U.S. DEPARTMENT OF INTERIOR

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# Reconnaissance geologic Map of the Clarksville North and Boydton 7.5-minute Quadrangles, Mecklenburg and Charlotte Counties, Virginia

by

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## ABSTRACT

The Clarksville North and Boydton 7.5 minute quadrangles include an area of about 260 square kilometers in southeast-central Virginia from about 9 km to about 21 km north of the Virginia - North Carolina State line, mostly north of and along a ponded part of the Roanoke River and it minor tributaries that form John Kerr Reservoir. Informal units of isoclinally folded greenstone and underlying phyllite are mapped in a structural recess in the southeastern part of the Boydton quadrangle and are tentatively correlated across strike with the Late Proterozoic Virgilina Formation and Aaron Formation of the Virgilina copper district in the western part of the slate belt. The phyllite unconformably overlies dominantly felsic volcanic and volcaniclastic rocks, mapped in eleven informal units in the central and eastern parts of the Boydton quadrangle, and tentatively correlated with the Hyco Formation of the Virgilina copper district. The oldest felsic volcaniclastic unit, very coarse-grained lithic-crystal metatuff, lies along the axis of an upright to slightly eastwardly-overturned isoclinal anticline identified by topping sense from relict bedding and repetition of stratigraphic units about its flanks in the central and eastern parts of the Boydton quadrangle. Rocks on the west limb of the anticline are breached by the Clarksville batholith in the western parts of the Boydton quadrangle and in the Clarksville North quadrangle.

The Clarksville batholith is a zoned pluton. Mapped phases, from oldest to youngest, include: metagabbro, foliated biotite quartz diorite, foliated biotite granite dated as Late Proterozoic, and foliated porphyritic granodiorite.The magmas were probably fed from a deeply-rooted (12 km) funnel-shaped core, associated with a 10 milligal regional gravity anomaly centered near the southwest corner of the Boydton quadrangle. Granodioritic crystal-mush magma, that developed an inward-dipping flow-foliation, surged through an earlier-crystallized carapace of finer-grained foliated biotite granite, invading the country-rock probably about 600 million years ago. The bodies of metagabbro and foliated biotite quartz diorite are now in pods and lenses marginal to the porphyritic granodiorite core. They were also early crystalline phases as evidenced by their being cross cut by granite and granodiorite.

Correlation of the phyllite and greenstone rock units in the Clarksville North and Boydton quadrangles with the Aaron Formation and Virgilina Formation in the Virgilina copper district, coupled with the observation of copper sulfide-quartz veins in the Boydton quadrangle and the presence of the Stith polymetallic sulfide mine in the adjacent Baskerville quadrangle, suggest these greenschist-facies units in the eastern part of the Carolina slate belt in Virginia may be favorable for the hosting of copper-gold deposits in low-sulfide quartz±carbonate veins.

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## ACKNOWLEDGMENTS

U.S. Army Corps of Engineers personnel at the main maintenance facility on Kerr Reservoir kindly helped with canoe motor-mount repairs. Clark Steves, Resident Attendant, Longwood Park, and Park Rangers, facilitated access to Corps of Engineers-managed land. Rangers at Occoneechee State Park aided in access to exposures in the park. Landowners that were particularly helpful in locating abandoned old roads and facilitating access to exposures include Clifton and Brenda Morgan, and Roy Polaski. Larry Artman, HDR Engineering, Pittsburgh, Pennsylvania, and Eric Holt, HDR Engineering, Omaha, Nebraska, consultants to the Virginia Department of Transportation, met with the senior author in Clarksville, Virginia, in 1994 to view and describe the character of bedrock core obtained from beneath Kerr Reservoir along a proposed right-of way for the relocation of U.S. Routes 15 and 58, and facilitated observation of additional core by the senior author in 1995. This data (Virginia Department of Transportation and HDR Engineering, 1993) contributed to resolving and depicting the location of plutonic rock boundaries and the location of zones of inclusions in plutonic rocks in the northern part of the Clarksville South quadrangle and the southern part of the Clarksville North quadrangle.

## GEOGRAPHIC LOCATION, PHYSIOGRAPHY, AND EXPOSURE

The Clarksville North and Boydton 7.5 minute quadrangles include an area of about 260 square kilometers in south-central Virginia that extends northward from about 9.3 km to about 21.2 km north of the Virginia-North Carolina State line (fig. 1). A tobacco-farming, lumbering, and recreational but mostly undeveloped rural region, with major industry concentrated in the towns of Clarksville and Boydton, and located on the southwest margin of the Mid-Atlantic Urban Corridor, the map area hosts major east-west and north-south transportation passageways (U.S. Highways 58 and 15), as well as hosting environmentally sensitive marsh and watershed along the Roanoke River and tributary valleys in western Mecklenburg County and a tiny part of eastern Charlotte County.

The map area is for the most part just north of the flooded valley of the Roanoke River and its minor tributaries, the John Kerr Reservoir, which is a lake about 2.7 km wide that extends west-northwestward through the southwestern part of the Clarksville North quadrangle. The confluence of the Dan and Roanoke River valleys is about 9.6 km northwest of Clarksville, Va., the major town in the quadrangles. The higher parts of the Piedmont upland surface are about 450 ft (128 m) above sea level. The elevation of the reservoir is kept at about 300 ft (91 m) above sea level by the hydroelectric John H. Kerr Dam, about 6.5 km east-southeast of the southeast corner of the Boydton quadrangle. The major streams, Bluestone and Little Bluestone Creeks in the Clarksville North quadrangle and Butcher and Allen Creeks in the Boydton quadrangle, drain generally southward to the reservoir and are characterized by low gradients of about 1.4 m/km, and broad (0.4-0.6 km wide) valley floors filled with alluvium and stream terrace deposits.

The upland surface is mostly open farmland on granitic rocks of the Clarksville batholith in the Clarksville North and western part of the Boydton quadrangle, but is heavily pine-forested on the stratified metavolcanic, metavolcaniclastic, and metasedimentary rocks in the eastern half of the Boydton quadrangle.

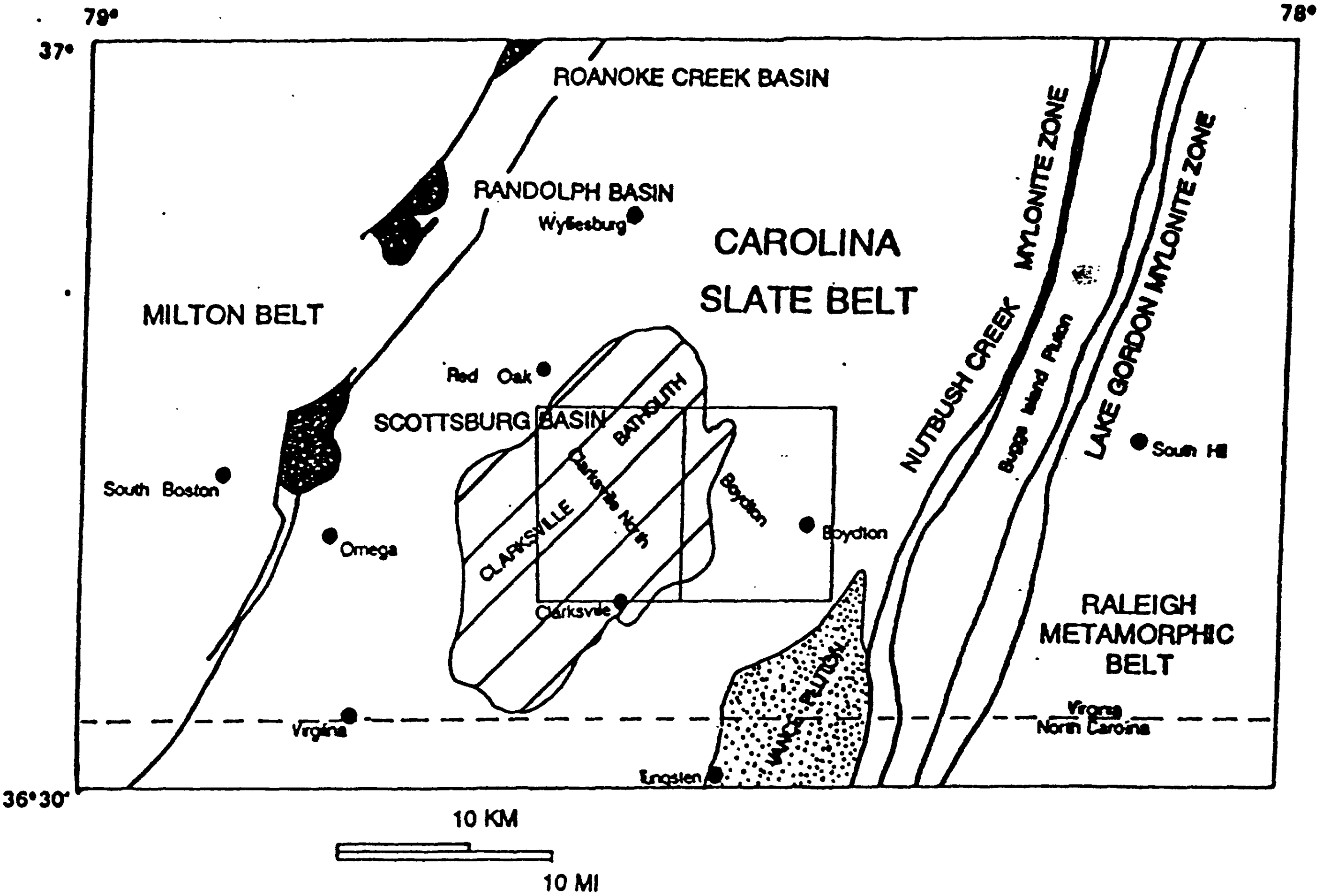



**Figure l. Geologic sketch map showing location of map area.**
Clarksville North and Boydton 7.5 minute quadrangles are in the Carolina slate belt in south-east central Virginia. Black areas show location of Mesozoic basins. Heavy lines show faults. Stippled area shows location of Vance pluton. Diagonally ruled area shows location of Clarksville batholith. Modified from Horton and others (1993) and Peper and others (1996).

The bedrock is mostly metamorphosed Late Proterozoic volcaniclastic rock and associated volcanic and sedimentary rocks of the Carolina slate belt, and Late Proterozoic and Paleozoic, and Mesozoic rocks intrusive into them. In an area of generally deep saprolitization and rock weathering, and low local relief, relatively recent lake ponding has raised the base-level of local streams 10-30 ft (3-10 m), with the result that hard, fresh bedrock was rarely observed in surface exposure. Rock suitable for geochemical studies can be obtained, for the most part, only in rare, scattered, mine or quarry exposures, or in borings. Most observations were in small weathered and saprolitized rock exposures in road cuts, or in stream cuts in the upland parts of tributaries not filled by recent alluvium during lake ponding. Larger and more extensive exposures are in wave-cut benches in saprolite along the lakeshore.

## PRESENT WORK

The quadrangles were broadly mapped by rapid road reconnaissance in October 1992 by J.D. Peper to provide linework for a preliminary geologic map of the South Boston 30x60-minute quadrangle (Horton and others, 1993), and for the 1993 Geologic Map of Virginia (Virginia Division of Mineral Resources, 1993). Adam W. Wygant, a National Association of Geology Teachers - U.S. Geological Survey Field Assistant aided Peper in reconnaissance mapping in May-July, 1993. Larry A Sago, a U.S. Geological Survey volunteer assisted in May, 1993. The map was compiled and text written by Peper in fall and winter of 1993-1994 and field checked in winter 1993-1994 by Peper. About 50 days were spent in fieldwork, mostly traversing the creeks and lakeshore in a canoe and the upland by 4-wheel drive vehicle and on foot. Notes on lithology and structural recordings were made at about 1200 sites. The areas of alluvium were initially compiled from soil maps (Henry; and others, 1956). These were subsequently modified from field observations.

## BEDROCK GEOLOGIC SETTING AND PREVIOUS WORK

The Clarksville North and Boydton quadrangles (fig. 1) are in the northern part of the Carolina slate belt in southern Virginia, between belts of high-grade gneisses, the Milton belt on the west, and the Raleigh metamorphic belt on the east across the Nutbush Creek mylonite zone (Casadevall, 1977; Hatcher and others, 1977; Horton and others, 1993; Parker, 1963, 1968; Stoddard and others, 1991). The Carolina slate belt is a region of greenschist-facies Late Proterozoic metavolcanic, metavolcaniclastic, and metasedimentary rocks, and younger intrusive rocks of Late Proterozoic and Paleozoic age (Glover and Sinha, 1973; Butler and Secor, 1991; Horton and others, 1993; Rader and Evans, 1993). The geology of these quadrangles has not been previously mapped, although there has been work in southerly adjacent (Peper and others, 1996) and flanking areas.

Laney (1917) mapped the Virgilina copper district (inch-to-mile scale on a planimetric base) in a belt 30 km wide, from near the west edges of the Clarksville North and Wylliesburg quadrangles southward into North Carolina. He identified, in a series of mostly upright isoclinal folds, a thick sequence of rocks (Table 1), from oldest to youngest, (1) the Hyco Quartz Porphyry-Goshen Schist (dominantly felsic metavolcanic and metavolcaniclastic rocks), (2) the Aaron Slate (meta-epiclastic and metavolcaniclastic rocks), and (3) the Virgilina Greenstone (dominantly mafic metatuff and lesser metabasalt flows). Tobisch and Glover (1969) and Glover

## Table 1

## Geologic names used in the south-central Virginia-Carolina slate belt

| Harris and Glover (1988) Carolina slate belt | Kriesa (1980) Omega area | Laney (1917) Virgilina district | Peper and others (1996) Clarksville South and Tungsten quadrangles | This Report |
|---|---|---|---|---|
| Upper part Virgilina Fm. | Upper Mb. Aaron Fm. | Aaron Slate | Not present in area | Not present in area |
| Lower part Virgilina Fm. | Middle Mb. Aaron Fm. | Virgilina Greenstone | Zg Greenstone<br>Zs Metasandstone | Zg Greenstone |
| Aaron Fm. | Lower Mb. Aaron Fm. | Aaron Slate | Zp Phyllite and diverse lenses of metaepiclastic rock: Zq, Zgp, Zvc, Zcms | Zp Phyllite and<br>Zsg Phyllite and Greenstone |
| Hyco Fm. | Hyco Fm. | Hyco Quartz Porphyry and | Zfm Fissile felsic metatuff, Zcm metatuff, Zft Coarse-grained felsic meta-tuff; and diverse metatuffs and flows: Zmm, Zqm, Zd, Zft Zmb, Zm, Zpm | Zc Felsic crystal metatuff, Zf Fissle felsic metatuff, Zl Coarse-grained felsic metatuff; and diverse tuffs and flows: Zq, Zd Zh, Zfp, Zs |

and Sinha (1973) identified these layered rocks as Late Proterozoic, and described the faults and some isoclinal folds as products of an approximately 600-Ma Virgilina deformation. They considered the upright isoclinal folds to be older than the regional schistosity. The later schistosity, cross-folding and metamorphism they deemed a result of a Paleozoic (520-300 Ma) deformation. Harris and Glover (1988) modified and extended this framework through the northern part of the North Carolina slate belt, revising an earlier overview by Conley and Bain (1965). They used (Table 1) the names Aaron Formation, and lower part of the Virgilina Formation, respectively, for the slate and greenstone. Detailed mapping and description of the northern part of the Virgilina area in the South Boston-Omega area of Virginia (fig. 1) by Kreisa (1980) provided the most detailed published stratigraphic and petrologic description of the Virgilina sequence rocks.

Offield (1994) and Offield and others (1991) in a regional study of structural style and structural development, argued for a Taconic age of the generally northeastward-striking foliation and associated isoclinal folds in the central North Carolina slate belt.

Post-foliation folds and faults might be as young as the Virgilina copper-bearing quartz veins (340±6 Ma, whole-rock Rb-Sr age), which in detail transect the regional schistosity (Kish and Stein, 1989). Their study and dating of vein materials, suggested to them that the veins were generated by the fracturing of hot, deep-seated greenstone units. Later cleavage and faults might be as young as Alleghanian, the age of the Nutbush Creek mylonite zone and orogenic transpressive shearing (Horton and others, 1993).

Mineral ages from the Clarksville south and Tungsten quadrangles along strike to the south shed some light on structural development and are permissive of, but fail to identify, unique Taconic or Acadian ages of foliation. Igneous hornblende from the interiors of rounded Beaver Pond Creek and Spewmarrow Creek gabbro bodies that in detail transect folds and foliation in the nearby Clarksville South quadrangle (Peper and others, 1994, 1996; like the Eastland Creek gabbro body of this map) show complex Ar/Ar age spectra, with maximum ages of cooling through closure of about 600 Ma and 586 Ma (Kunk and others, 1995). These hornblende systems have not been reset by metamorphism. White mica, however, from foliated fissile felsite, evidences Alleghanian and older growth (Kunk and others, 1995). A preliminary U-Pb zircon crystallization age obtained on foliated biotite granite of the Clarksville batholith from an outcrop along the west side of Reedy Branch, just north of State Route 698 in the eastern part of the Clarksville North quadrangle (J.N. Aleinikoff, written communication, 1996; 602±9 Ma), indicates a Late Proterozoic age.

Peper and others (1994, 1996) mapped the geology of the Clarksville South and Tungsten 7.5 minute quadrangles. They identified a southeastwardly overturned anticline through the central part of the Clarksville south quadrangle cored and flanked by informal units of dominantly felsic metavolcanic and metavolcaniclastic rocks (Table 1) which they tentatively correlated with the Hyco Quartz Porphyry of Laney (1917; Hyco formation of Kreisa, 1980) of the Virgilina copper district across strike to the west. These felsic rocks are also similar to felsic rocks mapped and described by Hadley (1973, 1974) in the Oxford quadrangle of northern North Carolina. By position in the stratigraphic succession established by topping sense of relict bedding, and lithologic similarity, Peper and others (1996, text and fig. 2) correlated informal units of phyllite and greenstone, mapped in the western parts of the Tungsten quadrangle, with the Aaron Slate of Laney (1917; lower member of the Aaron Formation of Kreisa, 1980) and with the Virgilina Greenstone of Laney (1917; middle member of the Aaron Formation of Kreisa, 1980) respectively. Preliminary zircon crystallization ages of 618 Ma and 620 Ma (J. N. Aleinikoff written communication, 1996; from felsic crystal metatuffs) were obtained from samples collected (1) from an outcrop of the Hyco Formation 60 feet (28 m) below the contact with the Aaron Formation in the western part of the slate belt on the east limb of the Dryburg syncline in the Buffalo Springs quadrangle, and (2) from an outcrop in Allen Creek just south of State Route 677 along the eastern margin of the Boydton quadrangle, about 950 ft (912 m) below the schist and greenstone unit (Zsg), and near the base of the phyllite unit (Zp). These similar zircon crystallization ages are permissive and generally supportive of the cross-slate belt, cross-structure stratigraphic correlations. Peper and others (1996) informal rock units, extended by mapping northeastward along strike, are used and shown on this map with simplified unit designation symbols.

## STRUCTURE

### Bedrock Structural Fabric

An early mica foliation, variable in its intensity, strikes generally east-northeastward through the area. It is most strongly developed in schists and phyllite, and more weakly developed in the coarser-grained feldspathic rocks. The foliation is parallel to relict bedding and compositional layering in most exposures, but was locally observed at a distinct angle to bedding. Most bedding and foliation dip steeply to the west-northwest or east-southeast, and most folds are upright or overturned slightly to the southeast. Mesoscopic folds of foliation are rare and there is no intense foliation-fold fabric that would define the orientation of major fold axes from parasitic minor folds. Topping sense of graded beds was observed infrequently. Most lineation (crenulation axes, biotite streaking, and the long axes of stretched clasts) plunge gently to the northeast and southwest.

Foliation and bedding are locally deformed along a regularly-spaced slip cleavage associated with asymmetric similar folds and with open folds. This cleavage strikes dominantly N.40-50 E. And N. 0-5 W. Southwest-plunging similar minor folds, with 1-2 cm regularly spaced cleavage as axial surfaces indicate a left-lateral shear and occur along small faults that deform foliation and bedding, in a shear zone 600 m wide, along the west side of Tates Branch, about 2.4 km south of the Rudd Creek Recreation Area in the southern part of the Boydton quadrangle. Small faults with left-lateral shear sense, as determined from the drag of beds, and by projection of beds across the fault zone, are prevalent in the shear zone along the west side of Tates Branch.

### Inferred Major Folds

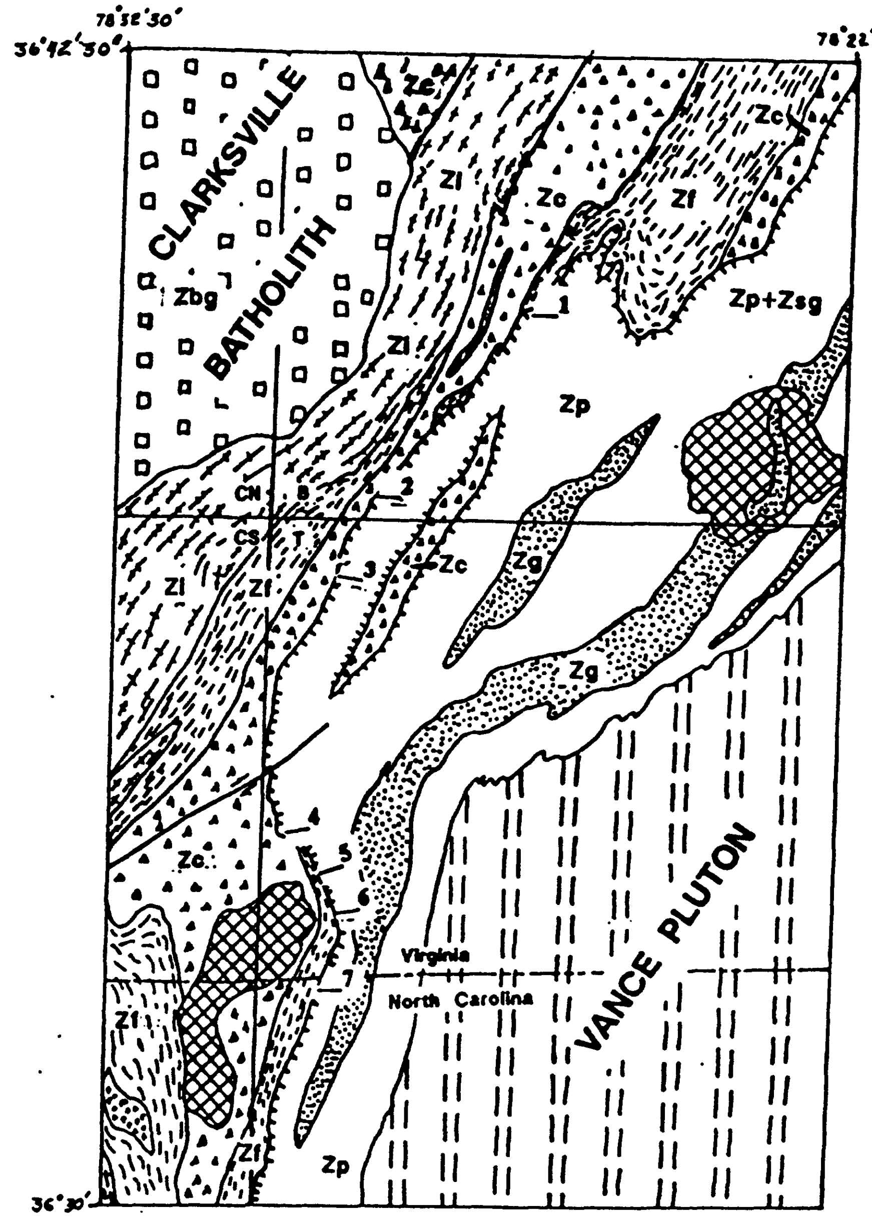
The geologic map shows the inferred axis of a major isoclinal anticline, extending northeastward through the middle of the band of coarse-grained felsic metatuff (Zl) in the southeastern part of the Clarksville North quadrangle and north-central part of the Boydton quadrangle. The anticlinal structure of the band of metatuff was suggested by overturned relict bedding on the southeast limb of the anticline in the Clarksville South quadrangle (Peper and others, 1996). The felsic metatuff (Zl) interfingers with schistose and micaceous felsic phyllite (Zfp) progressively northeastward along the axis of the anticline in the north-central part of the Boydton quadrangle and phyllite was mapped at this horizon in the northerly adjacent Chase City quadrangle (W.L. Burton, unpublished map, 1995). Bands of fissile felsic metatuff (Zf) and crystal metatuff (Zc) are repeated on the northwest and southeast limbs of the anticline. Felsic metatuff on the northwest limb of the anticline in the northwestern part of the Boydton quadrangle is breached by foliated biotite granite of the Clarksville batholith. A rafted lens of felsic metatuff (Zf) occurs in the granite in the northeastern part of the Clarksville North quadrangle. The beds on both limbs of the inferred anticline dip steeply to the northwest, except along the mid-reach of Butcher Creek, east of the eastward-projecting salient of foliated biotite granite in the southwestern part of the Boydton quadrangle. Here beds on the southeast limb of the anticline are upright and dip to the southeast.

A prong of the phyllite unit (Zp) extends northwestward into the area of felsic metatuffs in the Butcher Creek area of the southern part of the Boydton quadrangle. The general structure of this broad area is that of a southwestward-plunging, tightly folded recess. The axis of an upright anticline, cored by felsic crystal metatuff (Zc), plunges northeastward along Butcher Creek, parallel to minor digitations in the base of tightly folded phyllite (in a syncline) mapped to the west in exposures along the creek. This anticlinal axis is marked by a south-plunging re-entrant of felsic metatuff southwestwardly into the phyllite 2.3 km north-northeast of the Rudd Creek Recreation Area. Just to the east of the re-entrant, overturned beds of phyllite exposed along the abandoned railroad grade, mark the western eastwardly-overturned limb of a south-plunging inferred syncline of phyllite. The axes of 3 hypothetical synclines, overturned to the southeast are drawn through the bands of greenstone, extending northward from the Tungsten quadrangle where the greenstone was detected to overly the phyllite on the basis of relict bedding (Peper and others, 1996). Thin-bedded sandstone at the top of the phyllite was noted to be repeated across the axis of the syncline that is cut by the gabbro north of Eastland Creek in the southeastern part of the Boydton quadrangle. The structure of the north end of the westernmost greenstone lens is that of a southwestward plunging syncline as shown by strikes and dips of bedding about the axis of the syncline in the area between Eastland Creek and Tates Branch.

## STRATIGRAPHY

### Felsic Volcanic and Volcaniclastic Rocks

Units of felsic volcanic and volcaniclastic rocks, mapped mostly in bands in the east-central and northeastern part of the Boydton quadrangle, considered equivalents of the Hyco Formation (Peper and others, 1996, fig. 2). These include: a lowermost band of coarse-grained felsic metatuff (Zl) that interfingers northeastward with schistose and micaceous felsic phyllite (Zfp); fissile felsic metatuff (Zf) in two lenses; and crystal metatuff (Zc) in several lenses above and below felsic metatuffs (Zf), above coarse-grained felsic metatuff (Zl).These units lie below phyllite (Zp) and schist and greenstone (Zsg) considered to be Aaron Formation equivalents.




Geology mapped by J.D. Peper, 1992-1993, Assisted by T.W.Clark, K.A. Kanahele, 1992; A.W. Wygant, L.E. Sago 1993.

5 KM
3 MI

**Figure 2. Simplified geologic map.**

Map shows patterns of phyllite (Zp and Zp+Zsg) and greenstone (Zg), correlated with Aaron and Virgilina Formations respectively. Units of felsic volcanic and volcaniclastic rocks (Zl), (Zc), (Zf), and quartz dacite body are correlated with the Hyco Formation. Map shows parts of the Clarksville North (CN), Clarksville South (CS), and Boydton (B) and Tungsten (T) quadrangles. Hachure line shows unconformity at base of phyllite unit; tick marks are in rocks above unconformity. Gabbro bodies, diagonally cross-ruled pattern; quartz-dacite body, plus-symbol patterned. Foliated biotite granite of the Clarksville batholith (Zbg), open-square patterned; granodiorite and granite of Vance pluton vetical long-dash patterned Numbers designate localities discussed in text.

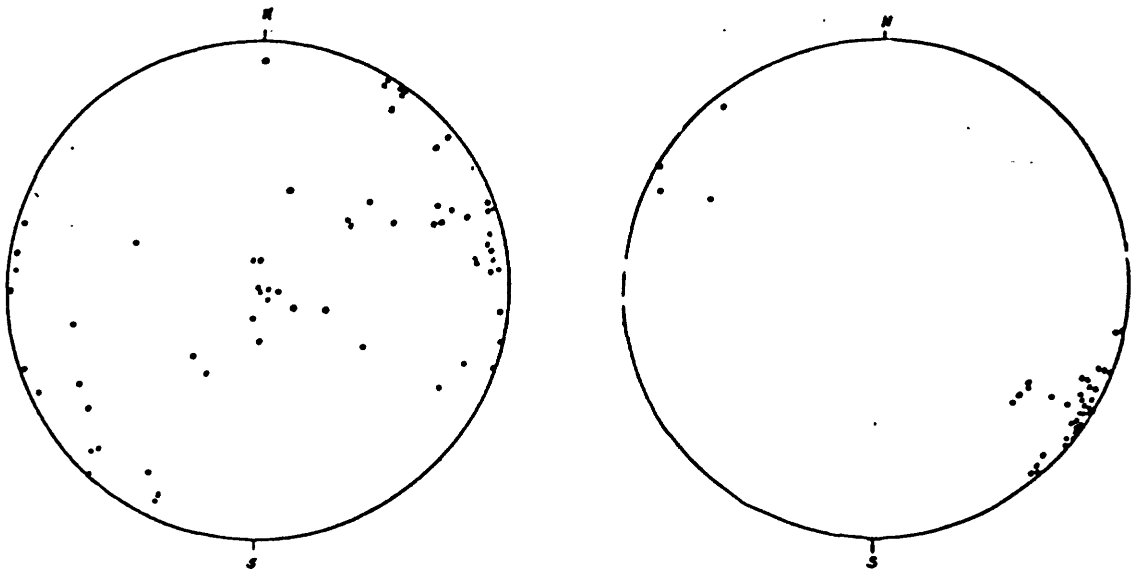
**Unconformity at Base of Phyllite**

Detailed mapping of the lower parts and base of the phyllite unit (Zp) southward through the Boydton, and earlier in the Tungsten quadrangle (Peper and others, 1996) showed that phyllite rests on lenses of felsic crystal metatuff (Zc) and fissile felsic metatuff (Zf). The base of the phyllite (fig. 2, this report) progressively truncates the contacts mapped between these lenses in the felsic volcaniclastic rocks. Cross-laminated phyllitic metasandstone, and a lens of volcanic breccia and conglomerate (fig. 2, area 7), are present in the lower part of the phyllite unit and at the contact with underlying felsic rocks. These suggest that the phyllite was deposited unconformably on the underlying felsic volcaniclastic rocks. The phyllite unit (Zp), with intercalated greenstones, occupies a northeastward-elongate basin that plunges to the southwest in the south-central part of the Boydton quadrangle and to the northeast in the northwestern part of the Tungsten quadrangle (fig. 2). Metasandstone and sandy phyllite were observed interlayered with phyllite in exposures for a distance of 10 to 50 m above the base of the phyllite unit along the west shore of Rudd Creek in the Boydton quadrangle (fig. 2, area 1), in the Tungsten quadrangle along the east side of Whetstone Branch (fig. 2, area 3), and along the south shore of Kerr Reservoir south of the big bend in the Roanoke River channel (fig. 2, areas 4-6). Gray to brown-weathering, fine-grained, thin-bedded phyllite is in sharp contact with underlying medium-bedded felsic crystal metatuff in saprolite exposures along State Highway 703 in the southern part of the Boydton quadrangle (fig. 2, area 2). Volcanic breccia and metaconglomerate are mapped in an 0.8 km long lens at the base of the phyllite unit and above fissile felsic metatuff across the Virginia-North Carolina State line (fig. 2, area 7).

## ROCKS OF THE CLARKSVILLE BATHOLITH

Most igneous rocks in the westernmost part of the Boydton quadrangle and in the Clarksville North quadrangle are assigned to the Clarksville batholith, a regional-scale body of dominantly granite-granodiorite and volumetrically lesser mafic igneous rocks. The body was identified by Horton and others (1993) in order to distinguish the batholith granites from granite in another pluton at Red Oak, Virginia, and from various granites in the south-central Virginia Piedmont mapped as Redoak granite by Laney (1917). The rock types mapped are: metagabbro (Zm), foliated biotite quartz diorite (Zdi), foliated biotite granite (Zbg), and foliated porphyritic granodiorite (Zpg). Bodies of unaltered hornblende gabbro (Zh) in the eastern part of the batholith are tentatively assigned to another igneous suite. These gabbros are inferred to be younger than the batholith; because of the unaltered nature of the hornblende gabbro, and because of the sharp intrusive contacts and round shapes of the hornblende gabbro bodies. Argon-release ages of hornblendes from similar bodies in the Clarksville South quadrangle (600 Ma, 583 Ma, Kunk and others, 1995) are essentially the same or slightly younger than a zircon crystallization age for foliated biotite granite (602 Ma) of the Clarksville batholith.

The sequence of emplacement of rocks of the batholith, as deduced from cross-cutting and contact relationships and other structural features (discussed below) is, form oldest to youngest: metagabbro, foliated biotite diorite, foliated biotite granite, and foliated porphyritic granodiorite. The metagabbro and the foliated biotite diorite are in the form of large inclusions in and along the northern margin of the foliated porphyritic granodiorite, and as smaller blocks or screens in the foliated porphyritic granodiorite (Zpg) and in the foliated biotite granite (Zbg).




3A Foliated porphyritic granodiorite
N=57

3B Foliated biotite granite
N=42

**Figure 3. Lower hemisphere equal-area stereographic projections of poles to foliations in the Clarksville batholith.**

In 3A, 57 poles to biotite flow-foliation parallel parallel to plane of tabular inclusions in foliated porphyritic granodiorite unit. In 3B, 42 poles to biotite foliation; essentially the northeast-trending regional foliation.

The metagabbro (unit Zm) is cut by dikes of leucocratic biotite diorite along the southeast side of State Highway 699, just south of Bluestone Creek in the northwestern part of the Clarksville North quadrangle. Dikes of foliated porphyritic granodiorite cut metagabbro, and rounded blocks of metagabbro with schistose margins occur as inclusions in the granodiorite, along the northeast side of Bluestone Creek, 1.4 km southwest of Cedar Grove Church.

The foliated biotite diorite (unit Zdi) is cut by dikes of foliated biotite granite in outcrops along Bluestone Creek 1.6 km west of Organville. Blocks of foliated biotite diorite form inclusions in the foliated biotite granite in outcrops along the north side of State Highway 762, 3.1 km northeast of Jeffress, and in the foliated porphyritic granodiorite in shoreline outcrops north of the parking circle at Bluestone Landing, north of U.S. Highway 15 in the southwestern part of the Clarksville North quadrangle.

The foliated biotite granite (unit Zbg) comprises mostly medium- to fine-grained biotite granites with rounded to anhedral potassium-feldspar crystals, typically less than 4 mm long. A medium- to coarse-grained, inequigranular granite, prevalent in the northern part of the Clarksville North quadrangle, could be called a sub-porphyritic granite. It contains rounded potassium-feldspar crystals typically 4 mm or less in longest dimension. The dominant foliation in the foliated biotite granite is the steeply dipping regional foliation (fig. 3, 3B). A southern lob of foliated biotite granite makes up the southeastern part of the Clarksville batholith south of the foliated porphyritic granodiorite in the Clarksville south quadrangle (Peper and others, 1996; Horton and others, 1993; see fig. 4, this report). In earlier mapping of the batholith rocks in the Clarksville South quadrangle (Peper and others, 1996), the foliated biotite granite was interpreted as the younger granitic phase, primarily because dikes of foliated biotite granite and aplitic biotite graophyre were noted to cut the porphyritic granodiorite. In the Clarksville North quadrangle, however, dikes of foliated biotite granite, aplitic biotite granophyre, and pink quartz monzonite were noted to cut both the foliated porphyritic granodiorite and the foliated biotite granite.

The foliated porphyritic granodiorite (unit Zpg) includes granodiorite and granite with biotite and lesser hornblende. This phase of coarse-grained granitoid rock is characterized by the presence of euhedral phenocrysts of potassium feldspar, typically 2-4 cm long. The dominant foliation in most exposures of foliated porphyritic granodiorite is moderately to steeply dipping protoclastic or flow foliation; parallel to the lane of aligned tabular inclusions or parallel to the plane of aligned potassium feldspar phenocrysts (fig. 3, 3A). This foliation broadly parallels the margin of the porphyritic granodiorite body, dipping inward in an arcuate funnel-shape, concave to the southwest in the southwestern part of the Clarksville North quadrangle (see geologic map). A northwest-striking, mostly southwest-dipping, protoclastic foliation is most intense in a marginal zone, 1.5 km wide, along the mid-reach of Bluestone creek, where the channel follows this foliation in the western part of the Clarksville North quadrangle.

Although not numerically modeled, a map of the regional gravity gradient over the batholith gives some relative indication of the extent at depth, and thickness, of the rocks in the batholith. A third order derivative map of the regional gravity gradient (David L. Daniels, written communication, 1994, see fig. 4, this report) shows a 10 milligal negative gravity anomaly centered over the porphyritic phase, about 1 km north of the four-corner area of the Clarksville North, Clarksville South, Buffalo Springs, and Nelson 7.5-minute quadrangles. To the northeast the negative anomaly is flanked by positive anomalies over the bodies of metagabbro and foliated biotite diorite. The negative anomaly indicates a downward-projecting "root" for the batholith. The zero milligal contour line closely approximates the margin of the body of foliated porphyritic

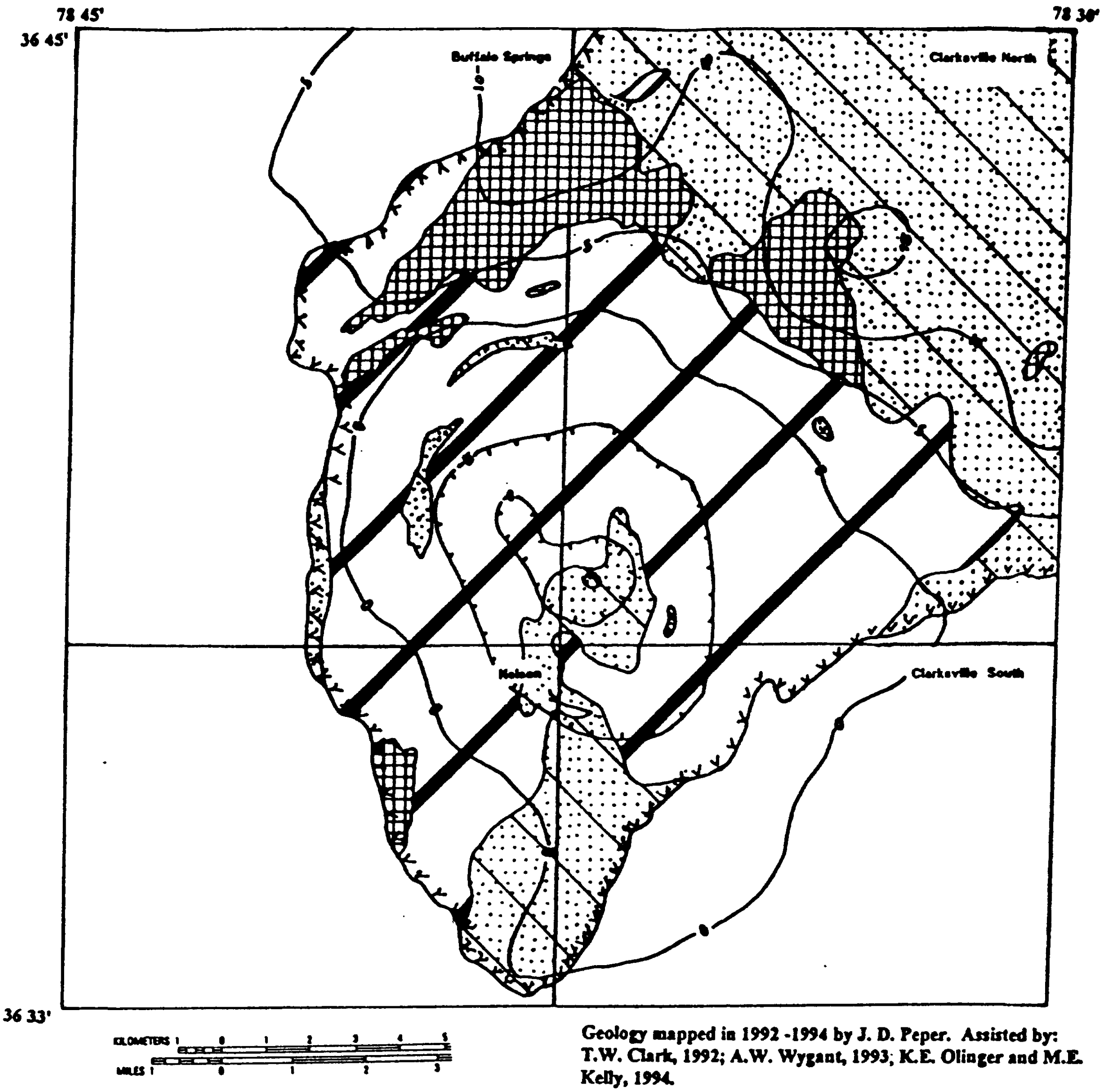



**Figure 4. Geologic sketch map of the Clarksville batholith in parts of the Buffalo Springs, Nelson, Clarksville North, and Clarksville South quadrangles.**
Foliated porphyritic granodiorite, diagonal-bar ruled. Foliated biotite granite, diagonal-line ruled and stippled. Metagabbro and biotite quartz diorite cross-hatched. Contour lines show regional gravity gradient in milligals.

granodiorite. If the "root" extends as deep as the anomaly is wide, it may extend to a depth of 10-12 km below the present land surface.

The gravity anomaly, the protoclastic foliation of the porphyritic granite phase, and the map distribution of the granitic phases, combined with the structural and petrographic features, are consistent with a hypothetical model of batholith formation and granite emplacement as follows. After the intrusion of the mafic metagabbro and foliated quartz diorite batholith phases, the medium-grained foliated biotite granite, in the northern and southern lobes, may have been emplaced in the upper parts of the magma chamber where it cooled to form a relatively thin, areally extensive carapace. Subsequently, porphyritic granodiorite magma was forced upward and outward as a crystal mush. At the level of current exposure, the crystal mush broke through the carapace, intruding the earlier-crystallized foliated biotite granite, and invading the country rock. The large crescent-shaped patch of foliated biotite granite in the southwestern part of the Clarksville South quadrangle could be interpreted as a large screen or roof pendant of the carapace, engulfed by foliated porphyritic granodiorite. The northeastward-elongate patch of foliated porphyritic granodiorite within the foliated biotite granite near the northwest corner of the Clarksville North quadrangle may be a dike of foliated porphyritic granodiorite breaching the carapace.

Rocks of the Clarksville batholith cut the axes of inferred regional isoclinal folds, and the plutonic rocks are themselves strongly to weakly metamorphosed and regionally foliated. With the exception of the foliated porphyritic granodiorite, rocks of the batholith were emplaced before the end of intense greenschist-facies metamorphism and development of regional foliation. The weakly foliated porphyritic granodiorite may have been emplaced in the late stages of regional metamorphism, and is distinctly younger than other rocks of the batholith.

## SURFICIAL DEPOSITS

Surficial deposits in the map area consist of artificial fill, alluvium, Roanoke River terrace deposits, and terrace deposits along major tributary streams. In general, these deposits are mapped where they are of substantial thickness (greater than 1 m). The surficial map units were derived by comparing field observations with soils maps (Henry and others, 1956).

Artificial fill (af) includes unconsolidated anthropogenically emplaced material used for the construction of roads, railroad grades, and dams.Only larger areas of artificial fill are shown.

Alluvium (Qa) includes material deposited by modern streams as channel deposits and flood-plain deposits. They are shown as thick and continuous even in now poorly drained areas. Current- and wave-worked beach sand forms thin (0.3-0.6 m) veneers unconformable over saprolite and bedrock along much of the lakeshore, and locally forms beach ridges, spits, and other shoreline features, particularly where sand is abundant in areas underlain by granitic plutonic rocks. These deposits are thin and discontinuous, however, and are not shown on the geologic map. Stream terrace deposits (Qs) are present locally along major tributary streams, notably Bluestone Creek in the Clarksville North quadrangle and Allen Creek in the Boydton quadrangle. The stream terrace deposits are mostly in remnants less than 5 m thick, and stand 3-5 m above the modern floodplain (Qa).

River terrace deposits (Tt) include sand, silt, and some gravel deposited by the ancestral Roanoke River; most terraces stand 20-30 m above its now-drowned floodplain. River terrace deposits, in remnants, are most prevalent between the mid-reach of Bluestone Creek and Kerr Reservoir in the western part of the Clarksville North quadrangle where deposits up to 30 m thick are draped over saprolite.

## ENVIRONMENTAL AND ECONOMIC GEOLOGY

### Wetland Habitats

Much land along the drowned parts of Bluestone Creek, the Roanoke River, Occoneechee Harbor, Butcher Creek, and Eastland Creek in these quadrangles include areas of grassy and shrubby marsh, along with narrow strips of steep-sloped rocky forest, both difficult to develop and/or frequently flooded. Otherwise these lands provide scarce habitat to rarer fishing-bird species, bald eagles, green herons, and the like, and may deserve several levels of natural conservation.

### Geohydrology

Acid-base status of soil and surface water, a critical ecosystem factor in forested upland areas of the central Piedmont, is strongly influenced by bedrock and derived soil composition(Peper and others, 1995). Thicker, sandier soils developed over the siliceous-aluminous felsic volcanic and volcaniclastic rocks and the granites and granodiorite have little acid-neutralizing capacity. The rocks and thinner, clayier soils in catchment basins over mafic rocks (here metagabbro (Zm), foliated quartz-diorite (Zdi), hornblende gabbro (Zh), greenstone (Zg), greenstones in the phyllite (Zp), and mafic inclusions in the foliated porphyritic granodiorite (Zpg)) are unique in their relative high level of acid-neutralization capacity. Regional greenschist-facies metamorphism of most mafic rocks, and deuteric (hydrothermal) alteration of the margins of the rounded gabbro bodies, generated widespread neomineralization of very fine-grained epidote-quartz-carbonate-(sericite) aggregate, dispersed throughout the rocks as minute veins and patches and as some larger veins. The carbonate is the active acid-neutralizer. Pond and stream waters in these catchment bsins are less vulnerable to general acidification impact from atmospheric acid deposition (acid rain). Ground waters in the rocks and derived soils, by analogy with data from identical rocks in Halifax County, Virginia (Legrand, 1960), tend to be neutral to slightly alkaline, although somewhat hard (high Ca+Mg).

### Stone, Aggregate

The local rock, slabby, porphyritic granodiorite (Zpg) was used as rough building stone for stone-walls and lentils probably in colonial times at Prestwold Plantation, along the north side of the roanoke River about a kilometer southwest of the intersection of U.S. route 15 and State Route 49 in the Clarksville North quadrangle. No active quarrying of this rock was detected in the quadrangles, but it appears to have been quarried in recent times along the north side of the Roanoke river about 3.5 km west of the west border of the Clarksville North quadrangle.

Most compositionally massive igneous rocks in the quadrangles are coarse-grained, feldspathic, and well-foliated. An exception is the foliated quartz diorite (Zdi). Although they have not been locally quarried, the interiors of these bodies are massive to weakly foliated. These rocks have not been tested for abrasion and adhesion as a source for potential aggregate.

**Clay Materials**

By analogy with recent analyses of clay weathered from schistose units of the Hyco Formation and th elower member of the Aaron Formation in Halifax County (Kreisa, 1980, p. 16-17), clays weathered from fissile felsic metatuff (Zf), and from phyllite (Zp) in the Clarksville North and Boydton quadrangles should have the most potential for sources of raw material for face brick, tile, or sewer pipe. Older studies and tests (Reis and Somers, 1917, p. 55-57) identified clays from cuts along U.S. Highway 58, about 1 mile west of Boydton and north and east of Clarksville, with all but the sandiest granite-derived clays as potentially suitable sources of raw material for common brick.

**Metals**

Correlation of the phyllite (Zp) and greenstone (Zg) rock units in the Clarksville North and Boydton quadrangles with the Aaron and Virgilina Formations in the Virgilina copper district (Peper and others, 1996) suggests that these units in the Boydton quadrangle are potential hosts for copper-gold deposits in low-sulfide quartz-(carbonate) veins. A recent synthesis and statistical analysis of veins in the Virgilina copper district by Lesure (1992) suggests that mafic rocks host copper-rich veins, whereas more felsic layers host copper-gold veins. Copper and gold are in the sulfide minerals chalcocite, chalcopyrite, and bornite. No mines are recorded in the units in the Boydton quadrangle, but the Stith mine, along Mine Creek in the adjacent Baskerville quadrangle, about 2.7 km east of the east edge of the Boydton quadrangle produced copper, gold, and silver from quartz veins from within an area mapped as greenstone (J.W. Horton, Jr., unpublished mapping,, 1996). Quartz-sulfide veins were observed in phyllite, and in phyllite and greenstone inclusions in granite by Peper and Kanahele (Peper and others, 1996) in the Tungsten quadrangle on the peninsula west of Eagle Point. In addition, Peper, Wygant, and Sago saw malachite (secondary green monoclinic copper carbonate) in quartz veins, and in phyllite interlsend with greenstone, in a outcrop southwest of the State Route 693 bridge across an unnamed tributary west of Butcher Creek in the southwestern part of the Boydton quadrangle. The area underlain by phyllite and greenstone is probably the most favorable area for geochemical prospecting for copper-gold bearing veins.

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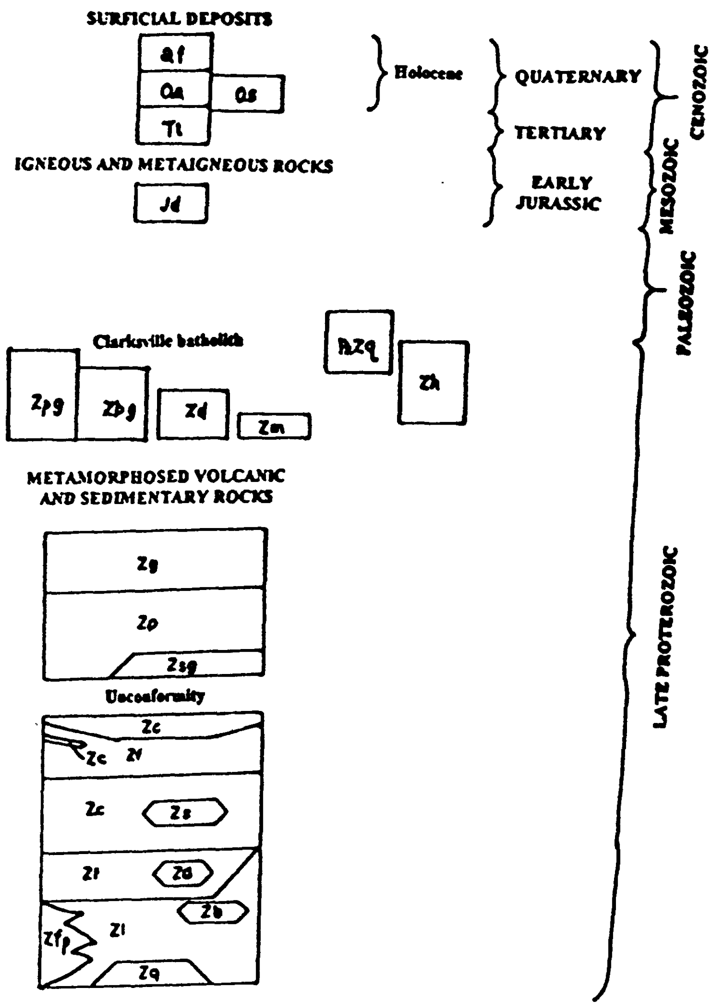
# CORRELATION OF MAP UNITS



## DESCRIPTION OF MAP UNITS

[Saprolite, which consists of a layer of variably oxidized, decomposed, and dissagregated rock, forms a blanket as much as 18 m thick that overlies undecomposed bedrock and underlies surficial deposits. Soil horizons are developed on the saprolite and on the surficial deposits.

Where hyphenated mineral names are used as descriptive adjectives to form rock names, minerals are listed in general increasing order of abundance in the rock. Minerals in parentheses may not be present in every sample of rock unit described.]

### Surficial Deposits

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

Qa **Alluvium (Holocene)**--Silt, sand, and minor gravel deposits along courses of modern streams generally less than 3 m above channel of present-day stream. Contains varied amounts of organic debris in poorly drained areas

Qs **Stream terrace deposits (Holocene and Pleistocene?)**--Silt, sand, and minor gravel in older, higher, terrace deposit remnants along tributary streams. Deposited generally 3-5 m above the floodplain of the modern stream

Tt **River terrace deposits (Tertiary)**--Sand, silt, and gravel deposited in channels and floodplains of the ancestral Roanoke River. Deposited as much as 50 m above the (now drowned) floodplain of the modern Roanoke River

### Igneous and Metaigneous Rocks

Jd **Diabase dikes (Early Jurassic)**--Very dark-gray, mostly medium- to fine-grained, locally coarse-grained, magnetite-clinopyroxene-augite-labradorite diabase in 0.5 to 150 m wide steeply dipping dikes. Diabase contains minor green hornblende, biotite, and traces of chlorite and apatite. Fine-grained basalt chill margin at edge of dike typically 2-5 cm wide. The positions of a series of en-echelon dikes that trend generally northward, from Clarksville through the central part of the Clarksville North quadrangle, are inferred generally from a few lakeshore exposures and positive linear anomalies on an aeromagnetic map (U.S. Geological Survey, 1994). Where exposed, dikes mapped by map unit Jd (see Explanation of Map Symbols). Where position of dike is inferred, dike mapped by dike symbol Jd

PZzq **Pink quartz monzonite (Late Proterozoic and Paleozoic)**--Weakly foliated to non-foliated, pink-weathering, equigranular, medium-grained biotite quartz monzonite containing distinctive gray quartz grains 4-6 mm across and pink feldspar. Biotite content is 3-5 percent. Found as dikes cutting foliated biotite granite and porphyritic granite; shown by labeled dike symbol PzZq (see Explanation of map symbols)

**Zh** **Hornblende gabbro (Late Proterozoic)**--Mapped in one large body that transects regional foliation and structure in the southeast corner of the Boydton quadrangle around Eastland Creek. Five smaller bodies, four within foliated biotite granite, mapped in western part of Boydton quadrangle. Eastland Creek gabbro body is medium-gray to dark-gray, medium- to coarse-grained hornblende-labradorite gabbro to local clinopyroxene-rich hornblende gabbro contaiing secondary epidote, sericite, and chlorite. Gabbro cut by bodies of melanocratic medium-grained hornblende quartz diorite and dikes of leucocratic hornblende quartz diorite laong shores of cove near eastern margin of map. Gabbro contains many inclusions of greenstone in exposures along Eastland Creek. Smaller gabbro bodies, 0.5 km noth of Skipwith, and 0.4 km north of Liberty Church, are mostly dark-gray to black, coarse- to medium-grained clinopyroxene-hornblende-calcic-plagioclase gabbro to melanocratic hornblende quartz diorite

## Rocks of the Clarksville Batholith

**Zpg** **Foliated porphyritic granodiorite (Late Proterozoic)**--Strongly to weakly foliated, very coarse grained, porphyritic biotite granodiorite, ranges to quartz monzonite and granite, hornblende granodiorite. Predominant foliation, arcuate in regional plan, is a magmatic flow-foliation, parallel to numerous tabular inclusions of mafic and felsic metatuffs present in most exposures, and generally parallel to margins of body. Granodiorite contains rectangular phenocrysts and aggregates 2-4 cm across of potassium feldspar in a groundmass of gray quartz crystals 4 mm across and rounded and tabular plagioclase and potassium feldspar grains 6 mm-1 cm across. Content of dark-green biotite, in books as much as 8 mm across, ranges 5-7 percent; hornblende 0-2 percent. Deeply saprolitized and poorly exposed in roadcuts; weathers to sandy soil containing aggregates of feldspar phenocrysts. Unit is probably the porphyritic granite described as Buffalo granite in the Buffalo-Lithia Springs area by Laney (1917, p. 36)

**Zbg** **Foliated biotite granite (Late Proterozoic)**--Light-gray to white-weathering, medium- to fine-grained, mostly strongly foliated muscovite-biotite granite; ranges to granodiorite, quartz monzonite,a nd tonalite. Consists of approximately equal amounts of flattened gray quartz grains 1-2 mm across, and altered and rounded and anhedral plagioclase and potassium feldspar grains 2-3 mm across. Biotite 3-5 percent; muscovite 0-3 percent. Unit forms 0.3 to 0.6 m wide dikes in, and sub-porphyritic inequigranular border around, central foliated porphyritic granodiorite unit Zpg. Some foliation is magmatic, internally at a high angle to the regional foliation and parallel to margins of body at borders. Body mapped in southwest corner of Clarksville North quadrangle is continuous with medium-grained granite mapped as Redoak granite in the Buffalo-Lithia Springs area 9 km northwest of Clarksville, Virginia by Laney (1917, p. 35-36)

**Zdi** **Foliated biotite quartz diorite (Late Proterozoic)**--Medium to light-gray, mostly strongly foliated, and medium-grained, compositionally massive leucocratic rock in which streaks of brown biotite are set in a matrix of cloudy and altered plagioclase (albite-sericite-epidote-carbonate) and fine mosaic of quartz grains. Plagioclase grains rounded, 4 mm wide. Biotite content 5-7 percent, quartz content 5-15 percent. Some rock weakly foliated, equigranular, and medium grained

**Zm** **Metagabbro (Late Proterozoic)**--Altered gabbro mapped in the Clarksville North quadrangle in two large bodies: (1) along the mid-reach of Bluestone Creek, and (2) along the lower reach of Little Bluestone Creek. Metagabbro retains relict texture of a coarse-grained plutonic rock. Dark green, weakly foliated, compositionally massive, melanocratic, green hornblende-chlorite-plagioclase rock. Stubby rectangular 1-2 cm aggregates of green-hornblende and chlorite are set in a epidote-sericite-carbonate-albite altered matrix of relict calcic-plagioclase grains. Rock is locally strongly foliated green-hornblende-chlorite-albite schist. Green hornblende plus chlorite constitute 75 percent of the rock. Contains trace of sulfide minerals. Body of metagabbro along west margin of map is contiguous with Abbyville gabbro of Laney (1917, p. 37). Laney (p. 38) noted relict broad-band twinning in the altered plagioclase matrix, as well as rare relict pyroxene, and referred to some schistose varieties of metagabbro as "impure soapstone"

### Metamorphosed Volcanic and Sedimentary Rocks

**Zg** **Greenstone (Late Proterozoic)**--Heterogeneous unit that includes massive greenstone, foliated and fissile mafic metatuff, chlorite-muscovite schist (foliated metaclastite), amygdaloidal metabasalt, and mafic crystal metatuff with chlorite-epidote matrix. Rocks weather dark reddish brown. Amygdaloidal metabasalt (flows 1-2 m thick) locally makes up 5 percent of unit. Relict bedding, as much as 10 cm thick, commonly visible in mafic metatuff. Includes a few subordinate lenses, 1-3 m thick, of schistose, fissile, tan- to yellow-tan weathering, felsic metatuff

**Zp** **Phyllite (Late Proterozoic)**--Brownish-gray to medium-gray, sericite-chlorite phyllite and feldspathic phyllite. Intercalated with locally more abundant thin-bedded phyllitic metasandstone; tan to white, schistose, fissile, thin-bedded felsic metatuff, massive greenstone; and thin-bedded chloritic metatuff. Rare crystal-lithic metatuff and gray phyllitic metasandstone have thin graded beds. Gray, cross-laminated metasandstone is rare. White, laminated metasandstone, in lenses as much as 10 m thick, is found in phyllite near northwest margin of greenstone unit along Virginia State Secondary Road 707 1.2 km southeast of Boydton

**Zsg** **Chlorite schist and greenstone (Late Proterozoic)**--Heterogeneous unit at base of phyllite unit (Zp) that includes epidote-albite-chlorite-quartz-carbonate greenstone interlayered with chlorite schist and with thick-layered mafic feldspar-crystal metatuff with chlorite-epidote matrix. Includes rare amygdaloidal metabasalt in 1-3 m thick flows northwest of Jerusalem Temple

**Zc** **Felsic crystal metatuff**--Mostly medium-grained, medium- to thin-bedded, dominantly felsic crystal metatuff that weathers tan to dark brown. Crystal metatuff is intercalated with lesser amounts of thin-bedded fissile felsic metatuff that weathers yellow-tan to white. Light-gray, thick-bedded to massive, medium-grained felsic metatuff and white, cross-laminated volcanic metasandstone are interlayered with crystal metatuff in shoreline exposures along the west side of Butcher Creek in the southern part of the Boydton quadrangle

**Zf** **Fissile felsic metatuff (Late Proterozoic)**--Mostly fine-grained, schistose, thin-bedded to laminated, metatuff composed of feldspar, quartz, and minor amounts of white mica. Tiny magnetite octahedra characteristic. Includes thin-bedded crystal tuff; rare thin volcaniclastic metasandstone; feldspar metaporphyry, thin-bedded quartz dacite metaporphyry; metamorphosed, hypabyssal, fine-grained quartz dacite; and minor (10 percent) extrusive or hypabyssal metabasalt and mafic metatuff

**Zd** **Fine-grained quartz dacite (Late Proterozoic)**--Mostly massive, tan-weathering, greenish-gray, very fine- to fine-grained quartz dacite and quartz-dacite porphyry mapped as a single pod within fissile felsic metatuff (Zf) west of Rocky Mount Church in the northwestern part of the Boydton quadrangle. Rock is probably hypabyssal

**Zl** **Coarse-grained felsic metatuff (Late Proterozoic)**--Heterogeneous unit composed chiefly (50 percent) of very coarse- to coarse-grained felsic metavolcaniclastic crystal and crystal-lithic tuff, but with appreciable (25 percent) fine-grained felsic metatuff, and lesser (15 percent) extrusive and hypabyssal metarhyodacite. Mafic extrusive rock, dikes, and volcaniclastic rocks are less abundant (10 percent), but mafic clasts are present in most exposures of felsic volcaniclastic rock. Very coarse-grained, clastic crystal-lithic tuff includes beds of metamudstone with angular to subrounded blocks 1 m in diameter of metabasalt. Crystal-lithic metatuff contains subangular to rounded clasts of fine-grained felsite porphyry, crystal-lithic tuff, fine-grained quartz (metachert?), rhyodacite, and mafic metamudstone; and broken and subhedral to rounded crystals of quartz and plagioclase. Intercalated fine-grained schistose quartz dacite and quartz dacite porphyry weather yellow-tan to deep red and reddish orange. These intercalated rocks contain quartz and plagioclase; and a few percent sericite, quartz (gray subhedral grains in augen with tails about 4 mm long), and tiny magnetite octahedra 1-2 mm across. Maximum clast size observed in outcrop decreases generally northeastward along the strike of the unit from boulder- to cobble-sized clasts south of the latitude of Finchley to pebble-sized clasts north of the latitude of Finchley. Mafic metatuffs, that typically compose 10 percent of exposures southwest of Finchley, decrease in abundance in the unit to compose less than 3 percent of exposures northeast of Finchley. Unit interfingers northeastward with felsic phyllite at about the latitude of the Dodson Center area

**Zfp** **Felsic phyllite (Late Proterozoic)**--White- to light-tan weathering, fine- to medium-grained, thin-bedded to laminated, schistose and micaceous phyllite and feldspathic phyllite. Interlensed southwestward with sandy and pebbly lithic-crystal metatuff. Schist and phyllite interlensed with lesser silvery-white splendent muscovite schist, lith-gray- to tan-weathering quartz and feldspar crystal metatuff, fine-grained, fissile felsite, and massive, fine-grained metarhyodacite, fine-grained, cross-laminated, volcanic metasandstone, and minor mafic flow-rocks and mafic volcaniclastic rock

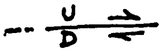
**Zb** **Metabasalt (Late Proterozoic)**--Heterogeneous unit mapped as two lenses in coarse-grained felsic metatuff (Zl). Includes metabasalt in dikes, chlorite schist, chloritic epidote-quartz-albite-sericite metatuff and rare felsic metatuff. Includes amphibolite at contact with rocks of the Clarksville batholith

**Zq** **Quartz metaporphyry (Late Proterozoic)**--Light-gray to white, medium grained, massive to weakly foliated, partly schistose and fissile, quartz-feldspar-muscovite metaporphyry containing augen of relict gray quartz phenocrysts 4 mm in diameter. Mapped as a single small pod 3 km south of Finchley in the southeastern part of Clarksville North quadrangle. Rock is hypabyssal with apophyses, dikes,a nd sills extending into bedded lithic-crystal metatuff

**Zs** **Phyllite and phyllitic metasandstone (Late Proterozoic)**--Light-gray to white weathering, fine-grained, phyllite and thinly-layered, fine-grained micaceous metasandstone in thin even beds

## EXPLANATION OF MAP SYMBOLS

**Contact** - Approximately located; dotted where concealed



**Fault** - Approximately located; dotted where concealed. Half arrows show direction of probable horizontal displacement; U, upthrown side; D, downthrown side

**Folds** - Dotted where concealed. Showing trace of axial surface and direction of plunge and dip of limbs


Anticline


Overturned anticline


Syncline


Overturned syncline

### Planar and Linear Symbols

[Symbols may be joined; where symbols are joined, observation is at point of intersection. Bedding type: C, cross-stratified; G, graded. Inclusion in igneous rock: ff, fissile felsite; f, felsic crystal metatuff; a, amphibolite; g, greenstone; m, mafic crystal metatuff; mb, metabasalt]

**Strike and dip of beds** - ball indicates top of bed determined from primary sedimentary

Inclined

Overturned

Vertical

**Strike and dip of foliation**

Inclined

Parallel to relict bedding

Parallel to overturned relict bedding

Vertical

**Strike and dip of igneous flow foliation**

Inclined

Vertical

Horizontal

**Strike and dip of closely spaced cleavage**

Inclined

Vertical

**Strike and dip of joints**

Inclined

Vertical

**Lineation** - showing bearing and plunge. Letter symbol shows elongate element: B, biotite streaks; C, mica or chlorite crenulation; e, axis of streched clast

## OTHER SYMBOLS

+ bg **Loose block observed at surface** - core-stone or block observed in deeply saprolitized exposure; inferred to be near site of origin. Map unit shown by labeled symbol: Jd, diabase. Lithology shown by letter symbol: bg, foliated biotite granite; f, fissile felsci metatuff; fc, celsic crystal metatuff; fx, coarse-grained felsic metatuff; hgb, hornblende gabbro; gs, greenstone, gb, metagabbro; mb, metabasalts; mv, mafic metatuff; pg, foliated porphyritic granodiorite; q, quartz; qd, foliated biotite quartz diorite; qp, quartz metaporphyry; ss, white quartz metasandstone


**Dike or vein** - Showing trend; steeply dipping. Lithology shown by letter symbol: qd, quartz diorite; pg, porphyritic granodiorite; bg, biotite granite; qp, quartz metaporphyry; qs, quartz with copper sulfides; unlabled, quartz