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

GEOLOGY AND MINERAL RESOURCES OF FLUVANNA COUNTY

James W. Smith
R. C. Milici
S. S. Greenberg

BULLETIN 79

VIRGINIA DIVISION OF MINERAL RESOURCES

James L. Calver
Commissioner of Mineral Resources and State Geologist

CHARLOTTESVILLE, VIRGINIA
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DEPARTMENT OF PURCHASES AND SUPPLY
RICHMOND
1964

DEPARTMENT OF CONSERVATION AND ECONOMIC DEVELOPMENT

Richmond, Virginia

MARVIN M. SUTHERLAND, *Director*
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GEOLOGY AND MINERAL RESOURCES OF FLUVANNA COUNTY

By

JAMES W. SMITH, R. C. MILICI, AND S. S. GREENBERG

ABSTRACT

Fluvanna County is situated in the central Virginia Piedmont on the southeast limb of the Blue Ridge anticlinorium. The rocks range from the Cambrian or Precambrian Catoctin Formation through the Upper Ordovician Arvonia Formation. The aggregate thickness of this metamorphosed sequence is about 21,000 feet. The lower 13,000 feet of strata are composed of paragonite phyllites and chlorite-muscovite- or muscovite-bearing graywackes, subgraywackes, argillites, phyllites, and quartzose phyllites interbedded with minor amounts of greenstone (metabasalt). The upper 8,000 feet of strata consist of a metamorphosed volcanic and sedimentary rock unit and the Arvonia Formation.

The sequence was folded into asymmetrical and overturned anticlines (Rivanna River, Hardware) and synclines (Columbia, Arvonia, Long Island) near the end of Ordovician time, and the granodiorite batholith was intruded between the time of folding and the end of the Devonian Period. All units were subjected to regional metamorphism near the end of the Mississippian Period. In the western portion of Fluvanna County formations are within the greenschist facies, and in the eastern portion formations are within the almandine-amphibolite facies. Metamorphic grade generally increases from west to east across the county; biotite and garnet isograds were mapped. Triassic diabase dikes generally trend northwestward across northeastward-trending Paleozoic structures. The dikes are composed principally of labradorite, pyroxene, and olivine.

Stone, talc, asbestos, quartz, garnet, gemstones, iron minerals, vermiculite, sand and gravel, clay, and gold occur within the area.

INTRODUCTION

LOCATION AND SIZE OF AREA

Fluvanna County includes an area of approximately 282 square miles in the central portion of Virginia (Figure 1). The county lies between lines of longitude 78°04′ and 78°30′W. and lines of latitude 37°42′ and 38°01′N. This area is shown on portions of five 15-minute quadrangle maps: Charlottesville, Scottsville, Columbia, Dillwyn and Lakeside Village. Counties bordering Fluvanna are Louisa on the north, Goochland and Cumberland on the east, Buckingham on the south, and Albemarle on the west. Palmyra, Fork Union, Columbia, and a portion of Scottsville are the towns in the county. The nearest city is Charlottesville, 10 miles to the west.

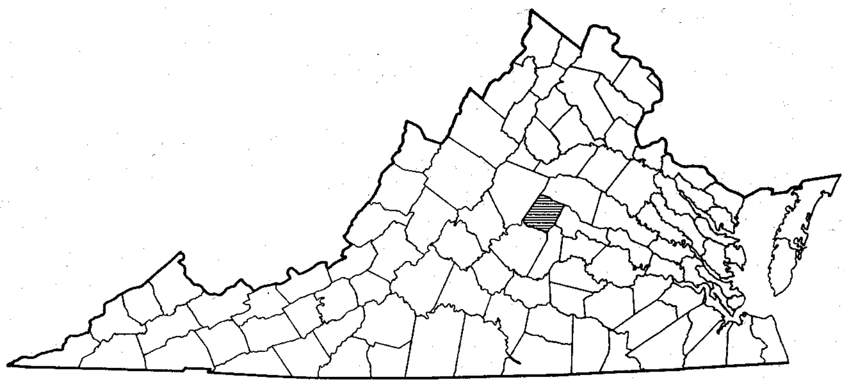

Figure 1. Index map showing location of Fluvanna County.

PRESENT INVESTIGATION

The purpose of this report is to describe the rock and mineral resources, and to discuss the geology of the county. J. W. Smith mapped in the eastern portion of the county from June 1960 to September 1962 and prepared the major portion of the report. R. C. Milici mapped and sampled the formations in the western portion of Fluvanna County between the period April 1962 and April 1963, and S. S. Greenberg studied the petrography of the formations in the area during this period; they wrote portions of the stratigraphy, structural geology, metamorphism, and geologic history and prepared Appendix I. About 2500 rock samples were collected. One hundred twenty-five thin sections, 2000 X-ray diffraction traces, 8 X-ray spectrographic traces, and several rock slabs were made to study the composition and texture of the samples. The X-ray traces were made on a General Electric XRD-5 direct-recording X-ray diffraction unit.

ACKNOWLEDGEMENTS

During the preparation of this report the Virginia Division of Mineral Resources employed the following persons whose work has

been incorporated in this report: H. Robert Hopkins, C. T. Spiker, and Clarke Jones mapped in portions of the county; Villard S. Griffin, Jr. and Richard F. Pharr made a magnetometer survey. William R. Brown of the University of Kentucky visited the writers in the field and contributed many ideas concerning the geology of Fluvanna County. James L. Calver, State Geologist, contributed materially to the improvement of the manuscript.

The Rb-Sr and lead-alpha age determinations were obtained through the courtesy of the United States Geological Survey. J. T. Nuckols III of the Solite Corporation, Richmond, Virginia, supplied information and cores that were collected in Fluvanna County in search of highway aggregate.

PREVIOUS WORK

Darton (1892), Watson and Powell (1911), Stose and Stose (1948), and Applegate (1955) reported on fossils in the Arvonia slate in Buckingham County which extends on strike into Fluvanna County. Extensive petrographic work was done by Taber (1913) in his consideration of the gold belt, and his maps include the eastern half of Fluvanna County; his discussion of gold mining in the area is the most comprehensive to date. Jonas (1927, 1932) mapped the county. Stose and Stose (1948) investigated the structure and stratigraphy of the Arvonia Formation. Brown and Sunderman (1954) mapped the southern half of the county in more detail than previous workers. Brown (1951, 1953, 1962), Espenshade (1954), and Redden (1963, 1964) discussed the stratigraphy and structural geology of the Virginia Piedmont, particularly in the area southwest of Fluvanna County.

Four formations are indicated in Fluvanna County on early State geologic maps published by the Virginia Geological Survey (1911, 1916): Precambrian crystalline schist and gneiss, Precambrian granite and granite gneiss, undifferentiated Cambrian, and the Ordovician (Cinncinnatian) Arvonia Formation. On the 1928 edition of the "Geologic Map of Virginia" (Virginia Geological Survey) no Cambrian rocks are shown in Fluvanna County, and small areas of hornblende gneiss or hornblende gabbro and aporhyolite are indicated. Cline, Watson, and Wright (1921) mapped two formations in the northeast corner of Fluvanna County: granite and schist. The soil map of Fluvanna County (Porter and others, 1958) shows the parent rock of each soil type. Most of the granite and slate contacts are accurately depicted.

Of interest are the earlier references on the geology of Fluvanna County. Samuel G. Lewis' map (in Maclure, 1809) of the eastern

United States shows two formations, Primitive Rocks and Transition Rocks, in the county area. The "Farmers' Register" of 1833 contains an article concerning gold discoveries in Fluvanna and nearby counties. Benjamin Silliman (1837) reported on the Tellurium (Fisher, Hughes) mine. He considered the quartz veins in the gold-mining area sedimentary. Genth (1855) and Credner (1869) described minerals from the gold mines. Hamilton (1865) described the Mosby, Chalk Level, Fountain, Cox, Snead, and Tellurium gold mines. Hotchkiss (1881) noted the mining of gold in Fluvanna County. Dale and others (1914) described the geology of the slate deposits in Fluvanna and Buckingham counties. Pardee and Park (1948) listed 11 gold mines in Fluvanna County. Rogers (1884, map) shows only one formation, Archean rocks, within Fluvanna County. Campbell (1882, map) indicated Archean metamorphic rocks in the county and some limonite near Bremo Bluff.

GEOGRAPHY

Fluvanna County lies entirely within the Piedmont physiographic province. Maximum relief is about 380 feet and in general the gently rolling land is between 300 and 500 feet in elevation. The highest elevations, between 540 and 560 feet, are near the Fluvanna-Louisa county boundary at Zion Crossroads, near the county border northwest of Antioch, and at Little Mountain Hill in the south-central portion of the county. The lowest point, approximately 170 feet in elevation, is in the valley of the James River where it crosses the southeast corner of the county. Temperatures average 38° in January and 78° in July. Yearly precipitation totals about 42 inches. Because of the warm, moist climate, chemical weathering is very active.

Deep saprolite (rock residuum) has formed over virtually all of the uplands in the county. The saprolite is exposed in many ditches along the roads and in the steeper banks along many of the streams; most of the structures and many of the minerals of the parent rock are preserved in the saprolite. A thin veneer of colluvium or alluvium is present in some areas, and alluvium fills the larger stream valleys. Terrace deposits are generally developed in upland areas adjacent to the James and Rivanna river valleys (Figure 2). Records of water wells which are on file at the Virginia Division of Mineral Resources indicate that the average depth to bedrock in upland portions of the county is about 50 feet; the thickest saprolite recorded is 98 feet near Wilmington, over the granodiorite unit. Depth to bedrock through the alluvium in the James River valley is generally greater than depth to bedrock through saprolite. Of the five wells drilled in the alluvium along the James River, the deepest casing indicates a depth of 93 feet to bedrock, and the average depth to bedrock is about 70 feet.

Figure 2. Alluvial terrace boulders about 200 feet above the present level of the James River in eastern Fluvanna County.

All but a very small portion of the county is in the James River drainage basin. The Pamunkey River-James River drainage divide is near the northern boundary of the county. Three rivers flow through Fluvanna County. The eastward-flowing James River forms the southern boundary of the county, and the Rivanna River flows eastward through the central portion. The Hardware River flows southeastward across the southwest corner of the county. The major tributaries that flow into the Rivanna River are, Mechum, Ballinger, Cunningham, and Raccoon creeks; Bremo, Rockfish, North, and Byrd creeks are tributary to the James River. The drainage pattern is generally dendritic although Bremo Creek, Cooke Creek, and a tributary to Hollman Creek have a structurally controlled trellis pattern. Many smaller stream segments are parallel to joint directions. The dendritic pattern probably reflects the homogeneity of rock type.

Four small ridges are parallel to the structure of the rocks. The ridge just north-northeast of Stage Junction is underlain by a thin bed of garnet-amphibole rock; the narrow ridge about 1.7 miles east-northeast of Yanceys Store closely follows the contact between the metabedrock through saprolite. Of the five wells drilled in the alluvium along the James River, the deepest casing indicates a depth of 93 feet to bedrock, and the average depth to bedrock is about 70 feet.

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Fluvanna County has extensive road and railway systems. There is no area in the county that is farther than 1.5 miles from a State-maintained road. U. S. Highway 15, a main route to Washington, passes north-south through the central portion, and U. S. Highway 250 passes through the northwest and northeast portions of the county. The route planned for Interstate Highway 64, passes just north of U. S. Highway 250 approximately parallel to that highway. State Highway 53 extends northwestward from Palmyra, and State Highway 6 extends from Scottsville through Fork Union to Columbia. The Chesapeake and Ohio Railway follows the course of the James River along the southern boundary of the county. Another branch of the Chesapeake and Ohio crosses the central portion of the county in a north-south direction.

About 75 percent of the county is forested, mostly in hardwood. The remainder of the area is largely farmland that is planted in grass, tobacco, and other crops. In recent years an increasing number of pine trees have been grown for the pulpwood industry, and many farms have been sold to large pulpwood companies. Agriculture is the county's principal industry, and livestock, dairy products, poultry, and tobacco are the major sources of farm income.

STRATIGRAPHY

Fluvanna County is underlain by a sequence of graywackes, siltstones and argillites, subgraywackes, phyllites, volcanic rocks, slates, and quartzites. These rocks have been folded, intruded by granodiorite, subjected to metamorphism of generally low grade, and intruded by Triassic diabase dikes. Fluvanna County is situated upon the southeastern limb of the Blue Ridge anticlinorium. The core of the anticlinorium, exposed in Albemarle County, is composed of Precambrian granitic and gneissic rocks of the Virginia Blue Ridge Complex (Brown, 1958, p. 7-17; Nelson, 1962). The Virginia Blue Ridge Complex constitutes the crystalline basement upon which the volcanic-sedimentary sequence was deposited. In general, stratigraphic units become progressively younger eastward across Fluvanna County.

The Catoctin Formation is overlain by metasedimentary units and by paragonite-bearing phyllites in eastern Albemarle and western Fluvanna counties. The paragonite-bearing phyllites are the oldest rock units exposed in Fluvanna County. The paragonite unit is overlain locally by chlorite-muscovite and muscovite-rich units. The middle muscovite unit (Plate 1, mm) is the basis for dividing the chlorite-muscovite-bearing sequence into lower and upper units (Plate 1, cml and cmu). Chlorite-muscovite and muscovite metasedimentary units are overlain by the metamorphosed volcanic and sedimentary rock unit, and above this is the Arvonia Formation.

EVINGTON GROUP

The units between the top of the Catoctin Formation and the base of the metamorphosed volcanic and sedimentary rock unit are probably Cambrian and Ordovician in age. They are at least partly equivalent to the formations of the Evington Group (Brown, 1951; 1953, p. 91-93; 1958, p. 28-38; Espenshade, 1954, p. 14-20). The metamorphosed volcanic and sedimentary rock unit may be partly equivalent to volcanic rocks in the upper portion of the Evington Group which are regarded by Brown (1958, p. 49) as no older than Upper Cambrian and no younger than Ordovician. Because the stratigraphic sequence of the Evington Group is not well understood (Brown, 1951, 1958; Espenshade, 1954; Furcron, 1935; Redden, 1963, 1964) and because of the general lack of stratigraphic information in the central Virginia Piedmont, only tentative correlations are made. Table 1 shows the formations exposed in Fluvanna County.

Paragonite Unit

The paragonite unit (Plate 1, p) is extensively exposed in eastern Albemarle County between the eastern foothills of Carter and Southwestern mountains and the Fluvanna-Albemarle county line. The unit is exposed in western Fluvanna County in the core of the Rivanna River anticline from the vicinity of Nahor northeastward to the Louisa County line and in the cores of smaller anticlines at or just east of the Fluvanna-Albemarle county line.

In Albemarle County the paragonite unit overlies the Catoctin Formation and is overlain by either the Everona limestone or chlorite-muscovite rocks. Carbonate rock is absent at the top of the paragonite unit in Fluvanna County; however, argillites rich in carbonate are present on the east bank of Briery Creek 3.2 miles northeast of Scottsville.

The paragonite unit of this report is equivalent to the unit that was mapped as the Loudoun Formation by Nelson (1962, p. 28-30); it is approximately the same rock sequence as the Candler Formation of Brown (1958, p. 41). If the Everona limestone is the approximate equivalent of the Arch Marble in the Lynchburg area, then the paragonite unit is equivalent to the Candler Formation, Joshua Schist, and Arch Marble (Brown, 1958).

Table 1.—Geologic formations in Fluvanna County.

Age	Formation Name	Character	Thickness in Feet
Triassic	Intrusive igneous rocks	Diabase dikes	
Late Ordovician to Devonian	Granodiorite unit	Medium-to coarse-grained granodiorite	
Late Ordovician	Arvonia Formation	Slate, schist, and quartzite	3200–3900
	Metamorphosed volcanic and sedimentary rock unit	Quartz-feldspar rock, quartzite, phyllite, amphibole schist and gneiss, biotite and chlorite schists, and plagioclase-chlorite-epidote rock	3000–6000
Cambro-Ordovician	Evington Group (?)	Metamorphosed graywacke, subgraywacke, quartzose phyllite, argillite, and phyllite with minor amounts of metabasalt (greenstone). The metasedimentary and metavolcanic units are divided on the basis of their phyllosilicate constituents into paragonite-, muscovite-, and chlorite-muscovite-bearing units.	13,000

The paragonite unit, composed largely of muscovite-paragonite and chlorite-muscovite-paragonite phyllites and argillites, is approximately 1500 to 2000 feet thick. Chlorite-muscovite-paragonite beds are composed of light-green, grayish-green, steel-gray, and rarely white or light-tan, moderately weak to tough phyllites. Argillites are present in minor amounts. The muscovite-paragonite lithology consists of light- to medium-gray, steel-gray, or greenish-gray, very fine- to fine-grained, moderately tough phyllites and argillites. Weathered exposures are yellowish to reddish-brown because of iron-oxide staining.

Muscovite-paragonite and chlorite-muscovite-paragonite rocks are grossly interlayered; locally the two lithologies are interbedded. These lithologies are very similar in appearance, particularly when they are weathered or structurally deformed; however, chlorite-muscovite-paragonite phyllites and argillites are generally softer than muscovite-paragonite phyllites and argillites. The units may be identified by X-ray diffraction analyses.

In thin sections, phyllosilicate layers alternate with layers that contain interlocked fine quartz (about 0.02 mm). The quartz content ranges from about 20 percent in the phyllites to about 80 percent in the argillites. In the muscovite-paragonite rocks the phyllosilicates are muscovite and paragonite (which are microscopically difficult to distinguish from each other), and in the chlorite-muscovite-paragonite rocks the micas are tinged green by admixed chlorite. The mica crystals are uniform in size (about 0.05 mm in the a-direction) and are well aligned. Pyrite and/or magnetite, both of which are slightly oxidized, occur as discrete grains that are approximately parallel to the alignment of mica crystals.

Chemical analyses (Appendix I) of the paragonite unit indicate higher proportions of Al_2O_3, Na_2O and K_2O than analyses (Clark, 1924) of phyllites of sedimentary origin. The chemical analyses of the paragonite unit more closely resemble analyses of known volcanic rocks than those of metamorphosed sedimentary units (Clark, 1924). This evidence, combined with thin-section and field evidence, indicates that the paragonite unit is largely of volcanic origin; chlorite-muscovite units contain materials both of sedimentary and volcanic origin.

Lower Chlorite-Muscovite Unit

The lower chlorite-muscovite unit (Plate 1, cml) is exposed in western Fluvanna County from the James River northeastward to Louisa County. This unit overlies the paragonite unit and is overlain by the middle muscovite unit. The lower chlorite-muscovite unit is approximately 5000 to 6000 feet thick. The unit is composed of metamorphosed graywackes, subgraywackes, quartzites, quartzose phyllites and argillites (metamorphosed siltstones), phyllites (metamorphosed shales), and minor amounts of greenstone. Most greenstones are aphanitic (rarely phaneritic) metamorphosed mafic igneous rocks that contain major amounts of chlorite, sodic plagioclase, and tremolite-actinolite; epidote, quartz, and hornblende are minor constituents. Graywackes grade into subgraywackes with a decrease in the amount of feldspar and interstitial materials. Quartzose phyllites grade into phyllites with a decrease in the amount of quartz and a consequent increase in phyllosilicate minerals. Argillites resemble quartzose phyllites but lack well-defined foliation; argillites tend to be more massive and slightly coarser than phyllites. The term schist and gneiss are misleading and generally do not apply to the coarser grained rocks; where banding is accentuated by deformation along the overturned northwest limb of the Rivanna River anticline, the graywackes and subgraywackes are gneissose. Segregation banding of rocks into quartz-feldspar and phyllosilicate layers is apparent with the aid of a microscope but generally not well developed on a megascopic scale in this unit.

Graywackes are grayish-green to olive-green, fine- to coarse-grained, moderately foliated to massively bedded rocks. Fresh exposures are generally tough and break with splintery fractures. The lithology is characterized by isolated quartz and feldspar grains embedded in a matrix of finely divided chlorite and muscovite. The quartz and plagioclase (albite to oligoclase) grains are very poorly sorted and are unaligned; some grains have secondary overgrowths. The individual phyllosilicate crystals in the matrix are less than 0.05 mm in their a-direction, and many are aligned. Euhedral pyrite crystals, 0.05 to 0.5 inch across, are abundant in places. Colors of weathered graywacke range from mustard yellow to brownish red with an increase in degree of weathering; manganese-dioxide staining is common. Graywacke saprolite is characteristically very weak and punky, and consists of quartz grains surrounded by clay minerals and goethite. In general, fresh exposures of graywacke are only in streams and along river banks; exposures along drainage divides are more weathered.

Subgraywackes are grayish-green, greenish-gray, generally very fine- to fine-grained, well-foliated to massively bedded rocks. Quartzites of this unit superficially resemble subgraywackes. Quartzites are greenish gray to very light gray. Carbonate cement is present. Pyrite crystals up to 0.15 inch are present locally. Weathered exposures of subgraywackes and quartzites resemble weathered exposures of graywackes except that exposures of subgraywacke and quartzite saprolite are more quartzose and even textured than graywacke saprolite.

Fresh exposures of quartzose phyllites and argillites are dark grayish green to olive green; they are hard, tough, well-to poorly foliated rocks that tend to break into bladed or tabular pieces. Phyllites are medium to dark grayish green, light green, light to medium olive green, and light to medium gray. Generally the darker colored phyllites have a greasy luster; all have a micaceous sheen. The well-foliated rock consists essentially of chlorite and muscovite with subsidiary amounts of quartz and feldspar. Fresh exposures are moderately hard and tough. Progressive weathering of the lithology results in the destruction of original coloration and the development of yellows, tans, reddish browns, brownish reds and reds; manganese-dioxide staining is common.

The chlorite-muscovite-bearing strata of the lower chlorite-muscovite units are predominantly subgraywacke, phyllite, and argillite. Graywacke and quartzite are present, but in subsidiary amounts. Muscovite-bearing strata are predominantly phyllite and argillite; subgraywacke is present in subsidiary amounts. Weathering tends to concentrate the finer grained lithologies as flakes or lenses in the residuum at the expense of the coarser grained lithologies. Thin sections of the subgraywacke, phyllite, and argillite show that interlocked quartz and minor amounts of untwinned to poorly twinned plagioclase are about 0.05 mm in size. The size of the phyllosilicate minerals that are interlayed with the quartz and feldspar ranges from less than 0.01 mm up to 0.1 mm in the a-direction; thus these phyllosilicates are more poorly sorted than those in the paragonite units. Alignment is good where the phyllosilicates are relatively coarse, but it is poor where they are fine. The mica is predominantly muscovite. Chlorite is more distinctive in this unit than in the paragonite units, and it occurs scattered among the micas as pale-green crystals. The opaques are similar to those in the paragonite units.

Middle Muscovite Unit

The middle muscovite unit (Plate 1, mm) is exposed within the core of the overturned Hardware anticline in south-central Fluvanna County and as a rather sinuous belt that extends northeastward from Paynes at the James River to Zion Crossroads near the Louisa-Fluvanna county line. The unit overlies and is overlain by chlorite-muscovite-bearing units. The middle muscovite unit is about 1000 to 1500 feet thick. The unit is composed primarily of phyllite, quartzose phyllite, and argillite. Subgraywacke is present in smaller amounts. Megascopically, the muscovite-bearing strata are similar in lithology to the chlorite-muscovite-bearing strata; the character of phyllomorphic constituents was determined by X-ray diffraction analyses. Microscopically, the muscovite-bearing strata are similar to the lower chlorite-muscovite unit, but the muscovite unit contains smaller amounts of chlorite, quartz, and feldspar. The absence or minor amount of chlorite in the middle muscovite unit and in subsidiary muscovite units within the lower and upper chlorite-muscovite units may be a reflection of different initial sedimentary composition. The generally finer grained nature of the muscovite-bearing units indicates that they were deposited in comparatively quiet environments where sedimentary chlorite was absent. By implication, therefore, the chlorite of low-grade metasedimentary rocks in this area may be recrystallized chlorite of sedimentary origin.

Upper Chlorite-Muscovite Unit

The upper chlorite-muscovite unit (Plate 1, cmu) is exposed in an area that extends from Paynes northeastward through Kidds Store to the Louisa-Fluvanna county line north of Bybee. The exposures between Hardware and Kidds Store are on the northwest limb of the overturned Hardware anticline. The unit is exposed on the southeast limb of the anticline from Hardware eastward along the James River to Shores, and northward to Central Plains.

The upper chlorite-muscovite unit is estimated to be from 4000 to 5000 feet thick. In general the unit is lithologically similar to the lower chlorite-muscovite unit; it has undergone a higher degree of metamorphism than the underlying units, and has more abundant gneissose and schistose textures. In areas of pronounced structural disturbance, such as along the overturned limb of the Hardware anticline, graywackes and subgraywackes have gneissose structures. Megascopic phyllosilicate minerals in the upper chlorite-muscovite unit are larger and more abundant than their counterparts in the lower chlorite-muscovite unit. Where megascopic phyllosilicates cover foliation surfaces completely, the term schist is applicable. Microscopically the upper chlorite-muscovite unit is similar to the lower chlorite-muscovite unit. In the upper chlorite-muscovite unit large flakes of muscovite (up to 2 mm in the a-direction) are aligned crudely at an angle to the orientation of the finer phyllosilicates. In this upper unit some chlorite occurs as large crystals (up to 0.5 mm), and green biotite (though much less abundant than muscovite) is more prevalent than in the lower chlorite-muscovite unit.

METAMORPHOSED VOLCANIC AND SEDIMENTARY ROCK UNIT

This unit was depicted on the "Geologic Map of Virginia," 1928 edition, as Peters Creek quartzite. The Peters Creek schist was named by Jonas and Knopf (1921, p. 446-447) for exposures along Peters Creek, Lancaster County, Pennsylvania. The term, metamorphosed volcanic and sedimentary rock unit, is used in this report because of the discontinuity of the outcrop belt between the type section and Virginia and consequent lack of certainty of correlation with the type section. In Fluvanna County the metamorphosed volcanic and sedimentary rock unit extends from just east of Shores on the James River northeastward toward Ferncliff, Louisa County; the unit is exposed in the eastern portion of the county from just north of Columbia northward to Kents Store and from there northward and eastward to the Louisa and Goochland county lines. The metamorphosed volcanic and sedimentary rock unit overlies the upper chlorite-muscovite unit, and is overlain by the Arvonia Formation.

This unit is composed of 3000 to 6000 feet of metamorphosed volcanic rocks that are interlayered with metamorphosed sedimentary rocks. The unit is subdivided into three phases based upon the composition of volcanic constituents. The predominant phase (Plate 1, Ov) is composed essentially of very fine-grained plagioclase-quartz gneiss (metamorphosed felsite) and sericite phyllite. Phenocrysts of quartz and feldspar are abundant in places. Metamorphosed felsite porphyrys, such as those exposed along the northeast bank of the Rivanna River 2.5 miles southwest of Palmyra, superficially resemble quartzites and conglomeratic quartzites. Very fine-grained quartzites and phyllites occur within the volcanic sequence.

A mafic phase (Plate 1, Ovm) of the metamorphosed volcanic and sedimentary rock unit consists of amphibole schist and gneiss, biotite and chlorite schists, and plagioclase-chlorite-epidote rock. In places amphibole gneiss contains amygdaloidal structures. The third phase (Plate 1, Ovfm) of the unit is composed of grossly interlayed (mixed) felsic and mafic phases. The metamorphosed volcanic and sedimentary rock unit contains some very fine- to medium-grained quartzite and slate near the contact with the Arvonia Formation. Microscopically, the felsic phase generally is composed of coarse (2.5 mm in the median dimension) feldspar and quartz and a lesser amount of fine (about 1 mm in the a-direction) muscovite; in some samples a small amount of biotite is present. Much of the feldspar has been altered to unaligned, fine flakes (less than 0.1 mm) of muscovite. The remaining feldspar is sodic plagioclase; it typically contains a few fine muscovite flakes that probably represent incipient alteration. Some of the feldspar is slightly kaolinized. Most of the mafic phase is composed of metamorphosed igneous rocks that are similar to the greenstones found in the lower chlorite-muscovite unit; in the mafic phase of the metamorphosed volcanic and sedimentary rock unit, however, the grain size generally is coarser than in the greenstones, and some of the original igneous rocks in the mafic phase of the unit probably were more intermediate in composition.

The metamorphosed volcanic and sedimentary rock unit is considered Ordovician in age because the contact with the Upper Ordovician Arvonia Formation is gradational. A small amount of slate occurs in the unit near the Arvonia Formation. This occurrence indicates that volcanic activity continued into Arvonia time.

ARVONIA FORMATION

The Arvonia Formation (Plate 1, Oa) was named by Watson and Powell (1911, p. 36-43) for exposures at Arvonia, Buckingham County, Virginia. The formation is preserved in three synclines in Fluvanna County, the Arvonia, Long Island, and Columbia synclines (Plate 1). In Fluvanna County the Arvonia syncline extends from Bremo Bluff northeastward to the vicinity of Carysbrook; the Long Island syncline extends as a linear feature from Strathmore northeastward to the vicinity of Wilmington; the Columbia syncline extends from just north of Columbia northeastward for a distance of 6 miles along the Fluvanna-Goochland county line.

The Arvonia Formation, composed essentially of slate and quartzite, has a thickness of 3200 to 3900 feet. In Fluvanna County the formation may be subdivided into two members, a lower unnamed slate member that is 700 to 1400 feet thick and the overlying Bremo Member (Plate 1, Obr), that is about 2500 feet thick. Taber (1913) reported a bed of tuff and a rhyolite flow in the Arvonia Formation. Amphibolite, probably metamorphosed mafic volcanic rock, is in the Arvonia Formation in the nose of the Columbia syncline.

In places the lowermost exposures of the Arvonia Formation consist of a quartzite up to 10 feet thick. Quartzite pebbles at the base of the quartzite unit near Carysbrook (Figure 3) overlie the granodiorite unit, and were previously regarded as evidence for the deposition of the Arvonia Formation upon granodiorite (Taber, 1913, p. 41-42, Plate 6, Figure 1). However, the present writers concur with Brown (1962) and regard the granodiorite unit as an intrusive which has affected the Arvonia. The slate member is medium to dark gray and is composed chiefly of sericite, quartz, chlorite, biotite, and a small amount of plagioclase feldspar and magnetite. The sericite is interlayered with fine (0.05 mm) interlocked quartz. The biotite generally occurs as small porphyroblasts, and green, magnesium-rich chlorite occurs in association with these biotite porphyroblasts. East of the garnet isograd (Plate 1) almandine porphyroblasts are abundant; locally carbonate minerals and small masses of interlocked quartz grains form porphyroblasts. The fine phyllosilicates generally are bent around the porphyroblasts.

The contact between the lower slate member and the Bremo Member is marked by a 5-foot-thick key bed of oolitic chlorite schist or almandine-amphibole-quartz schist, depending upon the degree of metamorphism; east of the garnet isogard the oolitic chlorite schist grades into almandine-amphibole-quartz schist (Figures 4, 5, 6). The

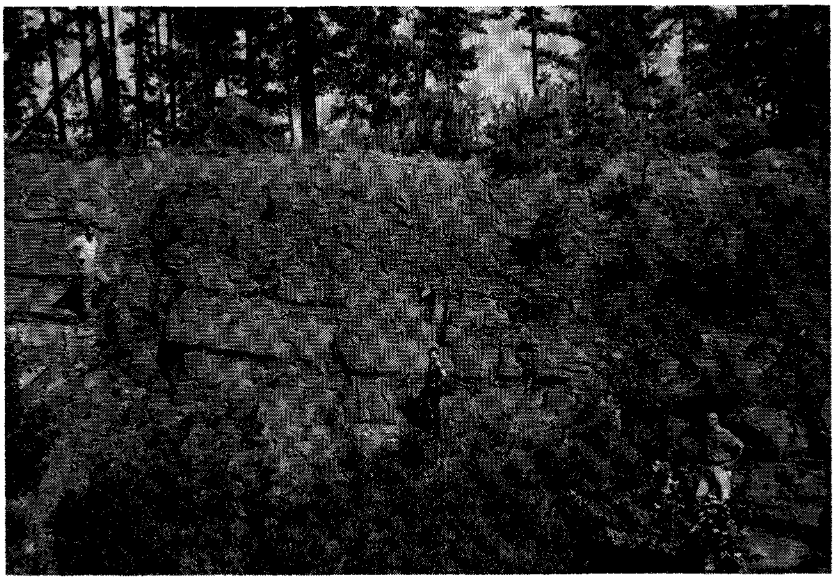

Figure 3. Quartzite at the base of the Arvonia Formation near Carysbrook. Slate overlies the 10-foot-thick quartzite, and sericitized granodiorite lies below it. All of the men are standing on the granodiorite-quartzite contact. A normal fault beside the man on the left has a dip slip of about 3.5 feet; another normal fault beside the man on the right has a dip slip of approximately 6.5 feet.

oolites (Figure 7) are about 1 to 2 mm across the long dimension. Quartz grains occupy the centers of some of the structures, and the shells are composed of alternating layers of chlorite and iron oxides. The lower slate member is overlain by the Bremo Member (Figure 8). The contact is very gradational, and the lower portion of the Bremo Member contains thin beds of slate that are lithologically similar to slates of the underlying unit. The quartzite is composed largely of fine- to medium-grained quartz; mica, feldspar, and carbonate are present in subsidiary amounts. At New Canton, Buckingham County, cross-bedding is present in massive units of quartzite up to 200 feet thick (Figure 9). Elongated fossils of crinoid stems and possibly of

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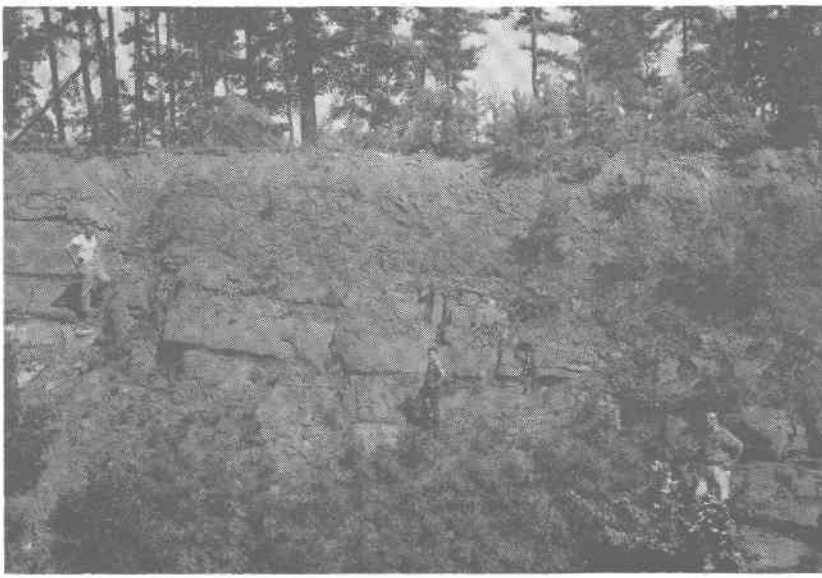

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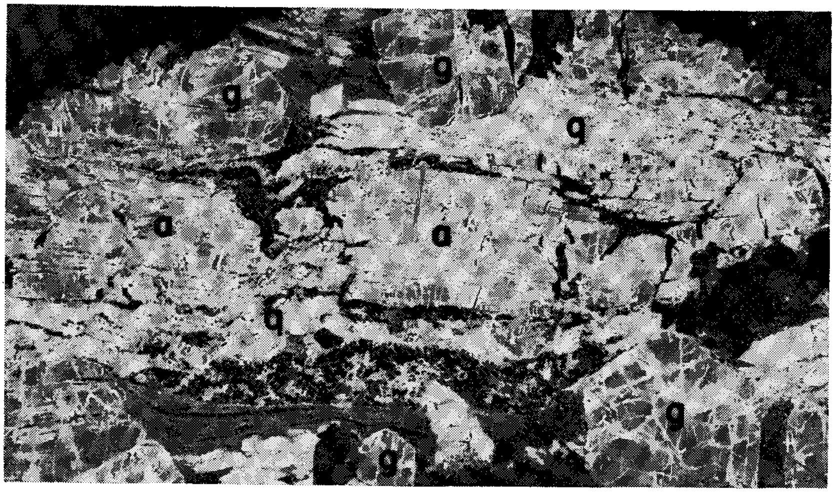


Figure 4. Negative photomicrograph of almandine-amphibole-quartz schist from the Arvonia Formation. Euhedral garnets (g) are in a matrix of amphibole (a) and fine-grained quartz (q). X 3.6.

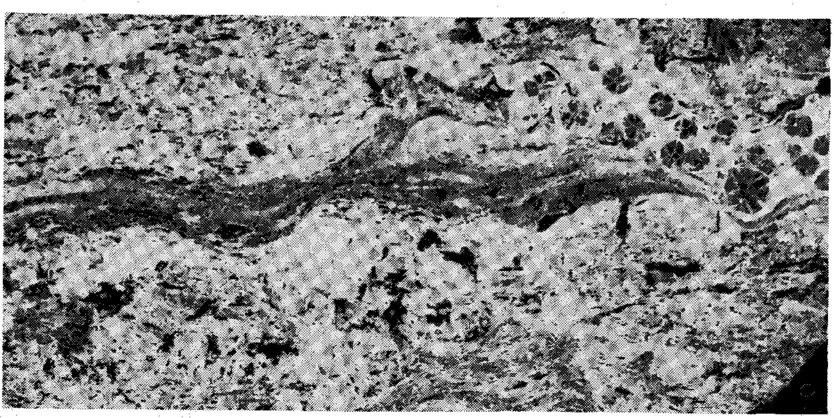
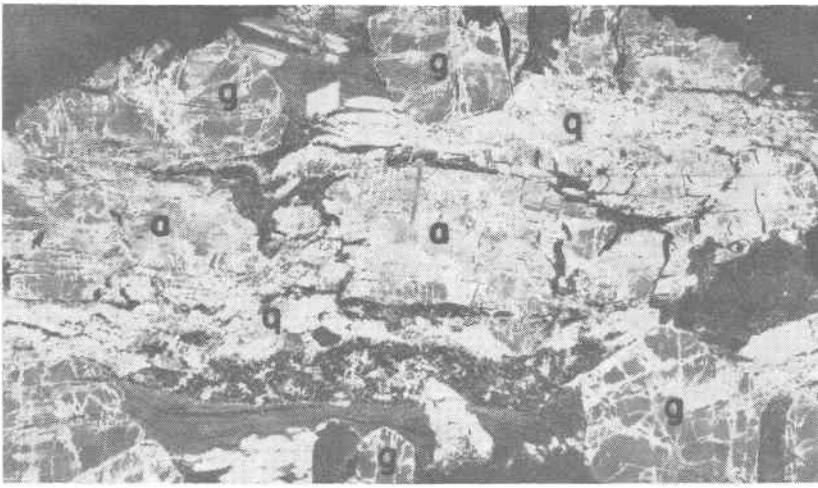


Figure 5. Negative photomicrograph of almandine-amphibole-quartz schist from the Arvonia Formation. Euhedral garnets (upper right corner) are in a matrix of amphibole and quartz. X 3.3.



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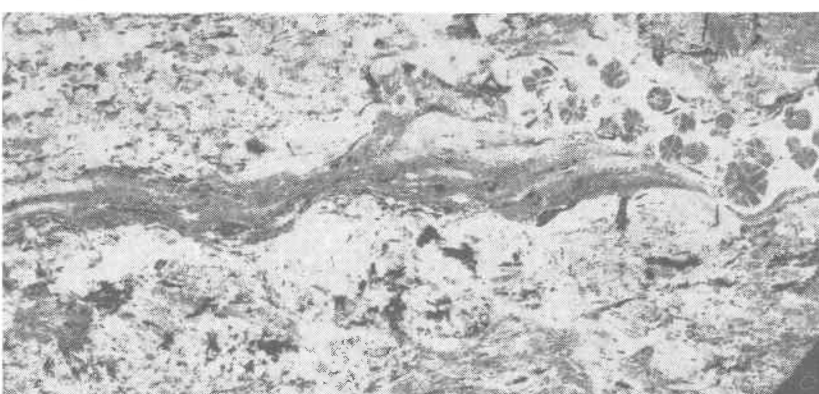

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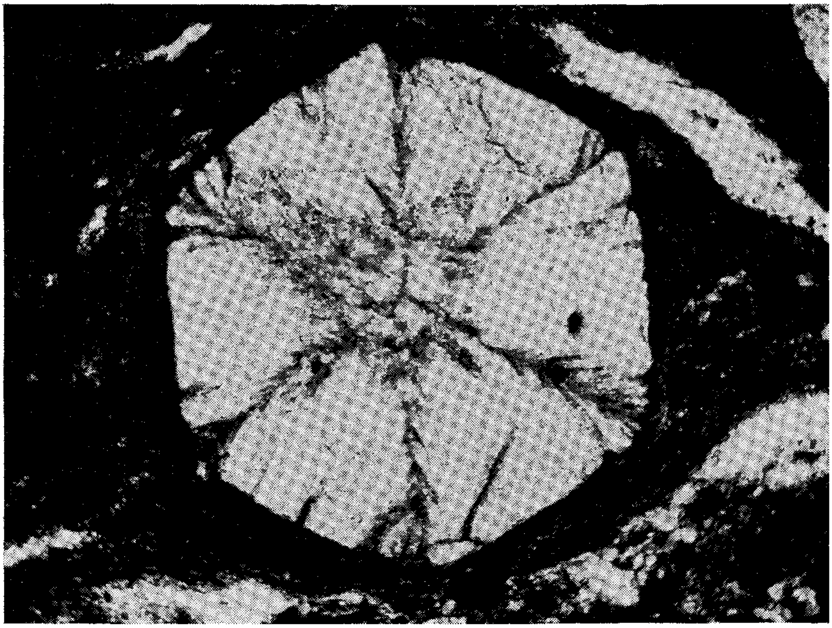


Figure 6. Photomicrograph of euhedral garnet containing graphite (?) inclusions. Almandine-amphibole-quartz schist from the Arvonia Formation. X 58.

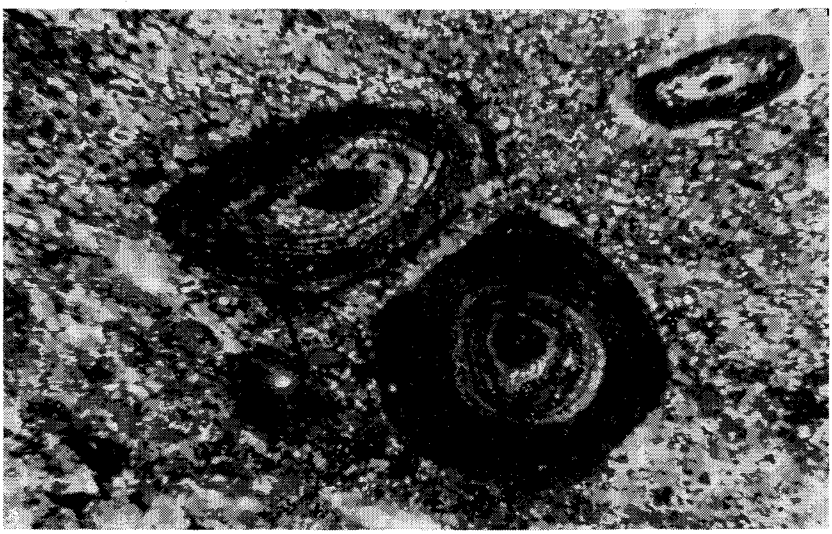
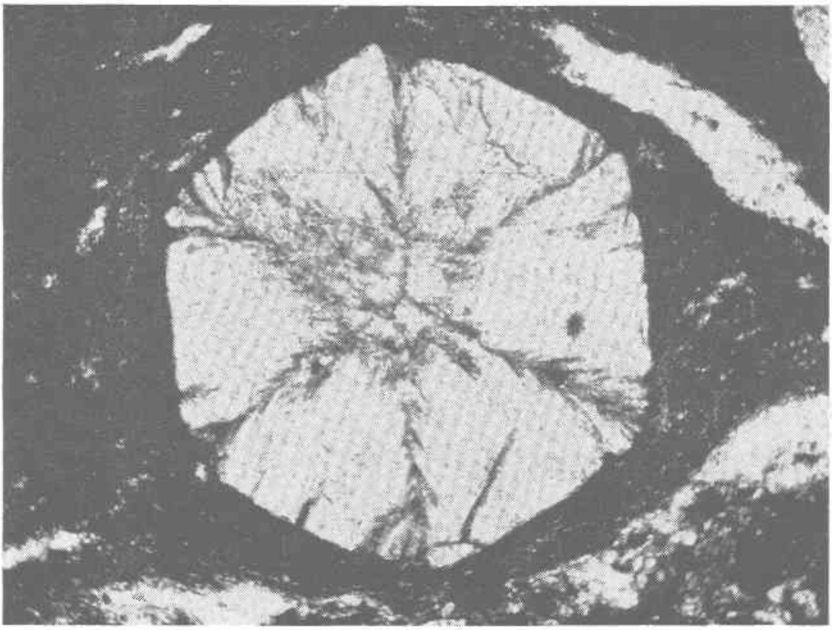


Figure 7. Photomicrograph of oolites composed of goethite in a matrix of chlorite and quartz. This rock type occurs near the middle of the Arvonia Formation and is equivalent to almandine-amphibole-quartz schist in regions of higher metamorphism. Crossed nicols. X 50.



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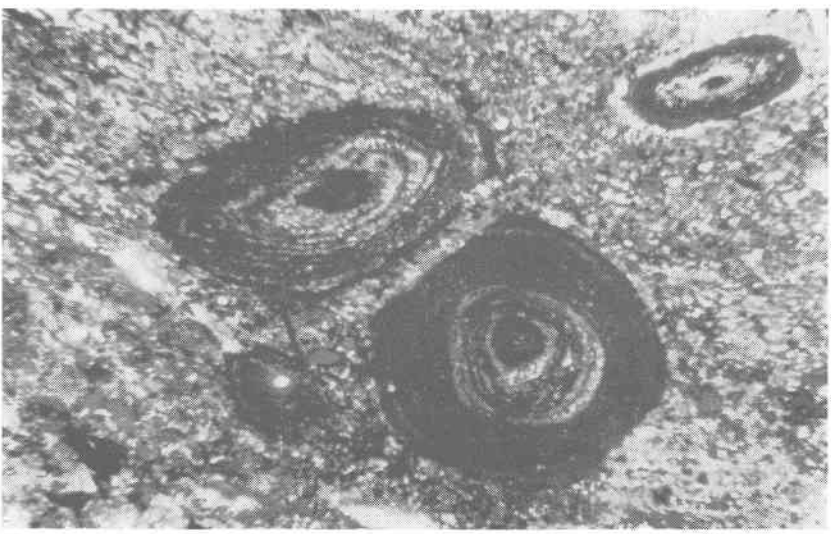

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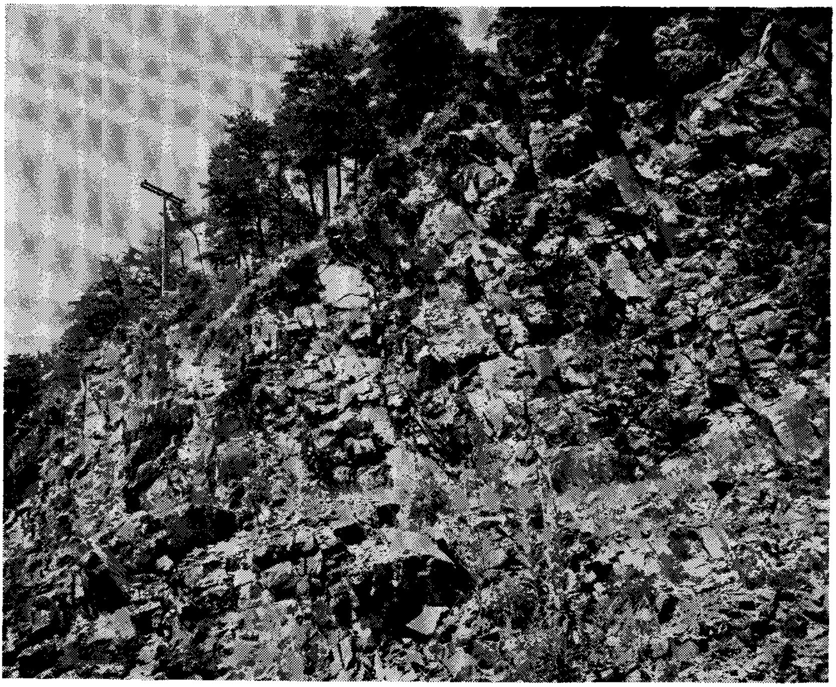

Figure 8. Bremo Member of the Arvonia Formation just west of the John Cocke Memorial Bridge at Bremo Bluff. The steeply dipping quartzite is on the west limb of the Arvonia syncline.

brachiopods were found in the Bremo Member at New Canton (Figures 10, 11), and along the Chesapeake and Ohio Railway 0.25 mile south of Carysbrook in the quartzite unit that overlies the granodiorite unit (Figure 12).

GRANODIORITE UNIT

Exposures of granite in the Cowherd quarries just east of Columbia were first described in detail by Taber (1913, p. 64-68). The name Columbia granite, which was first used on the "Geologic Map of Virginia," 1928 edition, was poorly chosen because of the priority of the name Columbia Group (Pleistocene) for units in eastern Virginia. The granodiorite unit (Plate 1, Pzg) extends across the eastern portion of Fluvanna County from the James River between Bremo Bluff and Columbia, northward to the Fluvanna-Louisa county line.

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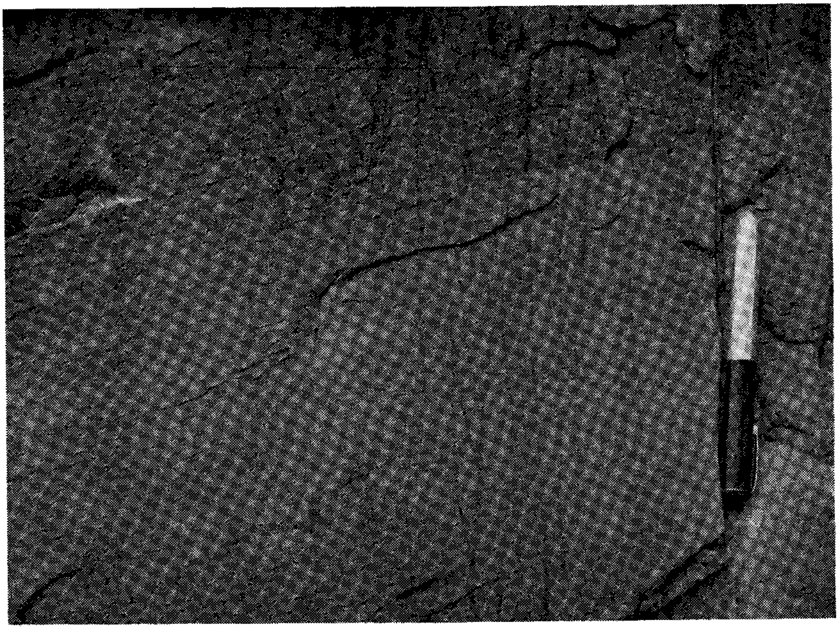
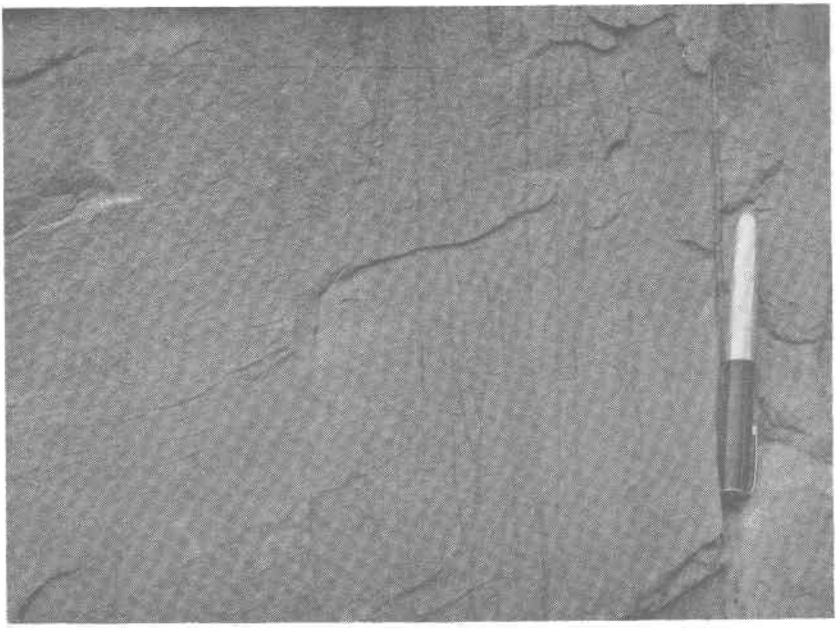


Figure 9. Cross-bedding within the Bremo Member at New Canton, Buckingham County. Top of the nearly vertical beds is to the right; the pen is aligned parallel to a bedding plane. This exposure is on the east limb of the Arvonia syncline.

Figure 10. Lineation resulting from stretching of crinoid columnals (?). Specimen collected from the Bremo Member at New Canton, Buckingham County. X 1.1.



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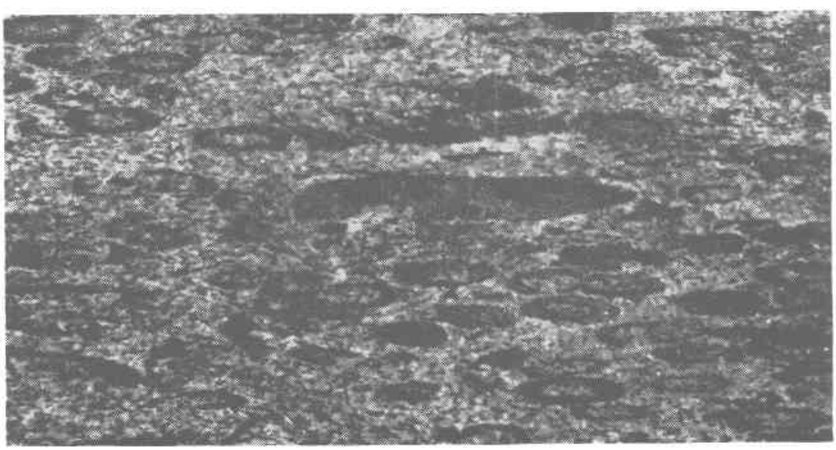

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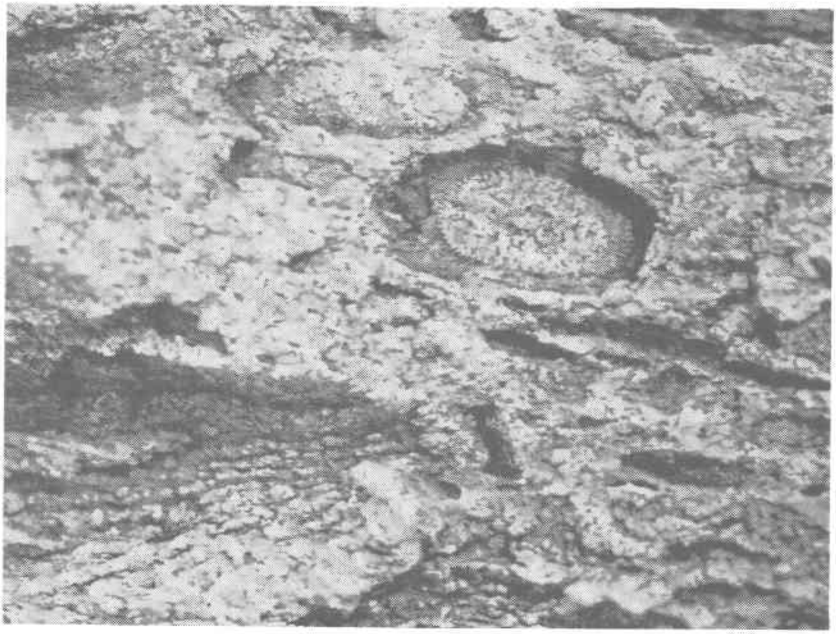
Figure 11. Elongated crinoid columnal from the Bremo Member at New Canton, Buckingham County. X 7.4.

Figure 12. Elongated brachiopod or pelecypod shell in Arvonia quartzite from cut along the Chesapeake and Ohio Railway, 0.25 mile south of Carysbrook. X 2.



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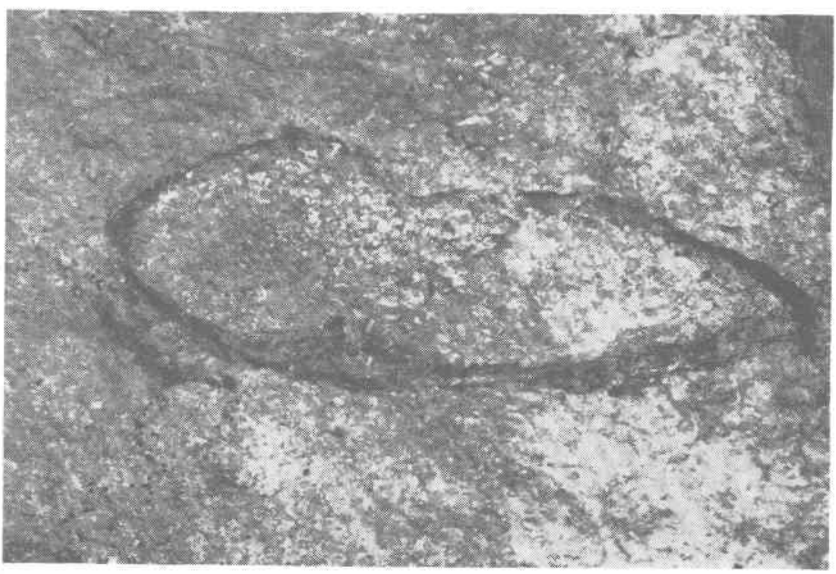

Figure 12. Elongated brachiopod or pelecypod shell in Arvonia quartzite from cut along the Chesapeake and Ohio Railway, 0.25 mile south of Carysbrook. X 2.

The granodiorite unit (Figures 13, 14) is predominantly a light- to medium-gray, coarse-grained, granular, quartz-plagioclase-biotite granodiorite gneiss that has a foliation parallel to the regional strike. The plagioclase typically is oligoclase. The unit also contains orthoclase, microcline, chlorite, garnet, epidote, and muscovite; the composition ranges between that of a quartz diorite and a granite in the area of study. Good exposures of granodiorite are at the quarries indicated on the geologic map (Plate 1) and also in railroad cuts along the southern boundary of the county. A typically weathered exposure of granodiorite is present in a roadcut 0.3 mile north of the Virginia Electric and Power Company power plant at Bremo Bluff. Only saprolite that contains kaolinitized phenocrysts and small amounts of vermiculite in a punky matrix of quartz and clay remains. Schlieren and xenoliths of amphibole-rich and biotite-rich rocks (Figure 15) are developed in places and probably represent altered inclusions of the intruded sedimentary and extrusive igneous formations. Hornblende-rich schlieren occur throughout most of the granodiorite area, but are much more plentiful in the vicinity of the borders (Taber, 1913, p. 66).

Contact metamorphism indicates that the granodiorite was emplaced subsequent to the deposition of the Arvonia Formation of Late Ordovician age. A lead-alpha date obtained by using a zircon concentrate from the granodiorite indicates an age of 400 ± 50 million years (Appendix II). A rubidium-strontium age of 400 ± 125 million years is based on analytical data (Appendix II) obtained from a concentrate of the potassic feldspar and from a whole-rock sample. These ages indicate that the intrusion probably occurred between Late Ordovician and Late Devonian. Potassium-argon ages obtained from mica concentrates from the granodiorite and related rock units (Appendix II) indicate that a regional thermal event affected the area about 300 million years ago (Carboniferous).

TRIASSIC DIKES

A large number of Triassic diabase dikes occur as tabular bodies within metamorphosed igneous and sedimentary units in the Fluvanna County area. Only the larger dikes are shown on Plate 1. Triassic dikes trend principally northwestward across the county and apparently follow the northwestward-trending joint set. A dike that was mapped in the southern portion of the county near Shores trends northeastward.

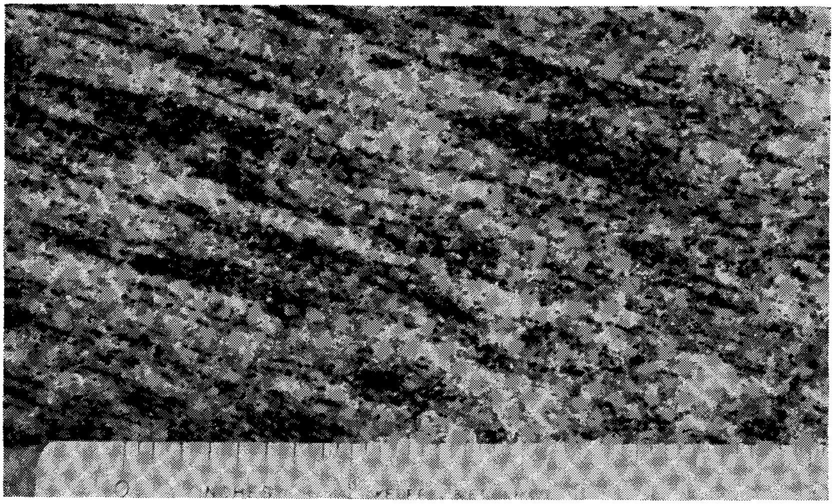

Figure 13. Granodiorite gneiss from the Cowherd quarry at Columbia.

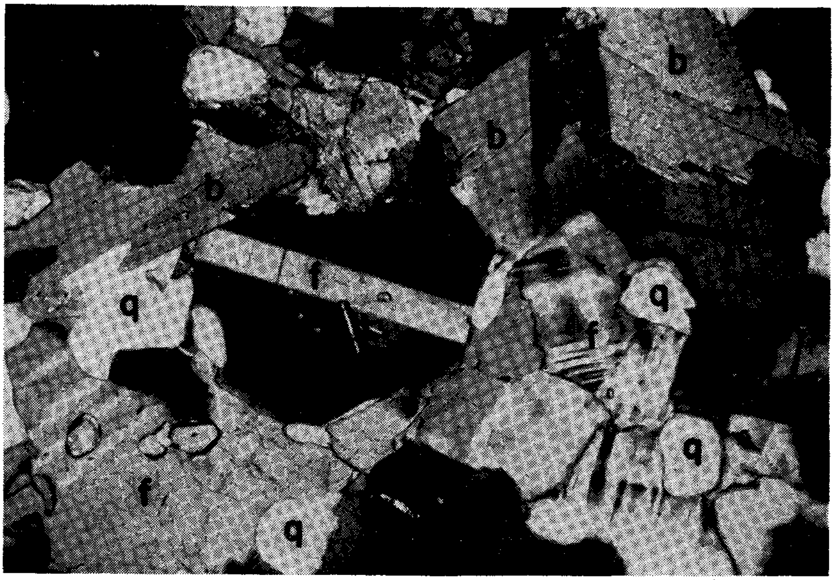

Figure 14. Photomicrograph of granodiorite from the Cowherd quarry at Columbia. Principal minerals are quartz (q), feldspar (f), and biotite (b). Crossed nicols. X 65.

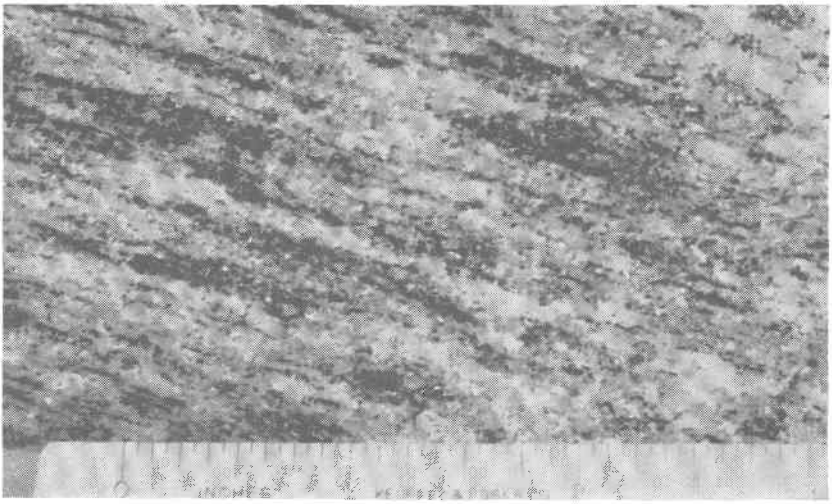

Figure 13. Granodiorite gneiss from the Cowherd quarry at Columbia.

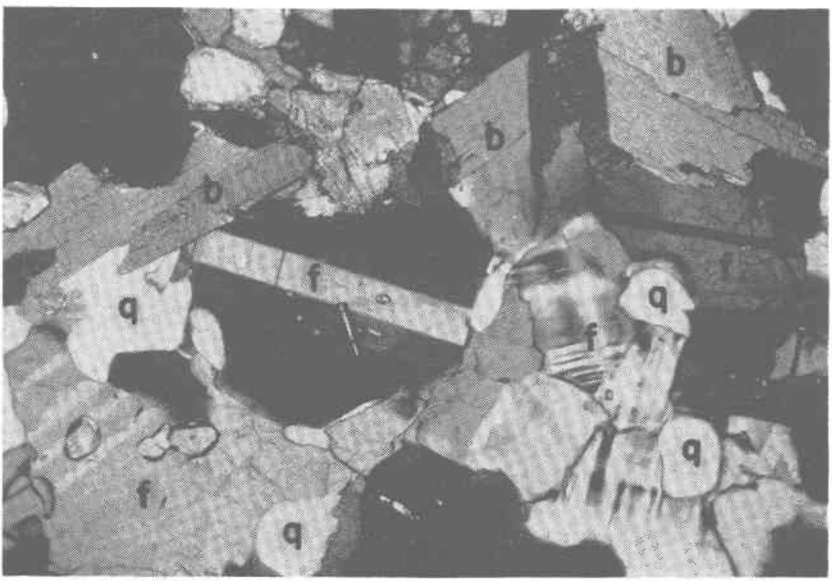

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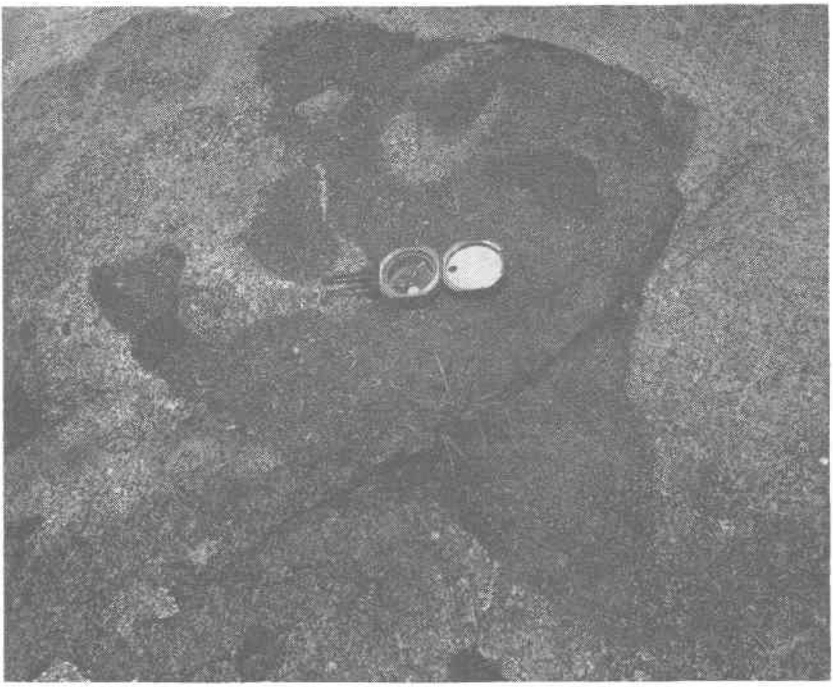
Figure 15. Biotite-rich xenolith within granodiorite exposed in the field east of the Fork Union Military Academy.

The dikes are up to tens of feet wide and up to 7.5 miles long, and they have steep dips. The dikes have rectangular joint patterns that were probably formed as the intruded mafic magma cooled, solidified, and contracted. The joints apparently influence the rate of weathering of dikes exposed at the surface; selective weathering along the joints produces rounded pieces up to 3 or 4 feet across which consist of concentric layers of weathering products (gibbsite, goethite) around a dense, hard core of unaltered rock. The fresh rock is medium to dark gray, hard, dense, and brittle. It is composed of labradorite, pyroxene (augite to diopside), and olivine (slightly altered to iddingsite). The texture is subophitic to intergranular.

STRUCTURAL GEOLOGY

The rock formations of Fluvanna County have been folded and faulted, and have undergone low- to medium-grade regional metamorphism. The major structures are northeastward-trending anticlines and synclines that are overturned or asymmetrical to the north-



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STRUCTURAL GEOLOGY

The rock formations of Fluvanna County have been folded and faulted, and have undergone low- to medium-grade regional metamorphism. The major structures are northeastward-trending anticlines and synclines that are overturned or asymmetrical to the northwest. No major faults were found. Minor faults are probably abundant, but only a few were mapped because of poor exposures (Plate 1). Minor structural features such as drag folds, rock cleavage, and lineation are prevalent in the rocks of the county.

FOLDS

Three major synclines, the Columbia, Arvonia, and Long Island synclines, were mapped in the Arvonia Formation in the eastern portion of the county. Intrusion of the granodiorite unit obliterated the structures between the Columbia and Arvonia synclines. An anticline in the metamorphosed volcanic and sedimentary rock unit occurs between the Arvonia and Long Island synclines.

Evidences for the Columbia syncline are the map pattern of the rock units, attitudes of bedding and foliation, and lineations near the nose of the fold. The garnet-amphibole bed, a key bed in mapping the structure, was traced around the syncline into Goochland County, where its topographic expression is a narrow ridge. The Columbia syncline is asymmetrical, with the axial plane dipping steeply toward the southeast.

The garnet-amphibole bed and its lower grade equivalent, oolitic chlorite rock, were utilized in mapping the Arvonia syncline. As in the Columbia syncline, the Bremo Member occupies the center of the fold, and slate and quartzite units overlie igneous units around the periphery of the structure. Attitudes of the bedding that has a steep southeasterly dip along the west limb of the fold, and a vertical or nearly vertical dip along the east limb of the fold, indicate that the Arvonia syncline is asymmetrical with its axial plane dipping steeply to the southeast.

The Long Island syncline is a long narrow structure occupied by tightly compressed Arvonia slate. Southwestward-plunging lineations at the north end of the structure, in addition to the stratigraphic relationship of the Arvonia Formation and the metamorphosed volcanic and sedimentary rock unit are the evidence for the syncline.

The older units in the western portion of the county are folded into large anticlines and synclines that are overturned to the northwest. These include the Hardware and Rivanna River anticlines. The Hardware anticline, first reported by W. R. Brown (1962), was mapped from its exposure along the James River near Hardware northeastward to Palmyra. The structure is represented near Palmyra by a prominent zone of overturning observable in rock exposures along Cunningham Creek. The evidence for the fold as a continuous structural unit is the presence of the middle muscovite unit in the core of the anticline and vertical or nearly vertical foliations and overturned bedding along the northwest limb of the fold between Hardware and Palmyra. The zone of overturning was not mapped northeast of Palmyra.

The Rivanna River anticline was mapped from the vicinity of Nahor northeastward to the Fluvanna-Louisa county line. Evidences for the structure are overturned beds and steeply dipping foliations along the northwest limb of the fold along Boston Creek, along the Rivanna River (Figure 16), and along Mechum Creek. The core of the anticline is composed of paragonite phyllites that are stratigraphically below the surrounding chlorite-muscovite and muscovite units.

Figure 16. Steeply dipping beds of subgraywacke along the south bank of the Rivanna River on the overturned limb of the Rivanna River anticline. Drag folds indicate that the top of the beds is to the right.

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Figure 16. Steeply dipping beds of subgraywacke along the south bank of the Rivanna River on the overturned limb of the Rivanna River anticline. Drag folds indicate that the top of the beds is to the right.

Several smaller anticlines that have paragonite phyllites in the centers were mapped at or near the Fluvanna-Albemarle county line from just north of the Hardware River northeastward to Louisa County. Locally, reversals of the widespread southeasterly dips and changes in strike of chlorite-muscovite and muscovite units are indicative of folding on a smaller scale. Smaller folds within chlorite-muscovite units are present near the Fluvanna-Albemarle county line northwest of Antioch and in the area between Hardware, Central Plains, and Shores. The fold mapped within the latter area is a northeastward-plunging syncline; it is well expressed along the north bank of the James River at Big Island, and is further evidenced by the outcrop pattern of a muscovite-rich unit to the east of Union Church. Two small synclines in the Arvonia Formation were mapped within 2 miles of the north end of the Long Island syncline.

FAULTS

Several faults of relatively small displacement were mapped in the county (Plate 1). A transverse fault 2 miles southeast of Carysbrook displaces the west limb of the Arvonia syncline. Upward movement of the northeast block relative to the southwest block, combined with the effects of erosion, has offset the contact between the Arvonia Formation and the granodiorite unit. Two small faults were mapped in the southern portion of the county between Bremo Bluff and Shores. One of these, located 0.25 miles west of the north end of the John H. Cooke Memorial Bridge, is within the Bremo Member; the other, located 0.75 mile north of Strathmore, is between the metamorphosed volcanic and sedimentary rock unit and the Arvonia Formation.

A thrust fault of somewhat greater magnitude was mapped along the northwest limb of the Rivanna River anticline at Nahor. The presence of the fault is evidenced by the fact that the muscovite-rich units immediately northwest of the axis of the Rivanna River anticline do not wrap around the nose of the southwestward-plunging fold.

MINOR STRUCTURAL FEATURES

Minor structural features are abundant in the central Virginia Piedmont. Folds, lineations, and foliations are common; the relationship of drag folds and cleavages to bedding or compositional banding proved useful in recognizing overturned beds.

Foliation

All planar structural elements are classified as foliation in this study; foliation symbols on the geologic map (Plate 1) indicate surfaces that may be bedding, bedding schistosity, compositional banding, flow and fracture cleavage, overturned bedding and compositional banding, and sub-parallel biotite streaks in granodiorite. In places drag folds and cleavages could be used to establish the nature of foliations as bedding, bedding schistosity, or compositional bands.

Bedding is well preserved in the majority of the metamorphosed sedimentary rocks. In some cases growth of phyllosilicate minerals parallel to bedding planes has resulted in the formation of bedding schistosity. Compositional banding in metasedimentary units generally parallels original bedding surfaces. Alternating light and dark quartz- and chlorite-rich bands probably reflect differences in initial composition of sedimentary units which have been accentuated by metamorphic processes; bands of this nature are generally up to 2 inches across. Compositional banding within metamorphosed volcanic units may represent intrusions of mafic dikes or flows of more mafic material within the felsic volcanic material. Where amygdules were present within the darker layers, the mafic rocks were considered as flows; and the compositional banding was interpreted as bedding.

Flow cleavages (axial-plane cleavages) related to growth of phyllosilicate minerals parallel or sub-parallel to the axial planes of folds are generally developed in fine-grained units (Figure 17); fracture cleavages, which are shear phenomena, are abundant in the more siliceous units. Thus the paragonite phyllites in eastern Albemarle and western Fluvanna counties, slates and schists in the Arvonia Formation, and the phyllites interbedded with impure quartzites and graywackes in the chlorite-muscovite and muscovite units generally have flow cleavage. Metamorphosed felsic and mafic igneous rocks have a distinct flow cleavage where they are weathered; it is more difficult to recognize the cleavage in fresh exposures.

Minor Folds

Minor folds, ranging from several inches to several feet in length, are present in many of the exposures along stream and river banks and along road cuts. The folds may be broadly classified into three catagories: drag folds, shear folds, and undulations.

Along the James River and Cunningham Creek near Palmyra well-developed drag folds were used to map the Hardware anticline; drag folds along the Rivanna River and Boston and Mechum creeks were

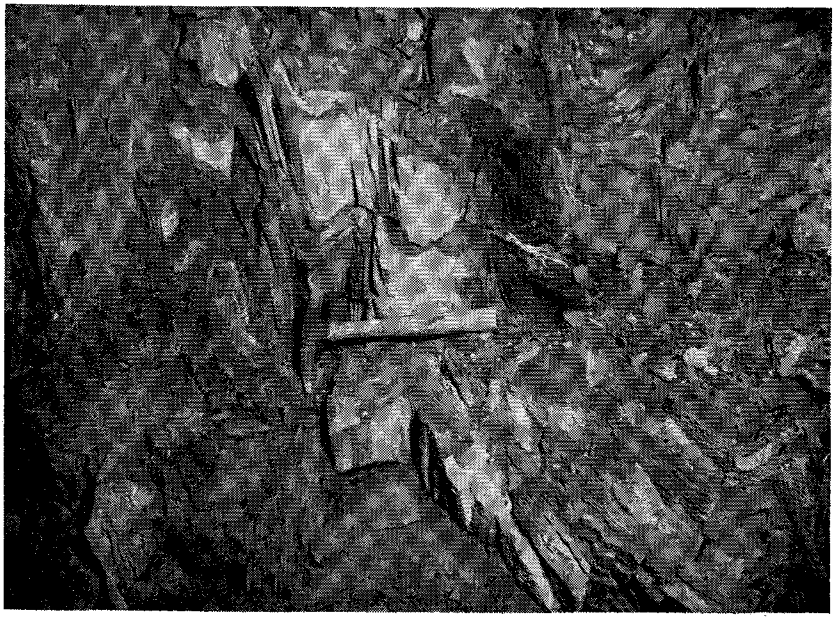

Figure 17. Minor folds and flow cleavage developed in quartzose slate of the Bremo Member at Bremo Bluff.

used to map the Rivanna River anticline (Figure 16). The folds are generally several inches in size and sharply asymmetrical. Larger drag folds up to several feet in size are present in places but are relatively uncommon.

Shear folds that result from slippage along closely spaced fractures (slip cleavage—see Brown, 1958, p. 58) are developed in places in Fluvanna County. Folds of this nature, which generally occur in phyllites and schists, were not useful in interpretation of larger structures.

Undulations are isolated folds, or folds with wave lengths generally of tens of feet. They are exposed in areas of low or moderate dip, such as between the zone of overturning of the Hardware anticline and the crest of the Rivanna River anticline on the Fluvanna-Albemarle county line. The undulations are asymmetrical, with axial planes generally dipping to the southeast. The symmetry of such folds indicates tectonic transport of younger rock over older rock toward the crests of the major anticlines in this area; therefore they may be used in much the same way as drag folds in deciphering direction of rock movement.

Figure 17. Minor folds and flow cleavage developed in quartzose slate of the Bremo Member at Bremo Bluff.

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Lineations

Lineations mapped are the attitudes of: the axes of crinkles or small folds; mineral streaks; oriented metamorphic minerals; elongated sedimentary features such as granules and pebbles, oolites, and fossils; rulings on quartz veins; and intersections of foliations. Lineations were used in places to indicate directions and amounts of plunge of folds. In general lineations trend northeastward parallel to the regional strike.

METAMORPHISM

The rocks of Fluvanna County, with the exception of Triassic diabase dikes, have been affected by metamorphic processes. The main agents of metamorphism were elevated temperatures and directed pressures associated with Paleozoic diastrophism (regional metamorphism) and with the intrusion of the granodiorite unit (contact metamorphism). Metamorphic processes have resulted in physical, mineralogical, and probably chemical changes within the rocks involved.

REGIONAL METAMORPHISM

The principal effects of regional metamorphism are: (1) the development of pervasive rock cleavage; (2) textural changes such as increase in grain size and reorientation of minerals; and (3) mineralogic changes. Rock cleavage is considered in the section on structural geology.

Textural and mineralogic changes in the rocks indicate that the grade of regional metamorphism increases eastward across the county. The rocks involved are largely within the greenschist facies; the almandine-amphibolite facies (Fyfe, Turner and Verhoogen, 1958) is in the eastern portion of the county. Most of the county is within the quartz-albite-muscovite-chlorite subfacies of the greenschist facies; this area is west of the biotite isograd (Plate 1). The area between the biotite and garnet isograds is within the quartz-albite-epidote-biotite subfacies of the greenschist facies. Some rocks west of the biotite isograd contain very small amounts of biotite; but in rocks east of this isograd the amount of biotite is significant. The area just east of the garnet isograd is within the quartz-albite-epidote-almandine subfacies of the greenschist facies (Plate 1). Along the eastern boundary of the county, the rocks are in the staurolite-almandine subfacies of the almandine-amphibolite facies.

Rocks west of the almandine isograd have not been subjected to higher grades of metamorphism than that which is indicated by the present facies because (1) delicate sedimentary features such as oolites that are preserved west of the almandine isograd were obliterated east of it, and (2) pseudomorphs of high-temperature minerals are absent in the areas of low-grade metamorphism.

Sedimentary rocks within the county were probably initially composed largely of quartz, feldspar, chlorite, and clay minerals. Metamorphic processes have altered rock units of different initial mineral composition and have resulted in the formation of units generally rich in quartz and muscovite, or quartz, chlorite and muscovite. Feldspar is associated with chlorite-muscovite-rich units, and is generally absent or present only in minor amounts in muscovite units. Biotite, almandine, andalusite, and kyanite occur in metamorphosed sedimentary units in the eastern portion of Fluvanna County and adjacent Goochland and Buckingham counties.

Almandine is abundant in the Arvonia Formation east of the garnet isograd, but garnets are rare in the granodiorite unit and the metamorphosed volcanic and sedimentary rock unit. The oolitic chlorite rock contains many iron-rich garnets immediately east of the almandine isograd. Andalusite occurs in the garnet-amphibole rock within the Columbia syncline 0.4 mile northeast of Stage Junction. Kyanite occurs in a quartzite just east of the Fluvanna-Goochland county line 1.3 miles north of Columbia, and in schists along State Road 667, 1.3 miles northeast of Columbia in Goochland County. It is also present in several places along the Fluvanna-Goochland county line (Brown, 1937), at the Young American gold mine 1.6 miles east-southeast of the Shaw (Hodges vein) gold mine (Taber, 1913) and in the White House Milk Division water well at Fork Union. Sillimanite was reported from the garnet-amphibole rock at New Canton, Buckingham County (Taber, 1913, p. 107) but was not found at this locality during the present investigation.

Igneous rocks are also affected by metamorphic processes. The effects are more recognizable in mafic igneous rocks than in the felsites or granodiorite. Mafic igneous rocks probably were originally composed of plagioclase, pyroxene, and biotite. These mafic rocks are now composed largely of plagioclase, amphibole, biotite, epidote, and chlorite. The paragonite units, which have essentially no plagioclase, may have been derived from fine-grained alkalic volcanic rocks. In felsites of the metamorphosed volcanic and sedimentary rock unit which have significant amounts of plagioclase, paragonite may have been converted to plagioclase during regional metamorphic processes of a higher grade.

The metamorphosed sedimentary sequence shows a marked increase in grain size eastward across the county. A line just east of the biotite isograd (Plate 1) separates aphanitic phyllites on the west from phaneritic phyllites or fine-grained schists on the east. Quartz-mica veins also show textural changes from west to east across the county. In the western portion of the county the quartz veins are largely barren; to the east very fine-grained masses of muscovite are associated with vein quartz, and farther eastward muscovite generally shows a progressive increase in grain size.

Potassium-argon determinations were made on micas from three localities in the area (Appendix II). Biotite from the granodiorite unit in the Cowherd quarry at Columbia was dated as 301 ± 15 million years old; biotite from Arvonia slate collected at the Le Sueur-Richmond Slate Corporation quarry, Arvonia, Buckingham County, was dated as 324 ± 12 million years old. A muscovite concentrate from metasedimentary schists collected from the railroad cut 0.75 mile west of Shores was dated as 287 ± 18 million years old. These determinations indicate that the last period of regional metamorphism to affect the area occurred during the Carboniferous (Kulp, 1961).

CONTACT METAMORPHISM

The evidences of contact metamorphism associated with the intrusion of the granodiorite unit are subtle. The intrusion was probably shallow, and subsequent regional metamorphism has complicated the problem. The evidence for the shallow nature of the intrusion is the lack of garnets at the granodiorite-Arvonia slate contact. Along strike the slate contains garnets that formed during regional metamorphism.

Tourmaline is present near the granodiorite unit contact in several places in the county. Black tourmaline crystals up to 0.5 inch long occur in quartzite at the granodiorite contact where it is crossed by U. S. Highway 15 at Fork Union. Fibrous tourmaline up to 0.75 inch long is associated with quartz veinlets near the contact of the metamorphosed volcanic and sedimentary rock unit and the granodiorite unit 2.75 miles north of Fork Union. Vein quartz contains a few small crystals of tourmaline 1.3 miles west of Jordans Store 0.2 mile southeast of State Road 629. Coarse-grained muscovite and feldspar in vein quartz occur within the granodiorite unit, metamorphosed volcanic and sedimentary rock unit, and Arvonia Formation in the eastern portion of the county. Gold is associated with pegmatites and with quartz veins. The gold-bearing veins, pegmatites, and tourmaline are probably from the granodiorite magma. Feldspar in the granodiorite near the Arvonia Formation has been partially sericitized. This alteration may be due to autometamorphism of the granodiorite during the latter stages of solidification of the magma. Andalusite in the Arvonia Formation within the Columbia syncline 0.4 mile northeast of Stage Junction may be a reflection of the proximity of the granodiorite unit (Fyfe, Turner and Verhoogan, 1958, p. 203-207). Several samples of phyllites and fine-grained schists collected near the granodiorite unit contain well-crystalline chlorite (determined by the "sharpness" of the X-ray diffraction peaks) that may be the result of recrystallization induced by contact metamorphism.

GEOLOGIC HISTORY

The rocks in Fluvanna County are a record of events in earth history which took place from Cambrian or Precambrian time to Triassic time. The Catoctin Formation is overlain predominantly by paragonite-, chlorite-muscovite-, and muscovite-bearing metamorphosed volcanic and sedimentary formations. These sedimentary formations are in turn overlain by the metamorphosed volcanic and sedimentary rock unit and the Arvonia Formation. The aggregate thickness of the units from the top of the Catoctin Formation to the top of the Arvonia Formation is about 21,000 feet.

The paragonite unit in general represents metamorphosed alkalic volcanic ash that was deposited on either the upper surface of the Catoctin Formation or upon intervening metasedimentary units. The ash deposits may have been related to Catoctin volcanism; perhaps influx of sea water into partially evacuated basaltic magma chambers resulted in contamination of the magma and change in the mode of eruption from quiet effusions of lava to explosions of pyroclastic material.

The metamorphosed sedimentary sequence above the paragonite unit and below the metamorphosed volcanic and sedimentary rock unit was probably derived largely from weathering and erosion of the Virginia Blue Ridge Complex, paragonite unit, and the Catoctin Formation. That the source of the sediments was basic rather than acidic rocks is reflected in the aluminous nature of the metasedimentary rocks (Appendix I), the great preponderance of plagioclase over potassic feldspar, and the abundance of chlorite in the chlorite-muscovite units.

The Ordovician volcanic rocks are possibly comagmatic in origin with the granodiorite. Perhaps islands of volcanic origin formed over conduits leading to the granodiorite magma chamber. Sedimentary quartz-feldspar rocks in the metamorphosed volcanic and sedimentary rock unit containing sercitized potassic feldspar grains and the more quartzose sedimentary portions of the metamorphosed volcanic and sedimentary rock unit and of the Arvonia Formation indicate a possibility of a new source of sediments for some of the younger formations. During the time of deposition of the Arvonia Formation, volcanic activity subsided, and the basin of deposition was probably shallower. This is reflected by the uniform character of slates and by the relatively pure, thick, cross-bedded quartzites of the Upper Ordovician Arvonia Formation.

The major folding of the sedimentary and volcanic formations probably took place between the time of the deposition of the Arvonia Formation and the time of intrusion of the granodiorite unit. An absolute age determination (Appendix II) made on zircon from the granodiorite unit indicates that the granodiorite unit was intruded about 400 ± 50 million years ago. Isotopic age determinations (Appendix II) made on micas from the granodiorite, Arvonia Formation, and older metasedimentary rocks indicate that the last and major period of regional metamorphism was about 300 million years ago. The mineral deposits of the area were probably formed during the intrusion of the granodiorite unit or are associated with later regional metamorphic processes. After the intrusion of the granodiorite unit, the processes of uplift and erosion were active throughout the area. Then in Triassic time renewed tectonic activity was accompanied by the intrusion of numerous diabase dikes in Fluvanna County.

ECONOMIC GEOLOGY

BUILDING STONE

Stone from Fluvanna County has been used in the construction of canals, small dams, railroad foundations, and buildings. The granodiorite unit is the formation of chief economic value for building stone. Schists and gneisses have been quarried, and soapstone was reportedly quarried.

Granodiorite gneiss from the Cowherd quarry (Plate 2, No. 36) at Columbia was used in the construction of portions of the James River and Kanawha Canal that was built during the period 1835 to 1840. The canal extended along the James River from Richmond to Clifton Forge, a distance of over 200 miles. The Cowherd quarry was reopened in about 1882 for a short period of time. Watson (1910) indicates that the quarry was inoperative between 1885 and 1910; there is no record of production since then.

There are two small quarries in the granodiorite unit southwest of Columbia along the James River, and stone from these quarries was probably used in the construction of the James River and Kanawha Canal. The quarry to the south (Plate 2, No. 40) extends about 35 feet into the bank of the river and has a face 10 feet high and about 75 feet wide. The quarry to the north (Plate 2, No. 39) has approximately the same dimensions. The rock at both quarries is medium-grained gneiss composed largely of quartz, feldspar, and biotite and has prominent foliation that has resulted from the concentration of biotite. Taber (1913) notes a quarry in the granodiorite unit 0.5 mile north of Rivanna Mills. Stone from this quarry was used in the construction of the dam and canal locks at the mill. A small quarry is located about 0.5 mile west of Rivanna Mills on the south side of Rivanna River (Plate 2, No. 37). A quarry in a fine-grained phase of the granodiorite unit 1 mile northwest of Carysbrook on the south side of the Rivanna River was operated to obtain stone for construction of the Chesapeake and Ohio railroad. The formation is fine-grained quartz-feldspar rock with irregular areas, up to 1 foot in diameter, of coarse-grained granitic rock composed largely of feldspar, quartz, and biotite (Taber, 1913).

Soapstone was reportedly quarried on a small scale many years ago near the mouth of the Hardware River and in the southern part of the county at Bremo Bluff. The stone was used locally for construction of hearths, jambs, and chimneys (Watson, 1907). Only a small quarry in fine-grained mica schist could be found in this area.

Schists and gneisses used to build the James River and Kanawha Canal along the southern portion of the county probably were quarried from the many cuts made to build the canal. The Chesapeake and Ohio railroad foundation along the James River contains riprap that probably came from railroad cuts along the southern portion of the county. Metamorphosed quartz conglomerate was quarried on a small scale near Union Mills (Plate 2, No. 2).

TALC

The Solitude Plantation talc mine near Palmyra was operated around 1910 for approximately 18 months (Plate 2, No. 5). The product was metal-worker's crayons; the county clerk, Mr. Richard F. George, furnished one of the old crayons for analysis. It is composed of about 85 percent talc and 15 percent chlorite, and magnetite is present as an accessory mineral. Actinolite occurs with talc and chlorite at places in this mine, and serpentine was identified in rocks on the mine dump.

SLATE

The Arvonia Formation, quarried for slate in Buckingham County since the early 1800's, has been prospected at several places in Fluvanna County (Plate 2, Nos. 9, 11, 42, 43, 46, 47, 48, 49). Of these, three (Kie prospect, No. 43; Dale prospect, No. 47; and Cocke prospect, No. 49) are known to be slate prospects; the others, in view of their locations, were probably opened in search for slate. The Dale Slate Company, Incorporated produced slate from its quarry 3 miles north of Strathmore intermittently from 1921 to 1933.

ASBESTOS

Asbestos has been prospected 2 miles east of Bybee (Plate 2, No. 15). The prospect now consists of a hole about 12 feet in diameter and 10 feet deep. A small amount of stiff actinolite or tremolite fibers, up to 3 inches long, is all that remains to indicate the nature of this prospect.

Anthophyllite, a major constituent of the garnet-amphibole unit, was identified in garnet-amphibole samples collected along the railroad at New Canton, Buckingham County, and 0.7 mile north-northeast of Stage Junction in Fluvanna County.

CRUSHED STONE

Two quartz veins at the Davis property (Plate 2, No. 53), 1.25 miles east of Scottsville on State Highway 6, were prospected in 1925. Thirty holes, each about 300 feet deep, were drilled, and a cut, 30 feet long, 30 feet wide, and 8 feet deep, was made. In 1936 a number of holes were drilled to a depth of 6 feet on this property. The quarry was operated intermittently prior to 1960 for highway aggregate. It was reopened by the Stone and Mineral Corporation in October 1961 and has been operated sporadically since that date (Figure 18). The exposure of the north vein is about 65 feet wide and 95 feet long; it has a strike of N.30° E. Graywacke and phyllite are exposed on the east side of the vein; bedding has a strike of N.77° W. and a dip of 24° SW. The south vein, that has a strike of about N.30° E., is about 500 feet to the southwest and is not well exposed. An excavation, 45 feet wide, 150 feet long, and at least 6 feet deep, was made along this vein. Both veins are composed of milky quartz. Reported analyses of the quartz veins near Scottsville are 99.90, 98.99, 98.90 and 98.39 percent silica. The quartz is drilled, blasted, loaded into trucks, and shipped to Criglersville, Virginia where it is processed. It is used as a decorative aggregate in concrete. Quartz of this purity is probably suitable for chemical, glass, and metallurgical use. The quartz is moderately fractured and contains only a few visible impurities (pyrite, chlorite, muscovite, and iron-oxide staining).

Figure 18. Quartz vein and main pit at the Davis quarry, 1.25 miles east of Scottsville.

The Stone and Mineral Corporation prospected the quartz vein north of Nahor (Plate 2, No. 3) in the latter part of 1962; the prospect is intermittently active at the time of this writing. Quartz is exposed for about 200 feet along strike; the vein is about 50 feet wide and has a strike of N.34° E.

Six relatively large quartz veins not previously prospected were observed during the current study (Plate 2, No. 4 and Symbol Q). A large milky quartz vein is at the western county boundary about 700 feet north of U. S. Highway 250. The quartz exposure is about 60 feet wide, 150 feet long, and has a strike of N.57° W. Two large milky quartz veins are present 1.1 miles south of the intersection of the western county boundary and U. S. Highway 250. The exposure of the north vein is about 180 feet long and 60 feet wide. The other vein, about 300 feet to the south-southeast, has an exposure about 150 feet in diameter. A quartz vein that has an east-west strike and is 20 feet wide and 200 feet long is exposed 0.5 mile southwest of the highway bridge at Palmyra. About 1.6 miles northeast of Palmyra fragments of vein quartz are scattered over an area approximately 75 feet wide chemical, glass, and metallurgical use. The quartz is moderately fractured and contains only a few visible impurities (pyrite, chlorite, muscovite, and iron-oxide staining).

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Massive plagioclase-epidote-chlorite rock (metamorphosed mafic volcanic rock) was quarried between 1910 and 1925 along the Chesapeake and Ohio Railway about 0.75 mile southwest of Shores (Plate 2, No. 50). The stone was used for railroad ballast and concrete aggregate.

Solite Corporation prospected for highway aggregate at three localities: the Bank's property, 1 mile southeast of Dixie (Plate 2, No. 38); on a hill near the intersection of Little Byrd Creek and State Road 604 (Plate 2, No. 19); and an area 1 mile south of Kents Store (Plate 2, No. 18). The rock at the Bank's property is granodiorite; the rock near Little Byrd Creek and south of Kents Store is very fine-grained, quartz-feldspar rock with interlayered amphibole schist.

Much overburden has been removed in search of stone for highway aggregate on the east bank of Byrd Creek just north of its intersection with State Road 630 (Plate 2, No. 17). The rock is a fine grained gneiss composed of biotite, quartz, and plagioclase.

GARNET

Garnet is used extensively in manufacturing abrasive paper and cloth; as a sand-blasting abrasive; for grinding plate glass, optical lenses, and other glass surfaces; and for metal polishing. In Fluvanna County almandine garnets, 0.25 to 0.5 inch in diameter, constitute about 50 percent of a bed that has an approximate average thickness of 5 feet. This bed was mapped along strike for a distance of 4 miles near the eastern border of the county in the Columbia syncline. In the Arvonia syncline the garnet-bearing bed extends northward from Bremo Bluff for about 2 miles. Amphibole is associated with garnet in this bed, and in some areas quartz and chlorite are abundant. Biotite is a minor constituent. Several hundred feet of Arvonia schist adjacent to the garnet-amphibole rock contains approximately 5 percent garnet.

The garnet-amphibole rock has been mined near New Canton, Buckingham County, and the fresh rock was reportedly used in a dam built for the former iron smelters at New Canton. The weathered rock is rich in limonite and was mined in several areas south of New Canton for iron ore.

GEMSTONES

A rhodonite-quartz vein, previously described by Jonas (1942, p. 421), extends across South Fork of Cunningham Creek 1.1 miles north of Kidds Store (Plate 2, No. 51). It has a strike of N.40° E. and a dip of 45° SE. and is conformable to the foliation of the surrounding graywacke and phyllite. The vein was prospected for manganese on both sides of the creek at points 800 feet apart by Dr. J. T. Cleveland in 1918 (Plate 2, No. 51). At the north prospect the upper layer of the vein is composed of 4 feet of fine-grained, massive rhodonite. Below the massive rhodonite is a 4-foot brecciated zone of rhodonite, jasper, and milky quartz, and below this is about 2 feet of quartz that contains specularite veinlets. Two feet of quartz is present on the bottom side of the vein. Crosscutting the rhodonite-quartz vein are: veinlets of calcite which contain chlorite and amphibole; quartz veinlets; coarse-grained rhodonite veinlets; specularite veinlets containing a small amount of magnetite; and actinolite veinlets. The calcite veinlets crosscut the coarse-grained rhodonite veinlets. Weathered rhodonite surfaces have a black coating of goethite, hematite, pyrolusite, rhodonite, and possibly spessartine. A resident of Fork Union has tumble polished some of the rhodonite, mounted it as costume jewelry, and placed it on sale locally.

Amethyst crystals, up to 1 inch in length, have been reported from an area 1 mile east-northeast of Yanceys Store (Plate 2). Clear quartz crystals, up to 1.5 inches in length, have been found on the Rosson property 1 mile east of Palmyra. Some vein-quartz float on the property has cubic cavities, up to 0.5 inch on a side, which were probably formed by weathering and removal of pyrite cubes. Some fine-grained, massive magnetite float is also present at this location. A few clear quartz crystals, up to 0.75 inch in length, occur in the quartz veins at the highway-aggregate prospect on the east bank of Byrd Creek just north of State Road 630 (Plate 2, No. 17).

IRON-BEARING MINERALS

Campbell (1882, map) shows a limonite deposit at Bremo Bluff. This deposit probably was formed by the weathering of the 3-foot bed of garnet-amphibole-chlorite schist. This bed is exposed in the river bank near New Canton, Buckingham County. The garnet-amphibole-chlorite schist extends northward from Bremo Bluff for about 2 miles to where it crosses the garnet isograd (Plate 1). Northwest of the isograd the bed is represented by an oolitic chlorite rock that was mapped for about 3 miles to the north around the nose of the Arvonia syncline.

Massive magnetite, magnetite-quartz rock and limonite are present at several places in the county. The locations of iron-rich concentrations observed during this investigation are shown on Plate 2. Muscovite and chlorite-muscovite phyllite, schists, and gneisses generally contain accessory pyrite or magnetite. The magnetite occurs as octahedra, up to 0.05 inch in diameter, disseminated through the host rock. Pyrite cubes up to 0.5 inch in diameter are present in places.

Taber (1913, p. 19-22) reports ferruginous quartzites at several places in Fluvanna County: the Scotia (Hodges) mining property (Plate 2, No. 32); the Cassell gold prospect (Plate 2, No. 29); along State Road 659, 0.75 mile south of Stage Junction; near the intersection of State Road 605 and the eastern county boundary; near State Road 608 and its former extension between Palmyra and Wilmington; at Fork Union; and near the Hughes mine. According to Taber the ferruginous quartzites are composed of quartz, hematite, and magnetite; quartz generally is the most abundant component, although iron-oxide contents up to 80 or 90 percent have been reported.

VERMICULITE

Vermiculite is used principally as lightweight aggregate, as an insulator of heat and sound, and to improve soils. This mineral is a minor constituent of many of the rocks in the eastern part of Fluvanna County. Small concentrations are particularly abundant in the weathered portions of the metamorphosed volcanic and sedimentary rock unit. The vermiculite was apparently formed by the weathering of biotite.

SAND AND GRAVEL

Sand and gravel are present in the flood plains of the Rivanna and James rivers and along major tributaries to these rivers. Records of sand and gravel production show that a small quantity of sand and gravel was produced in 1916 from a locality near Carysbrook. A small tonnage of sand and gravel was obtained from Byrd Creek during the period 1943 to 1947.

CLAY MATERIALS

Clay of residual and alluvial origin is present in Fluvanna County. There has been no production of clay material in the county; however, lightweight aggregate is produced from weathered Arvonia slate across the James River in Buckingham County. Commercial deposits of clay material may be present in the alluvium along the larger streams and in the deep residuum that overlies mafic igneous rocks and fine-grained metamorphosed sedimentary rocks within the county.

Evaluation tests of clay materials for ceramic and lt.-wt. aggregate purposes were made on samples of residual and alluvial material from 13 localities in Fluvanna County (Calver, Smith, and Le Van, 1964). Recent (?) alluvial clay was tested from three localities. Two of the samples are probably suitable for the manufacture of brick and tile; the third could probably be used for common brick if mixed with less sandy clay. Clay collected from along the Chesapeake and Ohio Railway track 0.75 mile southwest of Columbia has good fired colors and good working properties.

Eight samples of slate or schist from the Arvonia Formation were tested; three may be suitable for common brick and one for quarry tile. Lightweight-aggregate bloating tests were performed on two samples; one sample showed positive results. Tests on one sample of phyllite indicated that it might be used for the manufacture of common brick. One sample of residual clay, probably derived from the weathering of greenstone in the metamorphosed volcanic and sedimentary rock unit, might be used in the manufacture of common brick. The potential uses for clay materials sampled in Fluvanna County are summarized in Table 2. Sample locations are shown on Plate 1.

GOLD

Gold was discovered in Fluvanna County about 1830 and was extensively mined until the early 1900's. One mine was prospected as late as 1936. The known gold deposits in the county are not of economic importance under present market conditions. Most of the mining was restricted to weathered rock and did not go deeper than 50 feet. Although the Tellurium (Plate 2, No. 28), and Hughes (Plate 2, No. 44) mines penetrated into fresh rock, their workings did not extend deeper than 150 feet. Native gold occurs in vein quartz, in pyrite associated with quartz-feldspar and quartz veins, and in placer deposits derived from weathering and erosion of the veins. Sphalerite, some of which is blue and contains copper, was observed during the present investigation in quartz-sericite rock that crosses Able Creek near the Hughes mine. Chalcopyrite, argentiferous galena, pyromorphite, and sphalerite are present at the Snead mine (Hamilton, 1865; Credner, 1869). Sphalerite (Taber, 1913) and tetradymite (Genth, 1855) occur at the Tellurium mine.

Table 2.—Data on Fluvanna County clay materials tested for ceramic and lightweight-aggregate purposes. (Evaluation tests by U. S. Bureau of Mines, Norris Research Laboratory, Tennessee.)

Sample No.	Formation or Age	Lithology	Potential Use	Location
R-1544	Arvonia Formation	Micaceous shale	Common brick	Exposure, 1.7 miles northwest of Fork Union, on the east side of State Road 671 about 0.8 mile north of east junction with State Highway 6.
R-1546	Recent?	Flood-plain clay	Brick and tile (with proper processing)	Exposure, along Carys Creek on the east side of U. S. Highway 15 about 0.9 mile south of Carysbrook.
R-1713	Recent ?	Clay	Brick and tile	Cut, 0.8 mile west of Columbia, along the south side of the Chesapeake and Ohio Railway about 0.1 mile west of the railroad bridge over the Rivanna River.
R-1714	Arvonia Formation	Slate	None	Abandoned slate quarry, 2.9 miles southwest of Fork Union, approximately 0.8 mile northwest of the south end of State Road 614 and about 0.5 mile east of the Chesapeake and Ohio Railway.
R-1780	Recent ?	Clay	None	Roadcut, 2.2 miles east of Scottsville, on the south side of State Highway 6 just east of the intersection with State Road 645.
R-1932	Arvonia Formation	Slate	Common brick, quarry tile, lightweight aggregate	Roadcut, 2.7 miles south of Palmyra, on northeast side of U. S. Highway 15 about 0.4 mile east of intersection with State Road 649.
R-1933	Arvonia Formation	Residual clay	None	Outcrop, in creek located 0.25 mile east of U. S. Highway 15 and 2.1 miles northeast of Bremo Bluff.

Table 2.—*Continued.*

Sample No.	Formation or Age	Lithology	Potential Use	Location
R-1934	Metamorphosed volcanic and sedimentary rock unit	Residual clay	Common brick ?	Roadcut, 2.2 miles northwest of Fork Union, on west side of State Road 671, about 0.3 mile south of intersection with State Road 672.
R-1935	Arvonia Formation	Slate	None	Railroad cut, 1.5 miles northwest of Dixie, on the northwest side of the Chesapeake and Ohio Railway about 0.25 mile northeast of the crossing of State Road 672 over the railroad.
R-1936	Paragonite unit	Phyllite	Common brick	Roadcut, 0.6 mile west of Union Mills, on the north side of State Road 616 approximately 1.4 miles west of the intersection with State Road 600.
R-1937	Arvonia Formation	Schist	None	Roadcut, 2.1 miles north of Columbia, on the north side of State Road 606 about 0.4 mile west of the intersection with State Road 659.
R-1938	Arvonia Formation	Slate	None	Inactive quarry, 3.1 miles northwest of Dixie, north of State Road 672 approximately 1.0 mile northwest of the intersection of State Roads 671 and 672.
R-1940	Arvonia Formation	Slate	Common brick	Outcrop, in a creek 2.2 miles east of Palmyra, east of State Road 678 approximately 0.4 mile northeast of the intersection of State Roads 625 and 678.

There are 11 abandoned gold mines in the county, several pits which were probably gold prospects and mines (Plate 2, Nos. 1, 4, 12, 13, 14, 16, 20, 23, 24, 25, 26, 31, 33, 34, 35), and 7 mines (Chalk Level, Cocke, Fountain, Mosby, Walters, Taugus, Manning), the localities of which are unknown. Following are the locations and map numbers (Plate 2) of the 11 abandoned mines:

Name	Location	Map Number
Bowles (Back Field)	1.5 miles W. of Tabscott, Goochland County	(22)
Cassell	2.5 miles WNW. of Caledonia, Goochland County	(29)
Hughes	2 miles NW. of Cohasset	(44)
McGloam	2 miles W. of Tabscott, Goochland County	(27)
Page	1 mile W. of Wilmington	(8)
Scotia (Hodges)	0.5 mile N. of Caledonia, Goochland County	(32)
Scotia (Jennings, Perkins)	1.24 miles N. of Caledonia, Goochland County	(30)
Shaw	2 miles W. of Tabscott, Goochland County	(21)
Snead	1 mile N. of Fork Union	(41)
Stockton	1.5 miles NW. of Wilmington	(10)
Tellurium (Fisher, Hughes)	2.5 miles SW. of Tabscott, Goochland County	(28)

The geology of these gold mines has been described in detail by earlier workers (Silliman, 1837; Genth, 1855; Hamilton, 1865; Credner, 1869; Hotchkiss, 1881; Taber, 1913; Pardee and Park, 1948), and only brief descriptions of two of the mines are given here. The Bowles gold mine (Plate 2, No. 22) on the Back Field vein is located 1.5 miles west of Tabscott, Goochland County. It was operated at an early date, probably before 1850, and a number of shafts and other openings were made. Ore from this mine was hauled to the Tellurium mill for treatment about 1890, and a few tons were mined and hauled to the Tellurium mill about 1913.

The gold-bearing quartz veins in the area, including the ones at the Bowles, Shaw, and McGloam mines, are in a fine-grained quartz-feldspar gneiss, that is probably felsic volcanic rock. The gneiss is intermediate in composition, between the granodiorite and the very fine-grained quartz-plagioclase gneisses that have relict volcanic textures. Amphibole-chlorite-biotite schists associated with the fine-grained quartz-feldspar gneiss may have originally been mafic volcanic rocks. The veins are characterized by the presence of pyrite crystals up to 1 cm wide; calcite is abundant in some of the rocks. Minor constitutents of the gold-bearing veins are zircon, leucoxene, apatite, and rutile. Fluid inclusions are common in some quartz grains. Tourmaline was found in vein quartz from one of the mine dumps.

The Tellurium gold mine (Plate 2, No. 28), located 2.5 miles southwest of Tabscott, was one of the earliest gold mines in Virginia. The initial discovery was made in 1832 by G. W. Fisher. The Tellurium mine differed from most other mines in that the gold-bearing veins were discovered and worked prior to the discovery of the associated placer gravels. Three veins were worked intermittently in the history of this operation. The "Big Sandstone vein" consists of a bed of quartzite, 2 to 6 feet thick, cut by irregular gold-bearing veinlets composed essentially of quartz, feldspar, and minor amounts of pyrite. A thin layer of rock underlying quartzite of the "Big Sandstone vein" resembles the garnetiferous beds that occur near New Canton and Gravel Hill in Buckingham County. A similar bed of rock is also present at the Bowles and Scotia (Tellurium vein) mines. The "Middle vein" is parallel to the "Big Sandstone vein" and is about 30 feet to the southeast. It consists of a series of gold-bearing veins, up to 3 feet thick, composed of quartz, feldspar, and pyrite. The veins are enclosed by a thinly foliated garnetiferous schist. The "Little vein" is 20 feet to the southeast of and parallel to the "Middle vein." It is similar in constitution to the "Middle vein." Another vein, 40 yards northwest of the "Big Sandstone vein" has also been mined. The gold-bearing veinlets are composed essentially of white to translucent, coarsely crystalline quartz and kaolinized feldspar. Pyrite is a common minor constituent, but rarely exceeds 0.1 percent. Native gold occurs as small grains and scales that may usually be detected by panning the crushed ore. Sphalerite and tetradymite are rare accessory minerals.

GROUND WATER

Fluvanna County is underlain by metamorphic rocks that cross the county in a northeasterly direction and by thin igneous dikes. Ground water is available from the lower portion of the 30- to 70-foot-thick zone of soil and weathered material which overlies bedrock and from fractures and other openings in the bedrock. The water table generally occurs in the weathered zone 30 to 40 feet below the ground surface.

Many of the older wells were dug by hand and were limited in depth to a few feet below the water table; the more recent wells were bored or drilled. Most of the bored wells are 30 inches in diameter and can be constructed only to the top of bedrock. Bored wells usually reach a depth of 8 or more feet below the water table which provides storage for several hundred gallons and insures against depletion when the water table is lowered during time of drought. The water from springs and shallow wells is generally less mineralized than water from greater depths.

Drilled wells are usually 6 inches in diameter and 50 to 150 feet deep, and yield 1 to 30 gallons per minute. Palmyra, Fork Union, and Columbia have municipal water supplies that are obtained from deep wells that yield up to 50 gallons per minute. The number of fractures and other openings present in the rock formation and penetrated by the well influences the amount of water available. At Fork Union, wells in the eastern part of town are drilled in granodiorite gneiss that has few openings; consequently the wells are practically dry. Wells drilled in the western portion of town encounter a slate formation that has fractures and other openings filled with water, and in this area the wells are productive. Fewer and smaller water-filled openings are encountered at depths greater than 250 feet. The water from bedrock aquifers is generally moderately hard to hard and may be high in iron; in some areas acid conditions are present.

The capacity of most wells in the county is unknown because few have been adequately tested, and most have been constructed to obtain only small quantities of water. Domestic supplies are available in nearly all areas, and yields greater than 100 gallons per minute from single wells may be available at sites where the permeability of the rock is high and where adequate recharge is available. Large supplies may also be available at selected sites on the flood plains adjacent to the James and Rivanna rivers where the alluvial deposits extend below the water level of the stream. Table 3 shows the data for water wells in Fluvanna County.

Table 3.—Data for water wells in Fluvanna County.

Well No.	Location (Nearest Town)	Owner	Driller	Total Depth (feet)	Static Water Level (feet)	Yield (gpm)	Casing Size (dia. in inches x length in feet)	Aquifers (Depth in feet)	Depth of Intake	Date Completed	Use
1	Fork Union	Stevens, C. O., No. 2	Falwell Well Corp.	103	65	10	5⅝ x 83	100		2/11/53	Pub.
2	Fork Union	Ranson, W. F.	Buckingham Drill.	100	35	6	5⅝ x 41	90–100		9/ 5/58	Dom.
3	Central Plains	Whitley, Dr. C. A.	Buckingham Drill.	103	45	8	6 x 90	95–103		5/26/58	Pub.
4	Palmyra	Colored Sch., No. 2	Buckingham Drill.	148	24	30	6 x 65			8/16/57	Pub.
5	Palmyra	Colored Sch., No. 1	Buckingham Drill.	150	25	20	6 x 64			8/ 8/57	Pub.
6	Palmyra	Bethel Baptist Ch.	Buckingham Drill.	80	35	5	5⅝ x 58			4/12/57	Pub.
7	Strathmore	Johnson, Forney	Buckingham Drill.	74	11	25	6 x 38			7/30/56	Dom.
8	Bremo Bluff	Morris, Robert A.	Buckingham Drill.	125	40	1.5	5⅝ x 54		105	6/10/56	Dom.
9	Bremo Bluff	National Bank and Trust Co.	Buckingham Drill.	73	35	25	5⅝ x 40			12/30/55	Pub.
10	Palmyra	Manning, Chas. C.	Buckingham Drill.	94	40	14	5⅝ x 74			8/25/55	Dom.
11	Fork Union	Armstrong, Mrs. C. P.	Buckingham Drill.	125	32	35	5⅝ x 81		80	7/12/55	Dom.
12	Palmyra	Duncan, C. E.	Buckingham Drill.	75	35	10	5⅝ x 43			3/30/55	Dom.
13	Fork Union	Snead, Ellis P.	Buckingham Drill.	60	10	10	6 x 24			1/27/55	Dom.
14	Wilmington	Harris, Richard I.	Buckingham Drill.	93	36	0.25	6 x 40			10/26/34	Dom.
15	Fork Union	Davis, Mrs. Nathaniel	Buckingham Drill.	90	48	8	6 x 65	Between 60 & 90		12/20/54	Dom.
16	Dixie	Snead, Kent	Buckingham Drill.	80	36	6	6 x 50			7/21/54	Dom.
17	Wilmington	Caldwell, H. B.	Buckingham Drill.	135	40	10	6 x 98	Between 98 & 135	125	7/ 2/54	Dom.
18	Palmyra	Bell, Cecil	Buckingham Drill.	65	34	10	6 x 47	Between 45 & 65		7/ 7/54	Dom.
19	Palmyra	Fleshman, Lettie	Buckingham Drill.	110	45	1	6 x 53	Between 40 & 60		4/ 2/54	Dom.
20	Bremo Bluff	Seay, E. W.	Buckingham Drill.	112	44	0.17	6 x 42			7/24/54	Dom.

21	Fork Union	Carroll, J. L.	Buckingham Drill.	64	24	12	5⅝ x 53			4/10/57	Dom.
22	Bremo Bluff	Lyels, Joseph	Buckingham Drill.	88	40	15	6 x 70			6/10/54	Dom.
23	Bremo Bluff	Wilson, Arnold	Buckingham Drill.	76	40	7	6 x 40	Between 40 & 76		5/29/54	Dom.
24	Cohasset	Fluvanna Public Sch.	Buckingham Drill.	88	28	6	6 x 34		75	10/14/52	Pub.
25	Kidds Store	Stokes, John P.	Buckingham Drill.	64	40	6	5⅝ x 52	Between 45 & 60		6/13/52	Dom.
26	Palmyra	Whittley, Dr. A. C.	Buckingham Drill.	86	52	4	5⅝ x 53	Between 75 & 86	75	5/30/52	Dom.
27	Palmyra	Dickenson, Bertha H.	Buckingham Drill.	55	32	4	5⅝ x 39	Between 38 & 55	44	5/24/52	Dom.
28	Palmyra	Greusel, James F.	Buckingham Drill.	56	20	5	5⅝ x 44	Between 40 & 56	44	4/21/52	Dom.
29	Palmyra	Webb, H. E.	Buckingham Drill.	75	20	5	5⅝ x 53	Between 53 & 75		4/26/52	Dom.
30	Fork Union	Fluvanna Public Sch.	Buckingham Drill.	79	18	10	5⅝ x 74	74–79		12/ 6/51	Pub.
31	Dixie	Marshall, Nelson	Buckingham Drill.	64	28	2	5⅝ x 60	60–64		7/10/51	Dom.
32	Dixie	Fluvanna High Sch.	Buckingham Drill.	87	14	20	6 x 64	Between 80 & 87		4/12/51	Pub.
33	Fork Union	Fork Union Baptist Parsonage	Buckingham Drill.	100	32	8	6 x 73	Between 70 & 100		3/28/51	Dom.
34	Fork Union	Carysbrook Furn. Co.	Buckingham Drill.	66	10	9	6 x 39	Between 50 & 66	60	12/ 5/50	Ind.
35	Bremo Bluff	Wilkerson, Miss F. C.	Buckingham Drill.	124	48	0.33	6 x 50	60–65	85	4/25/50	Dom.
36	Fork Union	Clements, A. C.	Buckingham Drill.	82	25	6	6 x 56	Between 65 & 75		1/30/50	Dom.
37	Fork Union	Egerton, Capt. C. R.	Buckingham Drill.	64	18	8	6 x 52	Between 45 & 64		1/26/50	Dom.
38	Fork Union	Blanvelt, E. M.	Buckingham Drill.	60	30	28	6 x 45	Between 45 & 55		1/24/50	Dom.
39	Columbia	Fluvanna Public Sch.	Buckingham Drill.	70	45	1	6 x 60	63		1/ 2/49	Pub.
40	Columbia	Rock Crest Gr. Sch.	Buckingham Drill.	88	25	3	6 x 80	Between 78 & 88	64	10/28/49	Pub.

Table 3.—*Continued.*

Well No.	Location (Nearest Town)	Owner	Driller	Total Depth (feet)	Static Water Level (feet)	Yield (gpm)	Casing Size (dia. in inches x length in feet)	Aquifers (Depth in feet)	Depth of In-take	Date Com-pleted	Use
41	Wilmington	Hollywood Gr. Sch.	Buckingham Drill.	86	30	15	6 x 73	Between 75 & 86	64		Pub.
42	Palmyra	Evergreen Gr. Sch.	Buckingham Drill.	73	20	3	6 x 67	Between 40 & 65	44	10/20/49	Pub.
43	Palmyra	Douglas Gr. Sch.	Buckingham Drill.	60	18	3	6 x 42		50	10/18/49	Pub.
44	Palmyra	Fluvanna Public Sch.	Buckingham Drill.	75	35	2	6 x 68	Between 70 & 75	64	10/14/49	Pub.
45	Shores	Buggs, Thomas	Buckingham Drill.	87	50	7	6 x 62	76–80	76	9/ 5/49	Dom.
46	Shores	Buggs, Thomas, Jr.	Buckingham Drill.	100	40	15	6 x 70	Between 68 & 100		5/ 6/54	Dom.
47	Fork Union	Alexander, Chas.	Buckingham Drill.	294	18	90 (?)	6 x 32	28–32	28	8/ 8/49	Dom.
48	Fork Union	Washington, Opie	Buckingham Drill.	73	20	90	6 x 65	65–73		6/27/49	Dom.
49	Cohasset	Whitlow, H. F.	Buckingham Drill.	90	20	15	6 x 14	Between 80 & 90		6/13/49	Dom.
50	Cohasset	White, L. E.	Buckingham Drill.	85	20	8	6 x 65			5/ 6/49	Dom.
51	Kidds Store	Fluvanna Public Sch.	Buckingham Drill.	90	18	20	6 x 74	Between 75 & 90		3/ 9/49	Pub.
52	Columbia	Farsyth, G. W.	Buckingham Drill.	110	50	1.33	6 x 56	Between 70 & 85		3/ 7/49	Dom.
53	Fork Union	Sneed, R. G.	Buckingham Drill.	70	23	20	6 x 44	65–70		3/ 2/49	Dom.
54	Columbia	Audregg, J. C.	Buckingham Drill.	303	70	0.67	6 x 96	Between 90 & 95		11/ 8/48	Dom.
55	Columbia	Hill, James	Buckingham Drill.	103	35	25	6 x 94		85	9/25/48	Dom.

56	Fork Union	Gentry, Jack	Buckingham Drill.	75	24	23	6 x 47			6/19/48	Dom.
57	Bremo Bluff	Cooke, C.	Buckingham Drill.	153	40	20	6 x 81	95–98, 140–153	141	4/19/48	Dom.
58	Columbia	Tony, Mary	Buckingham Drill.	110	40		6 x 95	Between 95 & 110	84	6/19/47	Dom.
59	Bremo Bluff	Ranson, W. F.	Buckingham Drill.	77	30	27	6 x 34	Between 50 & 77		6/17/47	Dom.
60	Central Plains	Francis White Cannery	Buckingham Drill.	60	4	11.5	8 x 47			4/24/58	Ind.
61	Hunters	Bishop, Mrs. Lena	Buckingham Drill.	79	25	20	6 x 61			4/21/47	Dom.
62	Troy	Hannum, R. E.	Buckingham Drill.	62	30	25	6 x 43			4/17/47	Dom.
63	Palmyra	McGehee, C. H.	Buckingham Drill.	90	32	1.33	6 x 52			4/15/47	Dom.
64	Cohasset	Robinson, W. C.	Buckingham Drill.	45	20	25	6 x 40	38–45			Dom.
65	Central Plains	Omohundro, B. C.	Buckingham Drill.	75	40	13.67	6 x 49	Between 55 & 75		2/13/47	Dom.
66	Bremo Bluff	Knuckles, R. A.	Buckingham Drill.	139		0				10/ 8/56	Dom.
67	Bremo Bluff	Knuckles, R. A.	Buckingham Drill.	74	65	1		73–74			Dom.
68	Bremo Bluff	Childress, A. K.	Buckingham Drill.	94	42	5	5⅝ x 78			8/30/56	Dom.
69	Fork Union	Brawen, J. E.	Buckingham Drill.	76	20	20	6 x 63			1/28/49	Ind.
70	Fork Union	Blanton, E. B.	Buckingham Drill.	80	30	15	6 x 70			9/ 5/48	Dom.
71	Fork Union	Hudgens, W. R.	Buckingham Drill.	50	15	4	6 x 34			9/ 2/48	Dom.
72	Columbia	O'Brine, W. F.	Buckingham Drill.	128	70	16	6 x 94			7/16/48	Dom.
73	Kidds Store	Corder, C. V.	Buckingham Drill.	70	30	20	6 x 42			4/16/48	Dom.
74	Kidds Store	Harris, B. A.	Buckingham Drill.	53	38	4	6 x 33	34–40		2/ 4/47	Dom.
75	Fork Union	Ranson, W. H.	Buckingham Drill.	100	35	20	6 x 70	75–100		1/31/47	Dom.
76	Fork Union	Ranson, W. H.	Buckingham Drill.	75	25	20	8 x 24			1/30/47	Dom.
77	Bremo Bluff	Jackson Trailer Court	Buckingham Drill.	95	20	10	6 x 40	Between 60 & 95	84	12/ 8/49	Pub.
78	Bremo Bluff	Jackson Trailer Court	Buckingham Drill.	80	18	12	6 x 52	Between 50 & 80		3/24/49	Pub.
79	Bremo Bluff	Broyles, Mrs. Nora	Buckingham Drill.	95	40	1	6 x 90	92		3/10/47	Dom.
80	Bremo Bluff	Adams, J. L.	Buckingham Drill.	93	67	2	5⅝ x 73	90	87	4/ 4/52	Dom.

Table 3.—*Continued.*

Well No.	Location (Nearest Town)	Owner	Driller	Total Depth (feet)	Static Water Level (feet)	Yield (gpm)	Casing Size (dia. in inches x length in feet)	Aquifers (Depth in feet)	Depth of In-take	Date Com-pleted	Use
81	Palmyra	Carter, R. B.	Buckingham Drill.	63	8	15	6 x 46			1/15/51	Dom.
82	Troy	Ogilvie, R. B.	Wm. Collier	245	20	15–18		85; 125		7/22/63	Dom.
83	Columbia	Colonial Pipeline Corp.	Farmville Drill. Co.	250	35	6	6¼ x 83	80; 150; 225		2/24/64	Ind.
84	Union Mills	Ryan, W. S.		816		0.03	6 x 40	280; 500			Dom.
85	Union Mills	Ryan, W. S.		134		2					Dom.
86	Fork Union	Fork Union Mil. Acad.		430		65					Pub.
87	Palmyra	Town of Palmyra	Palmer	501		2					Mun.
88	Palmyra	Bank of Fluvanna		20							Pub.
89	Palmyra	Courthouse (village)	Palmer	500		2–3		90		1934–35	Pub.
90	Palmyra	Fluvanna Hotel		210		10–15					Pub.
92	Palmyra	Town of Palmyra		90		3–5					Mun.
93	Fork Union	Wallace, Kelly		63		20	6 x 60				Dom.
94	Dixie	Glass, Roger W.	Buckingham Drill.	80	35	0.5	5⅝ x 60	60–70		6/15/59	Dom.
95	Fork Union	Summerville, A. M.	Buckingham Drill.	76	12	8	5⅝ x 52	52–76		5/18/59	Dom.
96	Palmyra	Anderson, Mrs. E.	C. R. Moore	85	57	1.5	6 x 13			1951	Dom.
97	Palmyra	Soyors, W. S.	C. R. Moore	86	51	1	6 x 38			8/15/51	Dom.
98	Bremo Bluff	Jones, Mansfield	C. R. Moore	102	72	1	6 x 53			1953	Dom.
99	Bremo Bluff	Carter, R. B.	C. R. Moore	81	28	15	6 x 55			1953	Dom.
100	Kents Store	Richardson, Lewis	C. R. Moore	106	26	7	6 x 73			1953	Dom.
101	Columbia		C. R. Moore	97	49	4	6 x 53			1949	Dom.

102	Shores	Colord, Mr.	C. R. Moore	95	47	40	6 x 70			1957	Dom.
103	Columbia	Galt, James	C. R. Moore	350	306	15	6 x 74			1955	Dom.
104	Palmyra	Jones, Mansfield	C. R. Moore	126	86	1	6 x 53			1957	Dom.
105	Fork Union	Smith, Ben	C. R. Moore	82	47	1	6 x 31			1954	Dom.
106	Shores	Washington, Virginia	C. R. Moore	85	63	8	6 x 77			1957	Dom.
107	Palmyra	Yancy, Mrs. W. G.	C. R. Moore	70	42	7	6 x 36			1955	Dom.
108	Troy	Ryalls, R. C.	C. R. Moore	120	100	20	6 x 66			1950	Dom.
109	Troy	Commonwealth of Virginia	C. R. Moore	87	20	20	6 x 49.5			1954	Ind.
110	Palmyra	Town of Palmyra		210		10–15				1934–35	Mun.
112	Fork Union	White House Milk	C. R. Moore	270	250	12–15	6 x 52		240	5/61	Ind.

MAGNETIC SURVEY

A magnetic survey of Fluvanna County was made during the summer of 1961. Eleven traverses were made in the county (Plate 3) utilizing an Askania Model GF-6 vertical magnetometer. The magnetometer readings were adjusted with respect to temperature and were corrected for diurnal variation by use of magnetograms recorded by the U. S. Coast and Geodetic Survey at the Fredericksburg Magnetic Observatory, Corbin, Virginia; the data on Plate 3 are absolute vertical magnetic intensity not adjusted for magnetic latitude.

Relatively large positive magnetic anomalies were measured over phyllite, metamorphosed graywacke, and muscovite rock of the Evington Group in the central portion of the county which contain accessory magnetite (Plate 3), and over mafic igneous rocks of the metamorphosed volcanic and sedimentary rock unit (Plate 3, Profiles I and K). The magnetic intensity is generally low over the granodiorite unit and Arvonia Formation, although local positive anomalies are present as shown in Profiles I and K (Plate 3). The metamorphosed volcanic and sedimentary rock unit is characterized by magnetic highs and lows that probably reflect the wide range in composition of the unit. Rock types in the western portion of the county show a relatively uniform magnetic intensity.

APPENDIX I

CHEMICAL ANALYSES

Maynard E. Coller, analyst

VDMR Repository Number	R-2198[1]	R-2162	R-2199[1]	R-2163	R-2202[1]	R-2201[1]	R-2200[1]	R-2161	R-2168	R-2165	R-2166	R-2164	R-2167	R-1784[2]
Constituent	Percentage													
SiO_2	45.0	42.0	43.7	61.6	55.5	62.0	71.3	46.4	58.0	58.8	66.6	59.4	54.6	72.43
Al_2O_3	31.3	29.7	30.4	18.9	24.1	18.2	15.0	28.7	20.8	20.8	15.1	20.7	23.1	13.93
Fe_2O_3	10.4	13.6	11.7	7.57	3.51	7.36	0.35	7.62	5.86	2.81	2.24	6.55	7.07	0.90
FeO	0.53	1.20	0.60	2.13	4.27	1.60	4.15	1.87	1.13	3.20	3.40	0.93	1.47	2.45
TiO_2	0.82	1.27	0.84	0.84	0.65	0.43	0.24	1.16	0.91	0.77	0.65	0.45	1.01	0.21
CaO	0.05	N. D.	N. D.	0.05	0.078	0.05	0.31	N. D.	0.29	0.55	2.57	0.08	0.03	3.38
MgO	0.39	0.67	0.36	1.10	1.33	1.16	1.39	1.24	1.81	1.79	1.77	0.99	1.12	0.58
Na_2O	2.01	2.40	1.33	1.14	1.29	0.55	2.08	0.57	1.21	0.15	2.85	0.027	0.047	3.20
K_2O	3.93	3.88	3.91	2.58	3.80	1.98	1.88	6.62	3.17	6.21	2.29	3.50	4.16	2.14
CO_2	N. D.	N. D.	N. D.	N. D.	0.13	0.03	N. D.	N. D.	N. D.	N. D.	N. D.	N. D.	N. D.	0.09
H_2O(—110°C)	0.45	0.46	0.66	0.25	0.34	0.50	0.12	0.45	1.32	0.35	0.13	2.01	0.73	0.11
H_2O(+110°C)	4.44	4.58	5.88	3.12	4.76	4.70	2.63	4.85	4.66	3.86	1.64	4.85	5.87	0.54
MnO	......	......	......	......	......	......	......	......	......	......	......	......	......	0.02
P_2O_5	......	......	......	......	......	......	......	......	......	......	......	......	......	0.04
S	......	......	......	......	......	......	......	......	......	......	......	......	......	0.01

N. D.—Not detected.
[1]Samples from eastern Albemarle County.
[2]Analysis from Taber (1913, p. 65, Dr. Roger C. Wells, analyst).

Data for Samples That Were Analyzed Chemically

Number	Unit	Lithology	Weathering	Mineral Constituents
R-2198	Paragonite	Phyllite	Slightly weathered	Muscovite, paragonite, potassic feldspar, hematite, kaolinite, quartz, magnetite
R-2162	Paragonite	Phyllite	Fresh	Muscovite, paragonite, hematite, potassic feldspar, quartz, magnetite
R-2199	Paragonite	Phyllite	Greatly weathered	Muscovite, paragonite, quartz, kaolinite, goethite, potassic feldspar
R-2163	Paragonite	Phyllite	Fresh	Chlorite, muscovite, paragonite, quartz, potassic feldspar, hematite
R-2202	Paragonite	Phyllite	Fresh	Chlorite, muscovite, paragonite, quartz, potassic feldspar
R-2201	Paragonite	Quartzose phyllite	Moderately weathered	Mg-chlorite, muscovite, paragonite, kaolinite, goethite, quartz, potassic feldspar
R-2200	Lower chlorite-muscovite	Subgraywacke	Fresh	Chlorite, muscovite, quartz, plagioclase (ab_{95}-ab_{80})
R-2161	Lower chlorite-muscovite	Quartzose phyllite	Slightly weathered	Chlorite, muscovite, quartz, goethite, potassic feldspar, plagioclase, kaolinite
R-2168	Upper chlorite-muscovite	Argillite	Moderately weathered	Vermiculite (chlorite), muscovite, quartz, plagioclase, goethite
R-2165	Middle muscovite	Quartzose phyllite	Fresh	Muscovite, quartz, plagioclase (ab_{95}-ab_{80}), biotite
R-2166	Middle muscovite	Quartzose phyllite	Fresh	Muscovite, quartz, plagioclase (ab_{95}-ab_{80}), biotite, epidote

R-2164	Lower chlorite-muscovite	Argillite	Very weathered	Muscovite, quartz, superlattice clay, goethite
R-2167	Upper chlorite-muscovite	Argillite	Very weathered	Muscovite, biotite, quartz, kaolinite, goethite
R-1784	Granodiorite	Granodiorite gneiss	Fresh (?)	Quartz, plagioclase (ab_{90}-ab_{75}), microcline, biotite, garnet, clino-pyroxene, muscovite

APPENDIX II

ANALYTICAL AGE DETERMINATIONS

Potassium-argon Method

Geochron Laboratories, Inc., Cambridge, Massachusetts, analysts

Sample	Material	% K	K^{40} ppm	$^*Ar^{40}$ ppm	% Radiogenic Ar^{40}	$^*Ar^{40}/K^{40}$	Age m. y.
R-1784	Biotite	7.72	9.35	0.179	92.3	0.0191	301±15
		7.59		0.178	93.6		
R-1931	Biotite	4.955	6.04	0.128	91.0	0.0207	324±12
		4.945		0.122	66.9		
R-1967	Muscovite ...	3.86	4.70	0.809	63.1	0.0181	287±18
	Biotite	3.85		0.081	62.9		

*Radiogenic element.

Rubidium-strontium Method[1]

C. E. Hedge and F. G. Walthall, U. S. Geological Survey, analysts

Sample	Material	Rb ppm	Sr ppm	Sr^{87}/Sr^{86}	Age m. y.
R-1784	Whole rock............	59.6	90.9	0.718	400±125
R-1784	K-feldspar............	182	159	0.727	

[1]Neither the whole rock nor K-feldspar contain sufficient radiogenic strontium to yield a precise age. Data were therefore combined to calculate this age.

Lead-alpha Method

T. W. Stern and Harold Westley, U. S. Geological Survey, analysts

Sample	Material	Lead content ppm	Alpha activity α/mg-hr	Age m. y.
R-1784	Zircon......................	41.7	253	400±50

R-1784 A medium-grained granodiorite gneiss obtained from the Cowherd quarry on State Highway 6, east side of Columbia, Fluvanna County, Virginia. Biotite, K-feldspar, and zircon concentrates and whole-rock split used for analytical age determinations.

R-1931 A dark-gray biotitic slate (Arvonia Formation) obtained from slate quarry 5000 feet west of U. S. Highway 15 and State Road 715 intersection at Ore Bank, Buckingham County, Virginia. Age analysis made on mineral concentrate containing 80% biotite, minor quartz, and some feldspar.

R-1967 A gray, medium-grained, chloritic, biotitic, quartz-plagioclase-muscovite schist (upper chlorite-muscovite unit) obtained from railway cut along Chesapeake and Ohio Railway about 0.25 mile west of railroad crossing for State Road 640, Fluvanna County, Virginia. Age analysis made on the following mixture: muscovite 35%, biotite 10%, quartz 30%, feldspar (mostly plagioclase) 20%, and others 5%.

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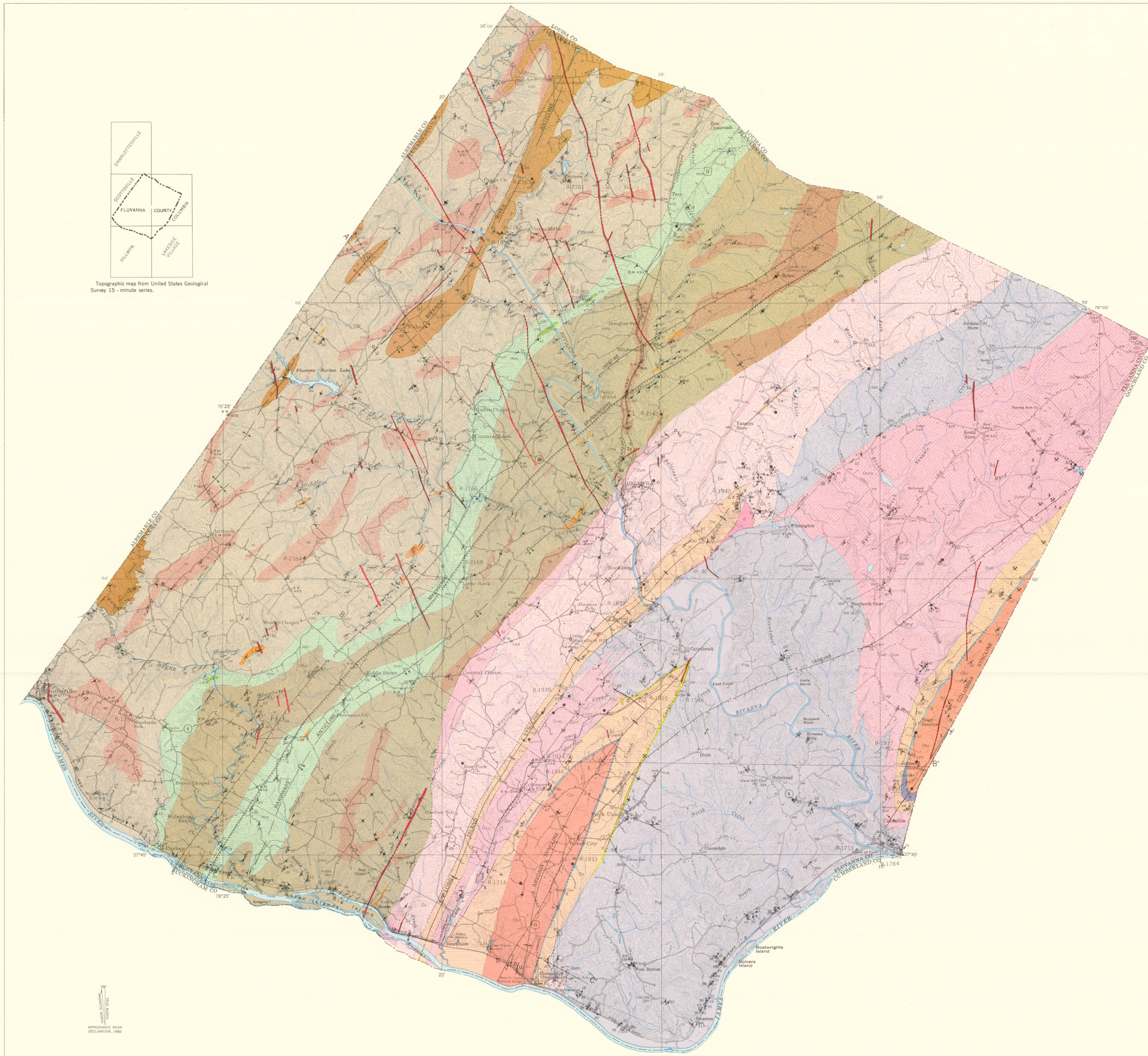
INDEX

COMMONWEALTH OF VIRGINIA
DEPARTMENT OF CONSERVATION AND ECONOMIC DEVELOPMENT
DIVISION OF MINERAL RESOURCES
James L. Calver
Commissioner of Mineral Resources and State Geologist



Geologic Map
FLUVANNA COUNTY

Geology by J. W. Smith and R. C. Milici

Scale 1:62500

1964

EXPLANATION

MESOZOIC — TRIASSIC

Diabase
Diabase dikes, fine- to coarse- grained.

PALEOZOIC

Granodiorite Unit
Granodiorite, medium- to coarse-grained; b, metamorphosed basic igneous rock.

ORDOVICIAN

Arvonia Formation
Slate in the Arvonia and Long Island synclines and schist in the Columbia syncline; Obr, Bremo Member, quartzite and slate in the Arvonia syncline and quartzite and schist in the Columbia syncline; c, oolitic chlorite schist; g, garnet-amphibole rock; b, amphibole schist (metamorphosed basic igneous rock ?); q, quartzite.

Metamorphosed Volcanic and Sedimentary Rock Unit
Ov, quartz-feldspar rock (aporhyolite), very fine-grained, and quartzite and phyllite, interbedded, very fine-grained; Ovm, amphibole schist and gneiss, biotite and chlorite schist, and plagioclase-chlorite-epidote rock (metamorphosed intermediate and basic igneous rock); Ovfm, interlayered Ov and Ovm; d, metamorphosed diorite.

Evington Group (?)
p, paragonite unit, muscovite-paragonite phyllite and chlorite-muscovite-paragonite phyllite (metamorphosed acid or intermediate volcanic tuff or ash); cml, lower chlorite-muscovite unit, phyllite and metamorphosed graywacke; mm, middle muscovite unit, phyllite and metamorphosed graywacke; cmu, upper chlorite-muscovite unit, phyllite and metamorphosed graywacke; b, metamorphosed basalt; cm, chlorite-muscovite rock; and m, muscovite rock and muscovite-rich residuum.

CONTACTS
- exposed
- approximate
- covered

FAULTS
- exposed
- approximate
- U upthrown side
- D downthrown side

SHEAR ZONE

FOLDS
- Anticline—trace of axial plane
- Syncline—trace of axial plane
- Overturned anticline—trace of axial plane

MINES, QUARRIES, AND PROSPECTS
- Mine or quarry
- Abandoned mine or quarry
- Prospect
- Quartz veins
- Mineral localities

SAMPLE LOCATIONS
- R-2161 Location of sample for chemical analysis or age determination
- R-1936 Location of sample for ceramic and lightweight aggregate tests

ATTITUDE OF ROCKS
- Strike and dip of beds
- Strike and dip of overturned beds
- Horizontal beds
- Strike and dip of compositional bands

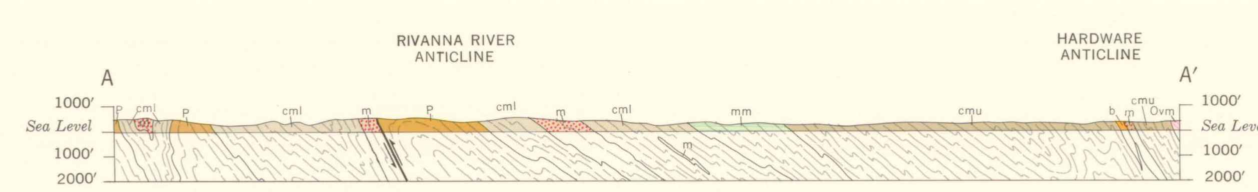
FOLIATION AND CLEAVAGE
- Strike and dip of foliation
- Strike of vertical foliation
- Strike and dip of rock cleavage or bedding schistosity
- Strike of vertical cleavage or bedding schistosity

BEARING AND PLUNGE OF LINEATIONS
- Axis of crinkle or small fold
- m Mineral streak
- s Elongated sedimentary feature

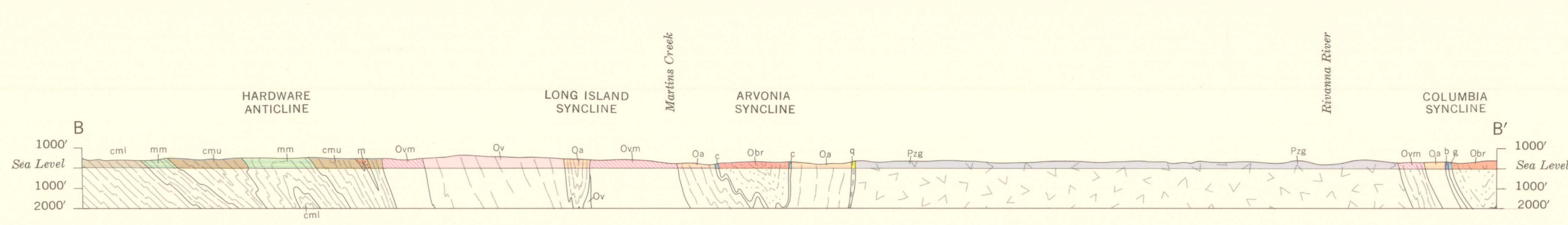
JOINTS
- Strike and dip of joints
- Strike of vertical joints

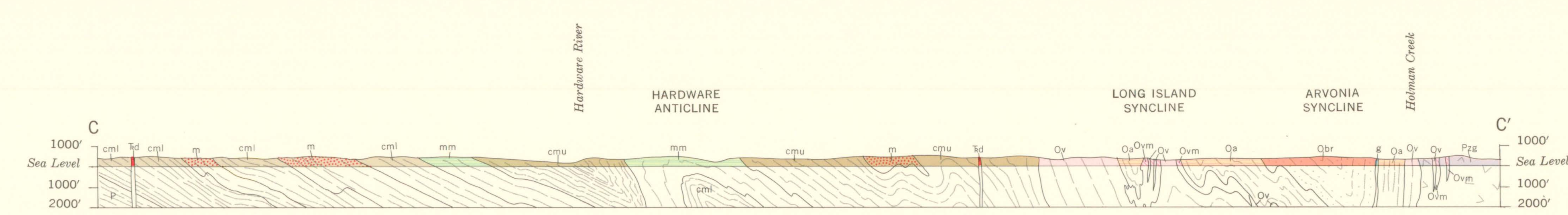
ISOGRADS
- Biotite, megascopic phyllosilicates (mica and chlorite), and almandine are on hachured side of the respective isograds

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



No Vertical Exaggeration





Mineral Resources of FLUVANNA COUNTY, VIRGINIA

Commonwealth of Virginia

Department of Conservation and Economic Development
Division of Mineral Resources

James L. Calver, Commissioner of
Mineral Resources and State Geologist
Charlottesville, Virginia

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1964

EXPLANATION

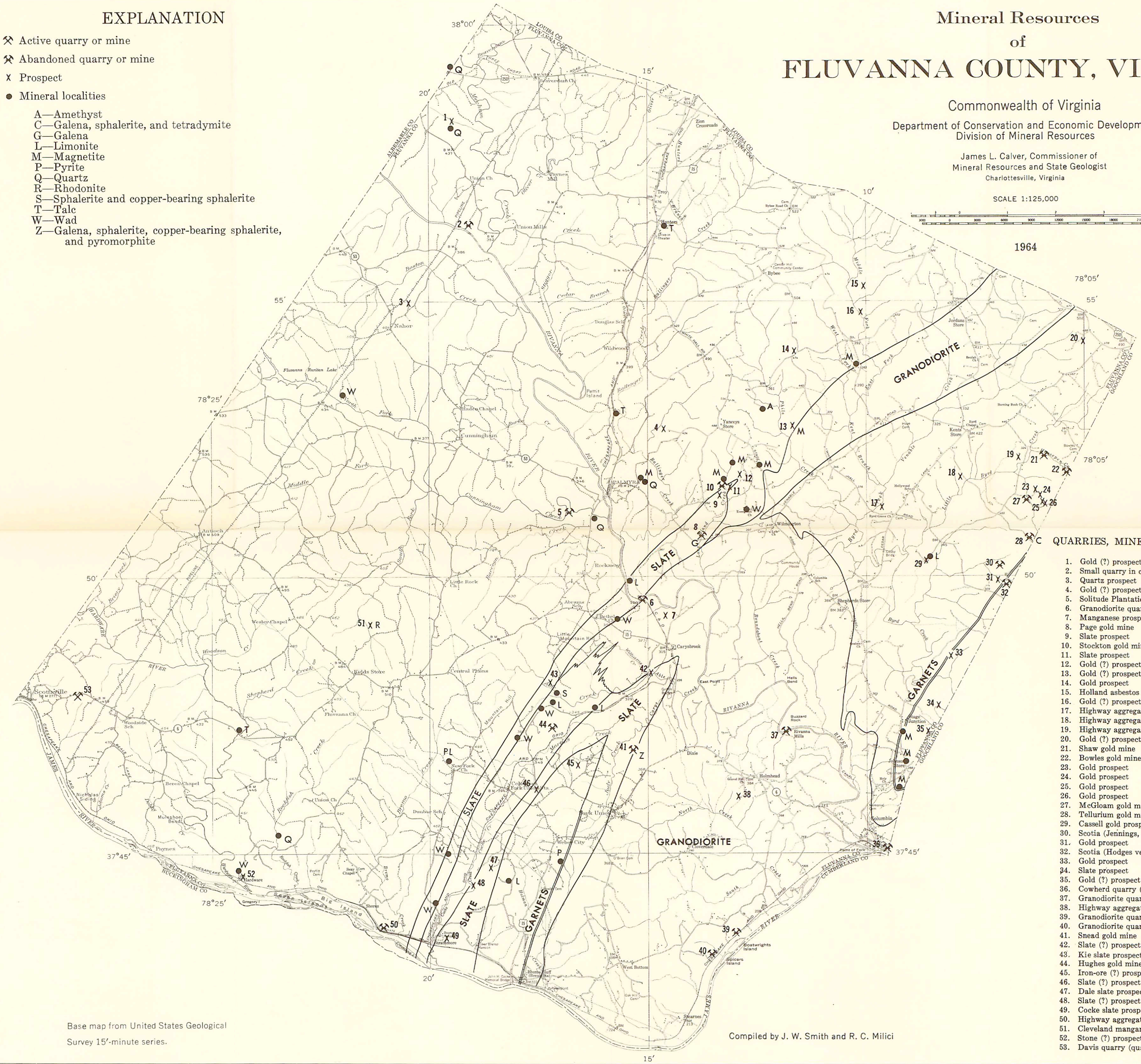
⚒ Active quarry or mine

⚒ Abandoned quarry or mine

X Prospect

● Mineral localities

A—Amethyst
C—Galena, sphalerite, and tetradymite
G—Galena
L—Limonite
M—Magnetite
P—Pyrite
Q—Quartz
R—Rhodonite
S—Sphalerite and copper-bearing sphalerite
T—Talc
W—Wad
Z—Galena, sphalerite, copper-bearing sphalerite, and pyromorphite



QUARRIES, MINES, AND PROSPECTS

1. Gold (?) prospect
2. Small quarry in conglomerate
3. Quartz prospect
4. Gold (?) prospect
5. Solitude Plantation talc mine
6. Granodiorite quarry
7. Manganese prospect
8. Page gold mine
9. Slate prospect
10. Stockton gold mine
11. Slate prospect
12. Gold (?) prospect
13. Gold (?) prospect
14. Gold prospect
15. Holland asbestos prospect
16. Gold (?) prospect
17. Highway aggregate prospect
18. Highway aggregate prospect (drilled)
19. Highway aggregate prospect (drilled)
20. Gold (?) prospect
21. Shaw gold mine
22. Bowles gold mine
23. Gold prospect
24. Gold prospect
25. Gold prospect
26. Gold prospect
27. McGloam gold mine
28. Tellurium gold mine
29. Cassell gold prospect
30. Scotia (Jennings, Perkins) gold mine
31. Gold prospect
32. Scotia (Hodges vein) gold mine
33. Gold prospect
34. Slate prospect
35. Gold (?) prospect
36. Cowherd quarry (granodiorite)
37. Granodiorite quarry
38. Highway aggregate prospect (drilled)
39. Granodiorite quarry
40. Granodiorite quarry
41. Snead gold mine
42. Slate (?) prospect
43. Kie slate prospect
44. Hughes gold mine
45. Iron-ore (?) prospect
46. Slate (?) prospect
47. Dale slate prospect
48. Slate (?) prospect
49. Cocke slate prospect
50. Highway aggregate quarry (greenstone)
51. Cleveland manganese prospect
52. Stone (?) prospect
53. Davis quarry (quartz)

Base map from United States Geological Survey 15′-minute series.

Compiled by J. W. Smith and R. C. Milici

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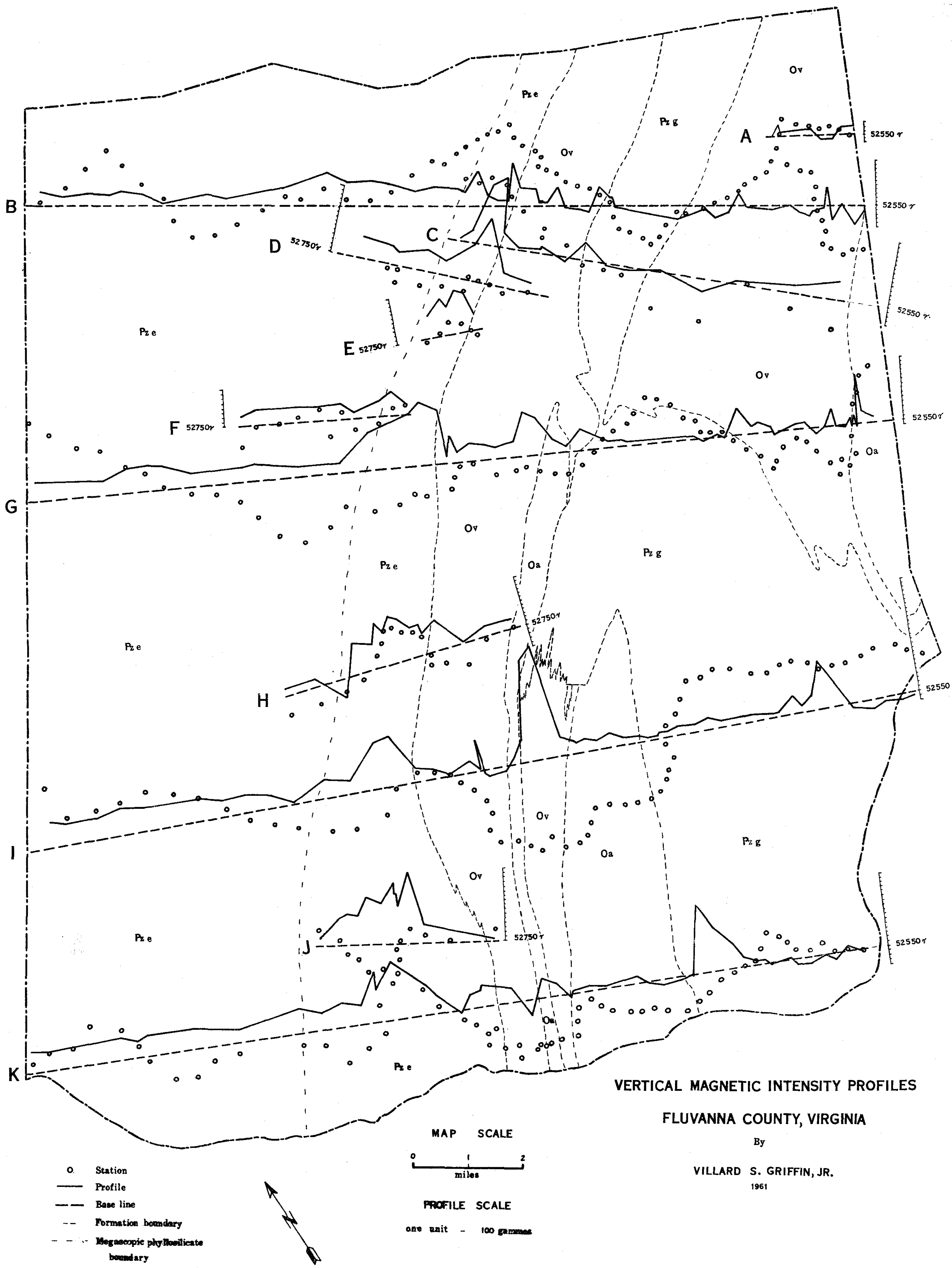

Plate 3. Vertical magnetic intensity profiles, Fluvanna County, Virginia. Formation boundaries and megascopic phyllosilicate boundary were taken from geologic map (Plate 1); megascopic phyllosilicates are present east of the boundary. Formations are: granodiorite unit, Pz g; Arvonia Formation, Oa; metamorphosed volcanic and sedimentary rock unit, Ov; and Evington Group, Pz e. Corrections for magnetic latitude were not made.