COMMONWEALTH OF VIRGINIA
DEPARTMENT OF CONSERVATION AND ECONOMIC DEVELOPMENT
DIVISION OF MINERAL RESOURCES

PREPARED IN COOPERATION WITH THE
PIEDMONT PLANNING DISTRICT COMMISSION
AND THE
COASTAL PLAINS REGIONAL COMMISSION

PUBLICATION 25
(GM 103B)
WILLIS MOUNTAIN QUADRANGLE

UNIT CHARACTERISTICS WITH GEOLOGIC AND ECONOMIC FACTORS AFFECTING LAND MODIFICATION

CENOZOIC
TERTIARY TO QUATERNARY

al

Alluvium: *Floodplain deposits, poorly sorted, rounded pebbles and cobbles in a crudely stratified sand and silt matrix, 0-30 feet (0-9 m) thick.*

Forms well-drained silty to sandy loam containing scattered clay lenses. Lowland subject to periodic flooding which discourages construction but replenishes soil nutrients. Slopes steepened during construction subject to sloughing and collapse. Unit well-suited for agricultural and recreational uses. Potential source of sand and gravel.

td

Terrace deposits: *Remnant fluvial deposits, rounded to subrounded cobbles and pebbles in a crudely stratified matrix with subrounded white quartz cobbles at base, 0-15 feet (0-5 m) thick.*

Consists of fine sandy loam with clay or gravel subsoil. Rapid percolation of water through gravel layers overlying impermeable clay lenses poses possibility of seepage in deep construction cuts. Gentle topography and loamy soils give unit high potential for agricultural purposes.

c

Colluvial deposits: *Gravity transported deposits, unsorted, angular, pebble- to boulder-sized rock fragments in an unsorted sand, silt and clay matrix, 0-20 feet (0-6 m) thick.*

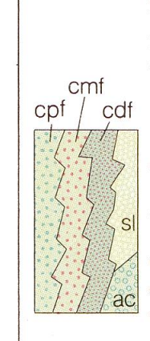
Deposits subject to gravity movements such as soil creep, earth falls and earth flows. Instability of unit places severe restrictions on construction. Areas underlain by colluvium are best suited for development as recreational areas and as woodlands.

MESOZOIC
TRIASSIC

d

Diabase dikes: *Dark-gray to black, fine- to medium-grained diabase with ophitic texture. Weathers to dark-red, clay-rich saprolite. Spheroidally weathered boulders are common in many places.*

Long narrow zones of dense, poorly-drained soils, that become sticky and highly plastic when wet, overlie the dikes. The contact between these dikes and the surrounding rocks provides a pathway for water seepage. Spheroidally weathered boulders, which are common in the saprolite, require heavy machinery or blasting to remove. The combination of sticky muds and spheroidal boulders narrows the uses of this unit. Some of the wider dikes may have potential as a source of dimension or facing stone.



Triassic sedimentary rocks: **cpf**, *conglomerate and breccia (proximal fanglomerate), massive, reddish-brown, angular, arkosic cobble-breccia-conglomerate. Characterized by angular metamorphosed lithic clasts in a reddish-brown arkosic matrix.* **cmf**, *conglomerate (medial fanglomerate), massive, reddish-brown to medium-gray, arkosic pebble conglomerate. Characterized by subangular to subrounded metamorphic clasts (6 mm to 50 cm) in an arkosic clay matrix. Upper portion contains channel fillings of angular cobbles aligned at slight angles to border fault.* **cdf**, *conglomerate and conglomeratic sandstone (distal fanglomerate), thick-bedded, medium-gray to brown arkosic granule conglomerate, (1-6 mm). Characterized by subrounded to rounded quartz clasts in a clayey arkosic matrix. Lower half of unit contains cross-bedding accentuated by accumulations of heavy minerals. Upper half of unit is more massive than lower half and contains numerous channel deposits of coarse pebbles.*

Unit grades from boulder conglomerate with associated thin stony soils on western edge into a granule conglomerate with well-drained loamy soils to the east. The western part of the deposit contains angular blocks in dense, poorly-drained soils whereas the eastern, finer part forms soils that are well-suited for agricultural purposes. The soils in the western part of the unit restrict septic tank drainage and reduce the potential for solid and liquid waste disposal. Deep construction cuts would be more stable here than in the eastern part of the unit, which is less highly indurated.

sl, *siltstone (fluvial-lacustrine), reddish-brown to yellowish-brown siltstone, shale, mudstone, arkose and some conglomerate representing over-bank, lake, swamp and channel deposits; interbedded on a small scale.*

Siltstones, mudstones and shales of this unit are moderately susceptible to weathering and underlie areas of gentle topography characterized by deep silty and silty-clay soils with local clay-rich lenses. Septic tank drainage would be adequate and some potential exists for solid waste disposal. Construction cuts are subject to sloughing. The unit is moderately well-suited to agriculture, timber operations, recreation and moderate-density housing.

ac, *arkose and arkosic conglomerate, poorly sorted, angular to subrounded lithic granule to pebble conglomerate. Relatively high feldspar content reflects composition of source rocks on east side of depositional basin.*

A thin unit which weathers to loose, well-drained soils. Septic tank drainage is adequate. Limited potential for solid waste disposal. Deep construction cuts would be subject to sloughing.

ORDOVICIAN

Oap
Oaq Ⓚ
Oac Ⓚ

Arvonia Formation: **Oap**, *porphyroblastic garnet-mica schist, light-gray to dark-grayish-green, medium- to coarse-grained, crinkle-folded, well-foliated; occupies folded cores of isoclinal synclines; resistant to weathering and underlies long linear ridges. Intersection of two cleavage surfaces at slight angles to pervasive foliation produces distinctive crinkle-folds. Graphite is disseminated throughout rock.*

Arvonia Formation rocks are confined to cores of synclines. The unit is moderately resistant to erosion and underlies upland areas. The schist weathers to a thin ocherous soil overlying moderately permeable saprolite. Septic tank drainage should be adequate for low-to moderate-density housing. The schist contains sulfides in sufficient quantity to locally affect the potability of groundwater. The schist has a pervasive foliation that can act as a slip-surface which requires deep construction cuts to be buttressed or slopes at such sites to be dug at the angle of pervasive foliation. The soils are generally acid and require lime for agricultural purposes.

Oaq, *quartzite, light-yellowish-gray, medium- to coarse-grained, banded to cross-bedded micaceous quartzite as much as 75 feet (23 m) thick occurs above the basal quartz-mica schist. The quartzite weathers to a very pale-orange, sandy micaceous saprolite.*

Unit weathers to a thin stony to sandy soil overlying solid bedrock that is impermeable, except where it is jointed. Septic tank drainage would be inadequate and the potential for solid or liquid waste disposal is low. Pyrite locally affects the potability of ground water. Deep construction cuts are moderately stable, but the bedrock requires blasting. These areas are currently being used for woodland, recreation and low-density housing. Kyanite and manufactured sand are produced from the kyanite quartzite at Willis Mountain.

PALEOZOIC

Oac, *quartz-mica schist with layers of micaceous quartzite and quartz-mica conglomerate, light greenish-gray to light-gray, medium- to coarse-grained, moderately foliated, moderately lineated, locally discontinuous and locally conglomeratic. Conglomeratic basal portion contains elongate, subrounded, light-blue, quartz pebbles in a matrix of muscovite and quartz. The schist weathers to a light-yellowish-gray, sandy, micaceous saprolite.* Ⓚ, *kyanite occurs locally as massive lenses and stringers segregated from quartz layers; locally contains "jelly bean" gravels. Kyanite constitutes as much as 30% of the rock at places. Primary sedimentary structures include: wedge-shaped quartzite and kyanite couplets; fining-upward sequences; channel fillings and both large- and small-scale cross-beds.*

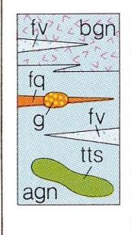
Schists occur on flanks of linear ridges held up by quartzites. The schists are moderately permeable and septic tank drainage should be adequate for low- to medium-density housing. This unit has a pervasive foliation that provides a potential slip-surface which requires slopes in areas of deep construction to be buttressed or to be cut parallel to the pervasive foliation. Unit produces thin inorganic soils that require fertilization.

p

Pegmatite: *Inequigranular, granitic pegmatites discordantly intruded into rocks of the Chopawamsic Formation; most numerous near border fault of basin containing Triassic rocks. The pegmatites are primarily composed of quartz, potassium feldspar and muscovite with minor amounts of plagioclase feldspar.*

Rock weathers to a very pale-orange to very light-gray saprolite whose surface is strewn with bits of feldspar and mica. The pegmatites are permeable and would provide good septic tank drainage. Fresh construction cuts are moderately stable, but the rock weathers rapidly and is then subject to sloughing. Some of the larger pegmatites have been mined for feldspar and muscovite. The small size of these pegmatites hinders the full exploitation of their resources.

CAMBRIAN



Chopawamsic Formation: **bgn**, *biotite gneiss and schist, light-gray, medium- to fine-grained, moderately foliated, moderately to well-banded biotite gneiss underlies and forms interlayers with amphibole gneiss. Contacts with amphibole gneiss are gradational over tens of feet and are characterized by an increase in the amount of interlayering of the two units. The biotite gneiss ranges from monotonous masses of salt-and- pepper granitic gneiss to a well-segregated, banded biotite-quartz-feldspar gneiss. The biotite gneiss is not resistant to weathering and occupies areas of gentle topography, where it forms thick, light- to pale-brown loamy saprolites.*

Rock is readily weathered and underlies areas of gentle, rolling topography which have deep loamy soils overlying a porous and permeable saprolite. Septic tank drainage should be adequate for moderate-to high-density housing. Some potential exists for solid waste disposal, however, the unit is not suited for liquid waste disposal as contamination of groundwater reservoirs may result from such use. Deep construction cuts are subject to sloughing. Areas denuded of vegetation are subject to extreme erosion.

fv, *felsic volcanic rock, yellowish-gray to white, equigranular, volcanic rocks of dacitic to rhyodacitic composition interlayered with amphibole gneiss and biotite gneiss units as lenses and layers 2 to 20 feet (0.6 to 6 m) thick. The volcanic rocks are primarily composed of quartz and feldspar with minor amounts of muscovite as porphyroblasts.*

Bodies of this rock, which are lenses, have characteristics similar to those of the biotite gneiss.

agn, *amphibole gneiss, greenish-black to black, medium- to coarse-grained, poorly to well-lineated, massive to well-banded amphibole gneisses interlayered with biotite gneisses in masses from one foot (0.3 m) to hundreds of feet thick. The amphibole gneiss is jointed and contains ptygmatic folds. Medium-grained, light-greenish-gray, quartz-epidote stringers are common and are locally associated with sulfide minerals. Amphibole occurs either as tremolite-cummingtonite or as hornblende-cummingtonite.*

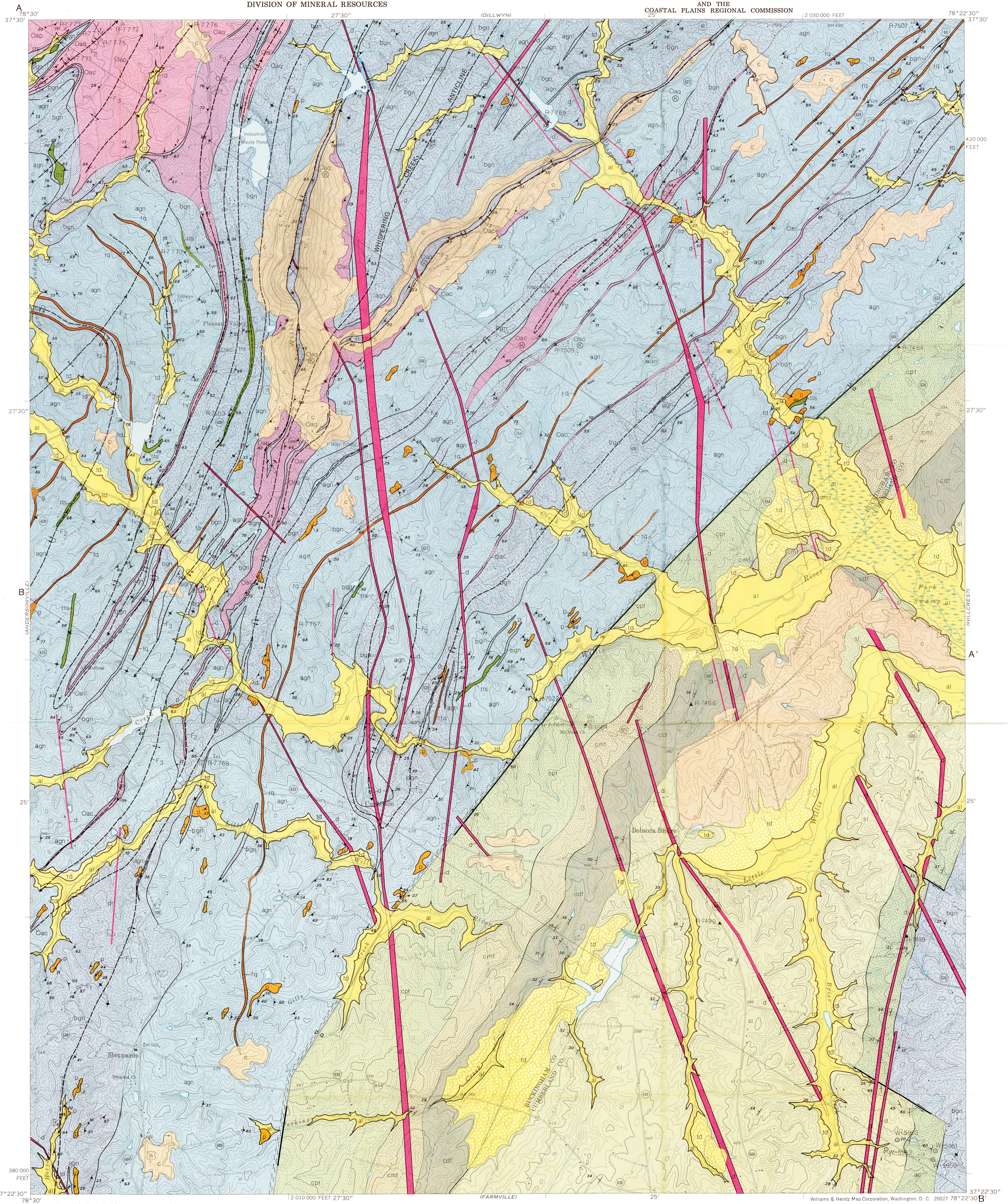
Rock is moderately resistant to weathering and forms a rolling topography; it weathers to a dark-reddish-orange, clayey soil that overlies a sticky, impermeable saprolite. When wet, the soils form a sticky, highly plastic mud. The rock is impermeable except in the many places where it is abundantly jointed. The joints promote seepage and, therefore, inhibit use of the unit for septic tank drainage and solid and liquid waste disposal. Construction cuts are stable when dry, but become unstable when wet. Soils are acid and require lime and fertilizer.

fq, *ferruginous quartzites as dark-reddish-gray, fine- to medium-grained, massive to well-banded, persistent to discontinuous lenses occur within the amphibole gneiss. Magnetite constitutes 15 to 25% of the rock and along with specular hematite is interlayered with quartz to produce banding. Ferruginous quartzites in many places are associated with weathered massive sulfide (gossan) zones.* **g**, *gossan zones, dark-brownish wad composed primarily of magnetite and hematite with minor amounts of spessartine garnet (mineral determinations by X-ray diffraction).*

Rocks are resistant to weathering and tend to form short, linear ridges. The unit weathers to shallow, stony soils. Septic tank drainage is poor because the rock is generally impermeable. Construction cuts are generally stable; blasting may be required for deeper cuts. Some potential exists for the mining of massive sulfide ores (gossans) associated with these rocks.

tts, *pale- to dark-greenish-gray, inequigranular talc-tremolite schists occur as irregular sill-like bodies in the amphibole gneiss. The compositions of the unit range from talc-tremolite schist to actinolite-chlorite schist. The unit is moderately resistant and, where extensive enough, tends to form small knobs and ridges.*

Rock is in elongate, pod-shaped bodies that weather to a heavy, sticky soil overlying dense, impermeable saprolite that forms a thick viscous mud when wet. Septic tank drainage is poor and the potential for solid waste disposal is low. Construction cuts in the unit generally require blasting and tend to be unstable. Some potential exists for quarrying dimension stone.



Base map from U.S. Geological Survey, 1968 (74-PR)
Willis Mountain Quadrangle, 7½ Minute Series

Williams & Heintz Map Corporation, Washington, D. C. 20027

KEY

CONTACTS

Exposed or approximate

Covered or inferred

FOLDS

Anticline: trace of fold and direction of plunge

Syncline: trace of fold and direction of plunge

Overturned anticline: trace of fold and direction of plunge

Overturned syncline: trace of fold and direction of plunge

Minor fold: strike and dip of axial plane; direction of plunge

Vertical minor fold: direction of plunge

F_1	Tight intrafolial isoclines (observed in outcrop)
F_2	Tight refolded isocline
F_3	Open, upright or overturned fold

FRACTURES

Shear zone

FAULTS

Exposed or approximate (black line); covered (gray line); U, upthrown side; D, downthrown side; arrows indicate direction of relative movement

ATTITUDE OF ROCKS

Strike and dip of beds

FOLIATION

Strike and dip of foliation

Strike of vertical foliation

MINES AND PROSPECTS

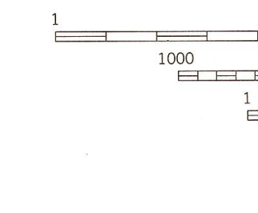
Active mine
1. Kyanite Mining Corporation
2. Kyanite Mining Corporation

Abandoned mine
1. Seay mine (gold)
2. Morrow mine (gold)
3. Mine (copper)

Prospect
1. Area of numerous prospects (gold)
2. Area of numerous prospects (iron)
3. Prospect (mica or feldspar)

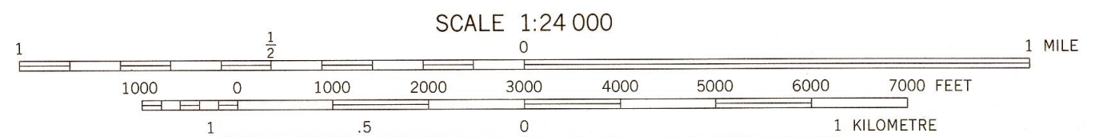
SAMPLE LOCATIONS

△ R-7771	R, repository number of rock sample on file at the Virginia Division of Mineral Resources
▲ R-7772	Sample of raw material having potential commercial use; R, repository number of sample on file at the Virginia Division of Mineral Resources
⊙ W-5953	W, repository number of core sample on file at the Virginia Division of Mineral Resources



UTM GRID AND 1974 MAGNETIC NORTH DECLINATION AT CENTER OF SHEET

SCALE 1:24 000

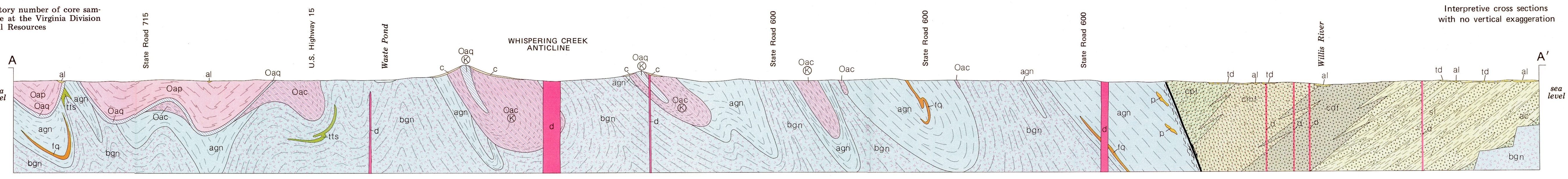


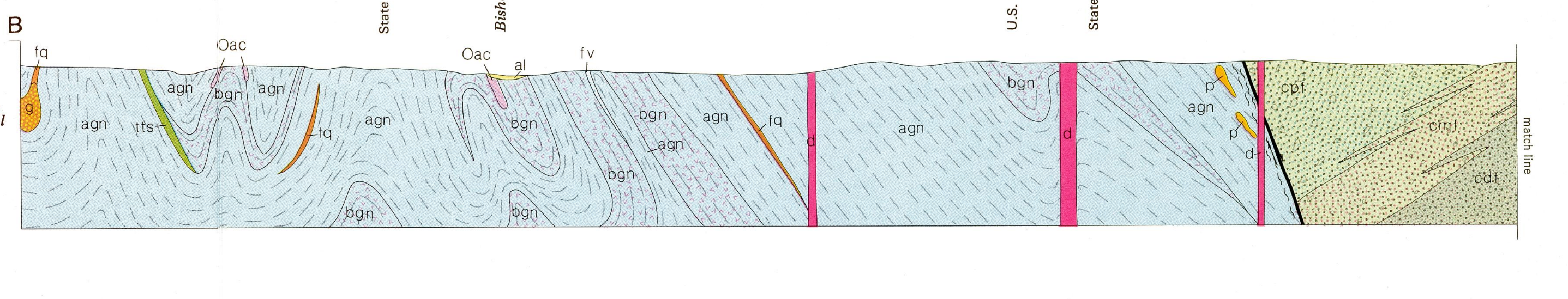
CONTOUR INTERVAL 10 FEET
NATIONAL GEODETIC VERTICAL DATUM OF 1929

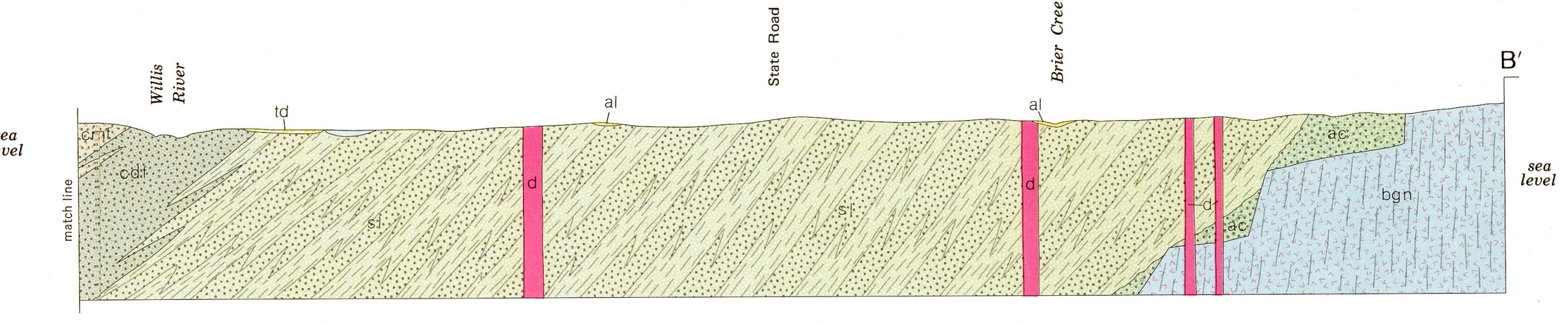
1980

QUADRANGLE LOCATION

Interpretive cross sections
with no vertical exaggeration







GEOLOGY OF THE WILLIS MOUNTAIN QUADRANGLE, VIRGINIA

By John D. Marr, Jr.

1980

STRATIGRAPHY

The Willis Mountain quadrangle comprises an area of approximately 56 square miles (145 square km) in southern Buckingham and eastern Cumberland counties in central Virginia within the Piedmont province. The area has been of great interest to several base-metal mining groups in recent years. It presently supports a large kyanite mining industry.

PRECAMBRIAN OR LOWER PALEOZOIC ROCKS

Chopawamsic Formation

The oldest rocks in the Willis Mountain quadrangle are a sequence of mafic and felsic metavolcanic rocks here assigned to the Chopawamsic Formation. The Chopawamsic Formation was named for exposures along Chopawamsic Creek in northern Virginia by Southwick, Reed and Mixon (1971). The Chopawamsic Formation has been traced into north-central Virginia by Higgins and others (1973), Pavlides and others (1974) and Conley and Johnson (1975). It was recognized in central Virginia by Conley (1978) and Conley and Marr (1979). In the Willis Mountain quadrangle, the Chopawamsic Formation is composed of biotite gneiss, amphibole gneiss, felsic (rhyodacitic) volcanic rocks, talc-tremolite schist and ferruginous quartzites with associated gossan (iron-bearing zones). The amphibole gneiss contains layers with high percentages of epidote and quartz. These layers appear to be associated with sulfide minerals and may prove useful as an exploration aid in locating massive sulfide deposits. Ferruginous quartzite lenses in the formation are extremely resistant to weathering and thus serve as stratigraphic markers. Much of the structural interpretation was made possible by recognizing these marker beds. Gossans, consisting predominantly of weathered pyrite and chalcopyrite with lesser amounts of galena and sphalerite, are intimately associated with the ferruginous quartzites. In many places the ferruginous quartzites provided "pathways" to the gossans, where garnets increase in size and become more manganese rich. The age of the Chopawamsic Formation is considered to be Early Cambrian based on discordant radiometric zircon ages obtained from felsic rocks (Higgins and others, 1971). Glover (1974) reports an age of 530 to 570 million years for the Chopawamsic.

Pegmatites

Numerous granitic pegmatites intrude the Chopawamsic Formation. These pegmatite intrusives increase in abundance near the fault at the western boundary of the basin containing Triassic sediments (Farmville basin). Most of the pegmatites associated with this fault exhibit cataclastic features including; polygonization of grains, undulose extinction and sericitization and albitization of feldspar. The rock also contains micrographic and myrmekitic intergrowths. Because the pegmatites intrude the Chopawamsic rocks, their maximum age is Early Cambrian; because they do not intrude the rocks of the Arvonia Formation, they cannot be younger than Middle Ordovician.

Arvonia Formation

The Arvonia Formation overlies the Chopawamsic Formation with angular unconformity (Taber, 1913). The basal unit of the Arvonia Formation is a locally discontinuous quartz-mica schist which contains layers of micaceous quartzite and quartz-mica conglomerate (Conley and Marr, 1979). Some of the conglomeratic clasts are composed of bluish quartz pebbles. These pebbles have come from sources other than the Chopawamsic rocks, which do not contain "blue" quartz within the area studied. Placer gold, probably derived from sulfides within the Chopawamsic rocks, is disseminated in the basal clastic rocks of the Arvonia Formation. The micaceous schist grades upward into a persistent, banded quartzite. Both the basal micaceous schist and the banded quartzite contain disseminated graphite and pyrite. Higher in the sequence, the Arvonia consists primarily of light- to dark-gray porphyroblastic muscovite-biotite schist with garnet as porphyroblasts. This schist consists of thin, interbedded metasiltstones and metaclaystones; pyrite is a common accessory mineral.

Conley and Marr (1980) described a stratigraphic sequence of kyanite-quartz-mica schist overlain by kyanite quartzite that in turn is overlain by graphitic schist in the rocks which make up Willis Mountain and Woods Mountain (Andersonville quadrangle). These rocks are mapped with the Arvonia Formation because the stratigraphic sequences and lithologies are similar to those of the more typical Arvonia; the kyanite quartzite at Willis and Woods mountains is equivalent to the banded quartzite of the Arvonia Formation (Conley and Marr, 1980). Both the quartz-mica schist and the kyanite quartzite contain small-scale and large-scale cross-beds and channel-fill structures. Within the quartzite unit are sequences of wedge-shaped deposits; each sequence contains basal "jellybean" gravel that grades upward into a nearly pure kyanite.

The rocks of the Arvonia Formation are probably Middle to Late Ordovician in age. No fossils were found within the study area; they were probably destroyed during metamorphism of Arvonia rocks. Metamorphic grade in Arvonia rocks increases toward the south, where characteristic minerals are fibrous sillimanite and kyanite. At the type locality, Arvonia, along strike to the northeast, fossil forms identified include: brachiopods, bryozoans, crinoids, pelecypods and trilobites of Middle or Late Ordovician Age (Darton, 1892; Dale, 1906; Watson and Powell, 1911; Smith, Milici and Greenberg, 1964; Brown, 1969; and Tillman, 1970). Harper and others (1973) dated the slates of the Arvonia Formation at 300 m.y. using the whole rock K-Ar method. This date does not correspond to any known orogenic event affecting rocks of the Virginia Piedmont and it probably represents a time of cooling when the rocks formed a closed K-Ar system following a metamorphic event (Hadley, 1964).

TRIASSIC SYSTEM [1]

Triassic sedimentary rocks in the quadrangle are within a part of the Farmville basin. The strike of rocks is generally between N20°E and N30°E; dips are between 20° and 35° to the northwest. The conglomerates of the western part of the basin represent a gravity flow regime all in which metamorphic rocks to the northwest of the Triassic border fault were eroded and transported to form fan-shaped conglomerate deposits (fanglomerates) along the western margin of the basin. The particle size of the deposits decreases eastward allowing distinction of proximal, medial and distal portions of them. These three parts of the unit are well exposed along Willis and Little Willis rivers.

Triassic deposits in the central part of the basin, which are poorly exposed, represent a fluvial-lacustrine facies. Rock types include siltstone, shale, mudstone and arkose; there are also conglomeratic lenses and thin coal seams. Reddish-brown siltstones and arkoses are the major lithologies.

Below the fluvial-lacustrine deposits is a poorly sorted arkose and arkosic conglomerate. The deposit contains silicified wood.

Several abandoned coal mines and numerous prospect pits are in the vicinity of Farmville but there are none in the Willis Mountain area, where the largest coal seam found was about four inches (10 cm) thick. It is unlikely that any significant coal reserves exist in the study area.

Diabase Dikes

Several diabase dikes ranging in width from a few feet to about 220 feet (67 m) cut throught the metamorphic and sedimentary rocks of the area. Some of these dikes were traced for several miles. They characteristically weather to a red sticky and clayey soil marked by rounded exfoliated boulders. These dikes clearly postdate all known tectonic events and are considered to be Triassic or slightly younger in age.

QUATERNARY SYSTEM

Deposits include: colluvium, terrace deposits and alluvium. Colluvium is formed by gravity transport and is located in areas of relatively steep topography. Deposit thickness is highly variable and is estimated to range from 1 to 20 feet (0.3 to 6 m) in thickness. Terrace deposits of unconsolidated gravels and cobbles in a sand, silt and clay matrix are along most of the drainage systems; these deposits are generally less than 10 feet (3 m) thick. The few such deposits in upland areas may represent an older drainage system. Alluvial deposits blanket floodplains of major streams. The alluvium is composed of unconsolidated sand and clay with subrounded to rounded cobbles and pebbles. These deposits reach thicknesses of 30 feet (9 m).

STRUCTURE

The rocks within the area have a complex deformational history. The oldest rocks bear evidence of three periods of folding. F_1 folds, which occur in outcrop as tight isoclinal, intrafolial folds on the flanks of the larger F_2 folds, were observed within the rocks of the Chopawamsic Formation and not in the rocks of the overlying Arvonia Formation. Pavlides (1973) described a similar relationship between the Chopawamsic Formation and the Quantico Slate, a younger formation, in northern Virginia.

F_2 folds occur as tight isoclinal, refolded synclines and broader, more open anticlines. The tight synclinal folds contain pelitic schists and quartzites of the Arvonia Formation in their cores; intervening anticlines are cored by rocks of the Chopawamsic Formation. The F_2 fold event imposed a pervasive foliation on the rocks. This foliation is disrupted where it is bent by F_3 folding. The F_2 folds generally trend northeast—southwest and are overturned to the northwest.

F_3 folds, which are more open and upright than the F_2 folds, can only be recognized where F_2 folds are bent around the noses of F_3 folds. F_3 folds constitute the largest folds in the area. These include a northeast-trending anticline, which plunges out in the western part of the quadrangle, and the Whispering Creek anticline in the north-central portion of the area.

WHISPERING CREEK ANTICLINE

The Whispering Creek anticline was named by Espenshade and Potter (1960) who interpreted it as a large, recumbent anticline with minor folds and with a tight syncline on its western limb. The eastern limb was described as having a homoclinal dip to the southeast. Brown (1969) described this structure to the northeast in the Dillwyn 15-minute quadrangle as a large asymmetric anticline; the northwestern limb is appreciably steeper than the southeastern one. New exposures unearthed by the Colonial Gas Company during construction of a pipeline revealed that the Whispering Creek anticline, is a broad, open, asmmetrical fold containing biotite gneiss and amphibole gneiss of the Chopawamsic Formation. The anticline is flanked on either side by two tight isoclinal synclines that contain a kyanite-bearing, quartz-mica schist overlain by kyanite quartzite. The strike of the kyanite-bearing rocks is discordant with the underlying gneiss and therefore the schist is not interlayered with the gneiss. Rather the schist belongs to the basal part of the Arvonia Formation and occurs in two tight F_2 synforms that lie on either side of the Whispering Creek anticline (antiform) which Conley and Marr (1980) interpret as an F_3 fold.

FAULTS

Rocks of Triassic age occupy the south-central to eastern area of the quadrangle. The western side containing these rocks, the Farmville basin, is bounded by a high-angle normal fault that dips steeply to the southeast.

This fault zone is delineated by the presence of a breccia and fine-grained siliceous mylonite. The metamorphic rocks immediately adjacent to the western side of the fault zone are extensively jointed, complexly folded and intruded by numerous discordant granitic pegmatites which contain porphyroblasts of potassium feldspar. This fault may be part of a larger fault system found northeast and southwest of the area in the Piedmont of central Virginia. Brown (1969) mapped this fault to the northeast through his Hatcher Complex; Pavlides (1980) correlated it with the Spotsylvania lineament (Neuschel's lineament, Neuschel, 1970).

Along the eastern boundary of the Farmville basin the Triassic sediments lie unconformably on biotite gneisses of the Chopawamsic Formation. One of four boreholes (Virginia Division of Mineral Resources core W-5951) drilled near the boundary penetrated the contact between the Triassic and older rock. The calculated dip of the contact is about 20° to 25° toward the northwest.

ECONOMIC GEOLOGY

By Palmer C. Sweet

KYANITE

Virginia is the leading state in the production of kyanite (Al_2SiO_5), a blue to white, transparent, non-metallic, high aluminum silicate mineral. The material is produced by the Kyanite Mining Corporation from deposits of kyanite-bearing quartzites at two sites south of Dillwyn. The resistant kyanite-quartzite forms Willis Mountain and a lower hill about 1 mile (1.6 km) east, East Ridge (not labeled on map). Mining of the kyanite-quartzite at Willis Mountain began in 1957 and has continued since that time. A new mine and plant established on East Ridge in 1978 doubled the productive capacity for kyanite in Buckingham County.

Kyanite is a source of high-alumina refractory material. About 10 percent of the total tonnage mined is marketed as raw material. The remaining kyanite is used to make mullite ($3Al_2O_3 \cdot 2SiO_2$) and vitreous silica by heating (calcining) the kyanite at temperatures of 1100° to 1480°C. When heated in this way, kyanite looses its bluish tint and its transparency in becoming mullite, which is white and opaque. At approximately 1810°C, mullite forms corundum (Al_2O_3) and silica; these materials recombine to form mullite if the temperature drops below 1810°C. The largest market for kyanite is in making brick for rotary kilns and furnaces (Dixon, 1980). New uses for kyanite are being developed in stainless steel foundries and in fiber insulation manufacturing. In future years, kyanite could become a chief source of aluminum metal.

CONSTRUCTION MATERIALS

There are no active rock quarries or sand and gravel operations within the quadrangle area, although manufactured sand is produced as a by-product of kyanite-mining operations. A fresh bulk rock sample (approximately 100 pounds) of granite gneiss (R-7522) was collected from the bed of the Willis River about 0.45 mile (0.72 km) west of Mt. Nebo Church and 1.5 miles (2.4 km) northeast of Curdsville. The sample was tested by the Virginia Department of Highways and Transportation with the following results:

Sample	Specific Gravity	Grading	Los Angeles Abrasion Loss	% Absorption	% Soundness Loss
R-7522	2.79	A	24	0.6	1.0

These tests show the rock to be a good aggregate material. Physical test data for rock material from additional sites in Buckingham County are in "Physical Test Results of the Virginia Highway Statewide Aggregate Survey" (Virginia Department of Highways and Transportation, 1954). A granite prospect northeast of Curdsville is in borderline Grade A stone. Material from an abandoned quarry in hornblende gneiss located southeast of Dillwyn and about three-fourths of a mile (1.2 km) north of the Willis Mountain quadrangle was used for roadstone by the State of Virginia.

Good exposures of diabase, a tough, greenish-black rock, occur along U.S. Highway 15 just north of Curdsville and on the east side of State Road 600 near the Buckingham-Cumberland county line. The rock occurs in typically thin, elongate dikes that are generally not suitable for commercial quarrying because the dikes are narrow and have steep dips.

An angular, white sand is produced as a by-product of kyanite processing at Willis Mountain by crushing of kyanite-bearing quartzite. The sand is mostly marketed as golf-course sand (Sweet, 1978, p. 72). The material has also been utilized as cleaning, blasting, engine, foundry, and ballast sand (Johnson, 1967, p. 6).

MASSIVE SULFIDES

There are sulfide deposits (zinc, copper, gold and lead mineralization) in the metavolcanic rocks of the Chopawamsic Formation; the origin of the mineralization has been reported by Gair (1978). There has been intensive drilling and other exploration work for massive sulfides in recent years.

GOLD

Gold is associated with the massive sulfides. Most of the pits and trenches of two old mines, the Morrow and the Seay (Sweet, 1980), are on linear ridges of micaceous quartzite and fine-grained, quartz-sericite schist of the Arvonia Formation. The deposits probably represent placers formed on the eroded surface of the Chopawamsic Formation. More than 250 troy pounds of gold were produced from placer deposits at the Morrow (Booker, Garnett, Moseley) mine in the 1850's. Shafts were sunk at the site in 1854-1865, 1880 and 1938. The Seay mine was developed with cuts and shafts before and also after the middle 1800's.

COPPER

There is a copper prospect on the southwest slope at the south end of Willis Mountain (Taber, 1913, p. 133). Specimens of pyrite and pyrrhotite are in the woods near an old cave in the area, but no evidence of a caved-in shaft was seen. The cave visited meets the location description by Maloney (1976, p. 4) of Woodson's Cave, a surveying station in the early 1700's.

IRON

Many of the ferruginous quartzites in the area have been prospected during exploration in associated massive sulfide deposits. There is currently substantial interest in the ferruginous quartzites and in the sulfides; both the iron and sulfide deposits were probably formed by volcanic exhalations.

MANGANESE

A deposit of manganese oxides near Curdsville was worked in the 1880's or the 1890's (Espenshade, 1954, p. 93). Field mapping of the area and querying of residents failed to reveal any information concerning this deposit.

CLAY MATERIALS

Clay-material resources include transported clays and residual clays formed over many types of rocks, including Paleozoic hornblende schists and gneisses and Triassic siltstones and shales. Residual clay from the Willis River west of Mt. Nebo Church, and near the crossing of State Road 621 was used for making crude bricks at a mill near the site.

Clay materials were sampled at eight selected localities and these were sent to the Tuscaloosa Metallurgy Research Laboratory for testing and evaluation under a cooperative program between the Division of Mineral Resources and the U.S. Bureau of Mines. The test data received from the laboratory are preliminary. In the northern part of the quadrangle, three residual-clay samples (R-7503, R-7507, and R-7509) were taken over amphibole and biotite gneisses. The hardness of the fired material for two of these samples was insufficient for commercial use; the hardness of fired test briquets for sample R-7507 was sufficient for commercial use even though shrinkage was excessive. Five samples of residual clays (R-7464, R-7466, R-7489, R-7490 and R-7504) collected from the central and southeastern portion of the quadrangle, an area of Triassic-age rocks, mostly have good plasticity and adequate hardness with tolerable shrinkage when fired. One sample (R-7504), collected in a roadcut near Mt. Nebo Church had excessive shrinkage at required firing temperatures. This clay, if mixed with a minor amount of silt or sandy material, would probably make an acceptable material for structural clay products. Floodplain and terrace deposits along Little Willis River, Willis River and Whispering Creek were explored for clay materials, but no good exposures of clay were found.

COAL

Several old coal prospects and pits are 2.7 and 4.2 miles (4.3 and 6.7 km) north of Farmville in the Farmville 7.5 minute quadrangle. A mine opened by the Piedmont Coal Company in the early 1860's produced coal intermittently until the early 1890's.

In the southeastern part of the Willis Mountain quadrangle, four holes were cored by the Virginia Division of Mineral Resources in 1979; the deepest hole was 180 feet (55 m). No coal was encountered, but a four inch (10 cm) seam of coal is in a stream-cut in this area.

FELDSPAR AND MICA

There are numerous small pegmatitic intrusives in the quadrangle. Two of these rock bodies appear to have been prospected. One of these is on the southern slope of the prominent saddle in Willis Mountain. At this location quartzo-feldspathic material and muscovite books up to five inches (12 cm) are spread about several small pits and one trench. There is another prospect pit (Forbes deposit?) one-half mile (0.8 km) west of the intersection of State Road 621 and U.S. Highway 15. Here the mica-bearing pegmatite contains clear and free-splitting, large books of mica (Griffitts, and others 1953, p. 182). The small size of most of the pegmatite bodies limits their potential as a source of either feldspar or muscovite.

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REFERENCE NOTE

Portions of this publication may be quoted if credit is given to the Virginia Division of Mineral Resources. It is recommended that reference to this report be made in the following forms:

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[1] Triassic rocks mapped and described by Michael B. McCollum