VIRGINIA DIVISION OF MINERAL RESOURCES PUBLICATION 59

GEOLOGY OF THE SOUTHWESTERN VIRGINIA PIEDMONT

James F. Conley

COMMONWEALTH OF VIRGINIA

DEPARTMENT OF MINES, MINERALS AND ENERGY
DIVISION OF MINERAL RESOURCES
Robert C. Milici, Commissioner of Mineral Resources and State Geologist

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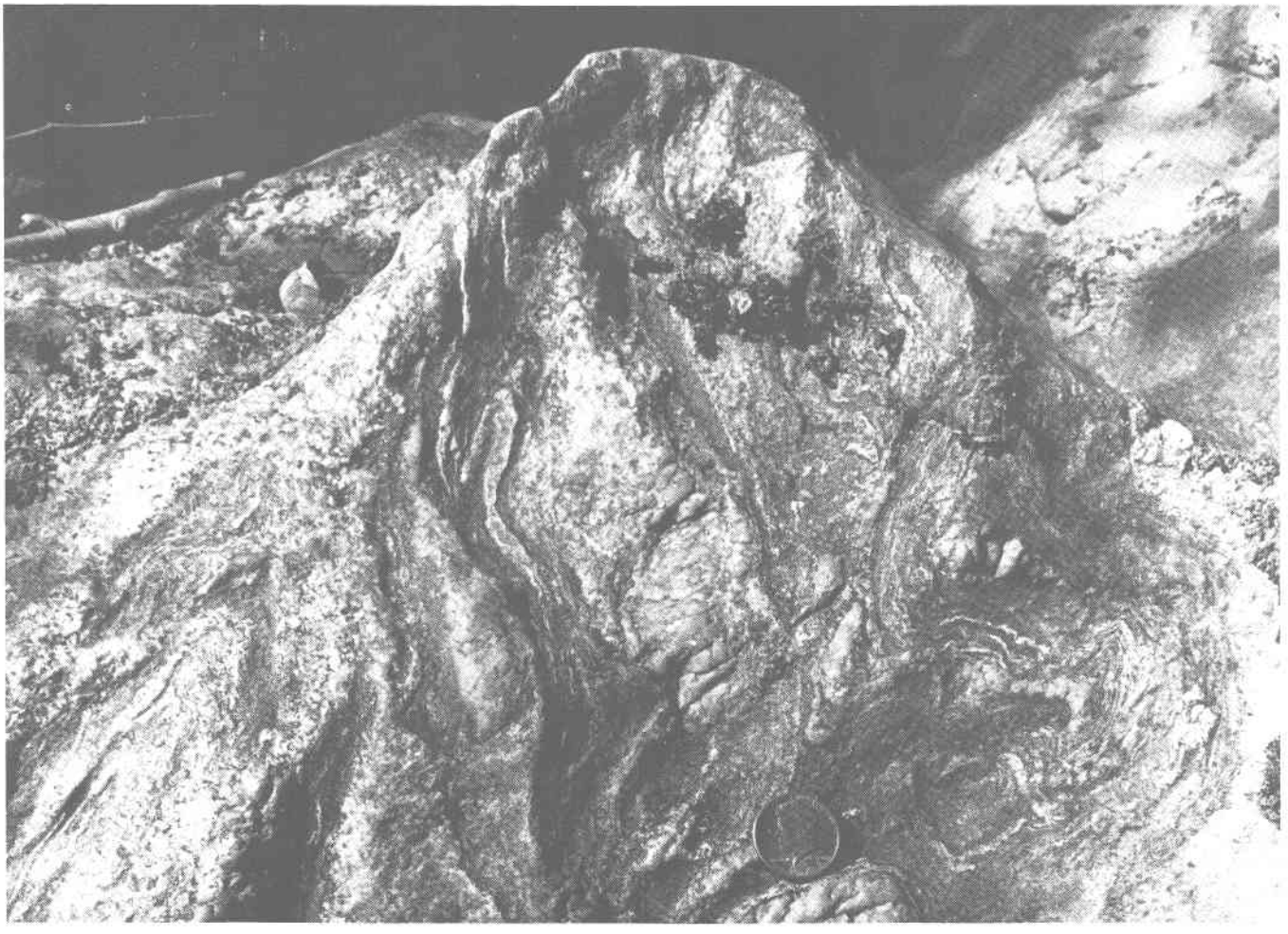

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FRONT COVER: Polydeformed gneiss from the Fork Mountain Formation near Fieldale, Henry County.

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DEPARTMENT OF MINES,
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1985

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GEOLOGY OF THE SOUTHWESTERN VIRGINIA PIEDMONT

James F. Conley

ABSTRACT

The area discussed in this report has a somewhat rectangular shape and is located in the southwestern Virginia Piedmont. It comprises 31 7.5-minute quadrangles and is the largest area in the Piedmont of Virginia geologically mapped at 1:24,000 scale. The geology of this region is naturally subdivided into five distinct areas that are generally separated from each other by either normal or thrust faults. These areas are: the Blue Ridge anticlinorium, the Smith River allochthon, the Sauratown Mountains anticlinorium, the Danville Triassic basin, and the central Virginia volcanic-plutonic belt. Individual units that underlie each of these areas are described and stratigraphic relationships are discussed. Normal and thrust faults which bound the five areas, and folding which has occurred within each area are described. The stratigraphy and structure of the southwestern Piedmont are reinterpreted because it was found that rocks previously thought to be part of the Evington Group on the southeast limb of the "James River synclinorium" are actually part of the Smith River allochthon. In addition, new stratigraphic relationships are reported for the southwestern part of the "James River synclinorium."

INTRODUCTION

The area discussed in this report is in the southwestern Virginia Piedmont and covers a somewhat rectangular area about 48 miles in an east-west direction by approximately 32 miles in a north-south direction and comprises 31 7.5-minute quadrangles (Figure 1). This group of quadrangles forms the largest geologically mapped area at a scale of 1:24,000 in the Virginia Piedmont, and it is one of the largest areas, if not the largest area, mapped in this detail in the Piedmont of the southeastern U.S.

Field mapping of individual 7.5-minute quadrangles was begun in 1966 and was continued to 1979. During this time many ideas both about the regional geology and about the interpretation of the local geology have changed, and many previous concepts have been slightly to drastically modified as new data became available. This report is an attempt to unify the geologic mapping of various people who have worked on this project and to update the interpretations of the geology and show the importance in these interpretations to the regional geology of the Piedmont and Blue Ridge provinces in southeastern U.S. The compiled map includes locations of mines and mineral deposits (Plate).

The area is wholly contained within the Inner Piedmont physiographic province (Fenneman, 1938) and is situated about 10 miles southeast of the Blue Ridge escarpment. The land surface is a well dissected rolling terrain. The northwestern half of the area is more rugged than other parts of the area and contains monadnocks typical of the Inner Piedmont.

The area is contained within parts of Patrick, Henry, Franklin, and Pittsylvania counties. The south-central and western parts of the area are drained by the Smith River and its tributaries; the southeastern part of the area is drained by the Dan River and its tributaries, and the north-central and northwestern parts of the area are drained by the Pigg River and its tributaries. The largest cities in the area are Bassett, Danville, Martinsville, and Rocky Mount. The area is served by U. S. highways 29, 58, 220, and 360; by State highways 40, 41, 57, and 87 and by a network of State roads. The area is served by three lines of the Norfolk and Southern Railway System. One of these lines connects Roanoke with Martinsville and other points to the south; the second connects Lynchburg and with Danville and points southward, and the third line connects Martinsville with Danville and points eastward.

Red and yellow podzolic soils (Hunt, 1972) are developed on the rocks of the region. A characteristic of these soils is the development of a deep saprolite forming the C soil-horizon. In areas underlain by rocks that are susceptible to chemical weathering (especially quartzo-feldspathic gneisses of this region), the saprolite is as much as 150 feet (45 m) thick. Mica schists, which are extremely resistant to chemical weathering, develop very shallow soils and subsoils. They underlie upland and mountainous terrains. Gneisses and gabbroic rocks decompose readily under chemical weathering. They produce deep saprolites and underlie relatively flat-bottomed basins and lowlands. In contrast metabasalts, amphibolites, diabase, and

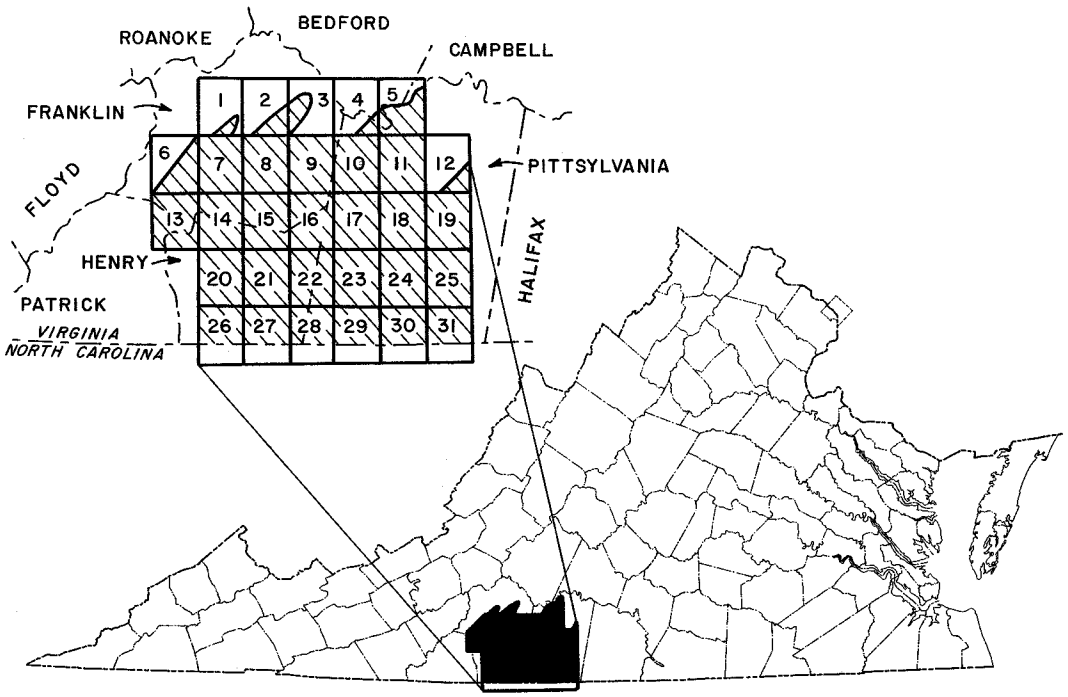


Figure 1. Location map showing quadrangles mapped at 1:24,000 scale.

1. Boones Mill quadrangle (McCollum, unpublished reconnaissance map).
2. Redwood quadrangle (McCollum, unpublished reconnaissance map).
3. Moneta SW quadrangle (McCollum, unpublished reconnaissance map).
4. Smith Mountain Dam quadrangle (Conley, Berquist and Marr, unpublished reconnaissance map).
5. Leesville quadrangle (Conley, Berquist and Marr, unpublished reconnaissance map).
6. Ferrum quadrangle (McCollum, Conley and Henika, unpublished reconnaissance map).
7. Rocky Mount quadrangle (McCollum, Open File Report, Virginia Division of Mineral Resources).
8. Gladehill quadrangle (McCollum, Open File Report, Virginia Division of Mineral Resources).
9. Penhook quadrangle (Conley, Piepul, Robinson and Lemon, unpublished manuscript map).
10. Sandy Level quadrangle (Berquist, unpublished manuscript map).
11. Pittsville quadrangle (Marr, 1984).
12. Gretna quadrangle (Thayer, unpublished manuscript map).
13. Philpott Reservoir quadrangle (Conley and Henika, 1970).
14. Bassett quadrangle (Henika, 1971).
15. Snow Creek quadrangle (Conley and Henika, 1973).
16. Mountain Valley quadrangle (Conley, Piepul and Lemon, unpublished manuscript map).
17. Callands quadrangle (Berquist unpublished manuscript map).
18. Chatham quadrangle (Marr, 1984).
19. Spring Garden quadrangle (Henika and Thayer, 1980).
20. Martinsville West quadrangle (Conley and Toewe, 1968).
21. Martinsville East quadrangle (Conley and Henika, 1973).
22. Axton quadrangle (Price and others, 1980B).
23. Whitmell quadrangle (Price and others, 1980A).
24. Mount Hermon quadrangle (Henika, 1977).
25. Blairs quadrangle (Henika, 1977).
26. Price quadrangle (Conley and Henika, 1973).
27. Spray quadrangle (Conley and Henika, 1973).
28. Northeast Eden quadrangle (Price and others 1980B).
29. Brosville quadrangle (Price and others, 1980A).
30. Danville quadrangle (Henika, 1977).
31. Ringgold quadrangle (Henika, 1977).

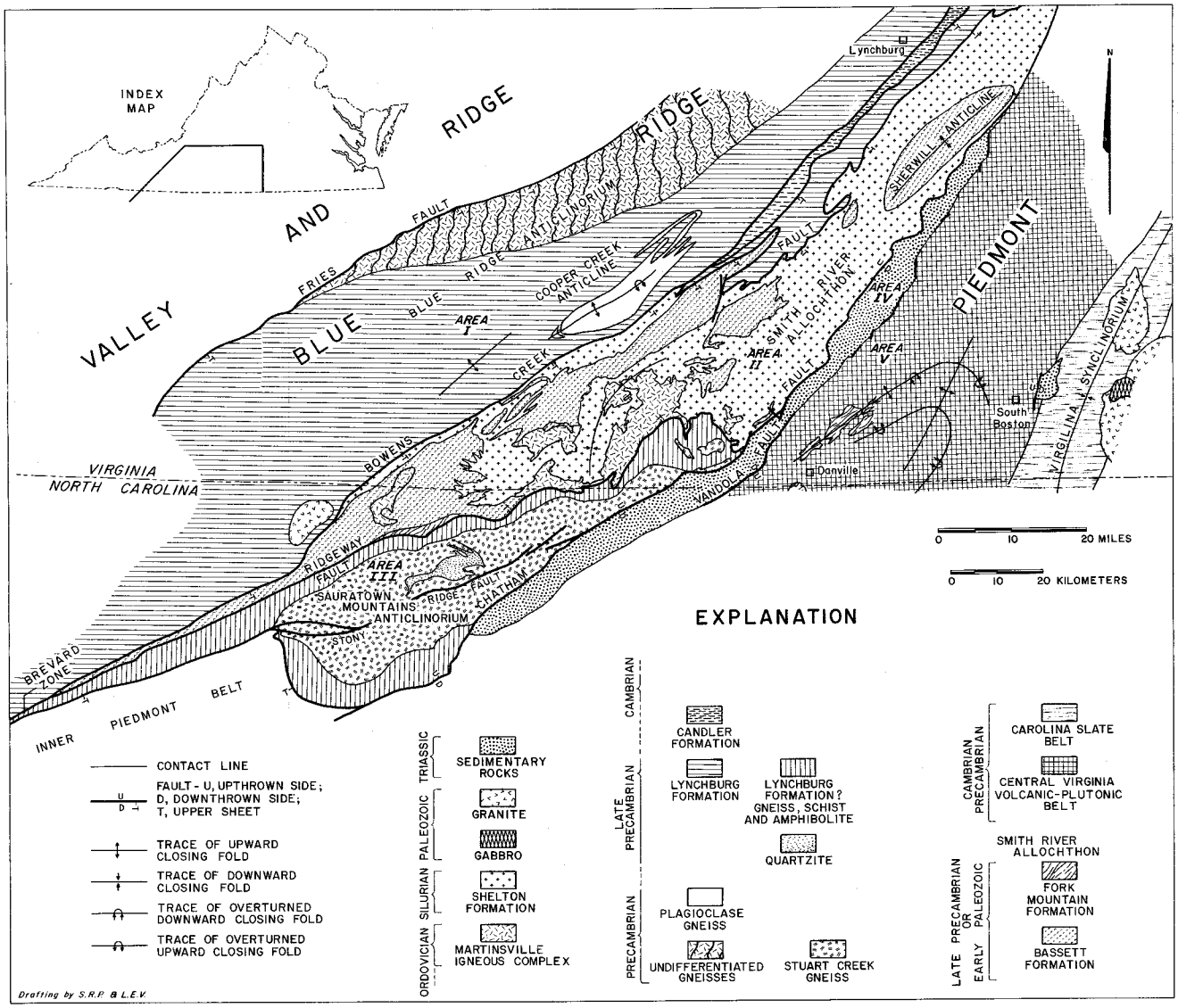


Figure 2. Regional geologic map showing locations of five areas that are underlain by a distinctive sequence of rocks. Each area is noted by Roman numerals.

ultramafic rocks, which are unstable under chemical weathering form thin, clay-rich soils which protect the chemically unstable rocks from further weathering. Thus these rocks generally underlie hills or mountainous terrain. The Triassic sedimentary rocks of the Danville basin develop soils of shallow to intermediate depth and the basin at present is a topographic depression. Along the western edge of the basin, tightly cemented Triassic sandstone produces a pronounced escarpment, which contrasts with the low rolling topography of the basin interior.

STRATIGRAPHY

The region of this report is naturally divided into five smaller areas, each underlain by a distinctive sequence of rocks. These areas are generally separated from each other either by a thrust or by a normal fault (Figure 2). These areas are from southeast to northwest: I. The Blue Ridge anticlinorium, II. The Smith River allochthon, III. The Sauratown Mountains anticlinorium, IV. The Danville basin, and V. The central Virginia metavolcanic belt.

AREA I: BLUE RIDGE ANTICLINORIUM

The term Blue Ridge anticlinorium is, in part, a misnomer because in Virginia, rocks of the Blue Ridge anticlinorium are not confined to the Blue Ridge physiographic province. In fact, the major part of the area underlain by these rocks is located in the northwestern part of the Piedmont province.

Rocks contained within the Blue Ridge anticlinorium crop out in the northwestern part of the study area (Plate and Figure 2); they are bounded on the southeast by the Smith River allochthon. In the area of study, two major stratigraphic units, the Lynchburg Group and the Candler Formation, are recognized in the anticlinorium. These two units are considered to be of late Precambrian age. They are located on the southeastern limb of the anticlinorium and overlie Grenville basement rocks that core the structure.

Lynchburg Group

The Lynchburg Group, named the Lynchburg Formation by Jonas (1927) for the City of Lynchburg, Virginia, is exposed across the northwestern part of the area of this report. Furcron (1969) raised the status of the Lynchburg from that of a formation to that of a group and named the lower massive gneisses of the Lynchburg the Bunker Hill Formation and the upper gneiss, schist, and marble sequence the Fauquier Formation. Rocks on strike with the Lynchburg to the south in North Carolina were named the Ashe Formation by Rankin (1970); later Rankin, Espenshade, and Shaw (1973) subdivided the Ashe into two formations. They retained the name Ashe Formation for the lower clastic sequence and named a sequence of gneisses, metapelites, amphibolites, and marbles that makes up the upper part of the unit, the Alligator Back Formation. These two formations have been mapped by Espenshade and others (1975) in the Philpott Reservoir quadrangle and along the western boundary of the Rocky Mount quadrangle within Area I of this report. In this report the Lynchburg Group consists of the typical Lynchburg as seen at Lynchburg, and the Ashe and Alligator Back formations are here described. It also includes the Moneta Gneiss as described next, and parts of the Evington Group as described later.

In this report (following the usage of Furcron, 1969), the Lynchburg is raised in rank from formation to group. The Ashe Formation is used to designate the massive plagioclase gneiss at the base of the Lynchburg Group in the core of the Cooper Creek anticline. Amphibolite grade gneisses form the core of the Cooper Creek and Otter Creek anticlines. The higher rank rocks in the cores of these structures were correlated (Conley and Henika 1970), with the Moneta Gneiss named by Pegau (1932). Rankin, Espenshade, and Shaw (1973) considered the Moneta, the Ashe, and the Lynchburg formations to be correlatives. Recent mapping and petrologic studies by the writer and Sr/Rb age dates (Mose and Conley, 1983) indicate that the rocks in the axial zone of the Otter Creek and Cooper Creek anticlines are the same age as the Lynchburg proper. Recent geologic mapping by the writer in the Lynchburg area and reexamination of the Moneta-Bells area now leads him to the conclusion that all rocks previously called Moneta Gneiss are part of the Lynchburg Group. Therefore the name Moneta Gneiss is not recognized as a formational name in this report.

The name Alligator Back Formation is applied to the interlayered schist-gneiss sequence containing mafic and ultramafic rocks, graphite schists, and marble that forms the top of the Lynchburg Group. Rankin, Espenshade, and Shaw (1973) correlated the Alligator Back with the so-called Evington Group, which supposedly overlies the Lynchburg. Data presented later in this paper shows that much of the Evington Group is actually the upper part of the Lynchburg Group.

Ashe Formation

The Ashe Formation is a two-mica plagioclase gneiss in which biotite is the predominant mica. The gneiss generally contains 30 to 45 percent quartz, 35 to 40 percent plagioclase and up to 20 percent biotite. Oligoclase is the common feldspar in the Ashe Formation and microcline has been identified in only two samples. Muscovite is not present in all samples but, in a few thin sections, makes up as much as 15 percent of the rock. Other minerals are allanite with overgrowths of clinozoisite, sphene, apatite, and opaque minerals. The rock is uniform in composition except for gneissic banding produced by oriented micas. The top of the Ashe is placed at its contact with a sequence of ultramafic rocks, metagabbros, and metabasalts belonging to the Alligator Back Formation which structurally overlies the formation. The Ashe Formation in the Cooper Creek anticline contains very little amphibolite, metagabbro, and ultramafic rock. A large body of ultramafic, metagabbroic and metabasaltic rocks that underlies Brier Mountain and trends across the central portion of the Cooper Creek anticline might be part of the Alligator Back sequence that has been folded into the Ashe. Graphite, which is ubiquitous in other metasedimentary parts of the Lynchburg, is absent from the Ashe in the Cooper Creek anticline.

The Ashe Formation in the Cooper Creek anticline is at higher metamorphic grade than the rest of the Lynchburg in the area and contains pegmatites and small granitoid bodies not present in the overlying units of the group. This would suggest

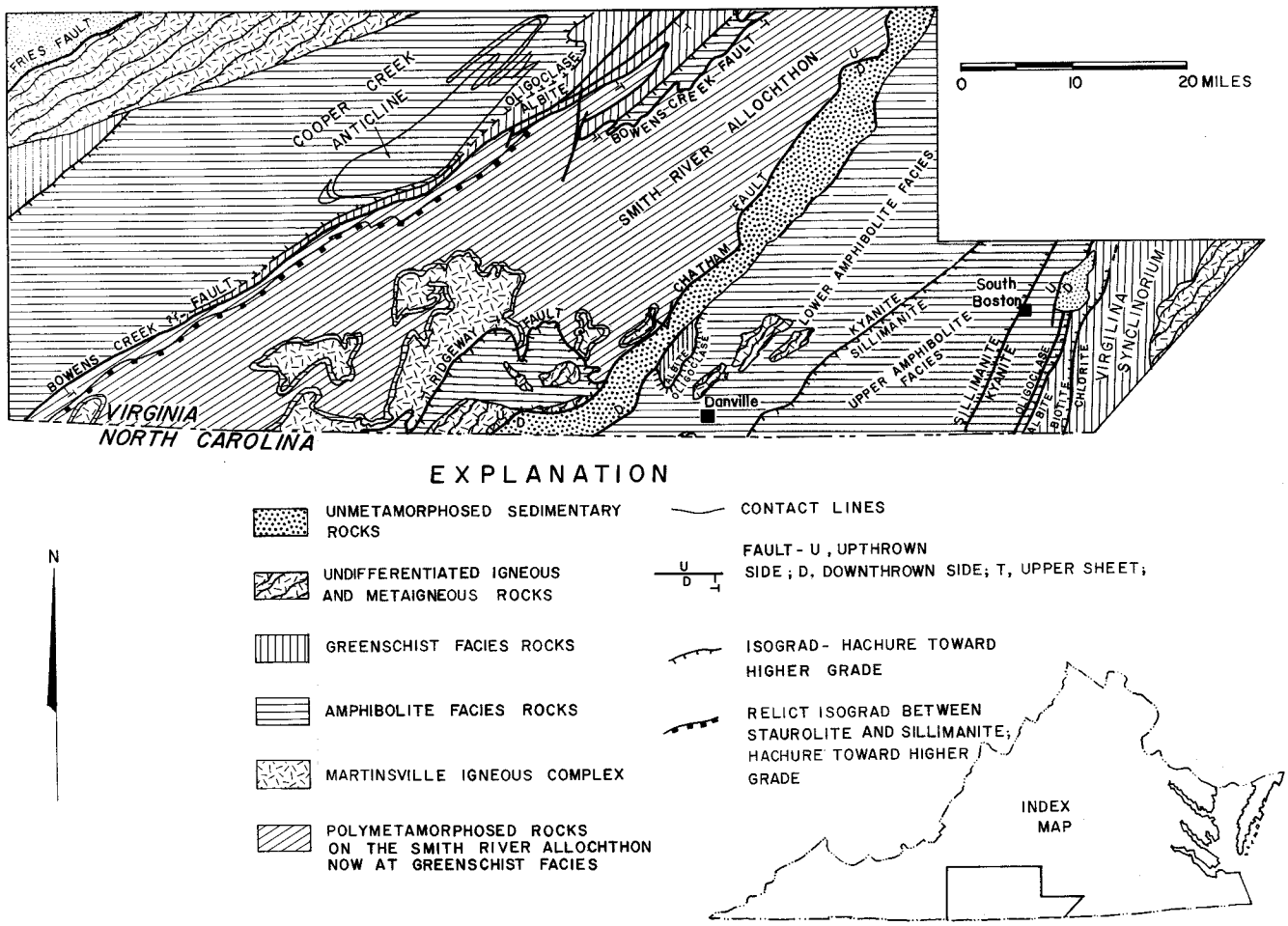


Figure 3. Regional geologic map showing metamorphic grade of rocks in south-central and southwestern Virginia.

metamorphism high enough to produce minimum melt granites. Much of the Ashe is porphyroblastic, with porphyroblasts ranging up to 6 cm across. Some of these porphyroblasts are attenuated, flattened, crinkle-folded and sheared (Michael B. McCollum, personal communication). At the contact with the overlying rocks of the Alligator Back, the Ashe shows a flaggy foliation that is parallel to this contact. Mylonites also occur near this contact suggesting the possibility of post-metamorphic thrusting of lower rank (greenschist and lower amphibolite grade) metamorphic rocks over higher rank (upper amphibolite grade) metamorphic rocks within the Lynchburg Group.

Alligator Back Formation

The Alligator Back Formation contains metamorphosed ultramafic rocks, gabbros and basalts, and a clastic sequence of interlayered metagraywackes, metagraywacke conglomerates, graphitic schists and pelitic schists. It also contains muscovite-sericite schists, impure marbles, and quartzites. With the exception of metabasalts, stratigraphic horizon markers are not traceable over great distances. The metaigneous/metavolcanic/metasedimentary sequences appear to be repetitious. The Alligator Back ranges in metamorphic grade from upper greenschist in the northeastern part of Area I to lower and middle amphibolite grade in the southwestern part (Figure 3).

Metaigneous rocks: Extensive stratigraphic sequences composed of metagabbro overlain by metabasalt occur throughout the Alligator Back. One of the most extensive of these sequences occurs at the base of the formation. Small bodies of metagabbro and ultramafic rock occur as lenses within the metasedimentary rocks (Plate). Three large bodies of metaigneous rocks underlie Grassy Hill,

Jacks Mountain, and Brier Mountain, (Plate). All three bodies contain ultramafic rock and metagabbro, and the outermost parts of the bodies generally contain metabasalt altered to amphibolite, indicating a close association among the ultramafic rocks, the metagabbros and the metabasalts. As previously noted, the Brier Mountain body is surrounded by Ashe Formation, the body is here interpreted as being folded down into rather than being an intrusive body into the Ash Formation.

The ultramafic rocks are metamorphosed dunites and metapyroxenites that are generally altered to serpentine, chlorite, talc, and tremolite. These rocks locally contain relict olivine and pyroxene. Opaque minerals occur in accessory amounts. Chlorite is commonly altered to vermiculite around the margins of the ultramafic bodies. These bodies in places are cut by metapyroxenite dikes and veins of anthophyllite.

The metagabbros are composed of actinolite (in part uralitic amphibole), albite, epidote, chlorite, and minor amounts of zircon, quartz, sphene, ilmenite, magnetite, and the relict minerals augite and calcic plagioclase partially altered to epidote. Some of the metagabbro is layered. The metagabbro bodies are generally coarser grained and lighter colored toward their centers and locally have relict ophitic textures. The metagabbros are locally sheared and altered to actinolite schist near contacts.

The metagabbros have not metamorphosed the country rocks with which they are in contact. Although Conley and Henika (1970) report a dense, gray hornfels-like rock at the top of the large metagabbro body north of Fairy Stone State Park; examination by the writer of thin sections of this rock indicates that it is a highly indurated quartzite, rather than a hornfels. No growth of contact metamorphic minerals or development of hornfels texture could be detected around the metagabbro. The metagabbros are cut by amphibolite dikes, which are probably feeders for the overlying metabasalts. Magnetite deposits are associated with the metagabbros and have been mined for iron ore on Stuarts Knob and west of Rocky Mount.

Dark-greenish-black basalts metamorphosed to well-foliated, fine-grained amphibolites generally overlie the metagabbros and are in places interlayered with and overlain by metasedimentary rocks. The amphibolites are composed primarily of nematoblasts of actinolite and variable amounts of epidote, chlorite, albite and quartz. The metabasalts are generally massive but locally contain small (1-2 mm) ovoid masses filled with intergrown quartz and feldspar. It is possible that these could be amygdules; although amygdules are generally filled with calcite, epidote and quartz at this metamorphic grade. Also present are lens-shaped structures that might represent transposed flow banding. Although those structures could be primary features, they are not definitive and could as easily be the products of metamorphism and tectonism.

Metasedimentary rocks: The metasedimentary rocks are locally interlayered with the metabasalts near the top of the metaigneous sequences, but the majority of the metasedimentary rocks stratigraphically overlie the metabasalts.

The metagraywackes in the Alligator Back Formation are composed of interbedded gray gneissic layers and muscovite-biotite schist layers. The gneissic layers are generally composed of 0.5-3 mm clasts of quartz and feldspar in a finer-grained, quartz-feldspar-mica matrix that in places grades upward into mica schist layers. The gneissic layers are variable in thickness and may locally be thick and massive and contain very few schist layers. Elsewhere they occur as thin lenses and interbeds in mica schists and in graphite schists. At Town Creek, north of Henry, a metaconglomerate contains rock fragments up to 1 foot long (Henika, 1971). The clasts are composed of granite, gneiss, and angular fragments of metaclaystones and graphitic metaclaystones. Graded bedding is common. The basal bed of some graded cycles is a coarse, structureless, polymictic conglomerate that grades upward into mica schist. In some exposures graded beds are overlain by a thin interval of finely laminated, impure metasandstones that in turn are overlain by thin, cross-bedded, micaceous quartzites. These rocks are similar to units A through C of a Bouma cycle, units common in proximal turbidite deposits near the mouth of submarine canyons (Middleton and Hampton, 1973). Henika (1973) reports that large angular blocks of actinolite gneiss (these, he speculates were derived from metabasalt in the Lynchburg) occur in the metagraywackes. This would suggest that the Alligator Back contains sedimentary melange sequences derived in part from ocean-floor basalts.

The metagraywackes are composed of quartz, microcline, perthite, plagioclase, muscovite and biotite and commonly contain small amounts (generally + 5%) of epidote, sphene, ilmenite, calcite, garnet, chlorite, zircon, and magnetite. Graphite occurs sparingly throughout the metagraywackes as disseminated material and as distinct graphite schist layers that generally lie on top of the metagraywacke beds.

In the area around the nose of the Cooper Creek

anticline, a sequence of silvery-gray, quartz-mica schist (and phyllite) interlayered with metagraywacke forms a distinct mappable unit within the Alligator Back Formation. The base of this subunit is interlayered with the uppermost part of a sequence of metabasalts. The mica schist is composed of varying amounts of biotite, muscovite, and quartz. It commonly contains minor amounts of tourmaline, garnet, plagioclase, microcline, and ilmenite. The mica schist also contains disseminated graphite and thin graphite schist layers.

Graphite-bearing rocks ranging from graphite schists to quartz- graphite schists occur throughout the Alligator Back Formation. Thin graphite schist and quartz-graphite schist bands are interlayered with the metagraywackes. The graphitic schists are gray to grayish-black and are composed of varying amounts of quartz, muscovite, chlorite, and graphite; lithologies range from a quartz-rich rock with flaggy foliation to a mica-rich rock with well-developed schistosity. These rock types are commonly interlayered. The quartz-rich graphite schists are composed of up to 50 percent quartz; the remainder consists mainly of about equal amounts of graphite and muscovite. The more schistose rocks have proportionately larger amounts of muscovite and chlorite. Accessory minerals include pyrite, ilmenite, and garnet; biotite may replace chlorite at higher metamorphic grades.

The graphite schists were probably hemipelagic sediments deposited in a closed basin under reducing conditions as indicated by the presence of graphite (preserved organic material) and pyrite. They probably represent sedimentation during times of quiescence, whereas the metagraywackes were probably deposited by turbidity currents.

White, pinkish-orange and gray, fine- to coarse-grained marbles occur interlayered with metagraywackes southeast of Rocky Mount (McCollum, in preparation), in the reentrant north of Dickenson (Conley, Piepul, Robinson, and Lemon, in preparation), in the reentrant south and southwest of Sandy Level (Berquist, in preparation), and along Rennet Bag Creek and the Smith River west of Dodson (Conley and Henika, 1970). Most of the marbles are finely laminated and contain thin, quartz-rich layers and numerous mica schist partings. One lens-shaped body of pinkish-white actinolite marble has been quarried in the Sandy Level quadrangle. This marble is strikingly similar to actinolite marble that occurs in the Lynchburg rocks in the Sauratown Mountains anticlinorium near Danbury, North Carolina.

Impure micaceous quartzites form interlayers in the metagraywackes and in the graphite schists. These quartzites are composed primarily of quartz, with lesser amounts of muscovite and biotite and accessory amounts of microcline, plagioclase, magnetite, sphene, ilmenite, zircon, and apatite. Quartz-rich layers are separated from each other by thin sericite layers. Graphite-schist fragments and biotite films are concentrated along foliation surfaces. These quartzites are commonly composed of upward-fining packages that contain laminar and fine cross-bedded sequences. The writer has observed festoon cross-bedded, isoclinally folded quartzite layers along the tracks of the Norfolk and Southern Railway at Town Creek in the Philpott Reservoir quadrangle.

A fine-grained quartzite is in contact with, and probably stratigraphically overlies, metagabbros on the west shore of Fairy Stone Lake; a similar quartzite also overlies metagabbros southwest of Rocky Mount. These two quartzites are white to rusty yellow to light gray rocks composed mainly of saccharoidal quartz. Sphene is an accessory mineral in the quartzites at Fairystone Lake, and magnetite is an accessory mineral in the quartzite near Rocky Mount. Both quartzites are massive; primary textures such as cross bedding, and relict clasts are absent. They have a rude, laminar, nonpenetrative foliation. These quartzites likely represent recrystallized cherts; the association with igneous rocks would suggest that they might be volcanic cherts.

The Lynchburg Group, A Repetitive Sequence Of Ophiolites? And Their Cover Rocks

Rankin (1975) has concluded that volcanic rocks in the Ashe Formation must have been deposited in a marine environment and speculated that future workers may discover ophiolites in these rocks. The stacked and repeated stratigraphic sequences consisting of altered ultramafic rocks overlain by metagabbros overlain by metabasalts, in turn overlain by a cover of metasedimentary rocks, within the Alligator Back would suggest that these rocks represent ophiolites and their cover rocks that have been repeated by thrusting (Conley, 1981 and in preparation). Some sequences contain ultramafic rocks, overlain by metagabbros, overlain by metabasalts; some contain metagabbros overlain by metabasalts, whereas others contain only metabasalts. Such variations indicate that some sequences are complete, and others are truncated successions. In addition, a number of isolated lens-shaped masses of ultramafic-metagabbro + metabasalt are enclosed by metasedimentary rocks. The angular

fragments of metabasalt found by Henika (1971) in the metasedimentary rocks near the base of the Alligator Back Formation in the Bassett quadrangle could be part of a melange sequence associated with the beginning of obduction and emplacement of the ophiolites.

Geochemistry of Ophiolites

Work by Pearce and Cann (1971, 1973) and Pearce (1976) indicates that ocean-floor basalts, low-potassium tholeiites, calc-alkaline basalts, shoshonites, ocean island basalts and continental basalts can be distinguished from each other by element analysis. Ophiolites are chemically similar to ocean-floor basalts (Pearce and Cann, 1971), which supports the widely held theory that ophiolites contain obducted ocean-floor basalts that originated at spreading centers (Coleman, 1977).

To test the hypothesis that the ultramafic-metagabbro-metabasalt sequences in the Lynchburg are ophiolites, samples from three metagabbros and four metabasalts were analyzed for major and trace elements. The elements Ti, Zr, and Y were chosen for analysis because these elements are not particularly mobile during low grade metamorphism (Pearce and Cann, 1973). Element analyses for titanium were made by Oliver M. Fordham, Jr., Virginia Division of Mineral Resources, and analyses of the trace elements zirconium and yttrium were made by David Whittington, Department of Geology, Florida State University.

A comparison of Ti and Zr contents of the samples (Figure 4) shows that they all follow the trend of ocean-floor basalts, although sample numbered 1 and 3 are lower in Ti than samples plotted by Pearce and Cann (1971). A triangular diagram for Ti-Zr-Y (Figure 5) shows that two samples plot within the field of ocean-floor basalts and that five plot outside of this field but not in any of the other basalt fields. This is because of high yttrium content of the samples. Each of the five samples is, therefore, much closer in composition to ocean-floor basalts than to other basalt fields in the diagram. Thus, the stratigraphic and (to a lesser extent) chemical data both tend to support the idea that these mafic igneous rocks are ophiolites.

Metamorphic Age Dates from Rocks of the Lynchburg Group

Fullagar and Dietrich (1976) found that north of 36°52'N. latitude Rb/Sr age dates in the Lynchburg Group are 520 to 583 m.y.o. and are 350 to 402 m.y.o. south of this latitude. They propose that

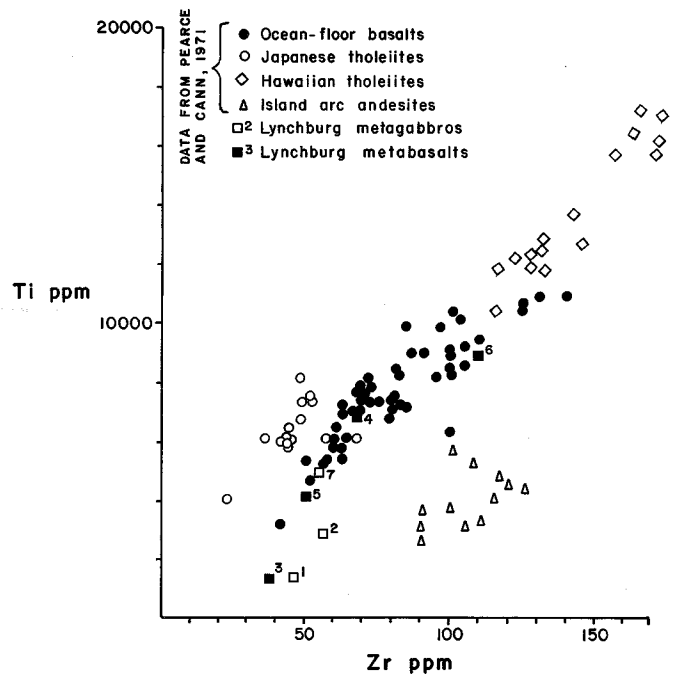


Figure 4. Ti-Zr plot for parental magma types.

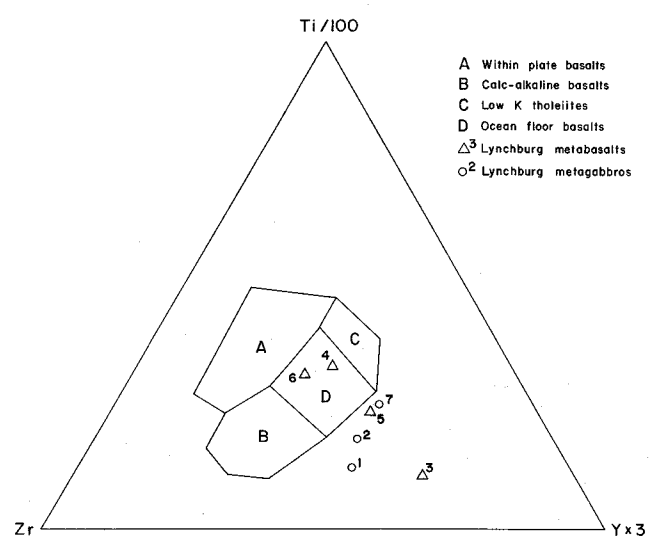


Figure 5. Discrimination diagram for Ti, Zr, and Y.

to the south of this latitude, rocks that record the 350-402 m.y. metamorphic event are exposed whereas, to the north of this latitude, rocks affected by this metamorphic event lie buried beneath rocks that record the older event. This would imply that rocks that record the later event have been overthrust by rocks that record the earlier event and therefore have not yet been exposed at the surface by uplift and erosion. Mose and Conley (1983) find

that the rocks of the Cooper Creek anticline (northwestern part of the map, Plate) at lower metamorphic grade (albite grade) yield Rb/Sr ages of 520-580 m.y. and at higher metamorphic grade (oligoclase grade) give ages of about 350 m.y. As high rank metamorphism can reset dates recorded by low grade metamorphism, it is indeed likely that to the southwest along strike the Acadian orogeny was more intense and reset Taconic dates, whereas to the northeast along strike, it was less intense and was unable to reset the older Taconic dates.

Candler Formation

In central Virginia, the Candler Formation overlies the continental basalts of the Catoctin Formation, which unconformably overlies the Lynchburg Formation (Conley, 1978). In the area of study, neither the top nor the bottom of the Candler is exposed because this unit is in fault contact with the Lynchburg Formation, both at its base and at its top (Berquist, 1980).

The Candler is a medium- to dark-gray or dark-greenish-gray phyllite that is composed predominantly of sericite and chlorite and weathers to a pink and grayish-purple saprolite. Paragonite-rich zones were defined in the unit in central Virginia by Smith, Milici, and Greenberg (1964). Porphyroblasts of magnetite and chloritoid occur locally. The chloritoid porphyroblasts (up to 3 mm in diameter) are oriented across foliation (foliation does not wrap around porphyroblasts) indicating that the porphyroblasts are of post-tectonic origin. Thin quartzite layers up to 3 cm thick occur locally in the unit. Thin sections reveal thin layers of quartz, only a single grain thick, interlayered with 1 to 5 mm thick phyllite layers. The Candler locally contains very dark-gray layers. Investigations by Berquist (in preparation) and by the writer show that this dark-gray color is generally because the presence of chlorite rather than graphite.

AREA II: SMITH RIVER ALLOCHTHON

The Smith River allochthon (Plate) was named by Conley and Henika (1973). This allochthonous mass occupies a broad synform in the area between the Blue Ridge anticlinorium and the Sauratown Mountains anticlinorium. It is therefore interpreted that Lynchburg and Grenville basement rocks, which make up the Blue Ridge and Sauratown Mountains anticlinoria on either side of the allochthon, also underlie the allochthon. The allochthon is composed of two sequences of rocks (Figure 6): a metasedimentary sequence containing some

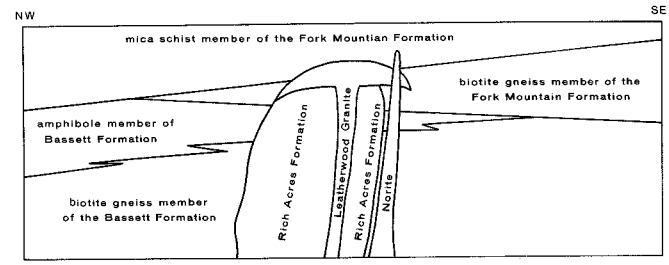


Figure 6. Stratigraphic relationships of rocks in the Smith River allochthon.

metavolcanic rocks considered to be of Late Precambrian or Early Paleozoic age and an Ordovician age plutonic-igneous sequence that intrudes the metasedimentary rocks (Rankin, 1975; Odom and Russell, 1975; Ragland, Conley and Odom, in preparation).

Three episodes of metamorphism are recognized in the metasedimentary rocks of the Smith River allochthon. The first episode was a regional Barrovian-type metamorphism, which was followed by regional, retrograde metamorphism either before or at the beginning of emplacement of the plutonic-igneous sequence of the Martinsville igneous complex. The third episode was contact metamorphism around plutons of the Martinsville igneous complex.

Rocks of the Smith River allochthon have been correlated with rocks of the Inner Piedmont belt of the Carolinas based on lithologic similarities and similar age dates of igneous rocks that intrude the allochthon and that intrude the Inner Piedmont belt (Conley and Toewe, 1968; Rankin, 1975; Odom and Russell 1975; Lemmon, 1980). Thus the Smith River allochthon is interpreted as a klippe of the Inner Piedmont rocks that lies to the northwest of the rocks of the main Inner Piedmont belt. Therefore it would seem logical that rocks of the Inner Piedmont belt were once part of a continuous sheet that extended as far westward as the Bowens Creek fault. Thus rocks now exposed in the Sauratown Mountains anticlinorium to the south and southwest would have been covered by rocks of this Inner Piedmont thrust sheet, which have since been stripped off by erosion. How far westward beyond the Bowens Creek fault this sheet might have extended is not known, as these rocks have also been eroded away.

Bassett Formation

The Bassett Formation occupies several polydeformed domes in the central and northwestern

parts of the Smith River allochthon. The Bassett is the lowest structural unit and probably the oldest stratigraphic unit in the allochthon and is subdivided into a lower biotite gneiss and an upper amphibolite. Although more work is required, preliminary Rb-Sr data indicate a 1000 m.y. age for the lower gneiss unit of the Bassett Formation (Douglas Mose, written communication, 1984).

Biotite gneiss: The biotite gneiss that makes up the lower part of the Bassett is a fairly homogeneous unit of generally equigranular, medium-grained, light- to medium-gray rock composed of biotite-rich laminae, about 0.6 cm thick, interlayered with 1 to 3-cm-thick laminae that contain less biotite. In addition, massive biotite gneiss layers (up to 0.5 m thick), quartz-rich (50 percent quartz), and epidote quartzite layers occur sparingly in the unit. At places where high metamorphic grade was attained during either regional or contact metamorphism, the rock reached minimum melt conditions and locally contains microcline porphyroblasts, migmatite zones, and coarse mica-quartz-feldspar melt zones. In such areas the rock is cut by numerous quartz-feldspar and mica-quartz-feldspar pegmatite dikes.

Altered pods and stringers of ultramafic rock and thin metagabbro bodies occur in the biotite gneiss, especially along the western boundary of the allochthon. The ultramafic rocks are predominantly altered to talc, tremolite, chlorite, serpentine, anthophyllite, opaque minerals and vermiculite but may contain relict olivine and pyroxene. Some of these ultramafic bodies have an outer shell composed of coarse amphibolite. The metagabbros are associated with the ultramafic rocks and occur primarily in the northwestern part of the allochthon. They are generally thin, conformable pods and sill-like bodies composed of clinopyroxene, orthopyroxene, garnet, hornblende and plagioclase. A striking feature of some of the metagabbros is that the garnets are surrounded by thin coronas composed of plagioclase and symplectic intergrowths of plagioclase-pyroxene. Mafic and ultramafic rocks are rare in the biotite gneiss in the southeastern part of the mapped area.

Amphibolite: The top of the Bassett is generally composed of amphibolite. The amphibolite is at, or near, its maximum thickness in the west-central part of the mapped part of the allochthon (Plate) and thins to the southeast. In the central and southeastern part of the mapped area, it occurs in thin, discontinuous stringers, and farther to the southeast in the map area it is absent. Although the mapping is incomplete, present data suggest that the amphibolite also thins to the southwest. The amphibolite is locally interlayered with the upper part of the underlying biotite gneiss, suggesting a conformable contact between the two units. Amphibolite also occurs as thin discontinuous layers in the overlying Fork Mountain Formation indicating that volcanism continued after deposition of the biotite gneiss of the Bassett Formation.

The amphibolite is a grayish-black to greenish-black, foliated, medium- to coarse-grained rock. In areas of relatively high metamorphic grade, such as exposures along State Highway 57 on the southwestern city limits of Bassett, it contains relic orthopyroxene and is segregated into feldspar-rich and amphibole-rich layers cut by thin, feldspar-rich dikes that outline ptygmatic folds (Figure 6). The amphibolite is composed predominantly of hornblende and plagioclase. Ovoid masses of plagioclase, epidote, and quartz that resemble flattened amygdules occur in the unit southwest of the town of Bassett, and beds of epidosite, up to two feet thick, also occur in the amphibolite in this same area. The amphibolite at the top of the Bassett Formation contains features that resemble graded bedding and cut-and-fill structures (Conley and Henika, 1970). Major element analyses indicate that compositions are similar to that of continental basalts (Paul C. Ragland, written communication, 1979). Achaibar and Misra (1984) also have concluded that these basalts were emplaced in a rift environment. However, these rocks have been metamorphosed at amphibolite grade and, because of mobility of many of the elements at this grade, the correlation of these rocks with continental basalts is extremely questionable (Paul C. Ragland, personal communication).

Fork Mountain Formation

The Fork Mountain Formation is composed of two units, a mica schist and a biotite gneiss that could be in part laterally equivalent to each other. The biotite gneiss is the basal unit of the Fork Mountain Formation in the southeastern part of the Smith River allochthon (Plate and Figure 6) and apparently wedges out to the northwest beneath the mica schist. Therefore, the mica schist overlies the Bassett Formation along the northwestern boundary of the allochton and the biotite gneiss overlies the Bassett Formation to the southeast. Contacts between these two units appear to be gradational or intertonguing over relatively short distances. These gradational relationships led Con-

ley and Toewe (1968) to propose that the gneiss resulted from contact metamorphism and metasomatic replacement of the mica schist. This suggestion was based on observations that were limited to areas where the Fork Mountain had been intruded by the Martinsville igneous complex and not on areas that were mapped later in the project which had not been affected by contact metamorphism. More recent mapping in the area (Price and others, 1980A and 1980B) indicates that the biotite gneiss unit is not restricted to contact zones of the Martinsville igneous complex and is indeed a stratigraphic unit.

Mica Schist: The mica schist is a light- to medium-gray, porphyroblastic, fine- to medium-grained, high-alumina metapelite. The high-alumina composition of this rock makes it an excellent indicator of metamorphic grade. The mineralogy is variable and dependent on grade of regional metamorphism, on the amount of alteration that has occurred during subsequent retrograde metamorphism, and finally on the grade obtained during the last contact metamorphism. Contact metamorphism is restricted to the area adjacent to the plutons of the Martinsville igneous complex.

The mica schist is mappable as two units separated on the basis of metamorphic grade obtained during the first regional metamorphic event (Plate, Figure 3). These two units are: garnet-mica schist containing relict staurolite, which lies northwest of the staurolite-sillimanite isograd along the northwestern boundary of the Smith River allochthon; and garnet-mica schist containing relict sillimanite, which lies to the southeast of this isograd. Masses of sillimanite (variety fibrolite), partially altered to sericite, occur southeast of the sillimanite isograd. Some of this sillimanite is pseudomorphous after staurolite and contains poikiloblastic inclusions of quartz and garnet inherited from the staurolite. This observation suggests that regional metamorphic grade increased to the southeast, and that staurolite was replaced by sillimanite in that direction within the allocthon. In areas southwest of the Smith River allocthon, Rankin, Espenshade, and Shaw, (1973) report that the contact between rocks containing relict staurolite and those containing relict sillimanite represents a thrust fault. This fault thrust the sillimanite-bearing rocks westward over staurolite bearing rocks. If so, this thrust fault probably does not extend into the present study area because the previously cited data indicate that in this area the boundary between the staurolite and sillimanite schists is a relict metamorphic isograd.

The mica schist contains some gneissic layers and lens-shaped, quartz-rich and mica-rich interlayers that could be primary compositional beds, which have been tectonically transposed. High-alumina minerals generally are confined to mica-rich layers. The quartz in the quartz-rich layers occurs as polygonal aggregates strongly suggesting that it has been annealed. Light- to dark-gray, fine-grained, equigranular quartzite, in lenses a few hundred meters wide and generally a few meters thick, occurs locally in the mica schist.

The mica schist is composed of muscovite, quartz, garnet, and high-alumina minerals with accessory amounts of plagioclase, magnetite and titanium-bearing minerals. Euhedral garnets are ubiquitous in the mica schist unit, but southeast of the relict sillimanite isograd they occur as globular-shaped aggregates, which may have grown together to form almost continuous garnet bands. The staurolite crystals that formed during regional metamorphism west of the sillimanite isograd are large (1-7 cm), typically amber in color, generally twinned and partially to totally altered to sericite pseudomorphs. Biotite occurs in the mica schist, but to the southeast of the sillimanite isograd it is almost universally altered to chlorite.

Contact metamorphic aureoles (Figure 3) surrounding the plutons of the Martinsville igneous complex have greatly affected the mineralogy of the mica schist for distances up to 200 feet (61 m). Near the contact, the rock has recrystallized under static metamorphic conditions that caused growth of unoriented micas, which produced a fels texture and obliterated the previously developed schistosity (Figure 7).

The contact with the plutonic rocks is marked by mica-quartz-microcline migmatite layers and cross-cutting pegmatites, all probably derived from anatectic melting. Coarse sillimanite porphyroblasts occur in the migmatite zone and are progressively replaced away from the contact by fibrolite; fine-grained kyanite; and microscopic, untwinned staurolite porphyroblasts. Thin sections show that these high-alumina minerals have nucleated and grown in lens-shaped masses of sericite that occur in a quartz-mica matrix (Figure 7). The sericite masses are interpreted as areas previously occupied by high-alumina minerals (either large sillimanite masses or large staurolite porphyroblasts). These porphyroblasts formed during regional metamorphism (M_1) and were retrograded to sericite during a second metamorphic event (M_2) which occurred either at the beginning of, or prior to, intrusion of the Martinsville igneous complex and development of its thermal aureole (M_3). Such sericite

Figure 7. Mica schist member of the Fork Mountain Formation from the contact metamorphic aureole around the Martinsville igneous complex. Large white areas are pseudomorphic forms of staurolite crystals that grew during regional metamorphism (M_1), now replaced by aggregates of coarse, unoriented sillimanite porphyroblasts that grew during contact metamorphism (M_3). Note that the matrix of the rock is completely recrystallized and has developed a fels texture, which has replaced the original schistose texture of the rock.

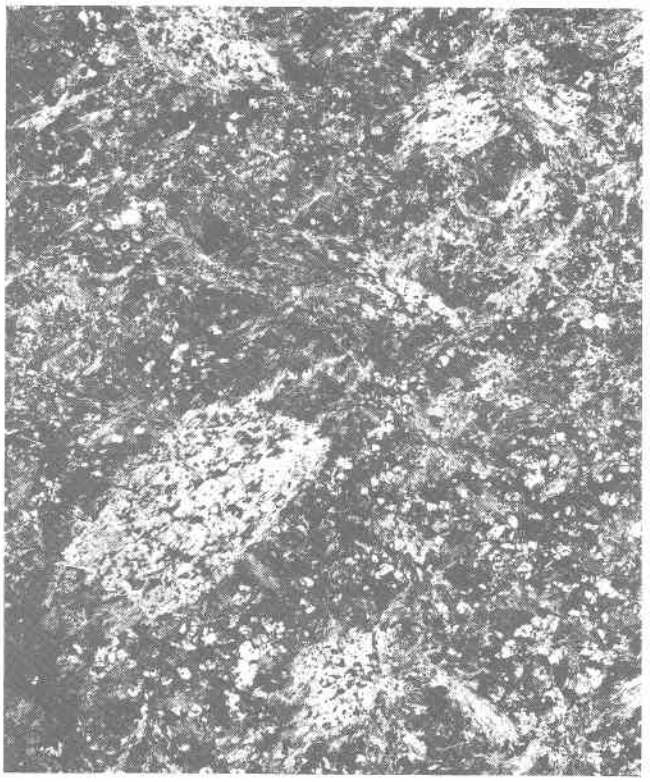
masses (formed during M_2) are rich in alumina and are favored sites for formation of new high-alumina minerals.

As here noted, it has not been conclusively determined when M_2 occurred in relationship to the intrusion of the Martinsville igneous complex. It could have occurred either prior to or at the beginning of emplacement of the igneous complex. This metamorphism might have occurred as a result of water migration from the plutons into the country rock during the initial stages of emplacement of the igneous complex before the development of a thermal aureole that resulted in contact metamorphism (M_3). Recent work by Allison and others (1984) shows that the gabbroic magma of the Rich Acres Formation was water saturated during crystallization.

Emery and magnetite deposits have also been locally developed in the contact aureole between the gabbros of the Martinsville igneous complex and the high-alumina schists of the Fork Mountain Formation (Conley and Toewe, 1968; Conley and Henika, 1973). The emery is a dark-gray, nonfoliated rock composed of interlocking green spinel (pleonaste or hercynite) and magnetite crystals, which envelop crystals of corundum (Conley and Henika, 1973).

Biotite gneiss: The biotite gneiss of the Fork Mountain Formation is a medium-gray, compositionally banded rock that is composed of interlayered quartzo-feldspathic gneiss and garnetiferous muscovite-biotite gneiss. The biotite gneiss contains about equal amounts of quartz (Locally the quartz grains may have a blue color, caused by microscopic rutile inclusions) and plagioclase and varying amounts of biotite, microcline, garnet, muscovite, and high-alumina minerals. Opaque minerals, garnet, and high-alumina minerals occur primarily in the biotite-rich layers; whereas, the quartzo-feldspathic layers are composed predominantly of quartz, plagioclase, microcline and minor amounts of biotite and muscovite. The interlayering of quartzo-feldspathic and mica-rich bands is thought to reflect original compositions of the sediments from which they were derived: the mica-rich layers were probably more pelitic in composition and the quartzo-feldspathic layers were probably of graywacke composition.

Clinozoisite-rich, quartzite boudins a few centimeters thick are scattered throughout the unit, and probably represent original carbonate-rich sandstone beds. Lithic, matrix supported breccias composed of biotite gneiss quartzites and quartz-rich gneiss fragments up to 45 cm across were found in the Martinsville stone quarry south of Fieldale (Figure 8) and along a small stream which flows across the Colonel Lester Farm near the southwestern terminus of Turkeycock Mountain (Figure 9). Some of the clasts seem to be identical in composition to those of the matrix, others are quartz-rich gneisses and some are fragments of quartzite. The foliation observed in the clasts is not parallel to the penetrative foliation developed in the matrix, indicating that foliation was present in the clasts prior to their deposition. This is further substantiated by the fact that the foliation in the matrix is a regional feature that is parallel to compositional layering, indicating that bedding has been transposed into parallelism with the penetrative foliation. Rankin (1975) has compared those rocks to the diamictite facies of the Wissahickon Formation



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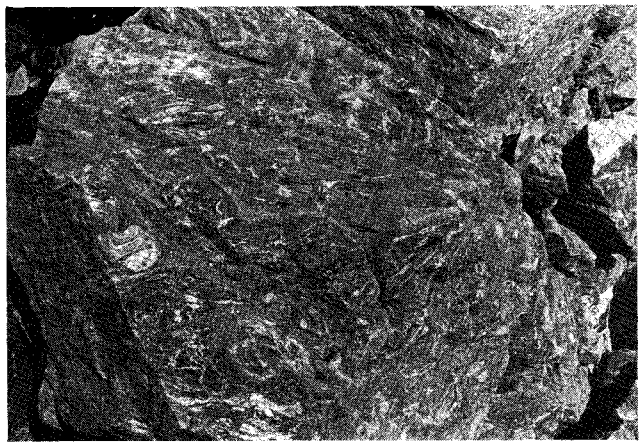


Figure 8. Biotite gneiss of the Fork Mountain Formation from the Martinsville Stone Company quarry south of Fieldale containing angular fragments of calc-silicate quartzite. Pencil in the center of the photograph is for scale.

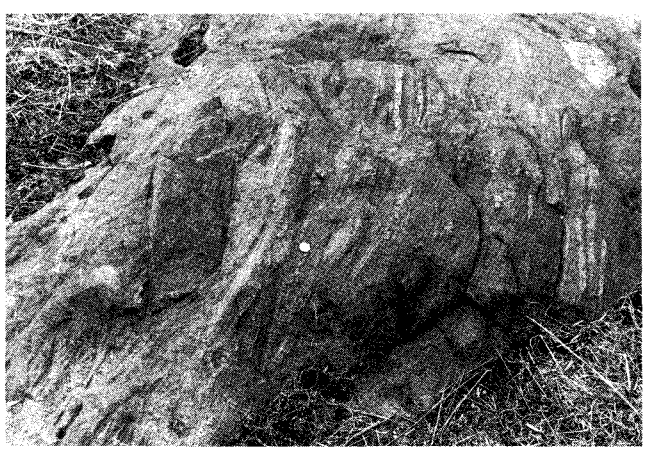


Figure 9. Biotite gneiss of the Fork Mountain Formation exposed on the Colonel Lester Farm near the southwestern terminus of Turkeycock Mountain. The rock contains angular fragments and blocks of biotite gneiss and quartzite in a biotite gneiss matrix. The coin (quarter) in the center of the photograph is for scale.

(Conowingo Gneiss), which is considered to be submarine slide breccia or slump deposit. Debris flows can also produce this type of deposit (Walker, 1978).

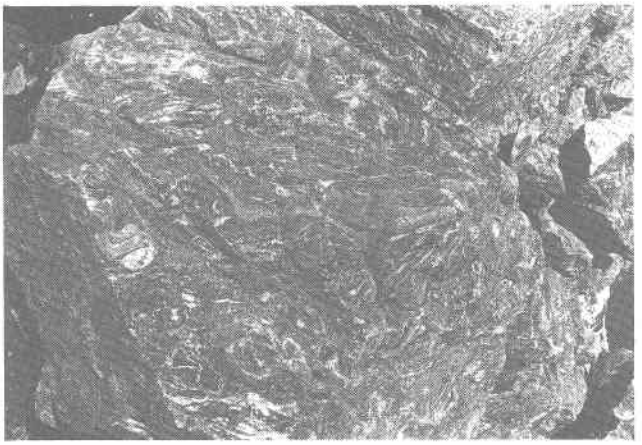
The biotite gneiss in the metamorphic aureole developed adjacent to the rocks of the Martinsville igneous complex is injected by cross-cutting pegmatites and contains migmatitic bands. Gneisses at the contact with the igneous rocks contain feldspar porphyroblasts that are not developed away from the contact. The garnets in the interlayers of garnetiferous muscovite-biotite gneiss have grown together into globular masses (as they did in the mica schist); also, coarse sillimanite is developed in the pelitic layers near contacts with rocks of the igneous complex, whereas fine-grained kyanite and microscopic staurolite formed in these layers away from the contacts.

Martinsville Igneous Complex

The Martinsville igneous complex was informally named by Ragland (1974). The igneous complex underlies a large area around Martinsville (Plate); isolated plutons also occur to the east of the main outcrop area. The complex is composed of three formations (Figure 6), the Leatherwood Granite (Jonas, 1928), the Rich Acres Formation (Conley and Henika, 1973) and norite. The norite was earlier included as part of the Rich Acres Formation (Conley and Toewe 1968; Conley and Henika, 1973). However, later work (Allison and others 1984; Ragland, Conley and Odom, in preparation) indicates that the norite is separate from, and younger than the Rich Acres and the Leatherwood. Analyses of strontium isotopes indicate that the Rich Acres and Leatherwood were derived from the same magma and were emplaced toward the end of a tectonic event (Ragland, Conley and Odom, in preparation). These two cogenetic rock units form an uncommon, high-potassium, calc-alkaline (Andean) plutonic sequence in which there was simultaneous fractionation of biotite and pyroxene indicating a high water content of the magma during crystallization (Allison and others, 1984). Radiometric age dates from the Leatherwood Granite (U/Pb, zircons and Rb/Sr whole-rock analyses) show that it is Middle Ordovician in age (Rankin 1975; Odom and Russell, 1975) and because it is sheared, it was probably emplaced and cooled during a tectonic (Taconic?) event. The norite was derived from a separate magma and lack of shearing indicates that it was emplaced later, in a post-tectonic environment (Allison and others, 1984; Ragland, Conley and Odom, in preparation).

Rich Acres Formation

The Rich Acres Formation generally occurs as concordant to slightly discordant plutons, which intrude the metasedimentary rocks of the allochthon. This formation makes up the major part of the complex and its major outcrop area is located east and southeast of Martinsville. The rock is dark-



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The biotite gneiss in the metamorphic aureole developed adjacent to the rocks of the Martinsville igneous complex is injected by cross-cutting pegmatites and contains migmatitic bands. Gneisses at the contact with the igneous rocks contain feldspar porphyroblasts that are not developed away from the contact. The garnets in the interlayers of garnetiferous muscovite-biotite gneiss have grown together into globular masses (as they did in the mica schist); also, coarse sillimanite is developed in the pelitic layers near contacts with rocks of the igneous complex, whereas fine-grained kyanite and microscopic staurolite formed in these layers away from the contacts.

Martinsville Igneous Complex

The Martinsville igneous complex was informally named by Ragland (1974). The igneous complex underlies a large area around Martinsville (Plate); isolated plutons also occur to the east of the main outcrop area. The complex is composed of three formations (Figure 6), the Leatherwood Granite (Jonas, 1928), the Rich Acres Formation (Conley and Henika, 1973) and norite. The norite was earlier included as part of the Rich Acres Formation (Conley and Toewe 1968; Conley and Henika, 1973). However, later work (Allison and others 1984; Ragland, Conley and Odom, in preparation) indicates that the norite is separate from, and younger than the Rich Acres and the Leatherwood. Analyses of strontium isotopes indicate that the Rich Acres and Leatherwood were derived from the same magma and were emplaced toward the end of a tectonic event (Ragland, Conley and Odom, in preparation). These two cogenetic rock units form an uncommon, high-potassium, calc-alkaline (Andean) plutonic sequence in which there was simultaneous fractionation of biotite and pyroxene indicating a high water content of the magma during crystallization (Allison and others, 1984). Radiometric age dates from the Leatherwood Granite (U/Pb, zircons and Rb/Sr whole-rock analyses) show that it is Middle Ordovician in age (Rankin 1975; Odom and Russell, 1975) and because it is sheared, it was probably emplaced and cooled during a tectonic (Taconic?) event. The norite was derived from a separate magma and lack of shearing indicates that it was emplaced later, in a post-tectonic environment (Allison and others, 1984; Ragland, Conley and Odom, in preparation).

Rich Acres Formation

The Rich Acres Formation generally occurs as concordant to slightly discordant plutons, which intrude the metasedimentary rocks of the allochthon. This formation makes up the major part of the complex and its major outcrop area is located east and southeast of Martinsville. The rock is dark-

greenish-gray and has an ophitic to subophitic texture. It has a medium grain size, but is locally porphyritic and contains stubby plagioclase phenocrysts that range up to 1.5 cm in length. These phenocrysts contain numerous minute unidentified inclusions. The rocks of the formation have chemical compositions on the borderline between gabbro and diorite (Paul C. Ragland, personal communication). They are composed of the minerals plagioclase, green hornblende, reddish-brown biotite, pale-green clinopyroxene, uralite, and quartz as vermicular intergrowths in hornblende and plagioclase.

Rocks of the Rich Acres Formation have large (2cm) clinopyroxene crystals filling the interstices between feldspars. Hornblende occurs as reaction rims on pyroxene and as subhedral crystals in the matrix. Biotite is in contact with hornblende and either is in contact with, or contains inclusions of opaque minerals. Uralite embays and has partially to totally replaced clinopyroxene and hornblende. Development of vermiform quartz within hornblende grains seems to have occurred after the partial replacement of hornblende by biotite, as biotite does not contain these quartz inclusions. Although the rock is not obviously sheared, some of the plagioclase grains are bent and the outlines of some grain boundaries and twin planes are offset by shear planes.

The Rich Acres Formation is brecciated at the perimeters of some plutons, and fractures are filled with injected material to produce agmatite texture. The injected material is coarser grained than the ground mass of the brecciated material, but much of the injected material is chemically (Paul C. Ragland, personal communication) and mineralogically similar to the brecciated rock. This indicates that little differentiation of the parent magma took place between the time of crystallization of the host rock and the time of injection of the material filling the fractures. The outer parts of some plutons are injected with thin veins composed of hornblende-plagioclase and hornblende-pyroxene-plagioclase, and with quartz-microcline-oligoclase pegmatites.

Leatherwood Granite

The Leatherwood Granite occurs as dikes, sill-like bodies and irregularly-shaped plutons. The major part of the Leatherwood occurs as thin sheets on top of the large pluton of Rich Acres that lies east and southeast of Martinsville. In the northern and northeastern parts of the allochthon, the Leatherwood occurs in oval-shaped plutons that are diapir-like intrusions.

The Leatherwood is a porphyritic, light-gray granite that generally shows rapakivi texture. However, some of the larger plutons are composed of coarse, equigranular, leucocratic granite. Microcline phenocrysts range from 2-5 cm and are generally white but locally may be pink. Some specimens contain oligoclase as well as microcline phenocrysts. The phenocrysts are set in a medium-grained xenomorphic-granular matrix composed of microcline, quartz, plagioclase, biotite and muscovite.

Post-magmatic processes of diffusion and unmixing in the Leatherwood are indicated by rapakivi texture and patch antiperthites. The perimeters of the microclines have been embayed by post-rapakivi lobes of myrmekitic albite which replaces both the albite rims and the microcline cores. The Leatherwood locally contains blue quartz (as do some of the gneisses in the aureole around the Martinsville igneous complex) which probably means that submicroscopic rutile exsolved from quartz lattices after crystallization (Mason, 1978).

The granite locally shows cataclastic textures. Formerly large quartz grains now occur as unstrained, recrystallized polygonal aggregates that show well-developed triple points. The epitaxial albite and the host microcline phenocrysts may not now be optically continuous, and the albite may now consist of a thin band composed of an equigranular aggregate of recrystallized grains. In some granite specimens distinct shear planes can be observed; in these shear planes the micas are aligned and wrap around feldspar phenocrysts. These data would suggest that tectonism continued after crystallization of the Leatherwood. In contrast, the myrmekitic albite which embays both the albite rims and microcline cores is not sheared and recrystallized, suggesting that it formed in a post tectonic environment.

Muscovite-quartz-microcline pegmatites of two ages cut the Rich Acres and the Leatherwood formations. One of these groups of pegmatites is slightly sheared (as is the Leatherwood) and the other is unsheared and is considered to be younger than the Leatherwood.

A U/Pb age of 450 m.y. from zircons (Rankin, 1975) and a whole-rock Rb/Sr age of 464+ 20 m.y. is reported by Odom and Russell (1975) for the Leatherwood Granite. Odom and Russell (1975) and Rankin (1975) have noted that these ages agree with dates obtained from intrusive rocks in the Inner Piedmont belt, which supports the suggestion of Conley and Toewe (1968) that rocks of the Smith River allochthon correlate with rocks of the Inner Piedmont belt. A previously published U/Pb date

of 1020 m.y. obtained from the Leatherwood Granite (Conley and Henika, 1973) is here considered to be incorrect because of error in analyses on which this date is based.

Unnamed Norite

An unnamed norite makes up a smaller proportion of the Martinsville igneous complex than do either the Rich Acres Formation or the Leatherwood Granite. It occurs as small, irregularly-shaped plutons and possibly as dikes. The exact shape of these plutons is hard to discern in saprolite because of similar weathering characteristics of the Rich Acres and the norite.

The norite is a dark-gray porphyritic rock in which large (1-4 cm) pyroxene and elongate plagioclase crystals (up to 1 cm in length) produce an ophitic texture. The rock is composed of plagioclase (bytownite-labradorite), orthopyroxene (predominantly hypersthene), clinopyroxene, brown pargasite, brown biotite, green hornblende (uralite) and olivine. Rims of partial reaction around nuclei of olivine indicate the order of crystallization, which is: olivine - orthopyroxene - clinopyroxene - pargasite - biotite. Green uralitic hornblende also forms as reaction rims on pargasite. Some plagioclase laths are embayed by orthopyroxene indicating that their crystallization began before completion of orthopyroxene growth.

The norite does not contain the bent feldspar crystals with displaced twin planes seen in the Rich Acres Formation, nor the sheared grain boundaries observed in the Leatherwood. This suggests that the norite is a post-tectonic intrusive rock.

AREA III: SAURATOWN MOUNTAINS ANTICLINORIUM

In the Sauratown Mountains anticlinorium (Figure 10), Grenville-age basement rocks are overlain by Late Precambrian metasedimentary rocks. Rocks of the Sauratown Mountains anticlinorium (Plate) are bounded on the north and northwest by the Ridgeway fault, the southeastern boundary fault of the Smith River allochthon, and on the southeast by the Chatham fault, the border fault of the Danville Triassic basin.

Stuart Creek Gneiss

The oldest unit in the Sauratown Mountains anticlinorium in Virginia is a granitic augen gneiss that occupies the cores of four structural domes in the area. This rock is correlated with the Elk Park Group of Southwestern Virginia and north central North Carolina by Espenshade and others (1975), who suggest that it "might be a porphyritic variety of Cranberry Gneiss," which is a part of the Elk Park Group. The granitic augen gneiss is

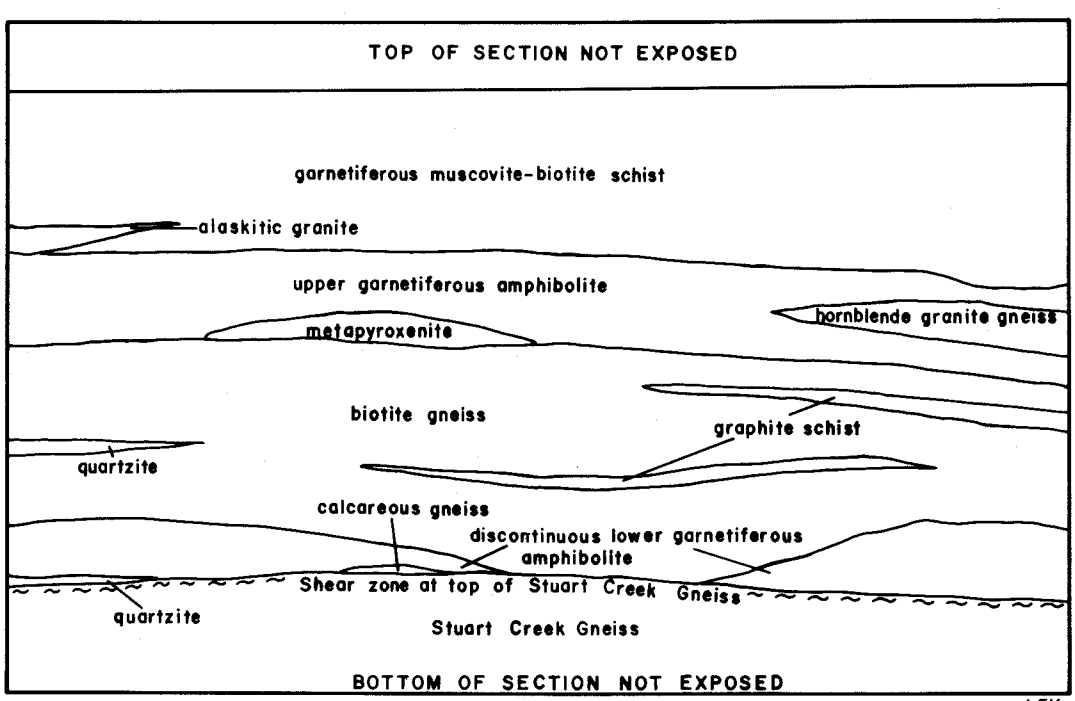

Figure 10. Stratigraphic relationships of rocks in the Sauratown Mountains anticlinorium.

a widespread, distinctive, and uniform rock unit that is here named the Stuart Creek Gneiss. Its type locality is designated as exposures along both sides of Stuart Creek from where State Road 632 crosses Stuart Creek, northwestward for a distance of 2 miles. The area of the type locality is within the Spray 7.5 minute-quadrangle, Henry County.

The Stuart Creek Gneiss is a porphyroblastic orthogneiss composed of euhedral and subhedral porphyroblasts of microcline (relict phenocrysts?) and perthite in a quartz-feldspar-biotite matrix, which generally lacks compositional banding. The rock ranges in texture from porphyroblastic gneiss to augen gneiss, to flaser gneiss. Flaser gneiss is generally in the sheared, upper part of the unit, near and at its contact with overlying, younger metasedimentary rocks. Thin amphibole schist and biotite schist layers have been observed in saprolite; these might represent mafic igneous intrusions into the Stuart Creek that have been altered during metamorphism.

The Stuart Creek Gneiss is thought to be of Grenville age. Rocks in a similar stratigraphic position below a metasedimentary cover in a quarry located about 25 miles to the southwest at Pilot Mountain, North Carolina are cut by granitic rocks which were dated at 1192 m.y. (Rankin and others, 1971). The rocks in this quarry, however, appear to be compositionally layered gneisses, unlike the porphyroblastic Stuart Creek Gneiss.

Lynchburg Group

The Stuart Creek Gneiss is unconformably overlain by a sequence of metasedimentary rocks of probable Late Precambrian age. These rocks are subdivided into two major units, a gneiss and an overlying schist. Amphibolites occur discontinuously at the base of the gneiss unit and amphibolites and ultramafic rocks occur at the base of the overlying schist unit. These metasedimentary rocks have been correlated with the Lynchburg Formation (Lynchburg Group of this report) (Conley and Henika, 1973). They have also been mapped as the Ashe Formation (the lower formation of the Lynchburg Group as defined in this report) by Espenshade and others (1975). Because of the intervening Smith River allochthon, rocks of the Lynchburg Group are not physically traceable into these rocks. However, from lithologic similarities and stratigraphic relationships, these rocks are considered by Espenshade and others (1975) to be the Ashe Formation that lies southeast of the allochthon. The lower unit of the sequence, the gneiss unit, is very similar lithologically to the Ashe Formation exposed in the Blue Ridge anticlinorium. The overlying schist contains very few alternating gneiss-schist sequences but does contain marbles, quartzites, metabasalts and ultramafic rocks typical of the Alligator Back Formation. Espenshade and others (1975) did not recognize the Alligator Back Formation in the Sauratown Mountains anticlinorium. However, in the writers opinion these rocks in the schist unit are more similar to Alligator Back than they are to the Ashe Formation.

Ashe Formation

The amphibolite at the base of the Ashe Formation exposed in the Sauratown Mountains anticlinorium pinches and swells and in places is totally absent. Therefore, the gneiss member of the Ashe locally rests directly on the Stuart Creek Gneiss with no intervening amphibolite unit. This basal amphibolite is a dark-green to greenish-black, generally schistose to well-foliated, medium- to coarse-grained rock. It is composed predominantly of hornblende and subordinate plagioclase. The rock also contains garnet, as well as accessory amounts of sphene, epidote, and opaque minerals.

The gneiss unit which overlies the amphibolite makes up the major part of the Ashe Formation in the Sauratown Mountains anticlinorium. It is a muscovite-biotite gneiss that contains many interlayers of muscovite-biotite schist. In the area east of Ridgeway, pods and stratiform bodies of ultramafic rocks are interspersed throughout the unit. Pegmatite and alaskite dikes and sills are common in the unit.

Gneissic layers range from 2 to 10 feet thick and the intervening schist layers are generally less than a foot thick. The gneiss is medium-grained, light-gray and composed of mica plates interspersed with elongate grains of quartz and feldspar. The rock is composed of approximately 60 percent feldspar, and plagioclase is predominant over microcline. Quartz ranges from 20 to 30 percent and biotite ranges from 10 to 20 percent of the rock. Muscovite is variable and ranges from trace amounts to 10 percent in the gneissic layers and composes almost all of the mica schist layers. The rock also contains minor amounts of tourmaline, zircon, sphene, rutile, epidote, and opaque minerals.

Alligator Back Formation

The amphibolite at the base of the Alligator Back Formation, where present, is a marker horizon that separates the Alligator Back from the underlying Ashe Formation. This unit is a massive to conspic-

uously foliated greenish-black "salt and pepper" rock. The major constituent is bluish-green hornblende with lesser amounts of garnet, plagioclase and quartz. The amphibolite locally contains oval-shaped masses of epidote and epidote-quartz up to 7 mm long that resemble flattened amygdules.

Lens-shaped masses of fine- to medium-grained granite gneiss composed of microcline, oligoclase and quartz with accessory hornblende, garnet, sphene and zircon occur in the amphibolite unit at the base of the Alligator Back. This amphibolite also contains several lenticular masses of metapyroxenite that seem to be at or near its base. The metapyroxenite is altered to talc, serpentine, chlorite, magnetite and tremolite. Large (1-3 cm) pyroxene phenocrysts generally occur in the metapyroxenite and are partially to totally altered to pseudomorphous talc. Locally there are isolated lenses of amphibolite that are entirely surrounded by the Ashe Formation (Price and others, 1980A, 1980B). These may represent synclinal folds of the basal amphibolite of the Alligator Back in the underlying Ashe Formation.

The amphibolite is overlain by a schist unit which makes up the major part of the Alligator Back Formation. This unit is a light-bluish-gray muscovite-biotite schist containing abundant garnets and locally may contain thin layers of graphitic mica schist and layers of quartzo-feldspathic gneiss. The schist is composed of muscovite, brown biotite, quartz and minor plagioclase; in addition it contains varying amounts of kyanite and staurolite.

Garnets in the schist are generally euhedral, pink to red, and range in size from 1 to 4mm. Poikiloblastic inclusions in the garnet porphyroblasts observed in thin sections indicate syntectonic rotation of about 90°. Staurolite porphyroblasts are euhedral, black, untwinned and may be up to 2 cm in length. Oriented mica laths, ranging in length from 0.5 to 1 mm, compose the matrix and produce a schistose texture. Micas, which form the foliation, wrap around the garnet and staurolite porphyroblasts. Chlorite, derived from alteration of biotite, and staurolite porphyroblasts are observed in slightly sheared rock near the Ridgeway fault zone.

AREA IV: DANVILLE BASIN

The Danville basin (Plate and Figure 1) contains continent derived, clastic sedimentary rocks that are correlated with early Late Triassic age rocks of the Lockatong Formation of the Newark Supergroup in Connecticut (Olsen and others, 1978). This correlation is based on fossil fish and phytosaurs.

The Danville basin is a northeast-trending structure that is about 123 miles long (Figure 2). The basin (Plate) is bounded on the northwest by the Chatham fault (Myertons, 1963). At the southeastern margin of the basin the sedimentary rocks may be either in unconformable or fault contact with metamorphic rocks (Myertons, 1963). Strike of bedding within the basin generally is parallel to the trend of the Chatham fault zone and the rocks have a rather consistent N44°W dip, except near the Chatham fault, where dips are steeper (Thayer, *in* Henika, 1977). Estimated thickness of strata in the Danville basin, calculated from outcrop width and average dips, ranges from 3600 feet in the narrowest part of the basin to 13,300 in the widest part (Henika and Thayer, 1980). The rocks are dusky red, yellowish-gray and medium-dark gray and show abrupt vertical and lateral changes in texture, color, composition and thickness.

Within the present study area the Danville basin was mapped by Paul A. Thayer (Thayer, *in* Henika, 1977; Thayer, *in* Price and others, 1980A and 1980B; and Henika and Thayer, 1980). Myertons (1963) thought that rocks of the Danville basin were an intertonguing sedimentary sequence and were roughly equivalent in time to each other. He believed that these rocks are unconformably overlain by a conglomerate that occurs on either side of the basin, which he named the Cedar Forest Formation (Figure 4). Thayer (1970) revised Myertons (1963) interpretation of the stratigraphy of the basin (Figure 11) and concluded that, in the southwestern and northeastern parts of the basin, the upper clastic sequence, which he named the Stoneville Formation could be separated from the lower clastic sequence, which he named the Pine Hall Formation by an intervening gray shale which he elevated in rank from Cow Branch member to Cow Branch Formation. The central part of the basin is narrow and does not contain the gray shale unit (Cow Branch Formation). As a result the lower unit cannot be distinguished from the upper unit and the rocks in this part of the basin are mapped as a single stratigraphic unit, which Thayer (1970) retained the name Dry Fork Formation of Myertons, 1963). Thayer (1970) found that the border conglomerates on the southeast side of the basin underlie and intertongue with the Pine Hall Formation, and that those border conglomerates on the northwest side of the basin overlie and intertongue with the Stoneville Formation. Therefore, he does not recognize the Cedar Forest Formation as a stratigraphic unit.

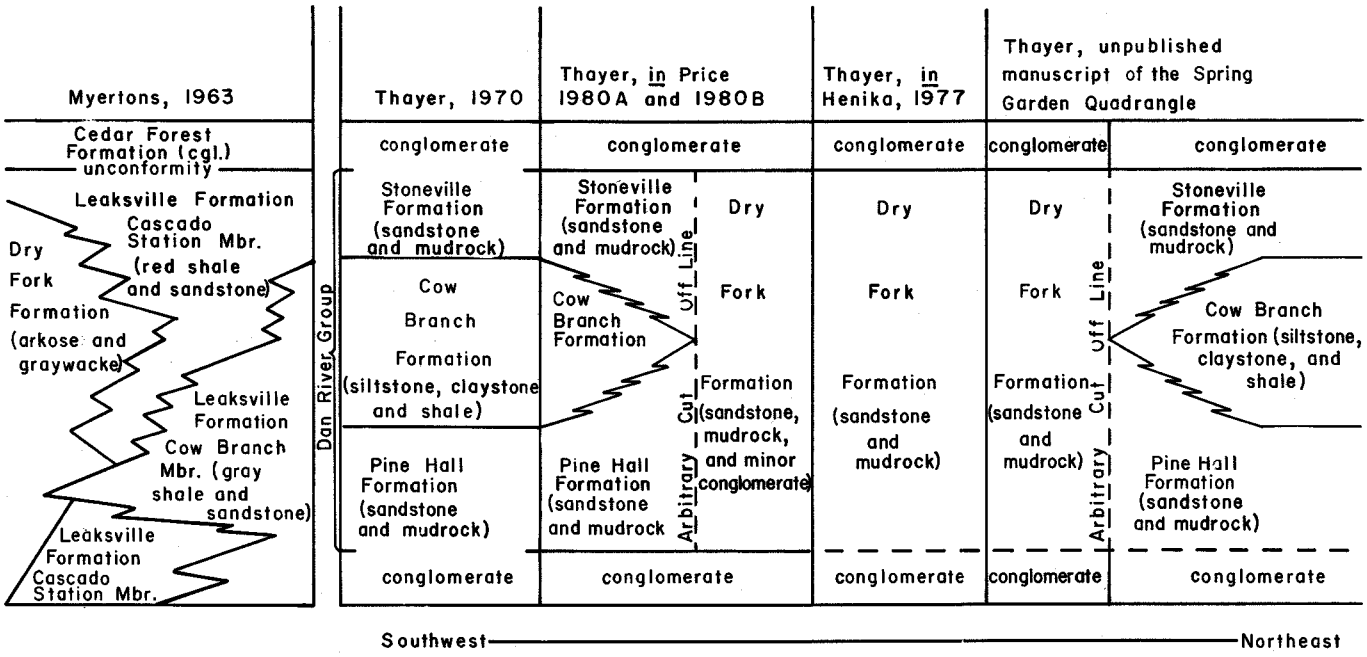

Figure 11. Stratigraphic relationships of rocks along strike from southwest to northeast in the Danville Triassic basin.

Both the Pine Hall and Stoneville formations become finer grained from the margins toward the center of the basin. The units generally change from coarse fluvial and alluvial fan deposits at edges of the basin to medium- to light-gray shales locally interbedded with coarser clastic rocks in the center of the basin (Thayer, 1970). Fossil evidence shows that these shales are at least partly lacustrine in origin.

AREA V: SOUTH CENTRAL VIRGINIA
Metavolcanic-Plutonic Belt
Metavolcanic and Metasedimentary Rocks

A sequence of felsic and mafic metavolcanic rocks that contains interlayered metasedimentary rocks lies along the North Carolina boundary (Figure 2 and Plate) from west of Danville eastward to beyond South Boston (Henika, 1977; Tobisch and Glover, 1971; Kreisa, 1980). These rocks are bounded on the northwest by rocks of the Danville Triassic basin and on the southeast by rocks of the Carolina slate belt contained in the Virgilina synclinorium. To the southwest in North Carolina this sequence is on strike with rocks of the Charlotte igneous belt and these rocks probably are the country rocks that the igneous plutons intruded to produce this igneous belt. To the northeast, beyond the study area in central and northern Virginia, these volcanic and sedimentary rocks are on strike with and are tentatively correlated with rocks of a volcanic island-arc suite named the central Virginia volcanic-plutonic belt (Pavlides, 1981). There is a discrepancy between the age of the rocks in the southern Virginia Piedmont and the preferred age for the rocks that make up the belt to the northeast. Pavlides (1981) considers the belt in central and northern Virginia to be of probable Cambrian age, whereas Glover and others (1971) report an age of 620 m. y. to 740 m. y. for rocks along the North Carolina boundary just west of the Virgilina synclinorium (Figure 2). These dates were from zircons that might contain lead inherited from older rocks.

The base of the section of metavolcanic and metasedimentary rocks is not exposed within this

study area. Tobisch and Glover (1971), Glover and others (1971) and Kreisa (1980) have mapped the contact between these rocks and the overlying Carolina slate belt (Figure 2) and have interpreted this contact to be conformable. The abrupt change in metamorphic grade from greenschist in the Carolina slate belt to upper amphibolite in the metavolcanic-metasedimentary rocks to the west was thought to be a tightly compressed metamorphic gradient. Similarly, Secor and others (1983) find the contact between the Charlotte belt and Carolina slate belt to be a metamorphic gradient, and further proposed that the slate belt is an exotic, terrain that was first deformed in early Paleozoic time. In contrast, because the rocks of the central Virginia volcanic belt are lithologically different from the stratigraphic units in the Carolina slate belt and because rocks of the Carolina slate belt physically overlie rocks of the central Virginia volcanic belt along the western boundary of the Virgilina synclinorium, Conley (1974) concluded that the rocks of the Carolina slate belt are younger than rocks of the central Virginia volcanic belt. Pavlides (1976, 1981) shows that the stratigraphy and the geochemistry of the central Virginia volcanic belt and the Carolina slate belt are entirely different and concludes that these two sequences of rocks were parts of separate volcanic and tectonic provinces. Perhaps in Cambrian time, rocks of the central Virginia volcanic belt formed as an island arc sequence bordering North America and the Carolina slate belt formed as a similar island arc sequence on the African Continent. Therefore, the contact between those two belts would indeed, represent a suture zone as suggested by Glover (1974).

In the area represented in the Plate, the metavolcanic and metasedimentary rocks are divided into a lower unit and an upper unit (Henika, 1977; Price and others, 1980A and 1980B). The lower unit of the metavolcanic-metasedimentary rocks is inhomogenous and composed of irregularly interlayered felsic and mafic metatuff beds at the base that grade upward into a more regularly layered sequence of closely spaced layers of felsic and mafic metatuffs containing minor metagraywacke layers (Henika, 1977). The contact between the lower and upper units is drawn at the top of a prominent mafic layer, which is the highest mafic layer in the sequence. The upper unit is composed of felsic volcanic rocks and volcanic-sedimentary rocks.

The core of this belt of metavolcanic and metasedimentary rocks is at sillimanite grade (Figure 3), and grade drops to greenschist facies along both its northwestern and southeastern boundaries (Henika, 1975, 1977; Tobish and Glover, 1971; Kreisa, 1980). In the area along the northwestern boundary, the rocks are at greenschist facies and welded tuffs, crystal tuffs, and volcanic breccias are still recognizable (Henika, 1977). Where the metavolcanic and metasedimentary rocks have reached sillimanite grade, the lower unit consists of a sequence of interlayered quartzo-feldspathic gneisses and hornblende-plagioclase gneisses that probably also represent highly metamorphosed volcanic and volcanic-sedimentary rocks. Interlayered schistose rocks observed in this unit could represent pelitic interbeds. At sillimanite grade the upper unit is a leucocratic, poorly layered, quartzo-feldspathic gneiss (Henika, 1977; Price and others 1980A). Other high-rank rocks found in the lower unit of this sequence are kyanite-mica schist and sillimanite quartzite (Henika, 1977).

Graphite schist bands occur in the area underlain by rocks of the central Virginia metavolcanic belt to the east as far as the vicinity of South Boston (Kreisa, 1980 and personal communication). Because of the structural and stratigraphic similarity of the graphite schist to the Arvonia Formation, which is on strike to the northeast, Conley (1978) suggested that the schist might be infolds of Arvonia Formation into the metavolcanic-metasedimentary rocks, rather than being graphitic interlayers in these rocks.

Shelton Formation

The Shelton Formation is a felsic igneous rock originally named the Shelton Granite by Jonas (1928) and renamed Shelton Formation by Henika (1977) because he found that at its type locality Jonas had included metamorphosed volcanic and sedimentary rocks of the central Virginia volcanic belt in the granite. Although areas mapped as Shelton Formation might contain very minor metasedimentary rocks, the Shelton as mapped by Henika (1977) is a pink to gray, coarse-grained, two-mica sheared plutonic igneous rock that ranges in composition from quartz monzonite to granite. The rock has been tectonically deformed and shows a faint gneissosity. This gneissosity is cut by a nonpenetrative foliation that produces a well-developed pencil rodding. The formation contains microcline and perthite augen that are enclosed by biotite in a quartz-plagioclase matrix. Intrusive contacts seem to be conformable with the enclosing metavolcanic-metasedimentary rocks, indicating either that the Shelton occurs primarily in concordant plutons or there has been extreme flattening and transposition of the contacts.

Henika (1977) originally thought that the lower unit of the metavolcanic-metasedimentary sequence unconformably overlay the Shelton Formation, and he considered the Shelton to be a Grenville basement rock. Stephen Kish (personal communication, June, 1980) obtained a radiometric age using Rb/Sr whole-rock method of 429± 7 m.y. from the Shelton. This Rb/Sr age date indicates that the Shelton is not basement but rather is more likely an intrusive pluton in the Precambrian-Cambrian metavolcanic and metasedimentary rocks. The Shelton slightly predates typical plutonic rocks of the Charlotte igneous belt, which range in age from 415 to 395 m. y. old (Fullagar, 1971; Fullagar and Butler 1975).

DIABASE DIKES

Swarms of north and northwesterly trending, en echelon diabase dikes occur in the eastern, central and western parts of the area (Plate). There seems to be two trends of diabases, one oriented about N20°W-N30°W and the other almost north-south. The northerly-trending dikes are wider than the northwest-trending dikes and generally pinch and swell (Plate). Ragland and others (1983) show that the north-south set of dikes were emplaced in a north-south set of fractures that converge near Charleston, South Carolina. These north-south dikes are more differentiated than the northwest-trending dikes (Ragland and others, 1968; Weigand and Ragland, 1970; Ragland and others, 1971).

The dikes are medium-gray to black and range from basalt at chilled margins to medium-grained gabbro in the centers of larger intrusive bodies. They are moderately resistant to chemical weathering, which begins along joint surfaces and proceeds inwardly into the rock. This produces spheroidally weathered boulders and ocherous saprolite.

The diabases are composed of about 50 percent calcic plagioclase (An_{56}) and about 30 percent augite. Magnetite is the major accessory mineral. Only three of the diabases examined in thin sections contain olivine (from 2 to 5 percent). Textures are generally ophitic. Alteration is rather common at contacts between dikes and country rock; the alteration is the product of hydration. As the dikes are generally most altered at the contact with country rock, the water probably came from the enclosing country rock. Alteration minerals include pale-green, fibrous serpentine, antigorite, talc and chlorite; also, plagioclase may be altered to sericitic mica. Some diabases show the results of hydrothermal replacement in the form of myrmekite and micropegmatite; biotite forms vermicular intergrowths in plagioclase along pyroxene boundaries.

The diabases are thought to have originated in the upper mantle and ascended so rapidly into the overlying continental crust that there was insufficient time for differentiation to take place (Ragland and others, 1971). The intrusion of these rocks was probably related to development of tensional fractures formed in response to release of stress just prior to the rending of the continent of Laurasia and formation of the Atlantic Ocean by sea floor spreading on opposite limbs of the North American-Caribbean rift in the middle and late Jurassic (Dietz and Holden, 1970).

The diabase dikes are probably of Jurassic age as indicated by a $^{40}Ar/^{39}Ar$ age date of 190 m.y. on the Palisades sill in New Jersey (Dallmeyer, 1975), by paleomagnetic data (De Boer, 1967), and by the occurrence of lava flows (probably fed by diabases) interlayered with early Jurassic sedimentary rocks in northern Virginia (Lindholm, 1979; Cornet, 1977). Ragland and others (1983) propose that the emplacement of the north-south trending dikes, postdates the emplacement of the northwest-trending dikes.

STRUCTURE

FOLDS

Blue Ridge Anticlinorium

Fold patterns in the Blue Ridge anticlinorium are delineated by the amphibolites in the Lynchburg Group. F_1 isoclinal folds are warped by F_2 isoclines to produce hook-shaped fold patterns typical of type-3 fold patterns (Ramsey, 1967). The folds are now almost coplanar, but are not colinear. Hinges of F_2 folds are subhorizontal, whereas F_1 folds plunge at angles on the order of 45 degrees both to the southeast and northwest. The F_1 folds initially trended more northwesterly and were refolded by the northeasterly trending F_2 folds. The F_1 and F_2 folds were warped by large, gently plunging, open, northeast-trending, F_3 structures such as the Cooper Creek anticline. A late-developed, sub-horizontal crenulation cleavage occurs throughout the area. It is extremely well developed along the Bowens Creek fault zone and might be related to sub-horizontal thrust movement.

F_1 folds in the Candler Formation are steeply plunging intrafolial isoclines. F_2 folds in the formation are overturned to the northwest; the axial surfaces of these later folds dip to the southeast at angles generally greater than 45 degrees. F_3 folds in the unit are broad, more open structures and trend northeastward.

Smith River Allochthon

The Smith River allochthon, is a northeastward-trending polydeformed, rootless structure (Figure 2 and Plate). Mathematical modeling of gravity and magnetic data indicates that the allochthon is a thin, sheet-like mass (Greenberg, 1975). It is bounded on the northwest by the southeastward-dipping Bowens Creek thrust fault and on the southeast by the northwestward-dipping Ridgeway thrust fault. To the southwest along strike, the Bowens Creek and Ridgeway faults converge and merge at the Brevard zone (Rankin, Espenshade and Newman, 1972; Espenshade and others, 1975). The eastern margin of the Smith River allochthon is truncated by the vertical to steeply southeastward dipping Chatham fault zone, which borders the Danville Triassic basin.

Folds within the Smith River allochthon now have a general N45°E trend. The earliest folds (F_1) developed in the rocks of the allochthon are seen at outcrop scale in the Fork Mountain Formation. These folds are so transposed in the plane of foliation that they probably do not greatly affect general outcrop patterns of rock units. Many of these F_1 folds are hook-shaped and many are rootless fold noses, as seen both in outcrop and thin sections. A second set of folds (F_2) is at map scale and warps the foliation. These F_2 folds have a northeasterly trend and an upright to steeply southeastward-dipping non-penetrative cleavage which is developed parallel to their axial planes. They are refolded by a more northerly trending set of upright folds (F_3). The F_3 system, which is probably equivalent in age to the F_3 system in the Sauratown Mountains area, formed during or after emplacement of the allochthon because it warped both the rocks of the allochthon and rocks that underlie the allochthon.

The allochthon is now preserved in a northeasterly trending, shallow basin that probably formed during the F_3 folding event as an interference pattern produced by the refolding of F_2 folds.

The Phase II fold system of Stirewalt and Dunn (1973), which, they proposed, produced the "James River synclinorium," probably developed at this same time. Development of the Sauratown Mountains anticlinorium and the Blue Ridge anticlinorium is also probably equivalent in age to this F_3 event. The development of these anticlinoria as major regional structures probably was either coeval with, or later than, emplacement of the Smith River allochthon because the Smith River allochthon is preserved in a synformal structure between these two anticlinoria.

Sauratown Mountains Anticlinorium

Rocks of the Sauratown Mountains anticlinorium have been warped into crescent-shaped folds (Price and others 1980A, 1980B) typical of the type-2 interference pattern (Ramsey, 1967). This pattern was produced by the refolding of a southeastwardly dipping isoclinal fold system (F_1) by a later (F_2) set of folds that had a trend almost normal to the trend of the F_1 set of folds. F_1 and F_2 folds are warped by upright north to northeast-trending folds (F_3). The intersection of the F_2 and F_3 folds produces basin-and-dome, or type-1, interference patterns (Ramsey, 1967) as shown on the Plate. The development of the anticlinorium as a major regional structure was followed by erosion causing the removal of the rocks which once connected the Smith River allochthon to the Inner Piedmont belt as a continuous thrust sheet.

Central Virginia Metavolcanic-Plutonic Belt

The unnamed metavolcanic and metasedimentary rocks east of the Danville basin contain an early set of recumbent isoclines (F_1 folds) that have U-shaped hinges and plunge gently either to the northwest or to the southeast (Henika, 1980). No foliation is developed parallel to the axial surfaces of these folds, indicating that they formed prior to the time of regional metamorphism. A second set of folds (F_2) are tight isoclines with V-shaped hinges that are overturned to recumbent. Penetrative foliation cuts the hinges of these folds indicating that they are synmetamorphic. Tobish and Glover (1971) interpreted these two fold systems as representing ongoing development; they envisioned folding to have begun prior to the onset of metamorphism and to have been completed before the end of metamorphism. A later set of open, upright folds (F_3) trend northeastward and plunge both to the northeast and to the southwest. These folds are colinear but are not coplanar with F_2 folds. A nonpenetrative shear foliation developed parallel to F_3 axial surfaces cuts the penetrative S_2 foliation developed during F_2 folding.

Henika (1977) states that early folds have the characteristic mushroom or crescent shape of a type 2 interference pattern (Ramsey, 1967). This pattern was produced when gently inclined isoclinal F_1 axial surfaces were refolded by F_2 isoclines, which are more steeply inclined. Hook-shaped folds (type 3 interference pattern; Ramsey, 1967) resulted from the superimposition of F_3 folds on F_2 folds (Henika, 1977). This fold pattern is also displayed just east of the study area (Tobish and Glover, 1977).

The only foliation in the Shelton Formation is the nonpenetrative shear cleavage developed during the F_3 fold event (Henika, 1977), indicating that the Shelton is post tectonic and intruded preexisting structures that contained earlier developed F_1 and F_2 folds. The F_2 folds are probably Taconic in age as they are older than the Shelton, which is a Silurian age intrusive. The F_3 folds are probably of Acadian age, because they postdate the Shelton.

Interregional Folds

Rocks throughout the study area contain northwestward-trending, broad, open warps that are evidently the youngest folds in the Virginia Piedmont. These folds were first recognized by Conley and Toewe (1968) in rocks of the Smith River allochthon. They have since been recognized by Henika (1977) in the area east of the Danville basin, by McCollum (Rocky Mount and Gladehill quadrangles) in the Blue Ridge anticlinorium, and in the central Virginia Piedmont (Poland, Glover and Mose, 1979). Henika noted that a local northwest-trending spaced cleavage is associated with these folds and postulated that the folds were formed by post-Triassic block movement along north- to northwest-trending shear planes. It is possible that the fold system developed at the time of formation of major faults such as the Stony Ridge (Butler and Dunn, 1968) and Chatham faults (Figure 2) as a result of north-south compressional forces which could generate left-lateral movement along these faults. A tensional complement to this stress regime would be in a northwest direction, which also is a major trend direction of the diabase dikes in the region. This is further supported by the fact that the northerly-trending set of diabase dikes are wider than the northwest-trending set of dikes. These dikes also pinch and swell, whereas the northwest-trending set generally have a fairly constant width. This indicates that the northerly-trending set was subject to dilation during emplacement, and that they were emplaced in fractures normal to the direction of maximum tension. This was an east-west direction and therefore perpendicular to a north-south direction of maximum compression suggesting that the fractures might have been produced by a right-lateral shear couple.

FAULTS

Normal Faults

Chatham Fault

The Chatham fault (Myertons, 1963) bounds the northwestern part of the Danville Triassic basin (Figure 2). It truncates the Ridgeway fault in the south-central part of the area and from there northeastward forms the northwestern boundary of the Smith River allochthon. At the North Carolina boundary, the fault has an approximate trend of N45°E, and it can be traced in this direction to an area east of Sandy Level (Plate and Figure 2), where it assumes an almost east-west direction. Farther northeastward the fault strikes approximately N50°E, which is its trend direction through the rest of the area to the north. The fault dips 60° to 70° south or southeast.

The Chatham fault consists of a zone of cataclasis that has been displaced by later, north-trending and northwest-trending vertical normal faults (Plate). Geologic mapping (Henika, 1977; Price and others 1980A, 1980B) indicates that highly sheared rocks occur in zones as much as 0.5 mile wide along the Chatham fault and that these zones include cataclastic rocks derived both from the igneous and metamorphic rocks that lie northwest of the Danville basin and the sheared Triassic age sedimentary rocks within the basin. Highly sheared gneisses, granites and pegmatites are locally recognizable.

The fault zone records more than one period of movement and a change from ductile to brittle deformation. It is thought that movement probably occurred over an extended period of time. Robinson (1979) reported undeformed pegmatite intruding mylonite along this fault zone. This pegmatite has not been dated, but mica from one of the pegmatites in the Ridgeway mica district was dated by the Rb-Sr method at 321 m.y. (Mississippian) (Deuser and Herzog, 1962). This dated pegmatite probably formed during what is thought to be the last major period of metamorphism in the region. Mylonites intruded by this unsheared pegmatite show recrystallization and contain prograde garnet whose formation postdates the last cataclasis (Robinson, 1979). A younger microbreccia (breccia composed of fragments of pre-existing mylonite and mylonite breccia) and massive cataclasite, which do not show recrystallization, are also present (Robinson, 1979; Price and others, 1980A and 1980B). The cataclastic rocks have been exposed to hydrothermal solutions because they are cut by quartz veins and are locally silicified. Some fractures are filled with chlorite containing pyrite inclusions. Riebeckite of apparent hydrothermal origin occurs in fractures in the cataclacite (W. S. Henika, personal communication, 1978) and in fractures in the Triassic rocks within the Danville basin (Allen, 1967). Samples of silicified microbreccia along the southwestern extension of the Chatham fault in North Carolina have been dated as Early Jurassic age, 180+ 3 m.y.

ago (Fullagar and Butler, 1980). The Chatham fault locally shows brittle deformation which indicates a later period of movement than the ductile deformation that produced the mylonites.

Local areas of relatively high potassium-uranium concentrations are shown along the fault zone by aeroradioactivity maps (Virginia Division of Mineral Resources, 1979) and prospecting for uranium was begun in 1978 in the environs of the Danville basin by Marline Uranium Corporation, a subsidiary of Marline Oil Corporation (Marline Oil Corporation, 1982). Drilling by Marline was begun in 1979, and the program identified a high grade uranium deposit located 6 miles northeast of Chatham. An average ore content is reported to be 4 lbs. per ton and reserves are estimated to be in the order of 30 million pounds of uranium oxide (U_3O_8). The host for the deposit is sheared rocks of the Fork Mountain Formation and other rocks of the Smith River allochthon (Marline Oil Corporation, 1982).

The sedimentary rocks within the Danville basin strike N44°E +11° and dip N44°W +9° (Thayer, *in* Henika, 1977). The consistency of the trend and dip of these rocks indicates that little movement occurred along the Chatham fault during deposition of the sediments that fill the basin. If movement had occurred during deposition it would be expected that the older sedimentary rocks within the basin would have a greater angle of dip than the younger rocks of the basin. The last movement along the Chatham fault probably postdates deposition. This last movement along the fault rotated the rocks within the basin from the horizontal to a northwest dip and thus produced a northwest dipping monoclinal sedimentary wedge within the basin.

Vandola Fault

The Vandola fault (Price and others 1980B) is a border fault on the east side of the Danville basin in the south-central part of the area (Plate). It has been traced for about 9 miles in a northeasterly direction from the North Carolina boundary. Farther to the northeast along strike, this fault is absent and Triassic sedimentary rocks rest unconformably on underlying metamorphic rocks. The fault dips to the northwest at angles ranging from 50° to 60°. Cataclasite occurs along the extreme northeastern part of the fault trace for about 1.5 miles (Thayer *in* Henika, 1977). It is inferred that movement on the Vandola fault preceded deposition of sediments in the basin because (as previously noted) rocks in the basin have a constant northwest dip both in the areas where it is present and areas where it is absent (Thayer *in* Henika, 1977). If movement on the fault had occurred after deposition, dips should be more shallow in the areas where the fault is present than where it is absent.

Unnamed Faults and Shear Zones

A major fault occurs in the north-central part of the area (Plate and Figure 2). The fault trends about N20°E; two splays have more easterly trends. The structure is a hinge fault that to the north movement is up to the east and to the south movement is up to the west. The fault has displaced rocks of both the Smith River allochthon and the Blue Ridge anticlinorium. Where gneisses (Bassett Formation) occur on either side of the fault zone, they have been altered to silicified mylonite and cataclasite, but where the fault is bounded by schists (Fork Mountain Formation and the metasedimentary rocks of the Lynchburg and Candler formations), the rocks are sheared into button schists, but no mylonites are developed. This fault displaces the Bowens Creek thrust fault and the thrust fault along the southeastern Candler-Lynchburg contact; therefore, it is younger than these major thrusts of the region.

A shear zone that has a trend of N80°E has been traced from the eastern boundary of the map (Plate) southwestward through Ringgold to about the center of the city of Danville, a distance of about 7 miles (Henika, 1977). This shear zone contains microbreccia and lenses of cataclastic rock. The new minerals calcite epidote and stilbite have grown in the sheared rocks of this shear zone. A body of microbreccia in this shear zone is located along the Norfolk and Southern Railway 0.7 mile northeast of Ringgold. This microbreccia is cut by a Mesozoic diabase dike indicating that the development of the shear zone preceded the intrusion of this dike.

A second shear zone that has a trend of about N15°E is located about 2.3 miles due east of New Mountain Cross (Plate). This fault can be traced in a northeasterly direction for approximately 2.8 miles to the southwestern edge of the Danville Triassic basin where it intersects the Vandola fault (Henika, 1977).

A third shear zone can be traced for about two miles in a N60°E direction from the southern boundary of the map (North Carolina state boundary) in the area 0.8 mile NW of Rutledge Creek southwest of Danville. This zone contains sheared and locally lenses of extremely sheared (cataclastic) rock (Henika, 1977).

Thrust Faults

Bowens Creek Fault

The Bowens Creek fault (Conley and Henika, 1970) bounds the northwestern edge of the Smith River allochthon and has a sinuous trace that trends generally N50°E (Figure 2). In the present study area the Bowens Creek fault is very close to the location of the Martic thrust fault as shown by Jonas on the 1928 edition of the Virginia State Geologic Map. As noted previously, mathematical modeling of gravity and magnetic data indicates that the Smith River allochthon is a shallow structure (Greenberg, 1975). The dip of the fault plane of the Bowens Creek fault is to the southeast and is less steep than that of the penetrative foliation developed in rocks bounding the structure. The fault plane dips most steeply in the southwestern part of the area and is almost flat to the northeast as indicated by the fault trace, which encircles a small window along Walker Creek in the north-central part of the study area; a reentrant at Dickenson, which is just east of the window; and a larger reentrant in the northeastern part of the area (Plate). Across the southwestern and central part of the area, a shear zone is developed along this fault. However, to the northeast, little or no shearing accompanies the fault, except for localized areas where a sub-horizontal, spaced cleavage is developed primarily in the footwall. The absence of major shear zones developed by thrust faults is interpreted by Elliott and Johnson (1980) to mean formation at shallow depths. If this interpretation is correct, it would indicate that the fault developed at shallow depths in the northeast and at greater depth to the southwest. An alternative explanation might be that to the north the allochthon moved on a sub-horizontal fault plane and was thrust forward with little effort, probably aided by high fluid pressure within the fault plane. To the south the steeper dip angle of the fault plane would suggest that, in this area, the thrust sheet was riding up a ramp surface, which afforded greater resistance to movement; with accompanying possible loss of fluid pressure, this may have resulted in a greater amount of friction and produced the resulting shearing.

Ridgeway Fault

The Ridgeway fault (Conley and Henika, 1973) is a thrust that bounds the southeastern part of the Smith River allochthon and separates it from the Sauratown Mountains anticlinorium, which bounds the allochthon to the south and southwest (Plate and Figure 2). The fault has a sigmoidal trace (Plate) and dips to the northwest, under the allochthon. An exception is in the area where it converges with the Brevard zone southwest of the present study area (Espenshade and others, 1975). There, the fault has been overturned and dips to the southeast. Reentrants along the trace of the fault suggest that the fault plane is folded. The lack of development of appreciable shearing along the fault zone suggests that it, like the northeastern segment of the Bowens Creek fault, either could have developed at relatively shallow depth or was a subhorizontal fault accompanied by high fluid pressure.

Termination of the Smith River Allochthon to the Southwest

To the southwest both the Bowens Creek and Ridgeway faults verge and finally merge with the system of faults that make up the Brevard zone in North Carolina. The Brevard zone is composed of a number of faults, each of which from its point of emergence can be traced northward in a direction that is more northerly than the trace of the Brevard zone proper. This is because the top thrust sheet in the stack, namely the Inner Piedmont thrust sheet, has a more easterly trend than the underlying sheets. This trend probably resulted from the development of later folds such as the Blue Ridge anticlinorium, the synform that preserves the Smith River allochthon and the Sauratown Mountains anticlinorium. Geologic mapping of the extreme southeastern edge of the Grandfather Mountain window (Conley and Drummond, 1981) shows that even the Blue Ridge thrust sheet verges with and finally merges with the Brevard zone. Bryant and Reed (1970) and Conley and Drummond (1981) have shown that the plane of the fault at the base of the Blue Ridge thrust sheet along the northwestern edge of the Grandfather Mountain window dips gently to the northwest, but to the southeast it is rotated and dips steeply to the southeast just before entering the Brevard zone. This is similar to what happens to the Ridgeway fault which, as previously noted, to the northeast dips to the west at a shallow angle, but to the southwest is rotated so that it dips to the southeast before entering the Brevard zone (Espenshade and others, 1975). This rotation is caused by the fact that both the Grandfather Mountain window and the Sauratown Mountains anticlinorium are windows of para-autochthonous rocks (Bryant and Reed, 1961; Conley, 1978). Both antiformal structures are gentle, open warps to the north, but their

northwestern limb becomes progressively steepened and finally overturned to the southwest before each enters the Brevard zone. The development of all these structures is probably controlled by development of a ramp in the subsurface and bending of westward moving subhorizontal thrust plates as they are forced to ride over this ramp surface.

Probable Thrust Faults At The Base of Ophiolites In The Lynchburg Group

As noted previously, the ultramafic and mafic metaigneous and metavolcanic rocks occur at several intervals in the stratigraphy of the Lynchburg Group in both the Blue Ridge and Sauratown Mountains anticlinoria. These repeated sequences of metamorphosed ultramafic, gabbroic and basaltic rocks overlain by metasedimentary rocks suggest that the formation is composed of stacked piles of ophiolites and their cover rocks repeated by thrust faulting. Two intervals of rocks of ultramafic, gabbroic and basaltic composition were recognized in the rocks of the Lynchburg Group in the Sauratown Mountains anticlinorium; one is at the base of the Ashe Formation and one at the base of the Alligator Back Formation. These two intervals may represent a single ophiolite and cover-rock sequence. In this scenario the coarser-grained quartzo-feldspathic rocks (probably proximal turbidites) of the Ashe Formation with ophiolites composed of ultramafic rocks, metagabbros and metabasalts at their base were overthrust by more pelitic rocks (probably distal turbidites) of the Alligator Back Formation, also with ophiolites at their base. This stacked sequence was then obducted onto Grenville age continental crust (Stuart Creek Gneiss).

The interpretation that these rocks are repeated sequences of ophiolites and their cover rocks would suggest that each sequence is separated by a fault at the base of each ophiolite. During geologic mapping, faults have not been recognized at the base of every mafic-ultramafic sequence. Shear zones have been mapped at the top of the Stuart Creek Gneiss (Grenville basement) in the Sauratown Mountains anticlinorium (Conley and Henika, 1973). Shear zones have also been recognized in rocks of the Blue Ridge anticlinorium both at the base of and within the metagabbro body west of Fairystone Lake (Conley and Henika, 1970), at the top of the Ashe Formation in the Cooper Creek anticline, and at the base of the gabbro-ultramafic body underlying Grassy Knob north of Rocky Mount. The eroded surface of the Lynchburg in central and northern Virginia (Conley, 1978) is apparently stratigraphically overlain (by the Catoctin) a relationship that would suggest that the Lynchburg was obducted onto the continental crust and subjected to erosion prior to the outpouring of the Catoctin metabasalts in late Precambrian or earliest Cambrian time.

Thrust faults bounding the Candler Formation

In the area of study, the Candler Formation crops out in the form of a northeast-oriented, V-shaped splay that dies out to the southwest. To the west the Candler Formation is in fault contact with the underlying Alligator Back Formation of the Lynchburg Group, and to the east the Alligator Back Formation is thrust back over the Candler. The fault, which has thrust the Alligator Back Formation over Candler, completely overrides and cuts out the Candler to the southwest. The fault disappears under the northwestern boundary of the Smith River allochthon. The two fault planes which enclose the wedge of Candler dip southeastward at angles of about 50 degrees.

Berquist (1980) suggests that both of the faults that bound the wedge of Candler are thrust faults. Berquist (1980) explained the structure as a recumbent syncline of Candler, thrust over the Lynchburg. Certainly such an explanation would account for the juxtaposition of younger rocks over older rocks. An alternative explanation is that the structure is a sequence of exposed decollement zones, wherein rocks of Candler and Lynchburg are stacked one above the other through the development of ramps. Recent Vibroseis data from the central Virginia Piedmont (Harris and others, 1982) indicate that the structure of the Piedmont is a major decollement off which ramp thrusts have been generated, thus telescoping the rocks into repetitive sequences. These sequences are generally separated by sub-horizontal thrust planes. Therefore, late developing ramp faults can thrust younger rocks that were deeper in the repetitive thrusted pile over older rocks that had been previously ramped and are higher in the stack (but not higher in the stratigraphic section). This leads to the conclusion that the Candler is indeed bounded by thrust faults, to produce a duplex similar to that proposed by Boyer and Elliott (1982) for other parts of the southern Blue Ridge and Piedmont. The presence of a ramp structure would explain both the straight-line trace of the fault and the rather steep dips (45°-50°) recorded along the fault trace. That normal, rather than thrust movement, might also have occurred on these ramp surfaces during

the time when the faults were active cannot be ignored, especially toward the end of this period, when relaxation of compressive forces might have occurred, producing listric normal faults.

REGIONAL SIGNIFICANCE OF THE PRESENT STUDY

SIGNIFICANCE OF OPHIOLITES? IN THE LYNCHBURG GROUP

The presence of possible ophiolites in the rocks of the Lynchburg Group shows that the Lynchburg meta-sedimentary rocks, some of which are interlayered with basalts at the top of the candidate ophiolite sequences, were likely deposited on oceanic crust, now represented by the ophiolites. The Lynchburg metasedimentary rocks and underlying oceanic crust (ophiolites) would have been obducted onto the North American continental crust (now represented by Grenville-age rocks in the cores of the Blue Ridge and Sauratown Mountains anticlinoria) during a late Precambrian closing event. This was prior to the vast outpouring of Catoctin continental metabasalts directly onto the Lynchburg on the southeast limb of the Blue Ridge anticlinorium, an event which heralded the beginning of continental break up and formation of the Iapetus Ocean in latest Precambrian—earliest Cambrian time. The absence of the Lynchburg on the northwestern limb of the Blue Ridge anticlinorium is the result of erosion prior to deposition of the Catoctin. The Catoctin flows poured out on an erosional surface (Reed, 1955) that had developed on the Lynchburg to the east and on Grenville basement to the west, where the Lynchburg had been eroded away.

A REINTERPRETATION OF THE JAMES RIVER SYNCLINORIUM

Work by Redden (1963) in the Altavista 15-minute quadrangle, which borders the northeastern part of the present study area, provides a connecting link with rocks mapped by Espenshade (1954) and Brown (1958) in what they called the James River synclinorium. A number of persons have mapped the rocks of the James River synclinorium and considerable controversy has developed concerning stratigraphic relationships within the structure (Table).

Figure 12 is a sequence of block diagrams that compare previous interpretations by Brown (1958) of the geology of the Lynchburg quadrangle with the present interpretation of a larger area from the Lynchburg quadrangle southwestward through the present study area. Major differences in these two interpretations are as follows:

1. The Catoctin Formation is a unit of subaerial metabasalts and arkosic metasedimentary rocks (Reed and Morgan, 1971) that lies stratigraphically between the Lynchburg Group and the Candler Formation. Mapping by the writer on the southeast limb of the Blue Ridge anticlinorium shows that the Catoctin thins and finally pinches out northeast of Lynchburg, and the rocks previously considered to be Catoctin greenstone interlayered with the top of the Lynchburg Group by Brown (1958) are actually metabasalts contained within the Alligator Back Formation of the Lynchburg Group. The top parts of these metabasalt sequences are interlayered with Lynchburg metasedimentary rocks that are deep marine metasedimentary rocks, in part of turbidite origin; therefore these basalts are not of subaerial flows.
2. The contact between the Candler and the underlying Alligator Back Formation of the Lynchburg Group is not a stratigraphic contact but a fault contact Berquist (1980). In the Buffalo Ridge 7.5 minute quadrangle, which is northeast of the Lynchburg 15-minute quadrangle, the writer has found a fault (probably the same fault mapped by Berquist farther to the southwest) that has cut out the Catoctin Formation, and the Catoctin is not exposed to the southwest beyond this point.
3. The Evington Group has been regarded as a continuous stratigraphic sequence of rocks that occupies the core of the James River synclinorium (Brown, 1958; Espenshade, 1954). It contains the Candler Formation at the base of the section and the Slippery Creek greenstone at the top. Work in the present study area shows that the geology is more complex than a simple stratigraphic sequence contained in an open synformal fold. The contact between the Candler Formation and structurally overlying formations has also been mapped in detail by Berquist (1980) in the Sandy Level quadrangle and by Conley and others in the Penhook quadrangle (in preparation), and the contact in these quadrangles is also a fault contact. To the southwest this fault cuts out the Candler and places the rocks that structurally overlie the Candler in contact with rocks of the Alligator Back Formation, a formation older than the Candler. The overlying rocks are metagraywackes and graphite schists that are identical to the typical Alligator Back Formation. Therefore, rocks that

Table. Chart of stratigraphic units.

BROWN (1958)	ESPENSHADE (1954)	REDDEN (1963)	THIS REPORT: Southeast Limb. Blue Ridge Anticlinorium	THIS REPORT: Smith River Allochthon
		Candler Formation	Candler Formation	
Slippery Creek greenstone	Younger greenstone			
Evington Group: Mount Athos formation	Evington Group: Mount Athos formation	Archer Creek Formation		
Pelier schist	Archer Creek formation			
Arch marble				
Joshua schist				
Candler formation	Candler formation	Mount Athos Formation		
Catoctin greenstone	Older greenstone	Greenstone	Catoctin Formation? (Slippery Creek greenstone of previous authors)	
Lynchburg gneiss	Lynchburg gneiss	Lynchburg Formation	Lynchburg Formation (Includes Lynchburg gneiss, "older greenstone" of Espenshade Catoctin and Catoctin greenstone of Brown, Archer Creek and Mount Athos formations of previous authors)	
				Schist unit, Fork Mountain Formation (On the S.E. limb of the "James River Synclinorium" the schist unit was previously correlated with the Candler Formation.)
				Amphibolite unit at the top of Bassett Formation (In the Sherwell anticline this unit was previously correlated with the Catoctin greenstone.)
				Biotite gneiss unit of the Bassett Formation (In the Sherwill anticline this unit was previously correlated with the Lynchburg Formation.)

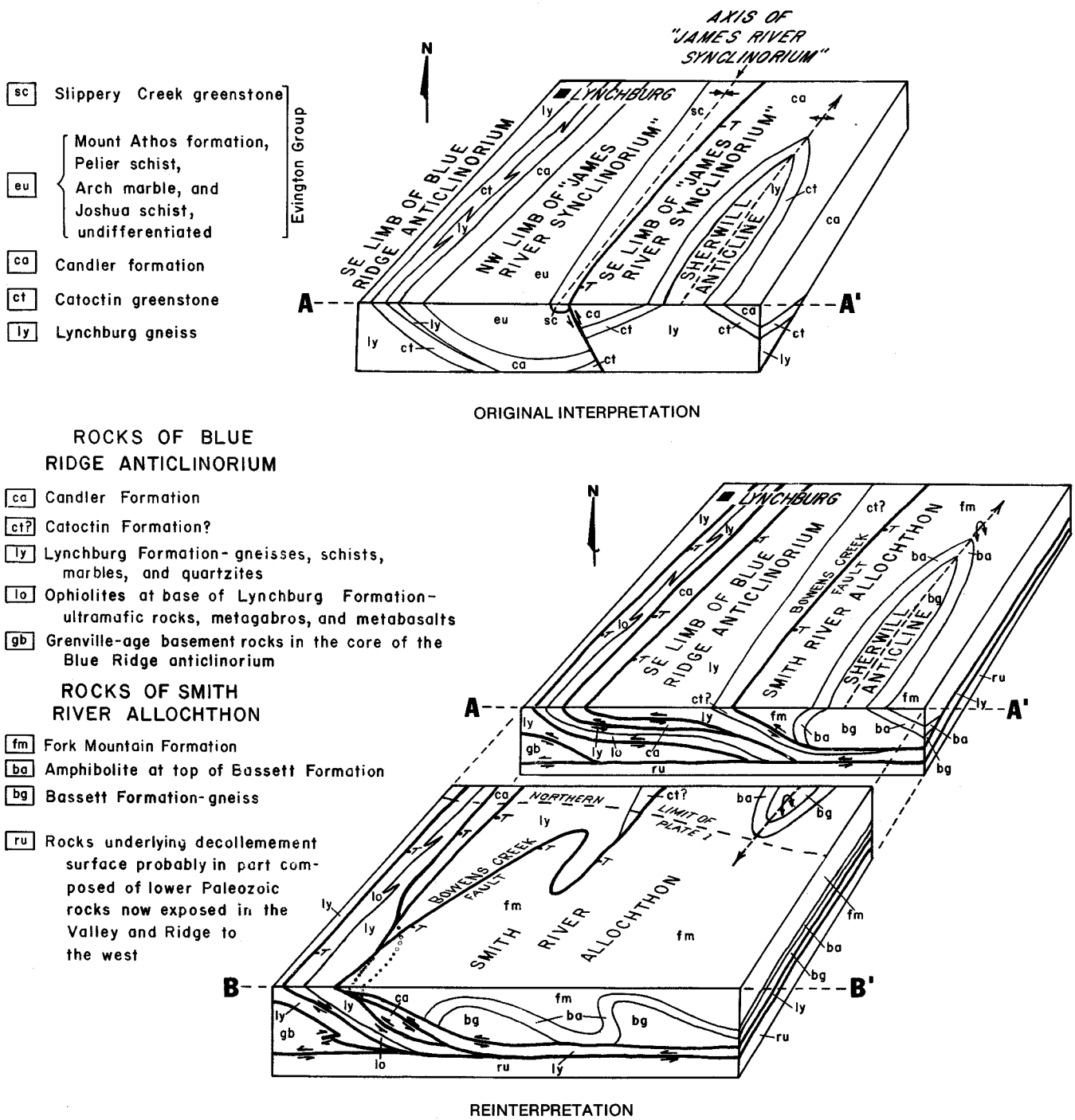

Figure 12. Block diagrams showing the original interpretation and reinterpretation of the stratigraphy and structure of the James River synclinorium.

physically overlie the Candler are not younger units belonging to the Evington Group but belong instead to the Alligator Back Formation, which has been thrust over the Candler. Thus it appears that there is no Evington Group that overlies the Catoctin, but rather a single formation, the Candler Formation, which overlies the Catoctin.

4. Bland (1978), by chemical analyses, found that the Slippery Creek greenstone, a greenstone at

the top of the sequence of rocks previously called the Evington Group, exhibits many characteristics of continental rift basalts, and furthermore, he found that it is chemically indistinguishable from the metabasalts of the Catoctin Formation. Therefore, the Slippery Creek greenstone would actually be the Catoctin Formation in normal stratigraphic order, overlying the Lynchburg Group, but contained in a more eastward thrust plate.

5. Present mapping shows that the thrust fault previously mapped just southeast of the axis of the James River synclinorium in the Lynchburg quadrangle (Brown, 1954) is a continuation of the Bowens Creek fault, which separates rocks of the Blue Ridge anticlinorium to the northwest from rocks of the Smith River allochthon to the southeast.
6. The schist which lies along the southeastern edge of the Bowens Creek fault is described by Brown (1958) as a garnet-mica and staurolite-garnet-mica schist that shows partial to complete retrograde metamorphism of staurolite to chlorite and sericite and garnets to chlorite. Because this schist shows polymetamorphism similar to that seen in the Fork Mountain Formation and because two stages of metamorphism an not known to occur in the Candler, it is inferred that this rock belongs to the Fork Mountain Formation. Similar schists of the Fork Mountain occur along the northwestern edge of the Smith River allochthon to the southwest. Schists of the Fork Mountain universally show polyphase metamorphism and the most obvious effect has been that amphibolite grade minerals have been retrograded to greenschists. Typically the Fork Mountain schists along the northwestern boundary of the Smith River allochthon contain staurolite that has been retrograded to chlorite and sericite. The Candler Formation has been examined by the writer from its type locality at Candlers Mountain east of Lynchburg, southwestward to where it terminates in the present study area. Throughout this area the Candler shows metamorphism that does not exceed greenschist facies. It never shows prograde metamorphism to amphibolite grade and retrograde metamorphism back to greenschist facies.
7. Rocks in the core of the Sherwill anticline have previously been correlated with the Lynchburg Group in the core of the structure overlain by Catoctin Formation on the limbs of the structure (Brown, 1958). As these rocks are within the Smith River allochthon, they are not directly correlative with the Lynchburg and Catoctin. They are actually the biotite gneiss and amphibolite of the Bassett Formation, the lowest stratigraphic unit in the allochthon, that, as previously noted, might be of Grenville age.
8. In summation, the rocks that were thought by Brown (1958) to occupy the southeastern limb of the James River synclinorium actually are rocks of the Smith River allochthon, which have been thrust tens of miles northwestward to their present position. They cannot physically connect with rocks that should compose the west limb of the James River synclinorium. Thus the inference by Brown that the James River synclinorium is a simple open fold containing younger rocks in its core and older rocks on its limb is not correct. These rocks are not continuously connected across a simple synclinal structure, and the rocks on what should be the northwestern limb of the structure have an entirely different geologic history from those on the southwestern limb of the proposed synclinorium.

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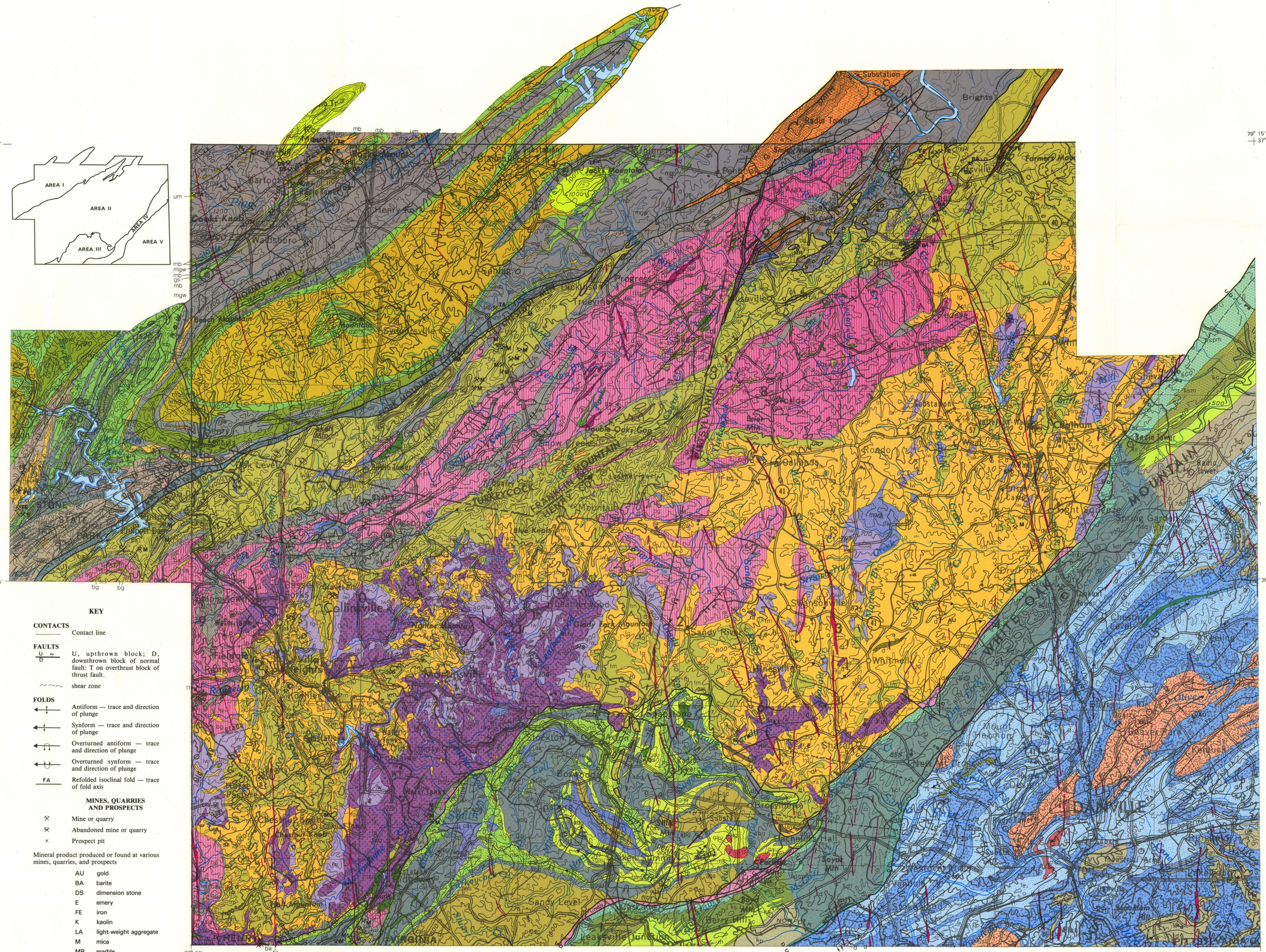
PUBLICATION 59
GEOLOGIC MAP OF THE
SOUTHWESTERN PORTION
OF THE PIEDMONT IN VIRGINIA



KEY

CONTACTS

Contact line

FAULTS

U, upthrown block; D, downthrown block of normal fault: T on overthrust block of thrust fault.

shear zone

FOLDS

Antiform — trace and direction of plunge

Synform — trace and direction of plunge

Overturned antiform — trace and direction of plunge

Overturned synform — trace and direction of plunge

FA — Refolded isoclinal fold — trace of fold axis

MINES, QUARRIES AND PROSPECTS

Mine or quarry

Abandoned mine or quarry

Prospect pit

Mineral product produced or found at various mines, quarries, and prospects

AU	gold
BA	barite
DS	dimension stone
E	emery
FE	iron
K	kaolin
LA	light-weight aggregate
M	mica
MR	marble
MZ	monazite
S	crushed stone
SD	sand and gravel
TA	talc

GEOLOGIC MAP OF THE SOUTHWESTERN PORTION OF THE PIEDMONT IN VIRGINIA

James F. Conley

1985

SCALE 1:125,000

1 ½ 0 1 2 3 4 5 6 7 8 9 Miles

3000 1500 0 3000 6000 9000 12000 Yards

5000 0 5000 10000 15000 20000 25000 Feet

1 0 1 2 3 4 5 6 Kilometers

EXPLANATION

CATACLASTIC ROCKS

LATE PALEOZOIC-MESOZOIC

amy — Silicified mylonite

cs — Cataclastic schist

mbr — Microbreccia

cr — Cataclastic rocks

INTRUSIVE ROCKS

JURASSIC

d — Diabase dikes

AREA I
BLUE RIDGE ANTICLINORIUM

PRECAMBRIAN - EARLY PALEOZOIC

ca — Candler Formation

LATE PRECAMBRIAN

gs, mbg, mr, lq, mgw, mw, mb, mg, lq, um, apg — Lynchburg Group

Alligator Back Formation: *gs, graphite-quartz-mica schist; mbg, massive biotite gneiss; mr, marble; mgw, metagraywacke; lq quartzite; mw, mica schist and metagraywacke; mb, metabasalt; mg, metagabbro; um, ultramafic rocks.* Ashe Formation: *apg.*

AREA II
SMITH RIVER ALLOCHTHON

Martinsville igneous complex

MIDDLE ORDOVICIAN

lw, lwg — Leatherwood Granite, *lw; equigranular granite; lwg, pegmatitic granite and alaskite.*

ra — Rich Acres Formation: *includes norite.*

PRECAMBRIAN - PALEOZOIC

fm, fq, a, fg — Fork Mountain Formation: *fm, mica schist; fg, biotite gneiss; a, amphibolite; fq, quartzite.*

PRECAMBRIAN?

ba, bq, bg, pg, tts — Bassett Formation: *ba, amphibolite; bg, biotite gneiss; gb, metagabbro; tts, ultramafic rocks; bq, epidote quartzite.*

AREA III
SAURATOWN MOUNTAINS ANTICLINORIUM

PALEOZOIC

ak — Alaskite

PRECAMBRIAN

ms, ag, gau, cas, abg, aga — Lynchburg Group

Alligator Back Formation: *ms, garnetiferous muscovite-biotite schist; gau, garnetiferous amphibolite; ag, hornblende granite gneiss; cas, chlorite amphibole schist.* Ashe Formation: *abg, biotite gneiss, aga, garnetiferous amphibolite.*

p€sc — Stuart Creek Gneiss

AREA IV
DANVILLE BASIN

LATE TRIASSIC

TRcu, TRsm, TRsp, TRm, TRc, TRdfm, TRdf, TRcl

TRcu, upper conglomerate. Stoneville Formation: *TRs, sandstone; TRspm, sandstone and mudrock; TRsm, mudrock. TRc,* Cow Branch Formation. Pine Hall Formation: *TRp, sandstone, m, mudrock;* Dry Fork Formation: *TRdf, sandstone, TRdfm, mudrock. TRcl, lower conglomerate.*

AREA V
CENTRAL VIRGINIA VOLCANIC-PLUTONIC BELT

SILURIAN

Sst — Shelton Formation

PRECAMBRIAN - CAMBRIAN

fv, mgs

fv, felsic metavolcanic-metasedimentary rocks; mgs, mica gneiss and schist.

mfv, msq, gn, umr

mfv, interlayered mafic and felsic metavolcanic-metasedimentary rocks; msq, mica schist and quartzite; gn, porphyroblastic biotite gneiss and schist; umr, ultramafic rock.