetite. Epidote, titanite, apatite and allanite are also present.
Olp *pyroxene monzonite*. Dark-gray to black, fine- to medium-grained, massive- to indistinctly-foliated; consists of large, locally-twinned augite, poikilitic in part, enclosing apatite, opaque oxide, biotite, and plagioclase. Compositionally-zoned and unzoned plagioclase is also a significant coarse-grained consitituent. This lithology is gradational into amphibole monzonite.
Olm *mafic and ultramafic rocks*. Composite mass that consists of partially serpentinized pyroxenite containing diopside rimmed by antigorite or by tremolite.

O€f *Falls Church Intrusive Suite* (Drake and Froelich, 1986; in press). Tonalite, granodiorite, monzogranite, and trondhjemite. Tonalite, medium-dark-gray, medium- to coarse-grained biotite-hornblende tonalite and biotite tonalite with abundant inclusions of mafic and ultramafic rock. Tonalite is typically well-foliated; in many places it has a strong quartz-rod lineation. Granodiorite, medium-gray, medium- to coarse-grained, poorly- to moderately-well-foliated, biotite- and biotite-muscovite-bearing. Monzogranite, medium-grained, muscovite-biotite and garnet-muscovite-biotite-bearing. Trondhjemite, light-pink to light-gray, medium-grained, muscovite-bearing; strongly deformed and recrystallized. Tonalite from this suite has been dated at 481±11 Ma (U-Pb single-crystal zircon; J.N. Aleinikoff, written communication, 1993).

O€d *Dalecarlia Intrusive Suite* (Drake and Flemming, in press). Medium- to coarse-grained, massive to well-foliated, biotite monzogranite and lesser granodiorite; locally contains plagioclase phenocrysts. Mapped bodies contain widespread leucocratic biotite-muscovite monzogranite.

O€gg *Goldvein pluton* (Pavlides, 1990). Mesocratic, coarse- to medium-grained, weakly- to strongly-foliated metamonzogranite. Altered feldspars commonly impart pink and green colors to the rock. Mineralogy includes perthite and plagioclase feldspars, each locally megacrystic; granoblastic quartz, muscovite, and sparsely distributed garnet.

O€o *Occoquan granite* (Lonsdale, 1927; Drake and Froelich, 1986). Light-gray, medium- to coarse-grained, muscovite-biotite monzogranite and lesser granodiorite and tonalite. In many places the rock has a strong quartz-rod lineation, and locally, two foliations. The Occoquan has been dated at about 560 Ma (U-Pb zircon; Seiders and others, 1975), 494±14 Ma (Rb-Sr whole-rock; Mose and Nagel, 1982), and 479±9 Ma (U-Pb single-crystal zircon; J.N. Aleinikoff, written communication, 1993).

O€pg *plagiogranite tonalite* (Pavlides, 1990). Includes leucocratic to mesocratic plagioclase- and quartz-rich metamorphosed intrusive rocks containing little or no potassium feldspar. Plagioclase is variably altered to epidote, white mica, and chlorite. Quartz, generally blue, forms granoblastic aggregates that locally have cores of coarse-grained quartz with wavy extinction. Garnet is present locally. Hornblende, generally a minor constituent, is particularly abundant in the southwest portion of the pluton. Many of the plagiogranitic rocks have undergone cataclasis and are protomylonitic to mylonitic.

€gi *Georgetown Intrusive Suite* (Flemming and others, in press). Tonalite, quartz gabbro, quartz diorite, metapyroxenite, and hornblendite. Tonalite, medium- to coarse-grained, massive to strongly-foliated, biotite-, biotite-hornblende-, and garnet-biotite-hornblende-bearing; color index 20 to 40; contains abundant mafic inclusions.

Quartz gabbro and quartz diorite, mostly medium- to coarse-grained quartz-augite-hornblende metagabbro, lesser quartz diorite, and much lesser quartz norite; commonly contains thin cumulus layers of metapyroxenite and augite-hornblende fels. Forms small to medium-sized layered sills and localized border zones of tonalite plutons.

Metapyroxenite and hornblendite, dark-green to black, massive to well-foliated, medium- to coarse-grained; includes serpentinite, soapstone, and talc schist. Forms small pods and xenolith swarms within or along the borders of larger tonalite and quartz gabbro plutons.

ЄZg *Garrisonville Mafic Complex* (Pavlides, 1990). Fine- to coarse-grained, massive to foliated amphibolite and hornblendite with lesser metapyroxenite, metawebsterite, and metanorite. Amphiboles in amphibolite are dominantly hornblende, which is poikilitic in places; actinolite and cummingtonite are present locally. Intermediate-composition plagioclase commonly shows alteration to clinozoisite or epidote. Quartz and chlorite are present in variable amounts in some amphibolites; magnetite and ilmenite are common accessory minerals. Hornblendite consists of coarse-grained hornblende in a groundmass of finer-grained hornblende, plagioclase, and quartz. At the western edge of the complex, talc-amphibole schist occurs near the contact with the country rock; metamorphic alteration is less intense in the western portion than in the east.

mgb *metagabbro*. (southwestern Piedmont, Conley, 1985). Dark-green and white, massive to layered, coarse-grained equigranular metagabbro.

Mineralogy: clinopyroxene + orthopyroxene ± garnet + hornblende + plagioclase + magnetite. Garnets are surrounded by thin coronas composed of plagioclase and symplectic intergrowths of plagioclase-pyroxene. Forms elongate concordant bodies intrusive into the Bassett Formation.

(northern Piedmont, Drake and Froelich, in press). Greenish-gray, fine- to coarse-grained, well-foliated epidote-plagioclase-hornblende amphibolite; locally contains relict clinopyroxene. Occurs as sills in the Mather Gorge Formation. Fisher (1971) reports that zircons from an amphibolite body on an island in the Potomac River have a Pb-Pb age of 525+/-60 Ma, and a concordia age of 550 Ma, assuming continuous diffusion; a Cambrian age for metagabbroic sills in the Mather Gorge would be consistent with regional geologic relations.

ak *alaskite* (Conley, 1985). White to light-gray, medium- to coarse-grained leucocratic muscovite granite and granite gneiss.

Mineralogy: potassium feldspar (perthite or microcline) + plagioclase + quartz + muscovite ± biotite ± epidote ± kyanite ± garnet.

Geophysical signature: negative or at magnetic signature; positive radiometric signature.

Commonly occurs as folded sheets parallel to schistosity and as lit-par-lit injections in the Bassett and Fork Mountain Formations (Smith River Allochthon) and near the base of the Lynchburg Group (Ashe Formation or Moneta Gneiss) in the Blue Ridge or Sauratown Mountains anticlinoria.

gs *actinolite schist metabasalt*. Dark-green, variably-schistose chlorite-actinolite-epidote greenstone metabasalt, amygdaloidal in part; massive yellowish-green epidosite segregations common.

ROCKS OF THE CENTRAL VIRGINIA VOLCANIC-PLUTONIC BELT

PMf *Falmouth Intrusive Suite* (Pavlides, 1980). Fine-grained to pegmatitic granite, quartz monzonite, granodiorite, and tonalite; consists of dikes, sills and small plutons.

Mineralogy: plagioclase + quartz + microcline + biotite + muscovite + hornblende ± garnet + epidote + apatite + titanite + opaque minerals; myrmekite common.

The unit has been dated at 300-325 Ma (U-Pb zircon and Rb-Sr whole-rock; Pavlides and others, 1982). These rocks intrude the Ta River Metamorphic Suite **(Єta)**, Falls Run Granite Gneiss **(Sf)**, Holly Corners Gneiss **(ЄZh)**, Quantico Formation **(Oq)** and porphyroblastic garnet-biotite gneiss (**Ym**; Po River Metamorphic Suite of Pavlides, 1980).

Sf *Falls Run Granite Gneiss* (Pavlides, 1980). Pink to white, coarse-grained, strongly-foliated hornblende-biotite granite to monzonite gneiss.

Mineralogy: microcline + plagioclase + quartz + biotite + muscovite ± hornblende; apatite, epidote, titanite, and magnetite-ilmenite are accessories; myrmekite is common.

The Falls Run has been dated at 410 Ma (U-Pb zircon and Rb-Sr whole-rock; Pavlides and others, 1982); the gneiss intrudes Ta River Metamorphic Suite **(Єta)** and the Holly Corners Gneiss **(ЄZh)**.

Ost *Shelton Formation*. Pink to gray, coarse-grained, massive, strongly-lineated gneiss ranging in composition from granite to quartz monzonite (Henika, 1977), composed of microcline and perthite augen enclosed by biotite in a quartz-plagioclase matrix. A characteristic linear fabric is produced by rod-like feldspar porphyroblasts and crystalline aggregates. Thin veins of purple uorite are common.

Mineralogy: quartz + potassium feldspar + plagioclase + biotite + muscovite ± pyrite ± uorite.

Geophysical signature: pronounced positive radiometric signature, at magnetic signature.

Originally named Shelton granite (Jonas, 1928), the unit was renamed Shelton Formation (Henika, 1977). Simple linear fabric was cited as evidence for an intrusive origin by Henika (1980). The Shelton has been dated at 424±7 Ma (Rb-Sr whole-rock; Kish, 1983) and 463 Ma (U-Pb; Hund, 1987).

Quantico Formation (Oq, Oqq; Pavlides, 1980)

Oq *slate and porphyroblastic schist*. Gray to black, graphitic, pyritic phyllite and slate (northern Piedmont); metamorphic grade increases to the southwest to produce porphyroblastic staurolite-, kyanite-, and garnet-biotite-muscovite schists. Locally the unit contains felsic metatuff, metagraywacke, and micaceous quartzite interbeds; thickness has been estimated at as much as 3000 feet (Pavlides, 1980).

Mineralogy: quartz + muscovite + biotite ± garnet ± staurolite ± kyanite + opaque minerals; chlorite is a common secondary mineral.

Geophysical signature: strike-elongated positive linear magnetic and radiometric anomalies.

The unit was originally named Quantico Slate by Darton (1894), and modified to Quantico Formation by Pavlides (1980). An Ordovician age for the Quantico is indicated by fossils collected by Watson and Powell (1911) and more recently by Pavlides and others (1980). The Quantico unconformably overlies older units in the northeastern Piedmont, and is correlated with the Arvonia Formation to the southwest.

Oqq *micaceous quartzite*. Light-gray, fine- to medium-grained quartzite and quartzose muscovite schist.

Mineralogy: quartz + muscovite + plagioclase ± microcline.

This lithology occurs as thin discontinuous lenses at the base of the Quantico; thin diopsidic calcsilicate layers are also found locally in the lower part of the Quantico (Pavlides, 1980).

Arvonia Formation (Oa, Oas, Obq, Okq)

Oa *slate and porphyroblastic schist*. Dominantly dark-gray to grayish-black, lustrous, very-fine-grained, graphitic slate (northeastern sector); and, medium-grained, porphyroblastic garnetiferous biotite schist (southwestern sector).

Discontinuous beds of quartzose muscovite schist, coarse-grained to pebbly micaceous quartzite, and conglomeratic schist occur along the margins of the outcrop belt, stratigraphically at the base of the section. Interbeds of dacite metatuff occur in the western portion of the slate outcrop belt.

Graded laminated metasiltstone and metasandstone are interbedded with slate in the central and eastern portions of the outcrop belt at the latitude of the James River (Evans and Marr, 1988); these rocks pass into porphyroblastic schists at higher metamorphic grades to the southwest. A distinctive garnet-amphibole-quartz interbed occurs within porphyroblastic schist south of the James River (volcanogenic marker?; Brown, 1969); north of the river, this passes down metamoprphic grade into what is described as an oolitic chlorite schist (Smith and others, 1964).

Mineralogy: (slate) chlorite + muscovite + plagioclase + quartz + magnetite ± biotite ± calcite ± graphite ± pyrite; (porphyroblastic schist) biotite + muscovite + garnet + quartz + plagioclase + magnetite ± kyanite ± calcite; tourmaline and zircon are common accessories.

Geophysical signature: The Arvonia is marked by positive magnetic and radiometric anomalies.

Originally referred to as the slate in the Arvonia belt by Rogers (1884), the unit was named Arvonia slate by Stose and Stose (1948), and raised to formation status by Brown (1969). An Upper Ordovician age for the Arvonia has been established from fossils collected by Watson and Powell (1911), Stose and Stose (1948), Tillman (1970), and Kolata and Pavlides (1986).

The Arvonia has long been considered unconformable on top of adjacent units. Micaceous quartzite, pebbly muscovite schist, and conglomeratic schist are common at the base of the section where that boundary is not faulted (Stose and Stose, 1948; Smith and others, 1964; Brown, 1969; Evans and Marr, 1988). The base of the Arvonia is exposed in an old railroad cut near Carysbrook, Fluvanna County (Smith and others, 1964); there, a micaceous quartzite containing quartz pebbles rests on granite of the Carysbrook pluton. The Stoses (1948) considered the Arvonia a sequence deposited on a post-Taconic-orogeny regional unconformity, and folded and metamorphosed during subsequent orogenies; that interpretation is consistent with geologic constraints as we know them today. The Arvonia is correlated with the Quantico Formation. History of the Arvonia district slate industry is discussed by Brown (1969) and Evans and Marr (1988).

Oas *porphyroblastic garnet-biotite schist*:. Porphyroblastic mica schist, characterized by 1- to 2-mm garnet porphyroblasts in an anastomosing, greenish-black biotite-rich, schistose matrix. Most exposures show complex microstructures suggestive of polyphase deformation and superimposed shearing. In Appomattox and Campbell counties, and locally elsewhere,this unit includes quartzose muscovite schist along the western and eastern margins of the outcrop belt (presumed base of the stratigraphic section); locally the unit contains thin interbeds of calcareous mica schist and marble.

Mineralogy: biotite + garnet + muscovite + quartz + plagioclase + magnetite ± kyanite ± calcite.

Geophysical signature: characterized by elongate positive magnetic and radiometric anomalies.

This unit was mapped in strike-belts southwest of, and not physicaly connected to the type section at Arvonia.

Obq Bremo quartzite (Stose and Stose, 1948). Light-gray, fine- to medium-grained, thick-bedded and locally crossbedded quartzite; includes quartz-muscovite schist, and quartz-pebble conglomerate.

Mineralogy: quartz + muscovite + chlorite ± plagioclase ± potassium feldspar ± calcite ± magnetite-hematite ± zircon.

The Bremo reportedly contains crinoid stems and brachiopods (Smith and others, 1964; Brown, 1969). Stose and Stose (1948) and Smith and others (1964) considered the quartzite stratigraphically above the slates and schists; Brown (1969) cited structural evidence that the Bremo does not occupy a position at the top of the Arvonia, but occurs locally in the middle or lower part. Smith and others (1964) and Brown (1969) considered the Bremo a member of the Arvonia Formation.

Okq *kyanite quartzite and schist*. White to light-gray, medium- to coarse-grained, well-foliated, locally crinkle-folded, quartzose kyanite schist and kyanite-bearing quartzite.

Mineralogy: kyanite + quartz + muscovite ± graphite ± pyrite ± garnet; kyanite constitutes as much as 30 percent of the rock.

Kyanite-bearing quartzites and schists have been correlated with quartzose muscovite schists that occur locally at the base of the Arvonia Formation (Conley and Marr, 1980). Those workers report primary sedimentary structures in kyanite quartzite including wedge-shaped quartzite layers and quartzite-metapelite couplets; fining-upward sequences; channel fillings; and, large-and small-scale cross-beds.

Obf *Buffards Formation* (Brown, 1969). Includes greenish-gray conglomeratic quartzose muscovite schist containing ellipsoidal clasts of milky quartz, dusky-red quartzite, dark-gray aphanitic rock, and greenish-gray phyllite; greenish-gray chlorite-muscovite schist with medium to fine, grayish-blue quartz grains; grayish-green chlorite-muscovite phyllite; biotite-muscovite-quartz schist. Mineral assemblages are those found in Arvonia slates and porphyroblastic schists. Conglomeratic schist occurs along the western margin of the principal Buffards outcrop belt, and as discontinuous lenses too small to show at 1:500,000 scale, at or near the western margin (stratigraphic base) of the Arvonia slate outcrop belt **(Oa)** (Evans and Marr, 1988).

Although Brown (1969) in defining the Buffards Formation considered these rocks to be a pyroclastic deposit stratigraphically above the Arvonia Formation, other workers have interpreted Buffards rocks to be at a lower stratigraphic position relative to the Arvonia. Conley and Marr (1980) considered the Buffards part of the Chopawamsic Formation, unconformably below the Arvonia. Stose and Stose (1948) and Evans and Marr (1988) considered the Buffards to be stratigraphically at or near the base of the Arvonia Formation.

Buffards conglomeratic schists contain tuffaceous and ferruginous-quartzite clasts similar to rocks that occur in the Chopawamsic Formation; this is consistent with the Buffards being derived in part from, and deposited unconformably on, the Chopawamsic. The chaotic, locally graded nature of the deposits is suggestive of a submarine fan channel deposit.

Ocg *Columbia pluton*. Light-gray, medium- to coarse-grained, foliated. Includes biotite-muscovite granite, granodiorite, tonalite, and granitic pegmatite; contains xenoliths of biotite gneiss, amphibolite, and felsic metavolcanic rocks.

Mineralogy: plagioclase + quartz + microcline; common accessories include biotite, muscovite, epidote, zircon, apatite, garnet, magnetite, and pyrite (Bourland and Glover, 1979).

Geophysical signature: diffuse magnetic lows and radiometric highs.

The pluton was originally named Columbia Granite by Jonas (1928); this name was objected to by later workers because of the relatively small percentage of true granite present. The pluton includes the southeastern portion of the granodiorite unit of Smith and others (1964). Granitic rocks in the Carysbrook area of Fluvanna County are here considered part of a separate Carysbrook pluton, following the usage of Stose and Stose (1948). The Columbia includes, in part, the Hatcher complex of Brown (1969). Bourland and Glover (1979) refer to the pluton as the Columbia metagranite. Given the heterogeneous nature of the pluton, multiple intrusive phases are likely present.

Tonalite in the eastern part of the pluton has yielded ages of 590+/-80 Ma, (Rb-Sr whole-rock; Fullagar, 1971). Mose and Nagel (1982) report a Rb-Sr whole-rock age for the Columbia of 454±9 Ma. Because samples for this age are described as coming from the western portion of the Columbia, it is possible that the rocks dated were taken from what is herein mapped as the Carysbrook pluton **(grc)**.

OЄtj *trondhjemite* (Pavlides, 1990). Light-gray, leucocratic, fine-grained, allotriomorphic-granular; composed of intergrown albite and quartz exhibiting granophyric texture. Blue-green amphibole and garnet are present locally.

OЄpg *plagiogranite* (Pavlides, 1990). Includes leucocratic to mesocratic, quartz- and plagioclase-rich metamorphosed intrusive rocks; typically light- to medium-gray, medium- to coarse-grained; cataclastic overprint common, locally protomylonitic to mylonitic; locally intruded by mafic dikes.

Mineralogy: plagioclase + quartz + amphibole + biotite + muscovite + chlorite; accessory epidote, garnet, calcite, and opaque minerals are present.

Geophysical signature: diffuse magnetic lows and clearly-defined radiometric highs.

Chopawamsic Formation (Єcv, Єcfv, Єcmv; Southwick, Reed, and Mixon, 1971)

Єcv *Chopawamsic Formation, undivided*, (Pavlides, 1981). Includes laterally discontinuous lenses and tongues of metamorphosed felsic, intermediate, and mafic volcanic ows and volcanoclastic rocks, with interlayered quartzite, quartzose graywacke, schist, and phyllite. Volcanic ows are locally highly vesicular; fragmental breccia and tuff are common. Felsic ows are typically light-gray aphanitic rocks with phenocrysts of quartz and feldspar; intermediate ows are dark-green amphibole-bearing rocks with fine-grained quartz-feldspar matrix; greenstone metabasalts contain blue-green amphibole, chlorite, albitic plagioclase, and quartz.

Geophysical signature: linear strike-elongate pattern of elevated magnetic anomalies.

The Chopawamsic is correlated with the James Run Formation in Maryland; the James Run has been dated at 570 to 530 Ma (U-Pb zircon; Tilton and others 1970). The Chopawamsic is unconformably overlain by the Late Ordovician Arvonia and Quantico Formations. Pavlides (1981 and subsequent works) has made the interpretation on the basis of geologic and geochemical data that the Chopawamsic and related plutons represent an ancient island-arc sequence.

Єcfv *foliated felsite*. Light-gray to white, medium-grained, foliated felsite ranges in composition from rhyolite to dacite.

Mineralogy: quartz + perthitic microcline + muscovite + biotite; beta-form quartz phenocrysts are characteristic.

Єcmv *mafic to intermediate metavolcanic rocks*. Dark greenish-gray, fine- to medium-grained, foliated, lineated, amphibole-bearing gneiss and schist. Also includes tuffaceous volcaniclastic rocks.

Mineralogy: amphibole + acicular actinolite + epidote + chlorite + titanite + plagioclase + magnetite.

Ta River Metamorphic Suite (Єta, Єtq; Pavlides, 1980)

Єta *Ta River Metamorphic Suite, (undivided).* Layered sequence consists dominantly of greenish-gray to black, medium- to coarse-grained, poorly to well-lineated, massive to well-layered amphibolite and amphibole-bearing gneiss and schist; includes interlayered ferruginous quartzite, and minor biotite gneiss, felsic volcanic rocks, gabbro and granite. Amphibolitic rocks commonly contain quartz-epidote lenses and veins. Porportion of biotite gneiss and schist increases from northeast to southwest along strike, as does grade of regional metamorphism.

Mineralogy: (hornblende, tremolite-actinolite, and cummingtonite) + quartz + calcic oligoclase ± epidote ± biotite ± garnet.

Geophysical signature: linear positive and negative magnetic and radiometric anomalies.

Pavlides (1981) correlated the Ta River with the Chopawamsic and James Run Formations, and considered the Ta to be a more oceanward facies of a Chopawamsic island arc sequence, on the basis of geologic and geochemical factors. The Quantico Formation generally overlies the boundary between the Chopawamsic and the Ta, obscuring the contact relationships.

Ꞓtq *ferruginous quartzite*. Dark-reddish-brown, fine- to medium-grained, thinly-banded, metamorphosed ironstone, contains discontinuous quartz-rich and magnetite- or specular hematite-rich lenses and layers. Quartzites are associated with gossan zones (Marr, 1980a; 1980b).

Geophysical signature: narrow strike-elongate positive magnetic anomalies.

Ferruginous quartzites are distinctive marker units that locally outline map-scale structures in some places. This lithology is recognizable in rocks of variable metamorphic grade and degree of deformation and has been mapped within the Ta River **(Ꞓtq)** and within correlative unnamed interlayered mafic and felsic metavolcanic rocks to the southwest **(Ꞓfq)**.

Ꞓg *amphibole metagabbro*. Dark-greenish-gray, coarse-grained, massive, hornblende metagabbro.

Mineralogy: plagioclase + hornblende + biotite + clinopyroxene + quartz; relict olivine and myrmekitic intergrowths of quartz in other minerals are characteristic.

Geophysical signature: small circular areas marked by positive magnetic anomalies.

Metagabbro intrudes Ta River Metamorphic Suite.

Interlayered mafic and felsic metavolcanic rocks (Ꞓfv, Ꞓmv, Ꞓbg, Ꞓfq, Ꞓsg)

Heterogenous layered assemblage correlates with the Chopawamsic Formation and Ta River Metamorphic Suite, on strike to the northeast, and in traceable into the Milton belt in North Carolina (Geologic Map of North Carolina, 1985).

Ꞓfv *foliated felsite*. Grayish-orange-pink to white, fine- to medium-grained, foliated to granular metavolcanic rocks range in composition from rhyolite to dacite. Includes muscovite-feldspar-quartz schist, gneiss and granofels; massive crystal metatuff; welded ash ow tuff; and, inequigranular metavolcanic breccia. Relict primary volcanic textures are recognizable where metamorphic grade is low (Henika, 1975; 1977).

This unit includes felsic gneiss with less common mafic and rare calcareous gneiss mapped by Tobisch (1972), in part the metamorphosed volcanic sequence of Gates (1981), and dominantly felsic-composition units mapped by Nelson (1992). The unit contains numerous granitic dikes, sills, and lit-par-lit injections where it occurs in close proximity to Shelton Formation **(Ost)**.

Felsites occur interlayered with amphibolite, amphibole gneiss and schist **(Ꞓmv)**, quartzofeldspathic biotite gneiss **(Ꞓbg)**, sillimanite-quartz-muscovite schist and gneiss **(Ꞓsg)**, and ferruginous quartzite **(Ꞓfq)**.

Ꞓmv *amphibolite, hornblende-biotite gneiss and schist*. Black to moderate-olive-brown, medium- to coarse-grained, lineated and foliated; light-greenish-gray quartz-epidote stringers are common.

Mineralogy: hornblende + tremolite-actinolite + oligoclase + biotite + epidote + garnet.

Includes Blackwater Creek Gneiss and Catawba Creek amphibolite member of Hyco Formation of Baird (1989), hornblende gneiss of LeGrand (1960), gneiss unit of Kreisa (1980), and dominantly mafic-composition units mapped by Nelson (1992). Amphibolite is interlayered with biotite gneiss, as discussed above.

Ꞓbg *quartzofeldspathic biotite gneiss*. Heterogeneous layered sequence consists of salt-and-pepper and segregation-layered biotite granite gneiss interlayered with biotite schist; dark-gray to black, fine- to coarse-grained, thin- to thickly-laminated hornblende gneiss and schist; lesser quartz-muscovite schist; and, locally, gray to green, medium-grained, calcareous gneiss and calc-silicate granofels (Tobish and Glover, 1969). This unit includes the upper and lower felsic gneiss units and intermediate volcanic rocks in the Hyco Formation as used by Baird (1989, 1991); and biotite gneiss and interlayered gneiss of Kreisa (1980), correlative with the biotite gneiss unit of Marr (1980a; 1980b).

Mineralogy: (quartzofeldspathic rocks), (1) quartz + albite + potassium feldspar + muscovite + chlorite + actinolite + epidote + calcite + magnetite + zircon; (2) quartz + oligoclase + muscovite + biotite + garnet + hornblende + magnetite + epidote + rutile + calcite + zircon; (mafic rocks), (1) quartz + albite + chlorite + epidote + actinolite + titanite + magnetite-ilmenite. (2) quartz + oligoclase + andesine + hornblende + microcline + biotite + garnet + cordierite + magnetite + rutile + titanite + scapolite;
(pelitic rocks), (1) quartz + albite + muscovite + chlorite + epidote + magnetite-ilmenite; (2) quartz + muscovite + biotite + kyanite + oligoclase + potassium feldspar + epidote + magnetite-ilmenite + garnet; (3) quartz + muscovite + sillimanite + magnetite-ilmenite; (calcareous rocks), (1) quartz + calcite + biotite + epidote + chlorite + tremolite + ilmenite; (2) calcite + quartz + epidote + hornblende + pyroxene + scapolite.

Geophysical signature: felsic rocks are delineated by strike-elongate positive radiometric anomalies (Henika and Johnson, 1980); mafic metavolcanic rocks and metasedimentary units are characterized by closed strike-elongate radiometric lows and closed strike-elongate aeromagnetic highs.

Ꞓfq *ferruginous quartzite*. (See description under Ta River Metamorphic Suite, **Ꞓtq)**

Ꞓsg *quartz muscovite schist and gneiss*. Very-light-gray to light-bluish-gray, fine- to medium-grained, layered kyanite-mica schist, kyanite and sillimanite quartzite, and interlayered biotite-garnet schist.

Mineralogy: quartz + muscovite + plagioclase ± biotite ± garnet ± sillimanite ± kyanite ± magnetite.

Includes the schist and gneiss unit of Tobisch (1972), and muscovite-quartz schist of Baird (1989, 1991).

ꞒZh *Holly Corner Gneiss* (Pavlides, 1980; 1990). Dark-gray to black, fine- to medium-grained, strongly-foliated hornblende-biotite-rich gneiss.

Mineralogy: hornblende + plagioclase + biotite + quartz + titanite; accessory minerals include zircon, epidote, microcline, chlorite; trace amounts of apatite, calcite, muscovite, and opaque minerals are present. Myrmekitic intergrowths are common.

Ꞓd *Dale City Quartz Monzonite* (Seiders and others, 1975). Medium- to light-gray, medium-grained, massive to well-foliated quartz monzonite, quartz monzodiorite, and subordinate quartz diorite.

The Dale City intrudes the Chopawamsic Formation and is unconformably overlain by the Quantico Formation (Pavlides and others, 1980). The age is considered 560 Ma (discordant U-Th-Pb-zircon; Seiders and others, 1975).

dgn *quartz diorite gneiss*. White to gray, fine- to medium-grained, massive to layered quartz diorite gneiss, contains minor biotite and epidote; lenses of gray to black, medium-grained, layered hornblende-plagioclase gneiss and quartz-epidote-clinopyroxene-hornblende-plagioclase gneiss occur locally (Tobisch, 1972).

ga *hornblende-plagioclase gabbro*. Dark-grayish-green, coarse- to medium-grained, massive to foliated metagabbro.

Mineralogy: amphibole + plagioclase + clinopyroxene + quartz + biotite + muscovite + epidote ± magnetite.

Geophysical signature: small circular positive magnetic anomalies.

Plutons of these gabbros intrude interlayered mafic and felsic metavolcanic rocks.

grb *biotite granite*. Gray to white, medium-grained, massive to layered granite and granite gneiss range in composition from granite to quartz diorite. Quartz diorite dikes and sills are locally abundant.

Mineralogy: quartz + potassium feldspar + plagioclase + biotite + epidote + muscovite ± clinopyroxene + hornblende.

This unit intrudes biotite gneiss unit **(Ꞓbg).**

grc *Carysbrook pluton*. Light-gray, medium- to coarse-grained, massive to indistinctly foliated biotite granite.

Mineralogy: quartz + potassium feldspar + plagioclase + biotite + chlorite + muscovite + epidote.

Geophysical signature: diffuse pattern of elevated radiometric anomalies.

Although Smith and others (1964) included the Carysbrook pluton in a granodiorite unit with granitoid rocks in the vicinity of Columbia, Stose and Stose (1948) recognized that the granite at Carysbrook was different in texture and composition from the granodiorite at Columbia. Our mapping affirms that these are separate plutons. The Carysbrook is unconformably overlain by the Arvonia Formation; this relation is well-exposed in an abandoned railroad cut south of Carysbrook (Smith and others, 1964). The pluton intrudes the Chopawamsic Formation.

lgn *lineated biotite granite gneiss*. Dominantly leucocratic to mesocratic, medium- to coarse-grained, strongly-lineated granite gneiss; includes porphyritic granite gneiss.

Mineralogy: quartz + potassium feldspar + plagioclase + biotite + muscovite ± garnet.

Geophysical signature: western portion coincides with strong positive radiometric anomaly.

This unit likely includes more than one intrusive body; portions may be derivative of felsic volcanogenic rocks. These rocks intrude and are interlayered with metavolcanic rocks of probable Cambrian age. The unit includes granite gneiss of Nelson (1992), and may be correlative in part with the Shelton Formation **(Ost)**.

pg *plagiogranite*. White to light-gray, medium- to coarse-grained, vaguely- to strongly-foliated plagioclase-rich granite and granite gneiss.

Mineralogy: quartz + plagioclase + biotite + muscovite ± potassium feldspar.

Small plutons occur within layered metavolcanic rocks of probable Cambrian age.

fbgr *foliated biotite granite*. Leucocratic to mesocratic, medium-grained, equigranular, crudely-layered; includes hornblende-biotite granite and, monzogranite.

Geophysical signature: strong positive radiometric signature; negative magnetic signature.

um *ultramafic rocks*. Small pods and plutons of gray to greenish-gray, medium- to coarse-grained, locally porphyroblastic schist and granofels.

Mineralogy: tremolite-actinolite + chlorite ± talc ± plagioclase ± quartz; locally contains relict olivine.

ROCKS OF THE CAROLINA SLATE BELT

Zph *phyllite and metasiltstone*. Dominantly light-gray, schistose chlorite-sericite phyllite and phyllitic metasiltstone with a well-developed phyllitic or slaty cleavage; includes minor interlayered mafic and felsic metavolcanic rocks.

Laney (1917)	Kreisa (1980)		Harris & Glover (1985)
Aaron slate	Aaron Formation	upper member	Virgilina Formation
Virgilina Greenstone		middle member	
Aaron slate		lower member	Aaron Formation
Hyco Fm.	Hyco Formation		Hyco Formation

Figure 6. Stratigraphic terminology in the Virgilina area.

Zhf *phyllite and metatuff*. Includes light-gray, very-fine-grained, foliated chlorite-sericite phyllite and phyllitic metamudstone, and dark-gray to white, fine- to medium-grained lithic and crystal dacite metatuff. Includes Goshen schist of Laney (1917).

Zmv *mafic metavolcanic rocks.* Greenish-gray to dusky-green, fine- to medium-grained, massive to amygdaloidal metabasalt with dark-gray to white, medium-grained mafic lithic and crystal tuff, and minor purple phyllite and metasedimentary rocks.

Geophysical signature: linear positive magnetic and negative radiometric anomalies.

Zfv *felsic metavolcanic rocks*. Very-light-gray, fine- to medium-grained crystal, lithic, and lithic-crystal andesitic metatuff with minor light-gray to white, fine-grained metasedimentary interbeds.

Zlv *layered mafic to felsic metavolcanic rocks.* Volcanogenic sequence includes felsic pyroclastic and volcaniclastic rocks with intercalated mafic pyroclastic and amygdaloidal ows and phyllitic metasedimentary interbeds.
Felsic rocks are crystal, lithic, and vitric tuff and tuff breccia ranging in composition from rhyolite to dacite. Mafic rocks consist of mafic lithic crystal and vitric tuff, with associated amygdaloidal pyroclastic rocks, and greenstone metabasalt.

Zvi *Virgilina greenstone* (Laney, 1917). Grayish-green, fine- to coarse-grained basaltic tuff, metavolcanic breccia, and porphyritic to amygdaloidal greenstone, with minor interlayered metasedimentary rocks. Hydrothermally mineralized zones occur within the greenstones; these contain bornite, chalcocite, and chalcopyrite, and have been mined for copper.

Mineralogy: plagioclase + hornblende + chlorite + epidote + calcite + apatite + quartz + opaque minerals.

Geophysical signature: linear positive magnetic anomaly.

Watson (1911) used the term Virgilina Group for a wide belt of rocks in the vicinity of Virgilina, Virginia. Mafic metavolcanic rocks in this sequence were named Virgilina greenstone, and felsic metavolcanic rocks and associated metasedimentary rocks were named Aaron slate by Laney (1917). Kreisa (1980) refined Laney's stratigraphy in defining the Aaron Formation as containing upper and lower members equivalent to Laney's Aaron slate, and a middle member equivalent to the Virgilina greenstone. The stratigraphy was further modified by Harris and Glover (1985), who combined the middle and upper members of Kreisa's Aaron Formation to make the Virgilina Formation. Virgilina greenstone is herein used in the sense of Laney (1917), but is equivalent to the middle member of the Aaron Formation of Kreisa (1980), and the lower portion of the Virgilina Formation of Harris and Glover (1985) (Figure 2).

Aaron slate (Za, Zac; Laney, 1917)
Za *phyllite and slate*. Very-light-gray, fine-grained, bedded volcaniclastic sediments, conglomerate, lithic feldspathic arenite, micaceous sandstone, siltstone, phyllite, argillite, and vitric tuff, with minor greenstone. Lithic fragments and relict euhedral crystals are common. The lower part of the unit is dominantly grayish-green slate interbedded with light-gray to grayish-green micaceous metasandstone; bedding is conspicuous and graded-bedding is common. The unit grades upward to bedded light-gray to moderate-red phyllite, metasandstone and slate.
Zac *metaconglomerate* (Kreisa, 1980). Metamorphosed sandy conglomerate, conglomeratic sandstone, and granule conglomerate containing pebbles and cobbles of polycrystalline quartz, with lesser diorite, diabase, chert, rhyolite, granite, schist, and quartz arenite. Cobbles are generally less than 2 cm but may range up to 25 cm in diameter (Kreisa, 1980). Unit occurs as beds of 0.3 to 6.1 meters thickness at base of and locally within the lower portion of Aaron section.

Aaron slate **(Zas)** and metaconglomerate **(Zac)** herein includes the upper and lower members of the Aaron Formation of Kreisa (1980), and the Aaron Formation and upper portion of the Virgilina Formation of Harris and Glover (1985) (Figure 6).

Zh *Hyco Formation*. Includes light-gray, fine- to medium-grained, foliated quartz-muscovite schist with relict quartz and plagioclase phenocrysts; lithic and crystal metatuff with relict volcanic fragments; and, minor felsic breccia and tuffaceous greenstone. A penetrative schistosity is defined by aligned mica grains; a lineation is defined by the ellipsoidal relict phenocrysts.

These rocks were originally named the Hyco quartz porphyry by Laney (1917); they were renamed the Hyco Formation by Kreisa (1980). The Hyco has been dated at 620±20 Ma (Pb-Pb zircon; Glover and others, 1971)

ro *Red Oak pluton*. Light-gray, medium-grained, foliated granite to granodiorite.

Mineralogy: quartz + potassium feldspar + plagioclase + biotite; accessory minerals include muscovite, apatite, and zircon. Hydrothermal alteration to sericite, epidote, kaolin, and chlorite is common.

Geophysical signature: positive radiometric anomaly.

This unit is equivalent in part to the Red Oak granite as defined by Laney (1917) and Horton and others (1993).

ag *Abbeyville gabbro* (Laney, 1917). Dark-greenish-gray, coarse-grained metamorphosed gabbro; includes some soapstone.

Mineralogy: uralitic hornblende + plagioclase + (zoisite, clinozoisite, epidote) + magnetite ± quartz; kaolin, sericite, chlorite, and calcite are also present.

Geophysical signature: positive magnetic anomaly.

bo *Buffalo granite* (Laney, 1917). Light-gray, coarse-grained, porphyritic granite to granodiorite.

Mineralogy: quartz + potassium feldspar + plagioclase + biotite; accessory minerals include apatite and zircon. Hydrothermal alteration to sericite, epidote, kaolin, and chlorite is common.

Geophysical signature: positive radiometric anomaly associated with elevated potassium and thorium values.

This unit is included in the Clarksville batholith of Horton and others (1993).

nv *North View granite* (Bentley, 1992). Light-gray, fine- to coarse-grained, lineated to foliated to massive alkali granite composed of blocky alkali feldspar mesoperthite, quartz, magnetite, and minor aegirine, riebeckite, biotite, allanite, titanite, uorite, zircon, and garnet. Minor microcline and albite form separate phases with recrystallization. Garnet, which may be metamorphic in origin, is grossular-almandine-spessartine with up to three percent yttrium; riebeckite is in the plane of foliation and is metamorphic in origin. The northern and western borders of the pluton are fine-grained and granophyric, with phenocrysts of mesoperthite, albite, and quartz; accessory and secondary minerals include magnetite, biotite, garnet, titanite, chlorite, epidote, muscovite, and calcite.

di *diorite and quartz diorite*. Diorite, gray, fine- to medium-grained, well-foliated, locally trondhjemitic; composition locally grades into granodiorite; quartz diorite, white to gray, fine- to medium-grained, massive to layered, foliated.

Mineralogy: plagioclase + quartz + biotite + amphibole + epidote.

ga *hornblende gabbro.* Grayish-green, coarse- to medium- grained, massive to foliated, with subophitic texture.

Mineralogy: amphibole + plagioclase + quartz + biotite + muscovite + epidote + magnetite.

Geophysical signature: positive magnetic anomaly.

grbi *biotite granite*. Light-gray, medium-grained, equigranular, broadly-layered, locally migmatitic, foliated.

Mineralogy: quartz + plagioclase + microcline + biotite + muscovite ± hornblende + apatite + zircon.

bgd *biotite granodiorite*. Light-gray, medium-grained, foliated.

Mineralogy: quartz + potassium feldspar + plagioclase + biotite + muscovite; accessory minerals include epidote, apatite, and opaque minerals.

grp *porphyritic granite*. Light-gray to pink, medium- to coarse-grained, coarse granular texture common; locally pegmatitic.

Mineralogy: quartz + porphyroblastic microcline + biotite + muscovite ± epidote ± titanite ± opaque minerals.

grt *metatonalite*. White to light-gray, medium- to coarse-grained, faintly foliated, locally porphyritic; ranges from granodiorite to quartz diorite.

Mineralogy: quartz + plagioclase + biotite + microcline.

This unit includes the Vance pluton of Horton and others (1993), dated at 571±17 Ma (U-Pb zircon; LeHuray, 1989).

ROCKS OF THE CENTRAL PIEDMONT

cm *polygenetic melange*. Pebbles, cobbles, and boulders of granite, gabbro, amphibolite, biotite gneiss, and quartzite in a polydeformed, mylonitic, schistose metagraywacke matrix. Includes interbedded garnetiferous meta-argillite, feldspathic metagraywacke conglomerate, and meta-arkose.

Mineralogy (matrix): quartz + plagioclase + biotite + epidote + apatite + titanite + muscovite ± garnet ± allanite.

This unit was named the Ca Ira melange by Marr (1991).

peg *granite pegmatite*. Typically leucocratic and coarse-grained; consists of lenticular bodies that are generally concordant with the regional foliation. Mineralogy includes microcline, albite, quartz, muscovite, biotite, garnet, and tourmaline.

um *ultramafic rocks*. Dark-greenish-gray, medium- to coarse-grained, talc-tremolite or actinolite-chlorite schist and granofels; and, locally, serpentinite.

Geophysical signature: small circular positive magnetic anomalies.

ga *gabbro, hornblendite, and norite*. Dark-gray to greenish-black, fine- to coarse-grained, massive to foliated metamorphosed mafic plutonic rocks.

Mineralogy: hornblende + biotite + plagioclase + quartz + magnetite + apatite; relict pyroxene is present locally.

Geophysical signature: circular positive magnetic anomalies.

bgr *Burkeville pluton.* Grayish-blue, fine- to medium-grained, massive to faintly foliated; composition ranges from granodiorite to monzonite.

Mineralogy: oligoclase + microcline + quartz + biotite + epidote + apatite + zircon.

Geophysical signature: diffuse pattern of negative magnetic and circular positive radiometric anomalies.

The pluton was originally referred to as the Burkeville granite (Husted, 1942), and is the “granite in the Burkeville granite quarry” of Steidtmann (1945); the pluton intrudes migmatitic paragneiss **(mpg)**.

fgb *biotite granite gneiss*. Light-gray, medium-grained, equigranular, broadly-layered, locally migmatitic.

Mineralogy: quartz + plagioclase + microcline + biotite + muscovite + hornblende; apatite and zircon are accessory minerals.

Geophysical signature: diffuse pattern of positive radiometric anomalies.

grpo *porphyritic granite*. Pink to white, medium- to very-
coarse-grained; mineralogy includes quartz, microcline porphyroblasts, plagioclase, muscovite, and minor biotite. This rock intrudes migmatitic paragneiss (mpg) southeast of Farmville Mesozoic basin.

amr *amphibolite and amphibole-bearing gneiss and schist*. Dark-gray to black, medium-grained, strongly foliated and lineated.

Mineralogy: hornblende + plagioclase + biotite + quartz + epidote; apatite, titanite, and magnetite are accessory minerals.

Geophysical signature: strike-elongate positive magnetic anomalies.

These rocks are interlayered with migmatitic paragneiss **(mpg)**.

bgs *biotite gneiss and schist*:. Dark-gray, medium-grained, foliated and broadly-layered.

Mineralogy: biotite + plagioclase + potassium feldspar + quartz + muscovite; accessory minerals include titanite, epidote, and opaque minerals.

ks *kyanite schist*. Light-gray to grayish-brown, medium- to coarse-grained, kyanite-quartz schist.

Mineralogy: quartz + kyanite + muscovite; accessory minerals include fuchsite, pyrite, rutile, and graphite.

fq *ferruginous quartzite*. Dark-reddish-brown, fine- to medium-grained, thinly-layered; composed of quartz, magnetite, and specular hematite; occurs as laterally persistent beds 1 to 10 meters thick.

Geophysical signature: narrow strike-elongate positive magnetic anomalies.

Quartzites are easily-mapped markers that outline map-scale structures.

bgp *porphyroblastic biotite gneiss*. Light-gray, medium-grained, segregation-layered gneiss, contains prominent potassium feldspar porphyroblasts.

Mineralogy: quartz + biotite + plagioclase + potassium feldspar + muscovite ± hornblende; accessory minerals include epidote, apatite, and opaque minerals.

mpg *migmatitic paragneiss*. Leucocratic to mesocratic, medium- to coarse-grained layered gneiss contains interlayered biotite-rich and quartzofeldspathic zones, locally migmatitic; includes lesser amounts of biotite schist, muscovite schist, and thin lenticular amphibolite bodies.

Mineralogy: biotite + muscovite + plagioclase + potassium feldspar + garnet ± hornblende.

ROCKS OF THE EASTERN PIEDMONT

Ppg *pegmatite* (Amelia district pegmatites). Leucocratic, coarsely crystalline pegmatite, occurs in discordant lens-shaped dikes and pods. Major minerals are quartz, microcline, albite, muscovite, garnet, and minor biotite; locally contains numerous rare and unusual accessory minerals (Pegau, 1932; Dietrich, 1990).

Biotite and muscovite from the pegmatites have yielded Rb-Sr ages ranging from about 261 to 289 Ma (Deuser and Herzog, 1962).

PMbi *Buggs Island pluton*. Light-gray, medium- to coarse-grained, massive to strongly foliated biotite-muscovite granite. The name first appears in the literature as the Buggs Island granite gneiss (Kish and Fullagar, 1978); those workers report an Rb-Sr whole-rock age of 314±16 Ma.

Sf *Falls Run Granite Gneiss* (Pavlides, 1980). Pink to white, coarse-grained, strongly-foliated; ranges from hornblende-biotite granite to monzonite gneiss.

Mineralogy: microcline + plagioclase + quartz + biotite + muscovite + hornblende; accessory minerals include apatite, epidote, titanite, and opaque minerals. Myrmekitic intergrowths are common.

The unit has been dated at 410 Ma (U-Pb zircon, and Rb-Sr whole-rock; Pavlides, and others, 1982). The gneiss intrudes the rocks of the Ta River Metamorphic Suite, the Holly Corner Gneiss, and porphyroblastic biotite gneiss **(Ymd)**.

PzYgr *granite gneiss* (Pavlides, 1990). Fine- to medium-grained, light-gray to white granite to tonalite gneiss; composed of biotite, oligoclase, quartz, and porphyroblastic microcline, with accessory muscovite, epidote, titanite, and magnetite; hornblende occurs locally within diffuse compositional layering. Inclusions of biotite gneiss and amphibolite are present locally. Unit occurs as irregular lenticular to tabular masses within porphyroblastic biotite gneiss **(Ymd)**.

PzYpm *quartzofeldspathic gneiss* (Bobyarchick and others, 1981). Light-gray, fine- to coarse-grained, foliated, layered muscovitie-bearing quartzofeldspathic gneiss; contains intercalated quartz-muscovite schist.

Mineralogy: quartz + plagioclase + microcline + garnet + muscovite + biotite.

Yms *muscovite schist and gneiss*. Light-gray to silvery-gray, medium-grained, strongly-foliated quartz-muscovite schist; occurs as discontinuous lenses within porphyroblastic garnet-biotite gneiss **(Ymd)**.

Ya *amphibolite, amphibole gneiss, and schist*. Melanocratic, fine- to coarse-grained, weakly to strongly foliated, irregularly layered amphibole-rich gneiss and schist.

Mineralogy: hornblende + clinopyroxene + plagioclase + magnetite + biotite ± scapolite ± garnet ± quartz ± epidote.

Geophysical signature: narrow, strike-elongate, positive magnetic anomaly.

Lenses and layers of amphibolite and amphibole gneiss are interlayered with porphyroblastic garnet-biotite gneiss **(Ymd)**. The mafic rocks constitute 50 percent or more of the section in a zone about 0.62 mile wide surrounding outcrop areas of State Farm gneiss **(Ysf)**; farther away from the State Farm contact, lenses and layers of amphibolite and amphibole gneiss are more widely scattered, but are laterally persistent and outline map-scale structures (Marr, 1985).

Amphibolite and interlayered biotite gneiss adjacent to the State Farm gneiss were named the Sabot amphibolite by Poland (1976), who characterized the formation as a tabular sheet 0.7 to 1.0 km thick. He and Goodwin (1970) interpreted these amphibolites as metamorphosed mafic volcanic or pyroclastic rocks. Glover and others (1989 and references therein) report a low-angle regional discordance between the base of the Sabot and the compositional layering in the underlying State Farm Gneiss.

Ymd *porphyroblastic garnet-biotite gneiss*. Heterogeneous layered sequence is dominantly garnetiferous biotite gneiss and porphyroblastic gneiss, migmatitic in part, with subordinate interlayered amphibolite and amphibole gneiss **(Ya)**, pelitic-composition gneiss, calcsilicate gneiss, biotite-hornblende-quartz-plagioclase gneiss, and garnetiferous leucogneiss. These lithologies contain amphibolite-facies metamorphic mineral assemblages consistent with rock chemistry. Farrar (1984) reports relict granulite-facies assemblages in some rocks.

This unit underlies a wide area that surrounds the State Farm antiform (Poland, 1976; Reilly, 1980; Farrar, 1984) and two subsidiary antiforms to the northeast; the unit includes the Maidens gneiss and portions of the Sabot amphibolite of Poland (1976), the eastern gneiss complex and Boscobel granodiorite gneiss of Bobyarchick (1976), and the Po River Metamorphic Suite of Pavlides (1980).

Poland (1976) and Reilly (1980) proposed that the Maidens gneiss and Sabot amphibolite were a Late Precambrian- to Early Paleozoic-age volcanic-sedimentary cover sequence unconformably overlying the State Farm gneiss. Farrar (1984) interpreted relict granulite-facies mineral assemblages to have equilibrated during Grenville-age regional metamorphism; this contributed to his conclusion that the Sabot and Maidens, in addition to the State Farm, are Grenville or pre-Grenville in age.

Porphyroblastic garnet-biotite gneiss **(Ymd)** is intruded by rocks of the Carboniferous-age Falmouth Intrusive Suite (Pavlides, 1980).

Yan *Montpelier metanorthosite* (Bice and Clement, 1982; Farrar, 1984). Metamorphosed anorthosite includes non-foliated extremely coarse-grained and foliated, recrystallized coarse-grained textural varieties. Primary mineralogy consists of antiperthitic plagioclase, clinopyroxene, apatite, and ilmenite. Amphibole, biotite, quartz, garnet, rutile, and titanite occur as later metamorphic minerals (Farrar, 1984). Xenoliths in the anorthosite could have been derived from the adjacent amphibolite and amphibole gneiss **(Ya)**, porphyroblastic garnet-biotite gneiss **(Ymd)**, and State Farm gneiss **(Ysf)**.

Geophysical signature: positive radiometric and negative magnetic anomalies.

Close geochemical similarities between the Montpelier and the Grenville-age Roseland anorthosite of the central Blue Ridge **(Yra)** have led to the hypothesis, as yet untested, that the Montpelier is Grenville in age (Clement and Bice, 1982; Farrar, 1984). This contributes to the case for assigning a Grenville or older age to the porphyroblastic garnet-biotite gneiss **(Ymd)** and amphibolite and amphibole gneiss units **(Ya)** which the anorthosite intrudes.

Ysf *State Farm Gneiss* (Brown, 1937). Leucocratic to mesocratic, medium- to coarse-grained, massive to moderately layered, locally migmatitic gneiss ranges in composition from granodiorite to tonalite. Quartzofeldspathic segregations and discordant pegmatites are common; leucocratic biotite-garnet-quartz-plagioclase gneiss, metagabbro, and thin pelitic schist interlayers are minor constituents (Poland, 1976; Reilly, 1980; Farrar, 1984).

Mineralogy: quartz + plagioclase + microcline + biotite + garnet + hornblende ± clinopyroxene; titanite is a ubiquitous accessory; other accessory minerals include magnetite and zircon. Farrar (1984) reports that the least deformed portions of the State Farm contain relict granulite-facies mineral assemblages.

Geophysical signature: characterized by negative magnetic and positive radiometric anomalies.

The age of the State Farm is reported as 1031±94 Ma (Rb-Sr whole-rock; Glover and others, 1982). The titanium-rich chemistry of the State Farm, as indicated by the abundance of titanite, is also characteristic of Grenville-age gneisses in the Virginia Blue Ridge.

fcm *Fine Creek Mills granite* (Poland, 1976; Reilly, 1980). Light-gray, medium- to coarse-grained, homogenous, foliated, ow-banded granite.

Mineralogy: microcline + plagioclase + quartz + biotite; accessory minerals include apatite, garnet, uorite, and zircon.

The Fine Creek Mills intrudes the State Farm Gneiss **(Ysf)**.

fr *Flat Rock granite* (Reilly, 1980). Light-gray, medium- to coarse-grained, homogenous, foliated granite.

Mineralogy: microcline + plagioclase + quartz + biotite; accessory minerals include garnet, apatite, uorite, and zircon.

The Flat Rock intrudes the State Farm Gneiss **(Ysf)**.

pgo *pegmatite* (Goochland pegmatite district of Pegau, 1932). Leucocratic, coarse- to very-coarse-grained granite pegmatite. Mineralogy includes microcline, albite, quartz, muscovite, biotite, garnet, tourmaline, sillimanite, and graphite; rutile, ilmenite, and zircon are present locally (Pegau, 1932). Pegmatite occurs as lenticular bodies intruding porphyroblastic garnet-biotite gneiss **(Ymd)**.

um *ultramafic rocks*. Gray to greenish-gray, medium- to coarse-grained, locally porphyroblastic chlorite-tremolite and tremolite-talc schist; occurs as pods and small plutons within porphyroblastic garnet-biotite gneiss **(Ymd)**.

ROCKS OF THE SOUTHEASTERN PIEDMONT

Mpg *Petersburg Granite*. Light- to dark-gray to pink, fine- to coarse-grained, equigranular to porphyritic, foliated to nonfoliated, ranges from granite to granodiorite in composition; multiple intrusive phases are present. The granite contains xenoliths of biotite gneiss and amphibolite.

Mineralogy: quartz + sodic plagioclase + potassium feldspar + biotite ± hornblende; accessory minerals include ilmenite, magnetite, pyrite, zircon, apatite, titanite, muscovite, and uorite (Goodwin, 1970; Daniels and Onuschak, 1974; Wright and others, 1975).

Current mapping restricts the Petersburg Granite to a contiguous unit that crops out in the Cities of Richmond and Petersburg; this roughly corresponds to one of four discrete plutons mapped as Petersburg Granite on the 1963 Geologic Map of Virginia. Samples from within this pluton were dated at 330±8 Ma (U-Pb zircon; Wright, and others, 1975). The northwestern edge of the pluton is mylonitized along the Hylas fault zone (Bobyarchick and Glover, 1979).

pbg *porphyroblastic granite gneiss:* Light-gray, medium- to coarse-grained, compositionally layered, well-foliated, commonly lineated gneiss composed of metamorphosed granite, leucogranite, and granodiorite, which locally contains feldspar megacrysts. This unit includes the granite at Lawrenceville; the rocks are variably mylonitic and lineated along the Lake Gordon mylonite zone near Kenbridge (Horton and others, 1993).

fg *gneissic granite and granodiorite*. Light-gray to white, fine- to medium-grained, massive to foliated, muscovite-biotite gneissic granite to granodiorite containing minor garnet, and xenoliths of biotite gneiss and amphibolite. Several different intrusive phases are present.

bmgl *biotite-muscovite granite*. Light-gray, fine- to coarse-grained, muscovite-biotite granite, biotite-muscovite granite, and leucogranite with accessory garnet. The granite is undated but interpreted as part of the Pennsylvanian-Permian suite of granites, and considered as part of the Wise pluton, which can be traced into North Carolina (McSween and others, 1991).

rbg *biotite gneiss*. Light-gray, medium- to coarse-grained, compositionally-layered and locally migmatitic rocks, include interlayered biotite gneiss, muscovite-biotite gneiss, muscovite-biotite schist, and sillimanite-mica schist; also includes minor interlayers and lenses of granitic gneiss, biotite-amphibole gneiss, amphibolite, garnet-mica schist, calc-silicate granofels, and rare ultramafic rocks. This unit correlates with Raleigh belt rocks in North Carolina (Parker, 1979; Geologic Map of North Carolina, 1985).

adg *altered diorite and gabbro*. Grayish-olive-green, medium-grained gabbro, hornblende gabbro, and diorite exhibit variable degrees of saussuritization and uralitization. The gabbros are commonly concordant with adjacent metavolcanic rocks.

g *granite*. Light-gray to pink, fine- to medium-grained granite and granodiorite; zoned plagioclase crystals with epidotized and saussuritized cores are characteristic. The granite contains xenoliths of mafic volcanic rocks near its margins.

The granite intrudes volcanic rocks east of the Hollister fault zone southeast of Petersburg. Samples from the quarry at Skippers were dated by Rb-Sr whole-rock methods (Bottino and Fullagar, 1968); these data show considerable scatter, implying age of crystallization ranging from 460 Ma to as old as 690 Ma. This unit was shown as Petersburg Granite on the 1963 Geologic Map of Virginia, but field relations, petrology, and the apparent age indicate that it is a separate pluton.

v *mafic and felsic metavolcanic rocks.* Heterogeneous layered metavolcanic sequence includes crystal and lithic tuff, dacite porphyry, chert, phyllite, and greenstone metabasalt; greenschist-facies metamorphic mineral assemblages occur in the various lithologies. This unit correlates with the Roanoke Rapids volcanogenic complex of the eastern slate belt in North Carolina (Farrar, 1985a, 1985b; Geologic Map of North Carolina, 1985; Horton and Stoddard, 1986). To the extent that correlation with lithologically similar Carolina slate belt rocks is valid, mafic and felsic metavolcanic rocks (v) are Late Proterozoic to Cambrian in age.

gns *gneiss and schist*. Includes graphite schist; garnet-staurolite-biotite-sericite schist containing kyanite, sillimanite, and less commonly muscovite; garnet-biotite gneiss; biotite-muscovite gneiss; phyllonite; and, mylonitic to ultramylonitic garnet-muscovite-biotite gneiss. This unit may correlate with biotite gneiss and schist (rbg), and with Raleigh belt rocks of North Carolina (Geologic Map of North Carolina, 1985; Stoddard and others, 1991 and references therein).

py *phyllonite*. Dominantly white to dark-gray metasedimentary rocks including quartz-chlorite-graphite phyllonite and button schist, and chiastolite-graphite phyllonite; includes mylonitic feldspathic sericite schist and quartz conglomerate, mafic and felsic metavolcanic rocks, mylonitic-ultramylonitic granite and biotite gneiss, and silicified brecciated mylonite. Shearing southeast of Lawrenceville was noted by Corbin (1989).

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MAPPED UNITS OF THE COASTAL PLAIN*

C. R. Berquist, Jr.

af *artificial fill.* Areas filled for waste disposal and construction

ALLUVIAL, SWAMP, INTERTIDAL, AND EOLIAN DEPOSITS

al *alluvium* (Holocene). Fine to coarse gravelly sand and sandy gravel, silt, and clay, light- to medium-gray and yellowish-gray. Deposited mainly in channel, point-bar, and ood-plain environments; includes sandy deposits of narrow estuarine beaches, and mud, muddy sand, and peat in swamps and in fresh- and brackish-water marshes bordering tidewater rivers. Grades into colluvium along steeper valley walls at margins of unit. Mostly Holocene but, locally, includes low-lying Pleistocene (?) terrace deposits. As much as 80 feet thick along major streams.

sp *swamp deposits* (Holocene). Reddish-brown fibrous peat, brown to black sapric peat, and peaty mud and sand. Constitutes fill of extensive, shallow, poorly drained Dismal Swamp basin southwest of Portsmouth. Radiocarbon ages from lower part of peaty fill indicate sediment accumulation began about 12,000 yrs B.P. (Otte and Smith, 1985). Thickness generally less than 10 feet.

sb *sand* (Holocene). Pale-gray to light-yellowish gray, fine to coarse, poorly sorted to well-sorted, shelly in part; contains angular to rounded fragments and whole valves of mollusks. Comprises deposits of coastal barrier islands and narrow beach-dune ridges bordering brackish-water marshes of Chesapeake Bay. Thickness is as much as 40 feet.

m *marsh and intertidal mud deposits* (Holocene). Medium- to dark-gray soft mud, and grayis-brown peat, comprising sediment of marshes in coastal areas and Chesapeake Bay; thickness is 0 to 10 feet. Also, sandy mud and muddy fine sand, light- to dark-gray. Locally, contains abundant shell material characterized by *Crassostrea virginica* and *Mercenaria mercenaria*. Comprises sediments of shallow bays and ats in area of Atlantic coastal lagoons of the Eastern Shore.

ds *dune sand* (Holocene). Sand, quartz, white to light-yellowish-gray, fine to medium, well-sorted, massive to cross-laminated. Comprises deposits of large, irregular dune fields on Nottoway River terraces and smaller areas of dunes in Surry County uplands. Thickness is 0 to 15 feet.

SURFICIAL DEPOSITS OF RIVERINE, ESTUARINE, AND COASTAL TERRACES AND PLAINS

Comprised of fining-upward and coarsening-upward sequences deposited mainly during interglacial high stands of the sea.

WEST AND SOUTH OF CHESAPEAKE BAY

QTu *Quaternary and Tertiary deposits*, undifferentiated. Tabb through Windsor Formations and alluvial/tidal prism deposits.

Qt *Tabb Formation, undifferentiated* (upper Pleistocene, Johnson, 1976). Sand, silt, and peat of coast-parallel plains seaward of the Suffolk and Harpersville scarps, includes coeval terrace deposits along major river valleys west to Fall Line. Subdivided into three members (Johnson, 1976).

Qtp *Poquoson Member* (Johnson, 1976). Medium to coarse, pebbly sand grades upward into clayey fine sand and silt, light- to medium-gray; underlies ridge and swale topography (altitude ranges from sea level to 11 feet) along the margin of Chesapeake Bay and in the lower and middle parts of Coastal Plain rivers. Thickness is 0 to 15 feet.

Qtl *Lynnhaven Member* (Johnson, 1976). Pebbly and cobbly, fine to coarse gray sand grades upward into clayey and silty fine sand and sandy silt; locally, at base of unit, medium to coarse cross-bedded sand and clayey silt containing abundant plant material fill channels cut into underlying stratigraphic units. Unit is surficial deposit of broad swale that is traceable southward from Norfolk; extensive lowlands bounded on landward side by river-, bay-, and ocean-facing scarps having toe altitudes of 15 to 18 feet. Thickness is 0 to 20 feet.

Qtlp *Lynnhaven and Poquoson Members, undifferentiated.*

Qts *Sedgefield Member* (Johnson, 1976). Pebbly to bouldery, clayey sand and fine to medium, shelly sand that grades upward into sandy and clayey silt; locally channel fill at base of unit includes as much as 50 feet of fine to coarse, cross-bedded sand and clayey silt and peat containing in-situ tree stumps. Sandy bay facies commonly contains *Crassostrea biostromes, Mercenaria, Anadara, Polynices, Ensis*, and other mollusks. Specimens of the coral *Astrangia* have yielded estimated uranium-series ages averaging 71,000 ± 7,000 yrs B.P. (Mixon and others, 1982). Unit constitutes surficial deposit to river- and coast-parallel plains (altitude 20-30 feet) bounded on landward side by Suffolk and Harpersville scarps. Thickness is 0 to 50 feet.

Qsh *Shirley Formation* (middle Pleistocene, Johnson and Berquist, 1989). Light- to dark-gray, bluish-gray and brown sand, gravel, silt, clay, and peat. Constitutes surficial deposits of riverine terraces and relict baymouth barriers and bay- oor plains (altitude 35-45 feet) inset below depositional surfaces of the Chuckatuck Formation (Johnson and Peebles, 1984). Upper part of unit is truncated on the east by the Suffolk and Harpersville scarps; locally, lower part occurs east and west of scarps. Fluvial-estuarine facies comprises (1) a lower pebble to boulder sand overlain by (2) fine to coarse sand interbedded with peat and clayey silt rich in organic material, including in-situ tree stumps and leaves and seeds of cypress, oak, and hickory, which grades upward to (3) medium- to thick-bedded, clayey and sandy silt and silty clay. Marginal-matrix facies in lower James River and lowermost Rappahannock River areas is

* (taken from Mixon and others, 1989, with minor modifications)

silty, fine-grained sand and sandy silt containing *Crassostrea virginica, Mulinia, Noetia, Mercenaria*, and other mollusks. *Astrangia* from lower Rappahannock River area has yielded a uranium-series age of 184,000 ± 20,000 yrs B.P. (Mixon and others, 1982). Thickness is 0 to 80 feet.

Qc *Chuckatuck Formation* (middle(?) Pleistocene, Johnson and Berquist, 1989). Light- to medium-gray, yellowish-orange, and reddish-brown sand, silt, and clay and minor amounts of dark-brown and brownish-black peat. Comprises surficial deposits of mid-level coast-parallel plains (altitude 50-60 feet) and equivalent riverine terraces. Eastward, unit is truncated by the Suffolk scarp; westward, along major stream drainages, unit is separated from the younger topographically lower Shirley Formation by the Kingsmill scarp and equivalent estuarine scarps. Fluvial-estuarine facies includes, from bottom to top, (1) channel-fill deposits of poorly sorted, cross-bedded, pebbly and cobbly sand interbedded, locally, with peat and sandy silt rich in organic matter, (2) moderately well-sorted, cross-bedded to planar bedded, fine- to medium-grained sand grading upward into (3) clayey silt and sandy and silty clay. Bay facies of coastwise plain includes a basal gravelly sand filling shallow paleochannels, a thin but extensive pebbly sand containing heavy mineral laminae and *Ophiomorpha* burrows, and an upper, relatively thick, medium- to fine-grained silty sand and sandy silt. Thickness is 0 to 26 feet.

Qcc *Charles City Formation* (lower Pleistocene (?), Johnson and Berquist, 1989). Light- to medium-gray and light-to dark-yellowish and reddish-brown sand, silt, and clay composing surficial deposits of riverine terraces and coast-parallel plains at altitiudes of 70 to 80 feet. Unit is adjacent to, and inset below, the Windsor Formation and older deposits. Bay or shallow-shelf facies of the Charles City (Johnson and Peebles, 1984), present beneath at to gently seaward-sloping plain in Suffolk area, includes a thin, basal, gravelly sand grading upward into fine- to medium-grained sand and an uppermost clayey and sandy silt; lower and middle parts of unit contain clay-lined, sand-filled burrows. Fluvial-estuarine facies in terrace remnants along major rivers consists of cross-bedded gravelly sand and clayey silt. Thickness is 0 to 55 feet, or more.

QTw *Windsor Formation* (lower Pleistocene or upper Pliocene, Coch, 1968). Gray and yellowish- to reddish-brown sand, gravel, silt, and clay. Constitutes surficial deposits of extensive plain (altitude 85-95 feet.) seaward of Surry scarp and of coeval, uvial-estuarine terraces west of scarp. Fining-upward sequence beneath plain consists of a basal pebbly sand grading upward into cross-bedded, quartzose sand and massive, clayey silt and silty clay; lower and upper parts of sequence were deposited, respectively, in shallow-marine or open-bay and restricted-bay or lagoonal environments. In terraces west of Surry scarp, uvial-estuarine deposits comprise muddy, coarse, trough cross-bedded sand and gravel grading upward to sandy silt and clay. Thickness is 0 to 40 feet.

EAST OF CHESAPEAKE BAY

Qk *Kent Island Formation* (upper Pleistocene, Owens and Denny, 1979). Pale-gray to yellowish-gray, medium to coarse sand and sandy gravel grading upward into poorly to well-sorted, fine to medium sand, in part clayey and silty. Unit is a surficial deposit of broad, bayward-sloping lowland (altitude ranges from sea level to about 20 feet) bordering east side of Chesapeake Bay. Thickness ranges from a feather-edge at scarp along eastern edge of lowland to about 40 feet in downdip areas.

Qwa *Wachapreague Formation* (upper Pleistocene, Mixon, 1985). Coarsening upward sequence, includes a lower member of clayey and silty, fine to very-fine, gray sand interbedded with clay-silt and an upper member of medium to coarse, gravelly sand. Mollusks, including *Mesodesma arctatum* and *Siliqua costata*, and ostracode assemblages dominated by *Elofsonella concinna* and *Muellerina canadensis* indicate cooling ocean temperatures during deposition of unit. Pollen assemblage dominated by pine, spruce, birch, and alder suggests cool- to cold-temperate conditions in nearby land areas. Unit is surficial deposit of narrow, arcuate coastal lowland ranging in altitiude from sea level, at eastern border with Holocene barrier-lagoon complex, to about 15 feet at toe of ocean-facing scarp forming western boundary. Thickness is 0 to 40 feet..

Nassawadox Formation (upper Pleistocene, Mixon, 1985). Surficial sandy and gravelly deposits of a narrow, at upland and adjacent bay-side terrace in Northampton and southernmost Accomack Counties.

Qno *Occohannock Member* (Mixon, 1985). Light-yellowish-gray, fine to medium sand underlying southwest-sloping terrace (altitude 30-18 feet) on west side of upland. Sand is dominantly massive to horizontally bedded, but shows some small-scale cross-bedding; locally contains clay and silt as matrix and thin beds. Unit was deposited in a low-energy, open-bay environment. Thickness ranges from a featheredge near bay-facing scarp along western margin of upland to 20 feet in downdip areas near present bay.

Qnb *Butlers Bluff Member* (Mixon, 1985). Pale-gray to light-yellowish-gray, fine to coarse, cross-bedded, pebbly sand and sandy gravel comprising surficial deposits of upland (altitude 35-40 feet.). Diverse molluscan assemblage in lower part of unit, including *Marginella, Mulinia, Nassarius, Spisula, Pleuromeris,* and *Olivella*, indicates a shallow, nearshore-shelf depositional environment. Unit was deposited as a southward-building complex of spit-platform sands and shallow shoals and is as much as 60 feet in thickness. In subsurface, unit overlies 140 feet, or more, of pebbly to cobbly sand, clay-silt, and muddy fine-grained sand of the Stumptown Member of the Nassawadox Formation, which fills a late Pleistocene paleochannel of the Susquehanna River system.

Qj *Joynes Neck Sand* (upper Pleistocene, Mixon, 1985)). Yellowish-gray, fine to coarse sand coarsening downward to gravelly sand and sandy gravel. Cross-lamination in finer-grained sands accentuated by black, heavy minerals. Unit was deposited in nearshore-shelf depositional environment; constitutes surficial deposit of coast-parallel terrace (altitude 23-26 feet) on eastern side of upland in Accomack County. Thickness ranges from 0 to 30 feet.

Qoa *Accomack Member of Omar Formation* (middle Pleistocene, Mixon, 1985). Light-to dark-gray, light-yellowish-gray, brownish-gray, and yellowish-orange sand, gravel, silt, clay, and peat of southwest-trending central upland (altitude 38-50 feet) in Accomack County. Upper part of unit is bounded on east and west by ocean- and bay-facing scarps; lower part present in subsurface of adjacent lowland areas where it is overlain unconformably by Upper Pleistocene and Holocene deposits. In northern part of county, unit is a barrier-backbarrier sequence of clean, cross-bedded, gravelly sand (above) and peat, clayey silt, and muddy sand (below); mollusks include *Crassostrea, Mercenaria,* and *Noetia*. In southern part of county, fine to coarse, trough cross-bedded sands of barrier-spit origin overlie fine- to very-fine-grained, muddy, nearshore-shelf sand containing *Spisula, Ensis, Anomia*, and *Mulinia*. At base of unit, pebbly to bouldery, medium- to very-coarse-grained sand and thick, compact clay-silts constitute the uvial-estuarine fill of a paleochannel of the Susquehanna River system. Accomack Member and underlying channel fill are as much as 200 feet, or more, in thickness.

MARINE, MARGINAL-MARINE, AND FLUVIAL-DELTAIC DEPOSITS OF TERTIARY AND CRETACEOUS AGE

Tm *Moorings unit* of Oaks and Coch (1973) (upper Pliocene). White, light-gray, and grayish-yellow quartzose sand and gray to grayish-brown clayey silt and silty clay. Constitutes discontinuous linear body along and just west of the Surry scarp; depositional surfaces range in altitiude from 130 feet along slightly higher, ridge-like topography at scarp to about 110 feet west of scarp. Eastern facies of unit is unfossiliferous, massive to cross-laminated, moderately well-sorted, fine sand believed to have been deposited in beach and near-shore environments. Upper part of fine sand facies interfingers westward with massive, bioturbated clay and silt deposited in a lagoon or shallow bay. Thickness is as much as 30 feet.

Tb^1 / Tb^2 *Bacons Castle Formation* (upper Pliocene, Coch, 1965). Gray, yellowish-orange, and reddish-brown sand, gravel, silt, and clay; constitutes surficial deposits of high plain extending from Richmond, eastward to the Surry scarp. Unit is subdivided into two members: Tb^1, massive to thick-bedded pebble and cobble gravel grading upward into cross-bedded, pebbly sand and sandy and clayey silt, and Tb^2, predominantly thin-bedded and laminated clayey silt and silty fine-grained sand. Tb^2 is characterized by aser, wavy, and lenticular bedding and rare to common clay-lined burrows including *Ophiomorpha nodosa*. Thickness is 0 to 70 feet.

Tc *Chesapeake Group* (upper Pliocene to lower Miocene,Darton, 1891). Fine-to coarse-grained, quartzose sand, silt, and clay; variably shelly and diatomaceous, deposited mainly in shallow, inner- and middle-shelf waters. Ages of units based on studies of foraminiferal, nannofossil, diatom, and molluscan assemblages in Virginia and adjacent states (Andrews, 1988; Gibson, 1983; Gibson and others, 1980; Poag, 1989; Ward and Blackwelder, 1980; Ward and Krafft, 1984). Includes the following formations, from youngest to oldest:

Chowan River Formation (upper Pliocene, Blackwelder, 1981). Gray to dusky-blue-green sand, fine- to medium-grained, clayey and silty, commonly very shelly; grades laterally into laminated, silty clay and upward into cross-bedded, biofragmental sand, clayey silt, and silty clay. Discontinuous pebbly to bouldery sand at very irregular base of unit. Mollusks include *Glycymeris hummi, Noetia carolinensis*, and *Carolinapecten eboreus bertiensis*. Thickness is 0 to 50 feet. Recognized only in southeasternmost Virginia and North Carolina.

Yorktown Formation (lower upper Pliocene to lower Pliocene, Clark and Miller, 1906). Bluish-gray and brownish-yellow sand, fine- to coarse-grained, in part glauconitic and phosphatic, commonly very shelly, interbedded with sandy and silty blue-gray clay. In lower York and James River basins, unit includes cross-bedded shell hash. Mollusks include *Glycymeris subovata, Chesapecten jeffersonius, Chesapecten madisonius, Mercenaria tridacnoides, Panopea reflexa*. Coarse-grained sand and gravel facies of the Yorktown in updip areas is mapped separately as unit psg. Thickness is 0 to 150 feet.

Eastover Formation (upper Miocene, Ward and Blackwelder, 1980). Dark-gray to bluish-gray, muddy sand, very fine to fine, micaceous, interbedded with sandy silt and clay. Lower part of unit is dominantly medium- to very-thin-bedded and laminated silt and clay interbedded with very-fine sand, lenticular and wavy bedding common; upper part is mainly very-fine- to fine-grained sand containing abundant clay laminae. Typical mollusks include *Chesapecten middlesexensis, Marvacrassatella surryensis, Glossus fraterna*. Thickness is 0 to 270 feet.

St. Marys Formation (upper and middle Miocene, Shattuck, 1902). Bluish- to pinkish-gray, muddy, very-fine sand and sandy clay-silt, locally abundantly shelly. *Chesapecten santamaria, Buccinofusus parilis*, and *Ecphora gardnerae* are characteristic mollusks. Occurs northeast of Mattaponi River. Thickness is 0 to 40 feet.

Choptank Formation (middle Miocene, Shattuck, 1902). Olive-gray sand, fine to very-fine, clayey and silty, shelly, and diatomaceous clay-silt; commonly forms fining-upward sequences. Mollusks include *Chesapecten nefrens, Mercenaria cuneata, Ecphora meganae*. Thickness is 0 to 50 feet.

Calvert Formation (middle and lower Miocene, Shattuck, 1902). Commonly consists of 2 to 7 fining-upward sequences. Each sequence includes a light- to dark-olive-gray basal sand, very fine to fine, clayey and silty, very sparsely to abundantly shelly; grades upward to sandy, diatomaceous clay-silt and diatomite. Typical molluscs include *Chesapecten coccymelus, Crassatella melinus, Ecphora tricostata*. Thickness is 0 to 600 feet.

psg *Pliocene sand and gravel*. Interbedded yellowish-orange to reddish-brown gravelly sand, sandy gravel, and fine to coarse sand, poorly to well-sorted, cross-bedded in part, includes lesser amounts of clay and silt in thin to medium beds. Commonly caps drainage divides (altitude 250-170 feet) in western part of Coastal Plain. Lower part of unit, showing aser and lenticular bedding and containing rare to abundant *Ophiomorpha nodosa,* represents deposition in marginal-marine environments and is, in part, a nearshore equivalent of the more downdip, marine facies of the Yorktown Formation. In the northern part of the Coastal Plain, the more poorly sorted and less cleanly washed upper part of unit, which lacks fossils, comprises uvial-deltaic sediments that prograded eastward across the shelf during a regressive phase of the Yorktown. To the south, the upper part of unit is massively bedded clayey sand in places containing heavy mineral concentrations that average 8 percent or more; the sands are nearshore, beach and dune origin; interstitial clay was derived, in part, from in-situ weathering of feldspar sand. Thickness is 0 to 50 feet.

msg *Miocene sand and gravel*. Fine- to coarse-grained sand, sandy gravel, silt, and clay, gray to light-yellowish-gray, commonly oxidized to yellowish-orange and yellowish-brown; pebbles and cobbles are deeply etched. Commonly caps inter uves at northwestern edge of Coastal Plain and constitutes thin Coastal Plain outliers in easternmost Piedmont where deposits directly overlie weathered crystalline rocks. In part, may represent a uvial to marginal-marine facies of the Choptank Formation. Thickness is 0 to 30 feet.

td *terrace deposits, undifferentiated*. Poorly sorted clay, sand, and rounded pebbles and cobbles; deeply weathered.

Tl *Lower Tertiary deposits* (Oligocene, Eocene, and Paleocene). Mostly fine- to coarse-grained glauconitic quartz sand and clay-silt, shelly in part; includes lesser amounts of sandy limestone and limey sand. In outcrop, unit comprises the Pamunkey Group (Brightseat, Aquia, Marlboro, Nanjemoy, and Piney Point Formations) and the Old Church Formation. In subsurface, unit includes Eocene and Oligocene strata not included in the Pamunkey and Old Church. Ages of formational units based on foraminiferal, nannofossil, dinocyst, pollen, and molluscan studies (Frederiksen, 1979; Gibson and others, 1980; Gibson and Bybell, 1984; Edwards, 1984, 1989; Edwards and others, 1984; Poag, 1989; Ward, 1985; Ward and Krafft, 1984). Stratigraphic sections vary widely, comprising one or more of the following formations:

Old Church Formation (Ward, 1985) and unnamed glauconitic sands (upper Oligocene). In inner and middle Coastal Plain, unit is 0 to 5 feet of olive-gray, fine- to coarse-grained, shelly, very sparsely glauconitic quartz sand of the Old Church Formation; typical fossils include *Anomia ruffini, Lucina sp.,* and *Mercenaria capax*. In subsurface of outer Coastal Plain, unit includes about 45 feet of dark-olive-gray to greenish-black glauconite sand with lesser amounts of quartz; sand has olive-brown clay-silt matrix.

Lower Oligocene beds. Olive-gray to grayish-olive sand, very-fine-grained, clayey and silty, micaceous, glauconitic; coarsens upward to a very-fine- to fine-grained sand. Unit is 0 to 50 feet thick; identified only in subsurface of Eastern Shore area (Exmore, core hole, R. B. Mixon and D. S. Powars, personal communication).

Chickahominy Formation (upper Eocene, Cushman and Cederstrom, 1945). Predominantly olive-gray clayey silt and silty clay, very compact, glauconitic, micaceous, contains abundant finely crystalline iron sulfide. Coarsens downward to a very-fine- to fine-grained sand, pebbles at base. Rare fragmental shell, microfossils very abundant. Thickness is 0 to 100 feet; present in subsurface of southeastern Virginia.

Piney Point Formation (middle Eocene, Otton, 1955). Olive-gray and grayish-olive-green, glauconitic quartz sand, medium-to coarse-grained, poorly sorted, contains scattered quartz pebbles, interbedded with carbonate-cemented sand and moldic limestone. Unit is characterized by large, calcitic shells of the oyster *Cubitostrea sellaeformis*, a middle Eocene marker. Aragonitic mollusks are generally leached, leaving only molds and casts. Thickness is 0 to 60 feet.

Nanjemoy Formation (lower Eocene, Clark and Martin, 1901). Dark-olive-gray, greenish-gray, and olive-black glauconitic quartz sand, fine- to coarse-grained, very clayey and silty, intensely burrowed, sparsely to abundantly shelly, interbedded with sandy clay-silt. Sand in upper part of unit is less clayey, very micaceous, and contains scattered quartz pebbles. Typical mollusks include *Venericardia potapacoensis, Venericardia ascia*, and *Macrocallista subimpressa*. Unit is 0 to 140 feet thick.

Marlboro Clay (lower Eocene (?) and upper Paleocene, Clark and Martin, 1901). Light-gray, pinkish-gray, and reddish-brown kaolinitic clay, massively bedded to laminated, interbedded with lesser amounts of laminated and ripple cross-laminated silt and very-fine-grained sand. Contains rare molds of small mollusks and arenaceous foraminifera. Thickness is 0 to 30 feet.

Aquia Formation (upper Paleocene, Clark and Martin, 1901). Light- to dark-olive gray, glauconitic quartz sand, fine- to coarse-grained, clayey and silty, thick- to massively bedded, sparsely to abundantly shelly. Lower part of unit is more poorly sorted and more calcarious than upper part and contains a few thin to medium beds of olive-gray, white, and pale greenish-yellow limestone. Upper part of unit is moderately well sorted and characterized by thin beds of the large, high-spired gastropod *Turritella mortoni*. Other common mollusks include *Cucullaea gigantea, Ostrea sinuosa*, and *Crassatellites alaeformis*. Thickness is 0 to 130 feet.

Brightseat Formation (lower Paleocene, Bennett and Collins, 1952). Olive-gray to olive-black, micaceous quartz sand, fine- to very fine-grained, clayey and silty, variably glauconitic. Thickness is 0 to 20 feet.

Kp *Potomac Formation* (Lower and Upper(?) Cretaceous, McGee, 1886). Light-gray to pinkish- and greenish-gray quartzo-feldspathic sand, fine- to coarse-grained, pebbly, poorly sorted, commonly thick-bedded and trough cross-bedded. Sand is interbedded with gray to green, massive to thick-bedded sandy clay and silt, commonly mottled red or reddish-brown. Includes lesser amounts of clay-clast conglomerate and thin-bedded to laminated, carbonaceous clay and silt. In the inner Coastal Plain, unit was deposited mainly in uvial-deltaic environments, intertongues eastward with thin glauconitic sands of shallow-shelf origin. Spore and pollen assemblages and leaf impressions of ferns and cycads indicate an Early Cretaceous age (Doyle and Robbins, 1977). In some downdip areas, uppermost part of unit may be of earliest Late Cretaceous age. Thickness ranges from a featheredge at western limit of outcrop to more than 3500 feet in subsurface of outermost Coastal Plain

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MAPPED UNITS OF THE MESOZOIC BASINS

G.P. Wilkes

INTRUSIVE IGNEOUS ROCKS

d *diabase* (Lower Jurassic). Fine- to coarsely-crystalline, subaphanitic or porphyritic with aphanitic margins; dark-gray mosaic of plagioclase laths and clinopyroxene, with some masses characterized by olivine or bronzite, others granophyric. Also occurs as dikes and sills in the Valley and Ridge, Piedmont, and Blue Ridge physiographic provinces.

NEWARK SUPERGROUP (LOWER JURASSIC)

EXTRUSIVE IGNEOUS ROCKS

jb *basalt* . Fine- to medium-crystalline, equigranular, porphyritic, vesicular, or amygdaloidal; medium- to dark-gray subophitic intergrowths of plagioclase laths and clinopyroxene with amygdules of calcite, zeolites, and prehnite. Occurs only in the Culpeper basin as three principle basalt ows separated by sedimentary rocks.

SEDIMENTARY ROCKS

jc *conglomerate*. Rounded pebbles, cobbles, and boulders of quartz, gneiss, schist, basalt, minor greenstone, and marble in a matrix of medium- to very-coarse-grained, reddish-brown to light-gray sandstone. Occurs only in the Culpeper basin.

jss *sandstone and siltstone*. Interbedded fine- to coarse-grained, pebbly, reddish-brown, and arkosic sandstone and reddish-brown siltstone; rhythmically interbedded with siltstone and shale unit **(sh)**. Occurs only in the Culpeper basin.

jsh *siltstone and shale*. Interbedded reddish-brown siltstone and reddish-brown, greenish-gray, dark-gray, fossiliferous shale. Occurs only in the Culpeper basin.

NEWARK SUPERGROUP (UPPER TRIASSIC)

c *conglomerate, mixed clasts*. Rounded to subangular pebbles, cobbles, and boulders of mixed lithologies including quartz, phyllite, quartzite, gneiss, schist, greenstone, and marble in a matrix of medium- to very-coarse-grained, reddish-brown to gray, locally arkosic, sandstone.

c^1 *conglomerate, carbonate clasts*. Rounded to subrounded pebbles, cobbles, and boulders of predominantly Cambrian and Ordovician limestone and dolostone in a matrix of fine- to coarse-grained, calcite-cemented, light-gray, silty sandstone. Occurs only in the Culpeper basin.

c^2 *conglomerate, greenstone clasts*. Rounded to subrounded pebbles, cobbles, and boulders of predominantly metavolcanic
Catoctin greenstone in a matrix of fine- to coarse-grained, silicified, ferruginous-cemented, greenish-gray to dark-green, clayey sandstone.

c^3 *conglomerate, arkosic*. Round to subround pebbles, cobbles, and boulders of mixed lithologies in a matrix of medium- to very-coarse-grained arkosic sandstone.

br *breccia, mixed clasts*. Angular to subangular pebbles, cobbles, and boulders of mixed lithologies in a reddish-brown matrix of indurated medium- to coarse-grained sandstone.

br^1 *breccia, mudstone clasts*. Angular to subangular pebbles and cobbles of predominantly mudstone in a siliceous cemented sandstone. Occurs only in the Scottsville basin.

s *sandstone, undifferentiated*. Fine- to coarse-grained, reddish-brown to gray, primary bedding features such as cross beds, channel lags, and ripple marks , minor conglomerate, siltstone, and shale beds.

s^1 *sandstone, arkosic*. Light-gray to light-reddish-brown, medium- to coarse-grained, micaceous.

ss *sandstone, siltstone, and shale, interbedded*. Sandstone, very fine- to course-grained, reddish-brown to gray, micaceous, minor conglomerate beds. Siltstone, reddish-brown to gray, micaceous. Shale, reddish-brown, greenish-gray, gray, yellowish-brown, laminated, fossiliferous. Upward-fining sequences, discontinuous vertically and horizontally.

cs *sandstone, siltstone, shale, and coal, interbedded.* Sandstone, fine-to coarse-grained, reddish-brown to gray, arkosic in places, micaceous, displays channel-type primary features. Siltstone light- to dark-gray, micaceous. Shale, light- to dark-gray, carbonaceous, micaceous, fossiliferous. Coal, bituminous, banded, moderate- to well-developed, fine- to medium-cleat, partings and inclusions of shale, siltstone, and sandstone; high methane concentrations recorded in the Richmond and Taylorsville basins. This lithologic unit occurs in the Richmond, Taylorsville, Farmville, Briery Creek, and Danville basins.

sh *shale and siltstone, interbedded*. Shale, light-greenish gray, light- to dark-gray, carbonaceous, and reddish-brown in cyclic sequences, laminated, silty to sandy, fossiliferous. Siltstone, typically reddish-brown to gray, sandy, micaceous, with minor fine-grained sandstone beds.

DISCUSSION

Mesozoic sedimentary and igneous rocks in Virginia are exposed in the Valley and Ridge, Blue Ridge, and Piedmont physiographic provinces and occur beneath the Cretaceous sedimentary cover of the Coastal Plain and Atlantic Shelf.

The most common Mesozoic igneous rock is diabase, which occurs as dikes and sills intruding the country rock from the Blue Ridge to the eastern edge of the Piedmont. The dikes vary in width and generally trend northwest or north-south.

Dikes of uncertain age occur in the Valley and Ridge,most notably in Augusta, Rockingham, Highland, and Bath counties (Johnson and others, 1971). Butts (1940) ascribed the timing of igneous injection to the Triassic, and two dikes in Augusta County have been K-Ar and Rb-Sr dated to ages corresponding to the Jurassic (Fullagar and Bottino, 1971). Some are reportedly Tertiary in age.

Extrusive igneous rocks occur only in the Culpeper basin as three primary basalt ows. The base of the lowest ow is near the Triassic-Jurassic boundary (Lee and Froelich, 1989).

The Mesozoic sedimentary rocks in Virginia are continental in origin and are confined to disjointed depositional basins. These basins are aligned in a northeast-southwest orientation, both in the Piedmont Province and beneath Coastal Plain and Atlantic Shelf sediments. The basins are part of a sequence of northeast-trending, sediment-filled grabens and half-grabens, all of early Mesozoic age, that lie along the east coast of North America from Georgia to Nova Scotia that are known as the Newark rift system. Virginia's exposed basins occur in three belts: western, central, and eastern. The western belt is parallel to the western edge of the Piedmont Province and is comprised of the Danville, Scottsville, Burnley, Barboursville, and Culpeper basins. The central belt consists of the Farmville, Briery Creek, Roanoke Creek, Randolph, and Scottsburg basins. The eastern belt, parallels the eastern edge of the Piedmont province and includes the Taylorsville, Deep Run, and Richmond basins.

All exposed Mesozoic sedimentary rocks in Virginia have been categorized as belonging to the Newark Supergroup (Redfield, 1856; Olsen, 1978; Froelich and Olsen, 1984). Formational stratigraphy has been defined for the Richmond basin (Shaler and Woodworth, 1899), Taylorsville basin (Weems, 1980), Danville basin (Thayer, 1970, 1980) and Culpeper- Barboursville- Burnley basins (Lee and Froelich, 1989). Luttrell (1989) correlates these basins with other basins of the Newark rift system where formational stratigraphy has been described. The remainder of Virginia's basins have been stratigraphically defined solely on local lithologic descriptions.

To the east of the Fall Line, several basins occur beneath the Cretaceous sedimentary units of the Coastal Plain (Wilkes and others, 1989; Benson, 1992). Because these "buried" basins are poorly understood as to lithology, origin, and age, they are not part of the Newark Supergroup (Froelich and Olsen, 1984) although they are considered to be of Mesozoic age.

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Appendix: Maps Used in the Compilation of the Geologic Map of Virginia

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Index I: Symbols Used on the Geologic Map of Virginia

Z

Index II: Names Used on the Geologic Map of Virginia

Symbols **Page**

A

B

C

D

E

F

G

H

I

J

K

L

M

N

O

P

Q

R

S

T

U

V

W

Y