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

GEOLOGY OF THE DILLWYN QUADRANGLE VIRGINIA

WILLIAM RANDALL BROWN

REPORT OF INVESTIGATIONS 10

VIRGINIA DIVISION OF MINERAL RESOURCES

James L. Calver
Commissioner of Mineral Resources and State Geologist

CHARLOTTESVILLE, VIRGINIA
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Richmond, Virginia

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GEOLOGY OF THE DILLWYN QUADRANGLE, VIRGINIA[1]

By

WILLIAM RANDALL BROWN[2]

ABSTRACT

The Dillwyn quadrangle includes a geologically complex area of 237 square miles in the west-central Piedmont of Virginia. It is underlain principally by metasedimentary and metaigneous rock types, most of which are of lower Paleozoic age but some of which are probably Precambrian. The north end of the Farmville basin that contains Triassic boulder conglomerates and arkosic sandstones extends into the southeastern part of the quadrangle, and dikes and sills of probable Triassic age are numerous throughout the area.

The Arvonia syncline with its deep infold of fossiliferous Arvonia slate extends diagonally northeastward through the central part of the quadrangle. This slate contains fossils that have been determined to be of Late Ordovician age. The formation consists mainly of porphyroblastic ("knotted") slate and schist as well as appreciable quartzite, including that at Bremo Bluff, and, in places, a basal conglomeratic schist. The Arvonia Formation is overlain, apparently unconformably, by conglomeratic schist of the Buffards Formation. The base of the Arvonia appears everywhere to be marked by unconformity. Along the west flank of the Arvonia syncline, the Arvonia Formation overlies metasedimentary and metavolcanic rocks of the Evington Group(?); along the east flank south of the James River, it overlies more highly metamorphosed units, in part equivalent to the Evington Group(?), and possibly older rocks that have been raised in the broad Whispering Creek anticline in the south-central part of the quadrangle. To the northeast the Arvonia Formation rests unconformably with basal conglomerate upon gneissic granodiorite and quartz diorite of the Hatcher Complex.

West of the Arvonia syncline, rocks of the Evington Group(?) have been folded in the large overturned Hardware anticline. The metamorphosed plutonic rocks in the vicinity of Diana Mills, chiefly of hornblende diorite composition, are present in the axial portion of this anticline. Most of the quadrangle east of the Arvonia syncline is underlain by the Hatcher Complex, chiefly gneissic

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quartz diorite that is migmatitically interlayered with hornblende gneiss toward its west and southwest borders. Rocks in the large Whispering Creek anticline in the south-central part of the quadrangle are chiefly metasedimentary biotite gneiss and mica schist, with hornblende gneiss, possibly of igneous origin, mainly about its flanks. These rocks grade without definite contact into the Hatcher Complex to the northeast.

Arvonia slate is the dominant mineral resource of the area. It is split for use in roofing, flagstones, and various architectural applications and is expanded by heating to produce lightweight aggregate. In years past, gold and ores of copper and iron were produced in the area. Kyanite quartzite is of potential value.

INTRODUCTION

The Dillwyn quadrangle includes an area of 237 square miles, mostly in northeastern Buckingham County, but small portions are also in western Cumberland County and southern Fluvanna County (Figure 1). It is bounded by parallels 37°30′ and 37°45′ and meridians 78°15′ and 78°30′, and is located in the west-central part of the Piedmont province of Virginia. Roofing slate of unexcelled quality has been produced in the Arvonia district for 200 years. It is the purpose of this report to provide a guide to the geology of the quadrangle and to present a geologic map of the Arvonia slate and other major rock units.

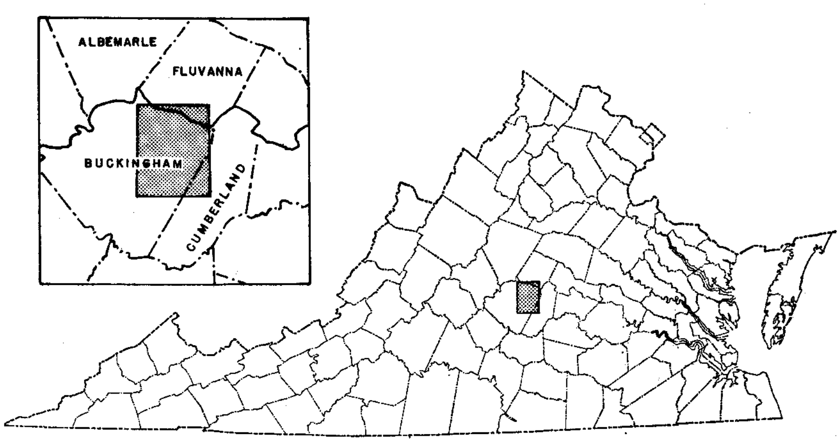


Figure 1. Index map showing the location of the Dillwyn quadrangle.

PREVIOUS INVESTIGATIONS

Rogers (1884), in his Annual Report to the Legislature of the State of Virginia for 1835, discussed the occurrence of slate, gold, copper, and iron in the Arvonia district. Credner (1868-69) described some of the gold mines in the area. Darton announced the discovery of fossils in the slates in 1892, and in 1911 Watson and Powell gave the first comprehensive discussion of fossils in the Arvonia slate. Watson (1907) also briefly described the mineral resources of the region. Dale (1906) and Dale and others (1914) in comprehensive reports on slate in the United States discussed the Arvonia district and characteristics of the slate. Taber (1913) published a detailed report on the metallic resources and the petrography of the rocks of the gold belt in the James River basin, which included most of the Dillwyn quadrangle.

The Virginia Geological Survey (1916) mapped the approximate extent of Arvonia slate in the Arvonia syncline as well as in the Fluvanna County portion of the Long Island syncline; other rocks in the area were shown as Precambrian schists, gneisses, granite, and granite gneiss. Jonas (1932) published a reconnaissance map of the kyanite belt of Virginia, described the main rock units, and made broad structural interpretations and long-range correlations. Stose and Stose (1948) made more detailed interpretations of the structure and stratigraphy of the Arvonia slate, postulated a Silurian age for it, and reached the important conclusion that the "knotted" slate to the east of the commercial slates is but a more highly metamorphosed facies of the Arvonia Formation. Brown and Sunderman (1954) described the geologic relationships in portions of the Dillwyn, Scottsville, and Covesville quadrangles. Espenshade and Potter (1960) included the south-central part of the Dillwyn quadrangle on their geologic map of the Willis Mountain-Woods Mountain area of Buckingham County, on which is shown the Whispering Creek anticline, and they described the rocks in this area in detail. Barnes (1963) presented the results of geophysical studies along the belt of sulfide mineralization near New Canton. Redden (1961) and McDowell (1964) described the occurrence and processing of the commercial Arvonia slate, and the latter presented a map of the quarries near Arvonia. Smith, Milici, and Greenberg (1964) made a comprehensive report on the geology of Fluvanna County that includes the northeastern portion of the Dillwyn quadrangle. Most recently, Ern (1968) mapped and described the geology of the Buckingham quadrangle that adjoins the Dillwyn quadrangle on the west.

FIELD WORK AND ACKNOWLEDGMENTS

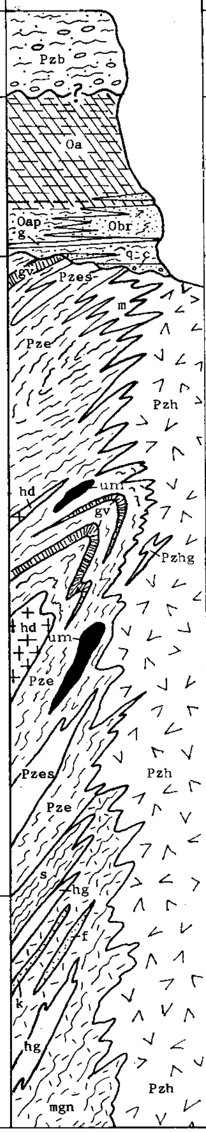
Field work was done by the writer chiefly during the summers of 1952, 1953, and 1954. In 1952 he worked partly in conjunction with H. C. Sunderman mapping portions of the Dillwyn, Scottsville, and Covesville quadrangles. The next year he was ably assisted by William E. Jackson and the following, by Harvey C. Young. From 1 to 2 weeks in each of the years 1961, 1962, and 1964 were also spent in completing the mapping of the quadrangle. At these times the writer was employed by the Virginia Division of Mineral Resources. During this phase of the work he was accompanied in the field and assisted in numerous ways by staff members of the Division.

During the course of the field work a number of people in the area were of assistance to the writer, particularly Mr. T. Aubrey Yancey, President of the Arvonia-Buckingham Slate Company, Inc.; Mr. Maury F. LeSueur, President of the LeSueur-Richmond Slate Corporation; and Mr. John Nuckles and Mr. Dewey Kirstein of the Solite Corporation. Mr. J. M. Burroughs provided information and assisted the writer in finding fossils. To more than anyone else, the writer is indebted to Dr. James L. Calver, Commissioner of Mineral Resources and State Geologist, for his patience, support, and assistance of many kinds which have made completion of the work possible.

ROCKS IN THE AREA

The rocks in the area, except for Quaternary alluvium and a small area of Triassic sedimentary rocks in the southeastern part of the quadrangle, are igneous or metamorphic (Plate 1; Figure 2). In broad pattern, the Evington(?) metamorphosed graywackes, subgraywackes, and impure quartzites with interlayered altered volcanic rocks, in total thickness of about 13,000 feet, underlie the northwestern two-fifths of the quadrangle. These rocks have been intricately and strongly compressed in the overturned Hardware anticline. In the vicinity of Diana Mills, rocks having the composition of hornblende diorite were intruded into the axial portion of this anticline, and a few sill-like masses of ultramafic rock occur interlayered with the rocks of the Evington Group(?). Some of the surficial rocks in this portion of the quadrangle dip southeastward beneath the Arvonia Formation and Buffards Formation in the axial portion of the Arvonia syncline that extends diagonally northeastward across the approximate center of the quadrangle.

Figure 2. Major rock units in the Dillwyn quadrangle.

Major Rock Units and Ages	Relationship Between Paleozoic and Older Rock Units	Thickness (Feet)	Map Symbol	Character
CENOZOIC Quaternary			Qal	Alluvium
MESOZOIC Triassic		2200	TRd TRn	Diabase dikes and sills Boulder conglomerate and arkosic sandstone
PALEOZOIC — Buffards Formation		1500	Pzb	Phyllite and quartz-muscovite schist; generally conglomeratic and pyroclastic
PALEOZOIC — Ordovician — ? — Arvonia Formation		3500	Oa Oap Obr g q c	Slate, dark-gray Porphyroblastic biotite and biotite-garnet slate and schist Bremo Member: chiefly quartzite; some schist and slate Garnet-amphibole-quartz rock Quartzite, micaceous Conglomeratic quartz-sericite schist, chloritoid common
PALEOZOIC — Evington Group(?) and associated intrusive rocks		13,000	hd Pzh Pzhg m um Pze gv Pzes	Hornblende metadiorite and related ultramafic rocks Hatcher Complex: Gneissic quartz diorite, granodiorite, some granite Hornblende gneiss Migmatite of hornblende gneiss and quartz diorite gneiss Ultramafic rocks; soapstone, serpentine, etc. Evington Group(?) Arkosic chlorite-quartz-muscovite schist and phyllite, commonly with pebbles (metagraywacke) Greenstone volcanic rocks (metamorphosed mafic igneous rocks) Altered dacitic volcanic rocks and interbedded arkosic schists, phyllites, and quartzites
? — Rocks of uncertain age			mgn s hg k f	Biotite gneiss Mica schist Hornblende gneiss Kyanite quartzite Ferruginous quartzite

Most of the quadrangle area east of the Arvonia syncline is occupied by the Hatcher Complex, composed of quartz diorite gneiss, hornblende gneisses, and migmatite. In most places between the Hatcher Complex and the Arvonia Formation there is at least a narrow zone of metasedimentary and metavolcanic rocks, some of which appear to belong to the Evington Group(?). In the Whispering Creek anticline in the south-central part of the quadrangle, however, biotite gneisses and ferruginous and kyanite quartzites that may be older than rocks of the Evington Group(?) are exposed. If these rocks are older, as interpreted, at least the area in the vicinity of the Whispering Creek anticline, and very likely the whole area of the Arvonia syncline, was raised and eroded before deposition of the Arvonia Formation.

Hatcher quartz diorite (now metamorphosed) intruded, and is therefore younger than, rocks of the Evington Group(?) as well as those in the Whispering Creek anticline. There is some uncertainty, however, as to the relative age of the Hatcher and the Arvonia Formation. Although radiometric age determinations and some field relations suggest that the Hatcher is younger than the Arvonia (Brown, 1962; Smith, Milici, and Greenberg, 1964, p. 21, 56), broad field relations suggest that the Hatcher is part of an older deeply eroded "basement" upon which the Arvonia Formation was deposited. It is interpreted, therefore, that the Hatcher and the Arvonia Formation are separated by a large unconformity.

EVINGTON GROUP(?)

The phyllites, fine-grained schists, quartzites, and metavolcanic rocks that occupy the approximate northwestern two-fifths of the Dillwyn quadrangle are designated Evington Group(?). In this report these rocks are considered to include both the "Evington Group(?)" and the "Metamorphosed volcanic and sedimentary rock unit" (Smith, Milici, and Greenberg, 1964) because the altered volcanic rocks in both units appear to be distinctly related and to have no clear separation between them. That part of the Evington Group(?) in the vicinity of the Arvonia slate has been called Peters Creek formation (Stose and Stose, 1948, p. 405 and Fig. 4) on the assumption that these rocks are correlative with the formation of this name in the Peach Bottom syncline of Maryland. Use of the name Peters Creek in this area, however, has not been continued because of the lack of detailed mapping in the intervening region.

Immediately northwest of the Dillwyn quadrangle, surface exposures believed to be Evington Group(?) are separated from known rocks of the Evington Group by Triassic rocks of the Scottsville basin, but they can be traced without marked lithologic change around the end of this basin into the Candler Formation, the oldest and by far the most extensive unit in the Evington Group. The Candler overlies the Lynchburg Formation, or the Catoctin greenstone where this unit occurs at the top of the Lynchburg (Brown, 1958, p. 28, 31). It is the writer's opinion that at least some of the greenstone volcanics within the Evington Group(?) of the Dillwyn area may be correlative with the Catoctin, and that the underlying units, lithologically indistinguishable from other metasedimentary rocks in this area classed as Evington(?), may be an eastern deeper water facies of the Lynchburg Formation that is typically coarser grained where it has been mapped to the west.

Near the central part of the Dillwyn quadrangle, rocks of the Evington Group(?) dip southeastward beneath the Arvonia and Buffards Formations in the trough of the Arvonia syncline. On the southeast side of this syncline, although of higher metamorphic grade, some of these rocks are recognizable where they are exposed between the Arvonia Formation and the quartz diorite and hornblende gneisses of the Hatcher Complex. The most readily recognizable unit consists of altered silicic volcanic rocks in the vicinity of Holman Creek on the north side of the James River. Similar rocks are present near the mouth of Bear Garden Creek on the south side of this river, but exposures are too small to be shown on Plate 1. Rocks of the Evington Group(?) are intruded by the small stock of hornblende diorite and related rocks in the vicinity of Diana Mills, by sills and dikes of hornblende diorite, by ultramafic rocks and by Triassic diabase.

Metasedimentary Rocks

Rocks of the Evington Group(?) consist predominantly of chlorite-quartz-muscovite schists and phyllites. Thin slaty and impure quartzitic zones occur locally. In most of the metasedimentary rocks, some phyllosilicates are visible, but the coarsest are seldom more than 0.5 mm in length. The metagraywackes (schists and phyllites) contain about 10 to 40 percent feldspar; they resemble and grade into quartz wackes (term from Krumbein and Sloss, 1963, p. 172-173) which contain less than 10 percent feldspar (Appendix, Part 1). Both are generally light to dark gray-green where fresh and weather yellowish tan to brown. Typically they contain grains of feldspar and quartz from 0.5 to 2.5 mm long; in some sheared material these have been distorted into lenses and streaks. In most places the rocks are moderately to strongly foliated, but a few massive units occur. Well-developed graded bedding, in units up to 10 inches thick, is evident in some of the less altered material.

In thin section detrital feldspars are predominantly plagioclase (An_{16-27}); albite and potassic feldspar occur sparingly (Figure 3A). Recrystallization has occurred in a variable degree in different parts of the group, becoming, in general, more pronounced from northwest to southeast across the area. In less altered rocks, some quartz is granulated and recrystallized, and muscovite or sericite and chlorite have developed in zones of shear between coarser clastic grains. In more highly metamorphosed rocks, epidote, clinozoisite, biotite, and sphene occur with muscovite and chlorite; secondary albite, in very irregular crystals filled with inclusions of these other minerals, forms overgrowths about detrital plagioclase and extends as replacements along zones of fracture (Figure 3B).

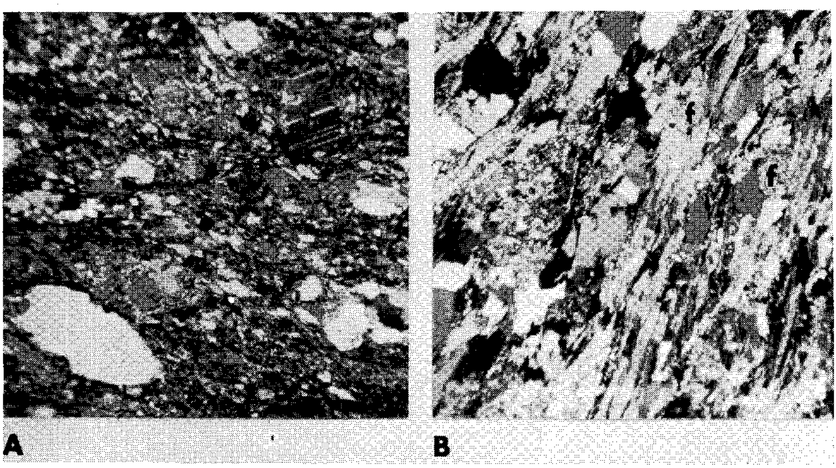


Figure 3. A. Photomicrograph of Evington(?) metagraywacke from north side of the James River, 1.5 miles west-northwest of Hardware. Note clastic nature of most grains. Cross-polarized light, X 24. B. Photomicrograph of largely recrystallized Evington(?) metagraywacke from north side of the James River, 0.7 mile southeast of Shores. Note large size of mica (long shreds) and the reorganized feldspar grains (f). Cross-polarized light, X 24.

Metasedimentary rocks of the Evington Group(?) are relatively nonresistant to chemical weathering, and fresh outcrops are material these have been distorted into lenses and streaks. In most places the rocks are moderately to strongly foliated, but a few massive units occur. Well-developed graded bedding, in units up to 10 inches thick, is evident in some of the less altered material.

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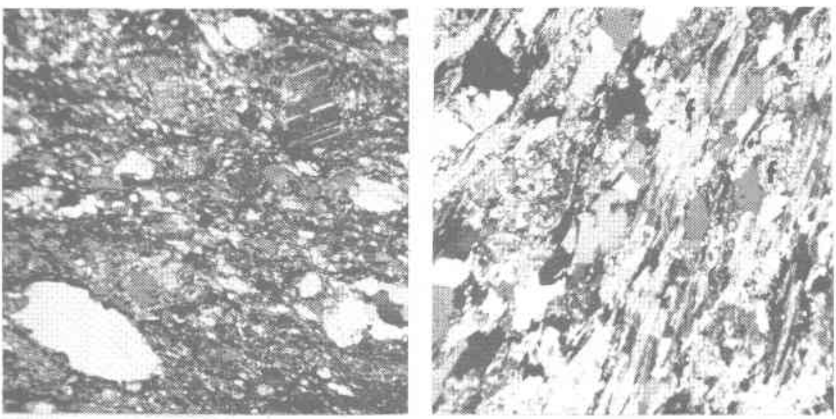

A B

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Metasedimentary rocks of the Evington Group(?) are relatively nonresistant to chemical weathering, and fresh outcrops are virtually lacking in upland areas; excellent outcrops are numerous in most deeper stream valleys such as those of the James River and Big George Creek in the northern part of the quadrangle, Slate River and its main tributaries in the west-central portion of the area, and Peyton and Turpin creeks in the southwestern part of the quadrangle.

Metavolcanic Rocks

Metamorphosed igneous rocks, interpreted to be of volcanic origin, occur interlayered with metasedimentary rocks in the Evington Group(?). They are especially numerous along the flanks of the Hardware anticline and just northwest of the belt of Arvonia slate outcrop. They are predominantly of two types: (1) green highly altered varieties, termed "greenstones", interpreted to be mostly altered mafic volcanic rocks, and (2) gray to pale green, generally less schistose and less altered, porphyritic rocks of dacitic composition. The first are readily mappable and are designated "greenstone volcanics" on the geologic map (Plate 1). In upland areas of deep weathering, the dacitic rocks are difficult to separate from associated feldspathic metasedimentary rocks; therefore, the unit as mapped contains variable amounts of each lithology.

The greenstones are mostly medium to dark green and from slightly to strongly schistose. They weather to a distinctive reddish tan or variegated saprolite. Cleavage surfaces are generally coated with chlorite. In thin section, actinolite, an important constituent of the rock, occurs in rough crystals as much as 0.3 mm long; chlorite and epidote are also generally abundant and predominate in some thin sections (Appendix, Part 2). Small grains and veinlets of quartz are plentiful in places. Plagioclase feldspar, in considerably altered anhedral grains or, locally, as phenocrysts and crudely aligned rough laths, is abundant in some of the greenstones but is largely or completely absent in others. Its composition is generally sodic oligoclase, but it was almost certainly more calcic before metamorphism, with appreciable calcium having gone into the formation of epidote, carbonate minerals, and sphene. Amygdaloidal facies occur in places, notably along the Chesapeake and Ohio Railway northeast of Strathmore. Massive light yellowish-green epidosite, consisting predominantly of quartz and epidote, is common as lenses and masses within other varieties of greenstone.

The metavolcanic rocks of dacitic composition are mostly light gray to pale green; some are dark gray and, rarely, purplish. Most are somewhat porphyritic; phenocrysts are plagioclase feldspar and quartz, commonly in stubby rounded to euhedral beta forms.

Where fresh, these rocks are hard and tough, somewhat resembling quartzite, and those with quartz phenocrysts can be easily mistaken for fine conglomerate. They are massive to schistose; a streaked arrangement of minerals is common. In places these rocks are sufficiently resistant to form low monadnocks.

In thin section some specimens of the dacitic rocks are remarkably unaltered (Figure 4). Feldspar phenocrysts, ranging in composition from albite to oligoclase (An_{5-16}), are generally present and commonly occur in clusters; in general they are not more than 1 to 2 mm long, although some 4 mm long were observed. The more calcic varieties occur east of the almandine isograd (Appendix, Part 2). Quartz phenocrysts, which occur in many of these rocks, tend to be somewhat larger than feldspar phenocrysts, and corrosion of the quartz is common. The matrix in most specimens is an intergrowth of anhedral more or less equidimensional plagioclase and quartz grains of 0.03 to 0.04 mm average dimension. In some, the feldspar is in the form of rough, somewhat aligned laths that average 0.06 to 0.16 mm in length. Epidote and clinozoisite occur scattered through most specimens but generally do not make up over 2 to 5 percent of the rocks. Secondary chlorite, muscovite, and/or biotite are plentiful in more schistose varieties. Actinolite and garnet occur near metamorphosed dioritic intrusives of the Hatcher.

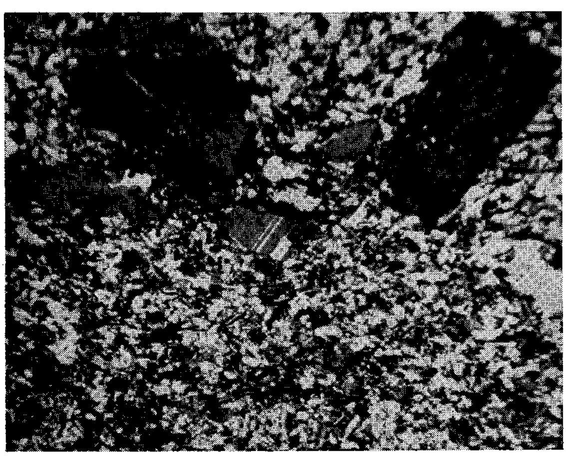

Figure 4. Photomicrograph of almost undeformed porphyritic dacite of the Evington Group(?) from 0.3 mile west of Penlan. Cross-polarized light, X 41.

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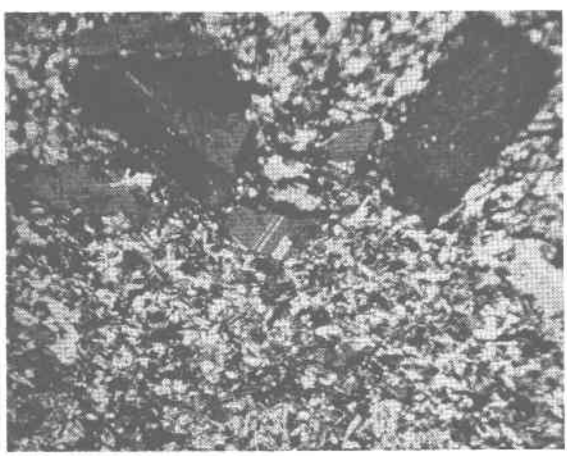


Figure 4. Photomicrograph of almost undeformed porphyritic dacite of the Evington Group(?) from 0.3 mile west of Penlan. Cross-polarized light, X 41.

ROCKS OF UNCERTAIN AGE

A heterogeneous group of metamorphic rocks, of uncertain age and mostly of sedimentary origin, are present in the broad Whispering Creek anticline in the south-central part of the Dillwyn quadrangle. They were intruded by quartz diorite and pegmatite of the Hatcher Complex. Northeastward and southeastward from this anticline they interfinger with and grade into the granitic rocks of this complex, and for some distance foliation attitudes in the granitic rocks are similar to those of rocks in the Whispering Creek anticline. These rocks of uncertain age have been described by Espenshade and Potter (1960, p. 36-42). They are chiefly biotite gneiss, hornblende gneiss, mica schist, and micaceous quartzites (Plate 1). Most of them are garnetiferous. About 4 miles east of Dillwyn some of the quartzites are sufficiently rich in magnetite and specular hematite to have supported small-scale mining. Kyanite-rich quartzites also occur in this area and to the south. One ledge, from 15 to 50 feet thick, is continuous southwestward to near the Willis Mountain kyanite mass which is presently being mined (Espenshade and Potter, 1960, Plate 2). A 1-foot-thick bed of fuchsite quartzite crops out beside State Road 650, 0.5 mile west of Zion Church and 6 miles east-southeast of Dillwyn. Several masses of garnet-amphibole-quartz rock and porphyroblastic slate, apparently of the Arvonia Formation, occur infolded with the older rocks of uncertain age. They are probably separated from these older rocks by marked unconformity.

Biotite Gneiss

Biotite gneiss occupies most of the central part of the Whispering Creek anticline in the Dillwyn quadrangle and occurs interlayered in variable proportions with hornblende gneiss along its flanks. The rock is generally nonresistant and along ridge roads has weathered to saprolite. Good exposures, however, occur along Whispering Creek and its tributaries, along Little Buffalo Creek, and in the vicinity of Tower Branch.

In general the rock is medium gray, fine to medium grained, and from weakly to moderately foliated. It contains numerous pegmatitic lenses and stringers. Quartz is the most abundant mineral; feldspar makes up about 6 to 30 percent of the rock and is mostly oligoclase (Appendix, Part 3). Feldspar in the gneiss on the northwest flank of the Whispering Creek anticline, just northwest of Tower Hill, however, ranges from andesine to bytownite. Biotite and muscovite are generally plentiful; and garnet, in places as much as 1.0 cm in diameter, occurs in most specimens. Common accessories are clinozoisite, epidote, carbonate minerals, sphene, zircon, tourmaline, iron oxides, pyrite, and pyrrhotite.

Hornblende Gneiss

Hornblende gneiss in the Whispering Creek anticline is essentially the same as that in the Hatcher Complex. The lithology of this gneiss is described in the discussion of the Hatcher.

Mica Schist

Quartz-mica and mica-quartz schists commonly occur interbedded with the gneisses and quartzites of uncertain age in the Whispering Creek anticline. In places, such as just south and east of Tower Hill and 1 to 2 miles west of Nuckols, they constitute the dominant rock type over sizable areas. These schists range from nearly white to dark gray or greenish where fresh; the darker varieties tend to weather red-brown. Most are coarse grained and garnetiferous. Muscovite is generally the chief micaceous mineral, but biotite and/or chlorite are commonly present. Feldspar, chiefly oligoclase, is distinctly subordinate to quartz in the schists but increases proportionately where they grade into the gneisses. Kyanite is locally present, particularly in the more quartzose schists. Accessory minerals include magnetite, zircon, tourmaline, pyrite and apatite.

Kyanite Quartzite

The kyanite-bearing rocks of this region have been mapped and described in detail (Espenshade and Potter, 1960). Just south of the Dillwyn quadrangle kyanite quartzite occurs in prominent ridges along both flanks of the Whispering Creek anticline. The band on the west flank, which is being quarried commercially for kyanite at Willis Mountain 1.7 miles south of the quadrangle, does not appear to extend into the Dillwyn quadrangle. The band on the east flank enters the quadrangle at the intersection of U. S. Highway 60 and State Road 632, 5.2 miles east of Sprouses Corner, and is continuous thence northeastward for at least 2.5 miles. Segments, presumably of the same band, occur offset to the southeast and 2.5 miles farther to the north. The thickness of the kyanite quartzite in this quadrangle ranges from about 10 to 50 feet. It is relatively resistant and tends to form distinct ridges. Where outcrops are lacking, it generally can be detected by the presence of plentiful blades of kyanite, 0.5 to 3 cm long, in the soil.

The kyanite quartzite is typically light gray to tan or brown where iron oxide stained and is weakly to rather strongly schistose. Elongate cleavage plates of kyanite, commonly accompanied by muscovite and lying within the planes of foliation, occur in a matrix of glassy quartz. The kyanite content of the rock in this area is from less than 10 to about 30 percent; the rock is predominantly quartz. Thin sections commonly contain accessory pyrite and rutile and very minor clinozoisite and zircon. Topaz, in rounded and irregular blebs included within and lying between quartz grains, locally makes up as much as 1.0 percent of the rock in the Willis Mountain area.

Ferruginous Quartzite

Quartzite, which is from sparsely to richly banded with concentrations of magnetite and specular hematite, occurs within the area of biotite gneiss and mica schist near the northeast end of the Whispering Creek anticline. Several shafts and prospect pits have been opened in the quartzite. The chief mineral is quartz, but iron oxides locally make up as much as 20 to 40 percent of the rock. Specularite, the most abundant iron mineral, occurs mostly in fine plates, that are aligned to give the rock a moderate to strong schistosity. Fine-grained magnetite is mixed with the specularite, and crystals 1 to 4 mm across locally occur in small concentrations. Veinlets of quartz containing abundant needles of tourmaline cut the rock in places. Masses of pink to brown garnets, reported to be manganiferous (Espenshade and Potter, 1960, p. 40, 53; Taber, 1913, p. 21), are locally present.

Fuchsite Quartzite

A 1-foot-thick bed of schistose fuchsite (chromian muscovite) quartzite crops out beside State Road 650, 0.46 mile west-northwest of its intersection with State Road 626 at Zion Church, 6 miles east of Dillwyn. This occurrence was brought to the writer's attention by James W. Smith. The bed is traceable only about 50 feet north of the road. The rock is pale green streaked with bright green, iron oxide stained in part, and has strong planar foliation. Thin sections show very pale green, weakly pleochroic fuchsite making up 16 to 20 percent of the rock, which is predominantly quartz. Kyanite, in blades as much as 3 mm long, is common, and there are some scattered grains of zircon and rutile. It is likely that the chromium was originally concentrated as placer chromite in the sand. Espenshade and Potter (1960, p. 39, Table 4) reported similar chromian muscovite near Madisonville in Charlotte County and at Baker Mountain in Prince Edward County.

HATCHER COMPLEX

The name Hatcher is here proposed for the complex of granitic gneisses, hornblende gneisses, and associated migmatitic rocks typically exposed in the vicinity of Hatcher in extreme western Cumberland County, 9 miles east-northeast of Dillwyn. The term "granitic" is used here to mean granite-like and refers to rocks ranging in composition from granite to quartz diorite. The granitic rocks of this complex are essentially the same as those previously called Columbia granite (Taber, 1913, p. 62-77; Jonas, 1932, p. 18-19). Renaming is considered desirable because the name Columbia conflicts with that of the Columbia Group (Pleistocene); furthermore, only a few small areas have rock that is compositionally a granite.

The Hatcher Complex underlies approximately the eastern one-third of the Dillwyn quadrangle (Plate 1). To the north, Smith, Milici, and Greenberg (1964, Plate 1) called it the "granodiorite unit" and showed it underlying about 60 square miles in southeastern and northeastern Fluvanna County. The "granite near Carysbrook" (Stose and Stose, 1948, p. 405-406), in contact with the Arvonia Formation around the northeast end of the Arvonia syncline, is considered by this writer to be part of the Hatcher Complex. On the Geologic Map of Virginia (Virginia Division of Mineral Resources, 1963), these granitic rocks are depicted as extending about 40 miles southward from the Dillwyn quadrangle.

In the Dillwyn quadrangle the complex merges westward and southwestward without definite limit into metasedimentary rocks older than Arvonia Formation which are present in the

Whispering Creek anticline, and it appears that at least this part of the Hatcher is the product of migmatization and granitization of the metasedimentary rocks. Masses of hornblende gneiss and dike-like granitic bodies occur wholly within these metasedimentary rocks. To the north in the vicinity of Carysbrook (Smith, Milici, and Greenberg, 1964, Plate 1), a lobe of the "granodiorite unit" (Hatcher Complex) extends around the terminus of the Arvonia syncline and transects metasedimentary and metavolcanic rocks interpreted by the writer as Evington Group(?). In the Dillwyn quadrangle west of the Arvonia syncline, a few small intrusive bodies of granitic rock, probably genetically related to the Hatcher Complex, occur within rocks of the Evington Group(?). Outcrops where this relationship may be seen are present along State Road 610, 1.3 miles west-northwest of Slate Hill, and on the north side of the James River 0.8 mile west-northwest of Shores. Tiny pegmatites of uncertain relation to the Hatcher Complex occur in porphyroblastic Arvonia slate near its contact with this complex at New Canton and just south and southwest of Arvonia.

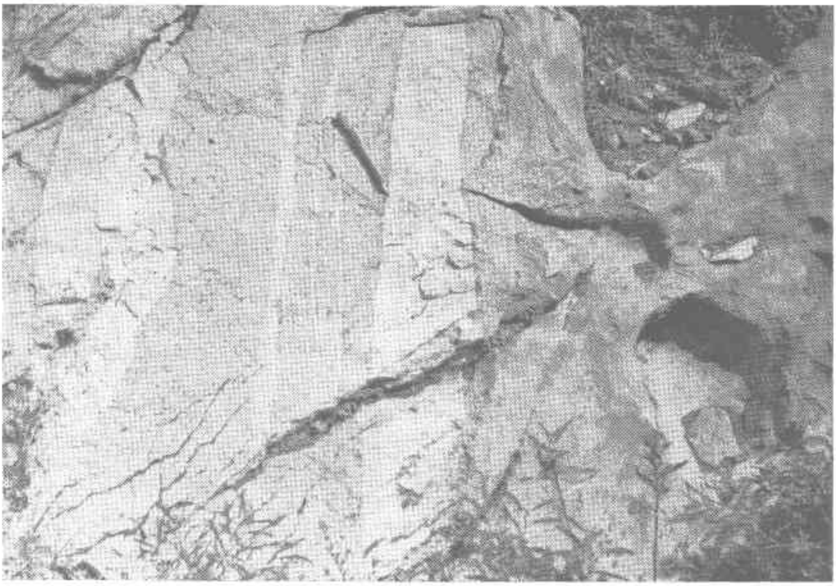
Rocks of the Hatcher Complex are weakly resistant to chemical weathering and tend to be well exposed only in stream valleys. The best exposures of material of granitic composition in the quadrangle are along the James River southeast of Bremo Bluff; typical, but much more restricted, exposures occur on the north side of Buck and Game Creek 0.5 mile north of Hatcher. Hornblende gneiss and migmatitic rocks are widely exposed in small stream valleys and along secondary roads in the southeast-central part of the quadrangle. Typical exposures occur along Halfway Creek west and southwest of Hatcher and along State Road 672 in the hillslopes on both sides of its crossing of Buck and Game Creek 1 mile northeast of Hatcher. Well-developed augen gneiss, presumably part of the complex, is well exposed below the dam of Bear Creek Lake and in tributary valleys to this lake in the extreme southeast corner of the area.

The Hatcher Complex in the Dillwyn quadrangle is composed chiefly of gneissic quartz diorite, hornblende gneiss of dioritic composition, and migmatitic combinations of these two (Figure 5); augen gneiss and gneissic equivalents of quartz monzonite and granodiorite occur locally. The granitic types appear to be younger than the hornblendic rocks, and small pegmatitic and aplitic dikes cut both granitic material and hornblende gneiss.

Figure 5. Migmatite, that is compositionally light-colored aplitic quartz diorite in darker hornblende-quartz diorite, of the Hatcher Complex 0.5 mile east of the town of Bremo Bluff.

Gneissic Granitic Rocks

The gneissic granitic rocks of the Hatcher Complex have a composition that is mostly quartz diorite and a lesser amount of granodiorite, quartz monzonite, and granite (Appendix, Part 4). These rocks are variable in color, texture, fabric, and gneissosity. For the most part they are medium to light gray, medium grained, and have moderately well-developed gneissic structure and strong mineral lineation. In thin section, textures are predominantly xenomorphic-granular. Biotite is the characteristic dark mineral, but hornblende is common in the rock near hornblende gneiss. Pegmatitic and aplitic bodies devoid of dark minerals are present. Porphyritic and/or porphyroblastic varieties are not unusual. About 0.75 mile northeast of Bremo Bluff, a schistose portion of the rock contains subhedral to euhedral crystals of feldspar as much as 4 cm long (Figure 6). The platy minerals abut against and wrap around the feldspar crystals. Carlsbad twinning is present in many of the crystals; they also have intricate twinning resembling that of anorthoclase, but indices of refraction



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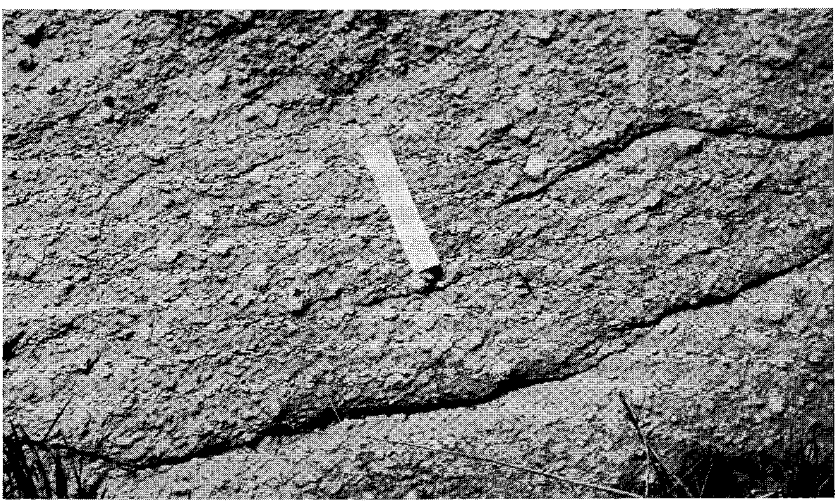

Figure 6. Porphyritic quartz dioritic rock of the Hatcher Complex 0.5 mile northeast of the town of Bremo Bluff. Phenocrysts are composed of albite.

Augen gneiss, found chiefly in the vicinity of Bear Creek Lake near the southeast corner of the quadrangle (Plate 1), appears to be the result of very strong granulation of Hatcher dioritic and quartz monzonitic gneiss. Augen from about 2 to 15 mm long, are chiefly plagioclase feldspar (An_{30-39}), but in places they are

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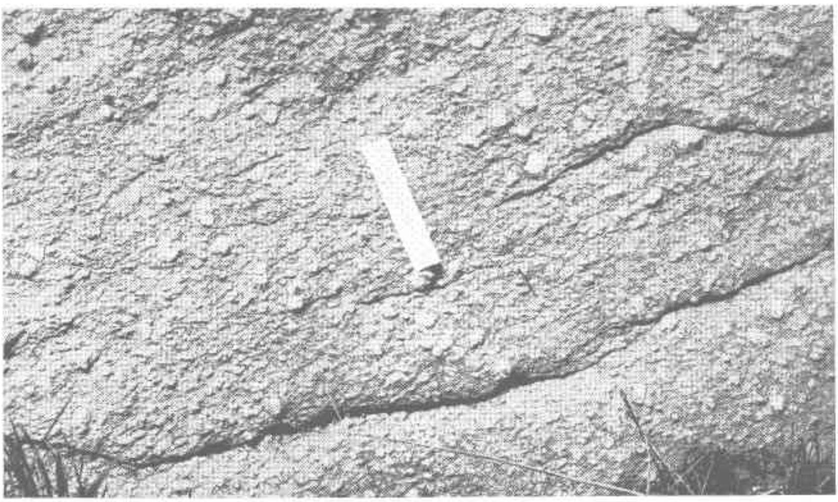

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Hornblende Gneiss

Hornblende gneisses occur widely within the Hatcher Complex in the Dillwyn quadrangle but are far less conspicuous in that part of the Hatcher which has been mapped north of the James River (Smith, Milici, and Greenberg, 1964, Plate 1). They constitute a dominant part of this complex in the Dillwyn quadrangle near the northeast end of the Whispering Creek anticline where igneous-appearing gneisses of the complex merge with metasedimentary rocks in this anticline (Plate 1). Hornblende gneisses, essentially like those associated with the metamorphosed granitic rocks of the Hatcher Complex, also occur interlayered with the metasedimentary rocks in the Whispering Creek anticline. The following description applies to hornblende gneisses associated with rocks of uncertain age in the Whispering Creek anticline as well as to the hornblende gneisses within the Hatcher Complex. The hornblende gneisses of the Hatcher Complex typically occur migmatitically interlayered with the granitic rocks (Figure 5) and also as irregular branching or sheet-like masses from about 1 foot thick to as much as 0.75 mile wide within these granitic rocks. Masses of hornblende gneiss within the areas of metasedimentary rocks have similar size and branching or sheet-like form.

The hornblende gneisses range from medium greenish gray to nearly black, fine to coarse grained, and weakly to strongly foliated. They are mostly of dioritic to quartz dioritic composition. Foliation is typically of linear type, but some fine-grained chloritic varieties have prominent planar foliation. A nearly massive variety in which the minerals have little preferred orientation, designated on Plate 1 as "hornblende gneiss with pattern," is common in the southern part of the quadrangle (Figure 7). In this type, rods of hornblende from 0.5 to 2.5 cm long, with or without plates of chlorite of similar size, occur in crudely radial masses within a matrix of light-colored granular glassy plagioclase and quartz.

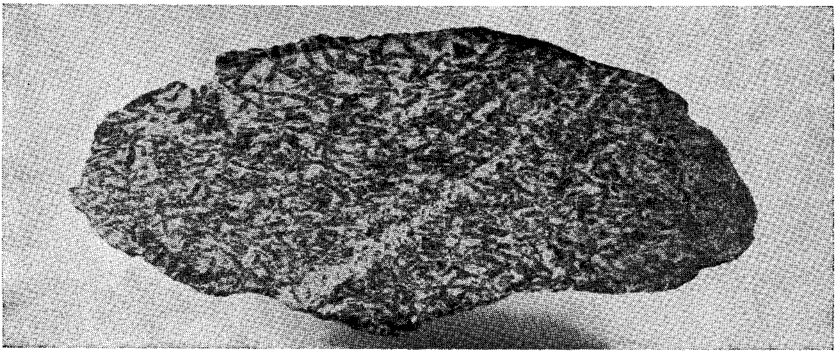


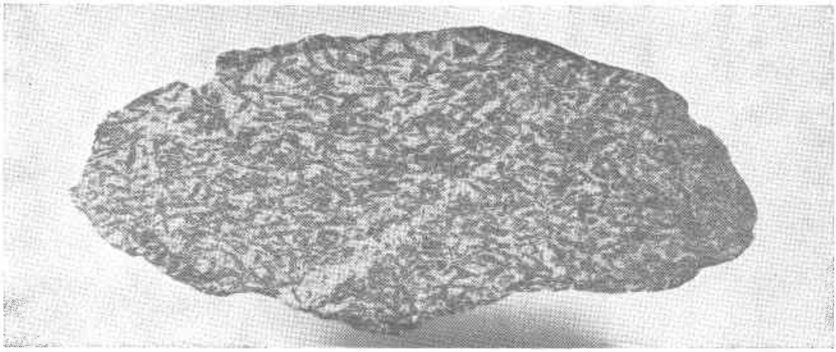
Figure 7. "Patterned" hornblende gneiss of the Hatcher Complex from the east side of Hatcher Creek at State Road 669, 1.5 miles northeast of Tower Hill, X 0.7.

In thin section the hornblende gneiss has textures that range from crystalloblastic to xenomorphic-granular. Hornblende, the predominant dark mineral, occurs in elongate crystals with very irregular outlines and many inclusions of plagioclase and, in some cases, quartz. Plagioclase ranges from oligoclase to calcic andesine and averages about middle andesine (Appendix, Part 5). Quartz is locally plentiful. Other minerals, in approximate order of abundance, include chlorite, hematite, and pyrrhotite. Kyanite is of limited occurrence. One thin section of hornblende gneiss from 0.3 mile east of Rosney contains about 10 percent of the scapolite mineral, mizzonite, in grains as large as 1 by 2.3 mm. The scapolite is concentrated mainly within certain medium-coarse bands in the gneiss. It is anhedral, commonly fractured, and occurs between and around other minerals.

ULTRAMAFIC ROCKS

Sill-like bodies of ultramafic rock, chiefly actinolite-chlorite schist and a lesser amount of soapstone, occur in rocks of the Evington Group(?) along both flanks of the Hardware anticline (Plate 1). The largest, over 4.5 miles long and about 1300 feet in maximum width, extends northeastward 0.4 mile east of Diana Mills. One small body within Hatcher quartz diorite gneiss 2 miles east-southeast at Bremo Bluff has been quarried on a small scale.

The ultramafic rocks are mostly pale to dark greenish gray or grayish green, and tend to make small knobs and low ridges.



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Soapstone, serpentinite, and actinolite-chlorite schist occur together, either as contrasting segregations in the same body, or, less likely, as composite injections. Parts of some bodies are slightly feldspathic. Thin sections show the rocks to be nearly or completely crystalloblastic. Ragged shreds and acicular crystals of actinolite are intimately intermixed with chlorite, or chlorite and talc in the soapstone (Appendix, Part 6). Both chlorite and talc appear to have been derived, at least in part, from actinolite. Much talc, however, is in rounded masses 0.6 to 1.0 mm across which were probably olivine; antigorite is similar in occurrence. Magnetite and a minor amount of chromite occur as accessories. A dark-green quartz-muscovite-chlorite rock occurs as part of, or associated with, the large body of ultramafic rock just east of Diana Mills. It may represent a late, high-silica, high-potash segregation, but the lack of feldspar and the presence of rounded zircons suggest that it is metasomatically altered wall rock.

HORNBLENDE METADIORITE

A body of hornblende metadiorite and related mafic and ultramafic rocks, oval shaped in outline, is associated with the Evington(?) metagraywacke along the axial portion of the Hardware anticline in the northwestern part of the quadrangle (Plate 1). The body is 4.5 miles long by 1.8 miles wide and is crossed by State Roads 671 and 611 which intersect at Diana Mills. Its border is generally concordant with foliation in the enclosing metagraywacke which, except for enlarged micas and mica porphyroblasts near the contact, shows little effect from the intrusion. The porphyroblasts have cleavages oriented at an angle to the foliation and they push the foliation aside; also tiny aplitic apophyses penetrate the wall rocks parallel to foliation. In addition, the intrusive body locally contains numerous inclusions of metasedimentary schist. Thus it is evident that the igneous mass was intruded after the dynamic metamorphism that produced the foliation. The rocks are chiefly of hornblende metadiorite and hornblende-quartz metadiorite; hornblendite, amphibolite, metaperidotite, orbicular serpentinite, and pegmatitic and aplitic bodies are also present (Appendix, Part 7). The rock assemblage is suggestive of a layered intrusive. All of these rock types have been mapped with the unit shown as hornblende metadiorite on Plate 1. Similar hornblende metadiorite occurs in sill-like bodies south of Spreading Oak Church just west of the main body, and 2 to 2.5 miles east and southeast of it.

The metamorphosed hornblende diorite and hornblende-quartz diorite are typically dark grayish green, medium grained, and porphyritic. Much of the rock is nearly massive, but in places it displays a crude foliation. Phenocrysts are white, somewhat glassy, plagioclase feldspar (An_{39-42}) in tabular subhedral to anhedral crystals, 1 to 10 mm long. The dark-green to black matrix is composed chiefly of phaneritic hornblende and plagioclase; in places biotite exceeds hornblende in amount. Microscopic examination of the rock indicates that it has undergone moderate to very strong alteration. Less altered portions have a primary hypidiomorphic texture, with some crystal faces on the plagioclase, hornblende, and biotite. Dark-green euhedral to subhedral hornblende crystals with interstitial plagioclase are thought to be pyrogenic; ragged to acicular pale-green amphibole, common in some sections, is of secondary development. Quartz, where present, is interstitial to plagioclase and amphibole, and is locally accompanied by minor amounts of potassic feldspar that replaces plagioclase. In highly altered parts of the rock, plagioclase has lost much lime to epidote minerals and its composition has been changed to An_{8-15}; much hornblende also has gone to chlorite, and ilmenite has altered to sphene and leucoxene. Apatite, zircon, muscovite, magnetite, hematite, and pyrrhotite occur in accessory amounts.

Hornblendites containing little or no feldspar occur near Dry Creek 0.5 mile south-southeast of Diana Mills. These are dark green and medium to coarse grained. Hornblende, the dominant mineral, occurs as blocky euhedral to subhedral crystals as much as 6 mm long. Highly altered feldspar and euhedral crystals of apatite 0.5 mm across fill some interspaces between well-formed hornblende crystals. Amphibolite, distinct from hornblendite in that it is composed dominantly of ragged crystals of pale-green uralitic hornblende, occurs along State Road 611 about 1 mile and 2 miles north of Diana Mills. Dark-green coarse-grained metaperidotite, similar in outward appearance to the amphibolite, is present 1.5 miles west-southwest of Taggart. In thin section this rock consists predominantly of anhedral pale-green crystals of amphibole, many of which contain irregular remnants of relict clinopyroxene and orthopyroxene and rounded blebs of serpentine with central cores of acicular tremolite. The serpentine-tremolite masses apparently replaced olivine.

An orbicular serpentine-rich rock occurs beside State Road 611 just south of Sharps Creek 1.8 miles north of Diana Mills.

The orbicules are mostly oval in outline, although some have squarish corners; they range from about 1 inch to as much as 9 inches in diameter (Figure 8). They are composed predominantly of fibrous antigorite with a tendency toward radial arrangement; concentric banding is present only at the periphery of these orbicules. The fresh antigorite is dark greenish gray; in weathered orbicules the interior is yellowish white. In thin section many orbicules appear to have been cracked and the cracks filled with magnetite, chlorite, and talc. Inter-orbicular material is mostly dark-gray serpentinite containing variable amounts of talc, amphibole, and chlorite and fragmentary remnants of pyroxene.

Figure 8. Block of weathered orbicular serpentinite 1.5 miles north of Diana Mills. Scale indicated by pencil at the top.

Pegmatitic bodies containing as little as 10 percent dark minerals and aplitic rocks lacking in dark minerals occur in the vicinity of Diana Mills and 1.5 miles to the southwest. In addition to plagioclase (An_{7-12}), both contain epidote, clinozoisite, muscovite, and generally quartz; hornblende crystals in some pegmatites are 2 inches long.

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ARVONIA FORMATION

N. H. Darton (1892) referred to "the roofing slate at Arvon, Buckingham County, Virginia," and Dale (1906, p. 114) described the "Arvonia slates" being quarried at and near Arvonia. In this paper, the Arvonia Formation is considered to include not only the roofing slates referred to by Darton and Dale but also the more highly metamorphosed equivalents (the "knotted schists" of Taber, 1913, p. 29-34); the quartzites in the vicinity of Bremo Bluff on the James River; quartzites and conglomeratic schists that occur in places at the base of the slates and schists; and a distinctive garnet-amphibole-quartz rock that occurs in the lower part of the "knotted schists." The total thickness of the formation so defined is estimated to be about 3500 feet.

The Arvonia Formation in the Arvonia syncline crops out in a belt 1.3 to 2.7 miles wide extending northeastward through the central part of the Dillwyn quadrangle (Plate 1). From just south of the James River southwestward, the belt of Arvonia rocks is separated into easterly and westerly portions by the overlying Buffards Formation. About 4 miles north of the Dillwyn quadrangle, near Carysbrook, this belt of Arvonia Formation terminates at the northeast end of the Arvonia syncline (Smith, Milici, and Greenberg, 1964, Plate 1). Slate, probably present as lesser synclinal infolds of Arvonia Formation, also crops out in two narrow belts just west of the Arvonia syncline. The westernmost and longer of the two has been called the Long Island syncline (Smith, Milici, and Greenberg, 1964, Plate 1).

Slate

The Arvonia Formation consists predominantly of slate and porphyroblastic slate and schist. Non-porphyroblastic, or slightly porphyroblastic, slate, which includes the commercial roofing slates, occurs chiefly in the northwest limb of the Arvonia syncline north of Alpha (Plate 1). Roofing slates have been quarried only within an area about 0.5 mile wide and 5 miles long, extending from the vicinity of Bremo Mansion just north of the James River southwestward to near Penlan.

Fresh Arvonia slate is dark gray, lustrous, and hard; the weathered slate is light gray or tan and soft in variable degree but still lustrous. Thin plates give a decided ring when struck with a hammer. It breaks with nearly flat surfaces, which in the best slate are almost parallel with bedding. Intersections of bedding and cleavage occur in much of the slate as lineations of variable prominence on the cleavage surfaces (Figure 9).

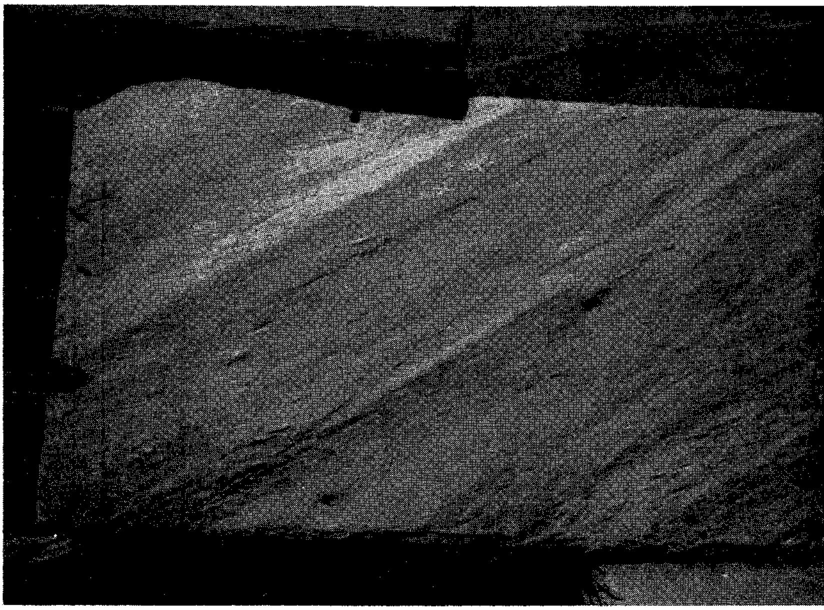

Figure 9. Arvonia roofing slate showing bedding-cleavage lineations (diagonal lines) and grain (faint horizontal lineation) on the large cleavage surface.

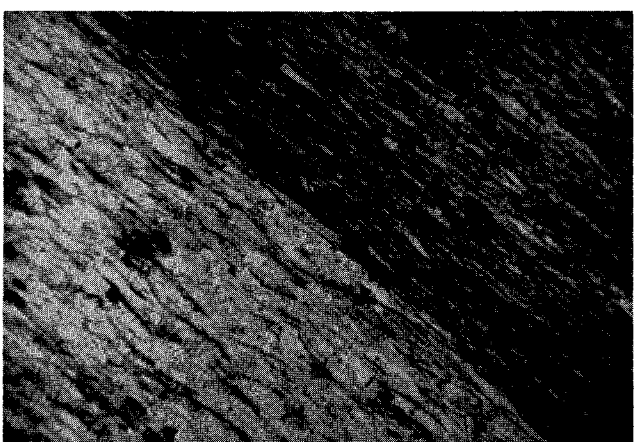

Figure 10. Photomicrograph of Arvonia slate cut perpendicular to bedding. The light-colored portion is highly quartzose; the darker portion is rich in muscovite. Plane-polarized light, X 68.

In thin section most of the slate consists chiefly of muscovite in nearly parallel flakes 0.02 to 0.065 mm long, with strong aggre-

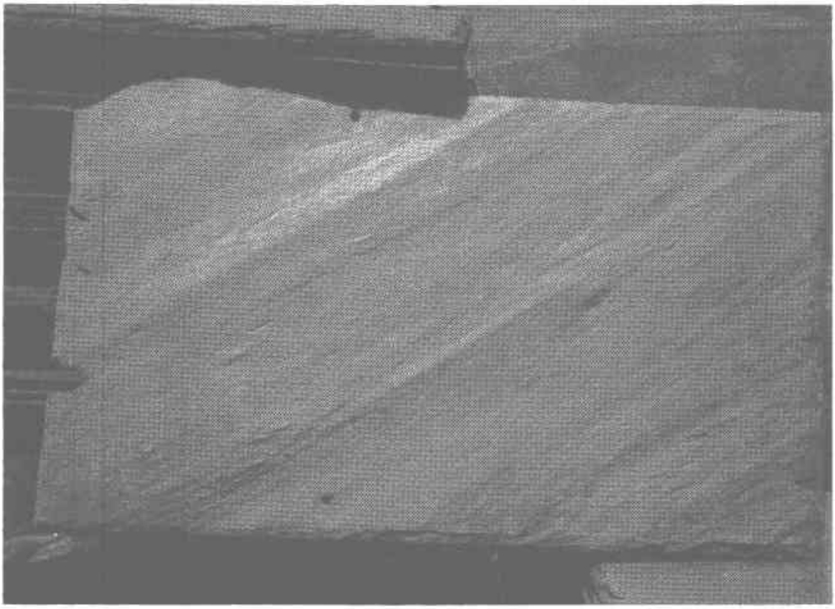

Figure 9. Arvonia roofing slate showing bedding-cleavage lineations (diagonal lines) and grain (faint horizontal lineation) on the large cleavage surface.

Figure 10. Photomicrograph of Arvonia slate cut perpendicular to bedding. The light-colored portion is highly quartzose; the darker portion is rich in muscovite. Plane-polarized light, X 68.

In thin section most of the slate consists chiefly of muscovite in nearly parallel flakes 0.02 to 0.065 mm long, with strong aggregate polarization, and variable quantities of interlayered flattened lenses of quartz of similar length (Figure 10). Local quartzose portions of the slate, however, contain more than 50 percent quartz. Some plagioclase feldspar is discernible in most sections (Appendix, Part 8); chlorite is lacking or occurs only in minor amount. Biotite porphyroblasts from 0.07 by 0.25 mm to 0.18 by 0.5 mm, oriented with cleavage at a large angle to the foliation, make up a few percent of most thin sections. Carbonate minerals, in broad irregular patches across the foliation, are plentiful in some layers but are largely absent in most of the slate. Detrital grains of tourmaline and zircon occur sparingly. Magnetite is the most abundant opaque mineral, but pyrite and pyrrhotite also occur.

The Arvonia slate has for many years attracted the attention of geologists because it is one of the few fossiliferous metasedimentary rocks in the southeastern Piedmont for which an accurate age is known. N. H. Darton (1892) announced the discovery of fossils in the roofing slates of Arvonia. Watson and Powell (1911, p. 43-44) listed forms discovered and stated that R. S. Bassler had concluded that the assemblage seems to be of middle Cincinnatian age. A further discussion of the age significance of the fossils was given by Stose and Stose (1948, p. 404-405). Since the initial discovery, other fossils have been found from time to time, mainly within the slate quarries (Figures 11, 12). Most are poorly pre-

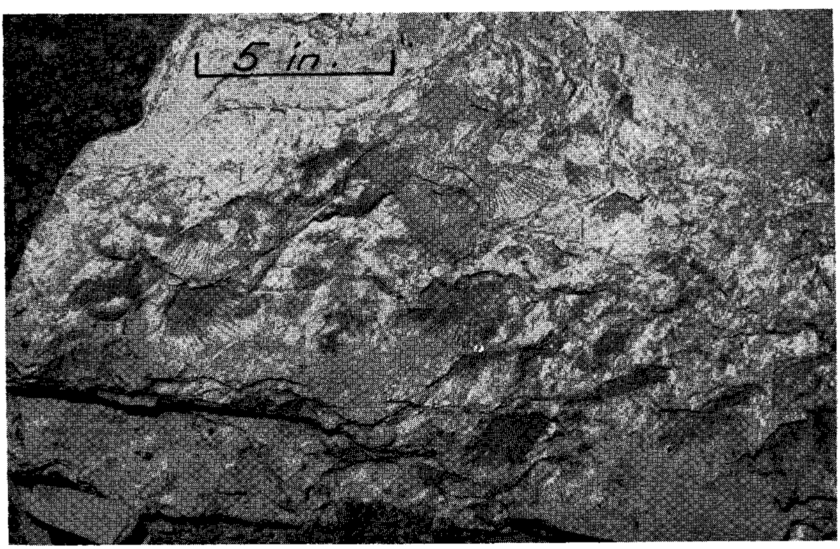

Figure 11. Fossil-bearing slab of Arvonia slate from the Pitts quarry, 0.8 mile west of Arvonia.

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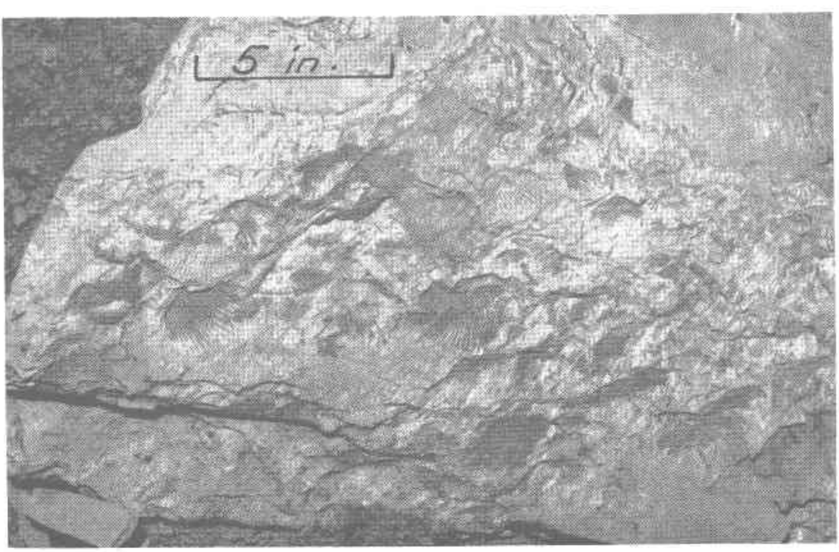

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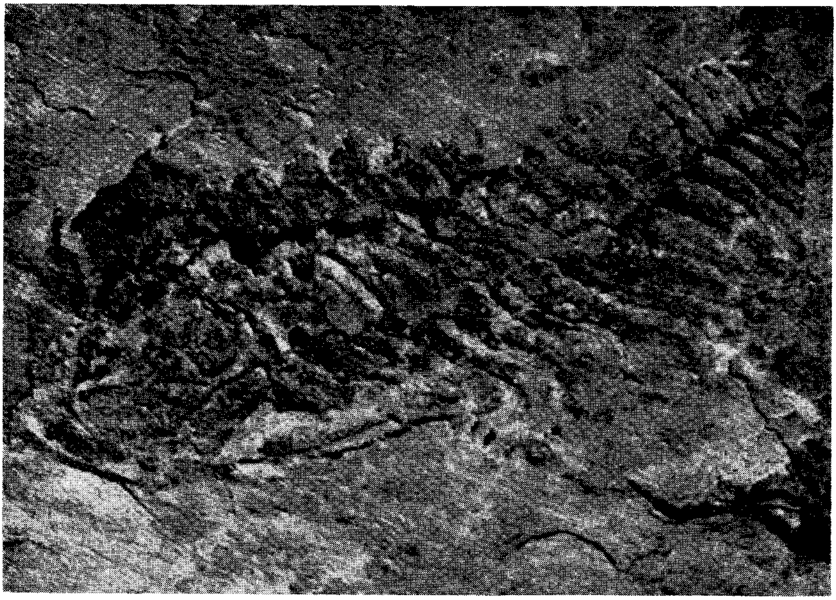

Figure 12. Fossil trilobite in Arvonia slate from the Arvonia-Buckingham Slate Company, Inc. quarry near Arvonia. This fossil was found by Frank Jacobeen and tentatively identified as belonging to the suborder Calymenina (Chauncey G. Tillman, personal communication). X 1.7.

Early fossil finds appear to have come chiefly from the Old Williams quarry and dump near Arvonia Station (Stose and Stose, 1948, p. 399). At the time of this writing, fossils can be found 1 mile south of Arvonia Station in the dump of the northern Pitts quarry and in the adjacent LeSueur-Richmond Slate Corporation quarry just to the north; fossils are also present in the bottom of the Yancey quarry of the Arvonia-Buckingham Slate Company, Inc., 0.2 mile south of Arvonia Station. The writer found primative bryozoa along State Road 652 just east of Bridgeport and a brachiopod beside the Chesapeake and Ohio Railway 1.2 miles southwest of Carysbrook. Smith, Milici, and Greenberg (1964, p. 16-18) reported the finding of crinoid columnals in the Bremo Member of the Arvonia Formation at New Canton and of a brachiopod or pelecypod shell in Arvonia quartzite 0.25 mile south of Carysbrook.

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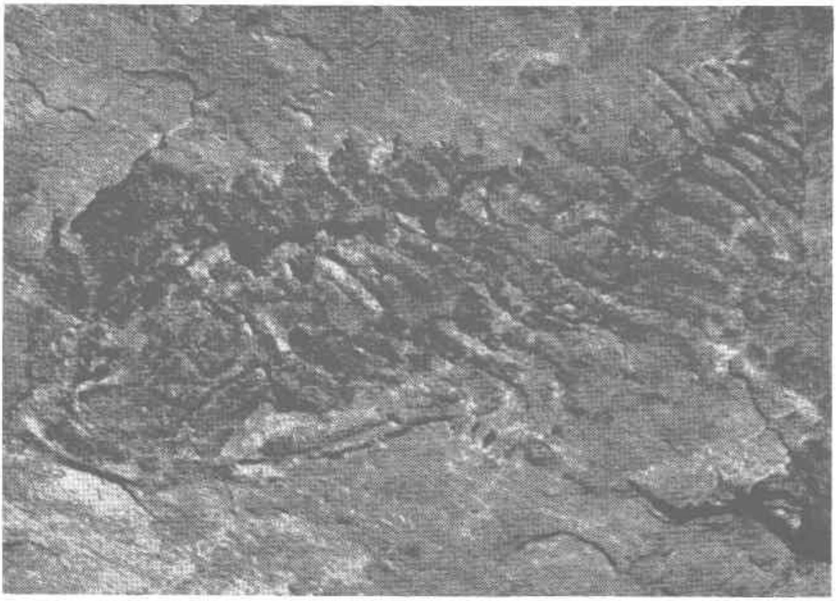

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Slate of the Arvonia Formation becomes slightly coarser grained toward the southeast where the effects of metamorphism have been more intense. Porphyroblasts of biotite and, farther southeastward, of garnet are present (Appendix, Part 8); the latter tend to be very numerous near the adjoining Hatcher Complex to the southeast. Except in some of the unusually coarse portions, the porphyroblastic slate generally retains a dark-gray color. Matrix minerals are predominantly quartz and muscovite, but average grain size, 0.06 to 0.08 mm, is generally larger than that in the roofing slates. Both biotite and garnet porphyroblasts are mostly between 1 and 2 mm in diameter, and both have sieve textures produced by included grains of quartz. The porphyroblasts developed later than the foliation, however, and pushed aside micas of the matrix as they grew.

Conglomeratic Schist and Quartzite

Thin micaceous quartzites occur in places at or near the base of the Arvonia Formation, particularly along the southeast flank of the Arvonia syncline. Where Arvonia Formation is in direct contact with metamorphosed dioritic rocks of the Hatcher Complex, from just east of Bremo Bluff on the James River northeastward around the end of the Arvonia syncline, a distinctive conglomeratic quartz-mica schist, 10 feet to several hundred feet thick, lies between Arvonia schist and the Hatcher (Plate 1; Smith, Milici, and Greenberg, 1964, Plate 1). The writer has not observed the schist and the dioritic rocks in actual contact. Just west of the crossing of State Road 672 by the Chesapeake and Ohio Railway 1.3 miles southwest of Carysbrook and 3.5 miles north of the Dillwyn quadrangle, slate is interbedded with conglomeratic schist. Good exposures of this schist are: in Holman Creek 0.25 mile east of Bremo Bluff; along the west side of U. S. Highway 15 at the southern town limit of Fork Union; along State Road 672 just west of its junction with U. S. Highway 15, 0.6 mile south of Carysbrook; and along the Chesapeake and Ohio Railway 0.5 mile southwest of Carysbrook. The last three localities are in the Scottsville quadrangle which adjoins the Dillwyn quadrangle on the north.

Arvonia conglomeratic schist is generally light greenish to yellowish gray, specked with iron oxide and/or chloritoid, and dotted with clear to smoky or pale-blue quartz pebbles from 2 to 4 mm long. Lineation tends to be fairly strong in the rock but schistosity is imperfectly developed. In thin section the conglomeratic schist (Figure 13) consists predominantly of muscovite and quartz, the former commonly comprising over 50 percent.

Most of the pebbles were derived from vein quartz and exhibit strong undulatory extinction; some are well rounded but generally they have irregular outlines as a result of replacement by sericite. Fragments of phyllite, quartzite, and fine-grained quartz-biotite-muscovite schist from 1.0 to 2.2 mm long, with their directions of foliation randomly oriented, locally make up as much as 5 to 10 percent of the rock; coarse grains and small pebbles of microcline are also plentiful in places. The included schist fragments are unlike typical Evington Group(?) schists. Chloritoid occurs in most sections; biotite, chlorite, and plagioclase feldspar are common in small quantity; and zircon, epidote, and clinozoisite occur locally. Garnet and staurolite occur sparingly east of the almandine isograd. X-ray analysis shows the rock at the southern town limit of Fork Union to contain more than 15 percent paragonite.

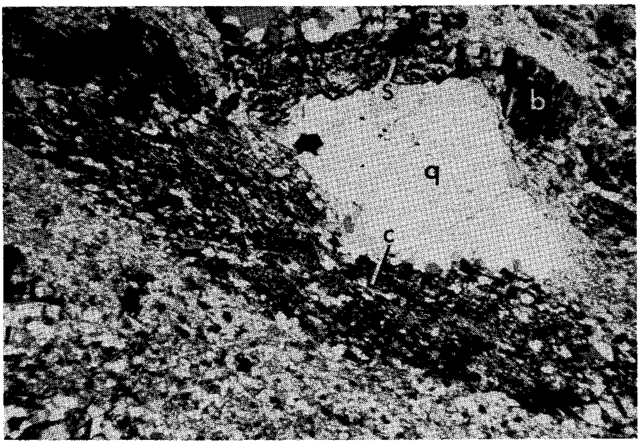

Figure 13. Photomicrograph of Arvonia basal conglomeratic schist from Holman Creek, 0.4 mile northeast of the town of Bremo Bluff. A pebble of quartz (q) lies against a shistose rock fragment, now largely replaced by chloritoid (c). Above the pebble are staurolite (s) and biotite (b). Cross-polarized light, X 24.

Garnet-Amphibole-Quartz Rock

A distinctive garnet-amphibole-quartz rock from 5 to 100 feet or more thick occurs, in places, in the lower part of the Arvonia Formation. West of the almandine isograd, this unit grades into an oolitic chlorite schist (Smith, Milici, and Greenberg, 1964, p. 15). This "key bed" marks the approximate base of the Bremo Member of the Arvonia Formation where this member is present in the

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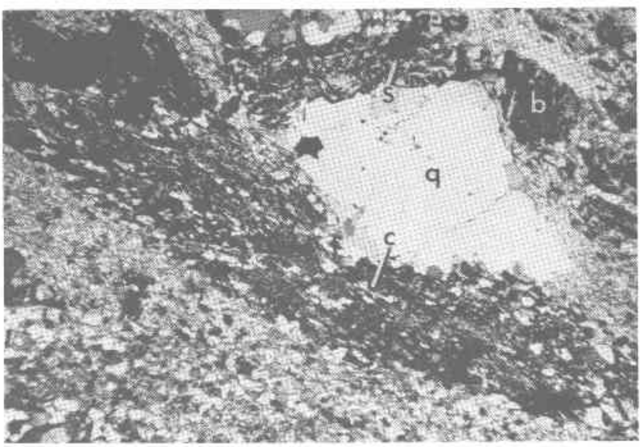

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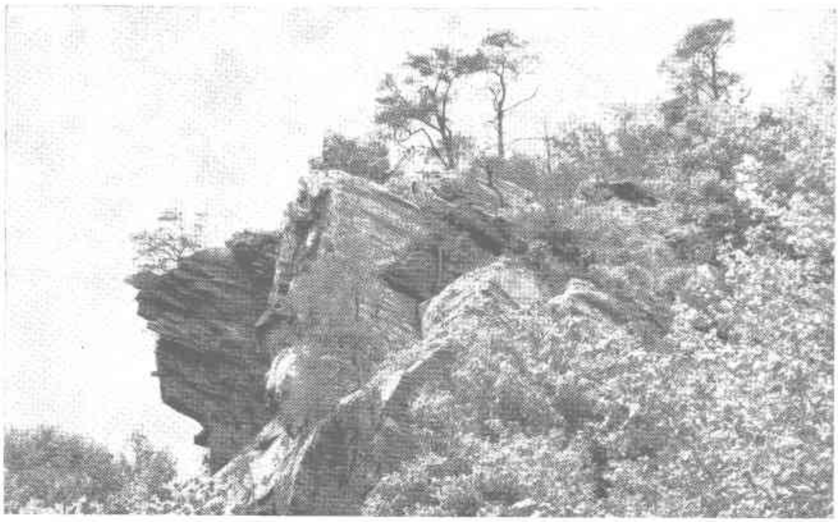
The garnet-amphibole-quartz rock is green to dark reddish brown and spotted with abundant red to brown garnets up to 1 cm across. In places the garnets occur as euhedral crystals, but more commonly they are somewhat broken and irregular. In some thin sections the garnets are granulated and shredded. Finely granular quartz is generally abundant; it occurs in irregular masses and as fillings between and inclusions within other minerals. Actinolite in blades as much as 3.6 mm long wraps around, abuts against, and is intimately intergrown with garnet. In places, particularly to the northeast, chlorite is a common constituent; it occurs mainly in association with garnet. In the weathered rock, hematite and limonite are prominent as crack fillings and replacements in garnet and as stains on other minerals. On the northeast side of Tower Hill 3.5 miles east-northeast of Dillwyn, iron oxides were sufficiently abundant to encourage the digging of prospect pits for iron ore. Espenshade and Potter (1960, p. 48) reported a few percent each of kyanite and sillimanite in garnet-actinolite-quartz rock in a narrow belt that extends east from Tower Hill.

Bremo Member

The Bremo Member of the Arvonia Formation is here considered to include the quartzite-bearing portion of this formation, 1000 feet or more thick, typically exposed at Bremo Bluff (Figure 14) and westward along the James River (Plate 1). Individual beds of quartzite tend to become thinner, and the proportion of quartzite to slate and schist diminishes from the vicinity of Bremo Bluff westward. The quartzite is mostly light gray, fine to medium grained, and weathers tan; beds of quartz-pebble conglomerate, some pebbles of which are about 2 cm long, occur locally. Cross-bedding is visible in places. In thin section the chief minerals are quartz, muscovite, and chlorite. Feldspar and carbonate minerals are common, and magnetite, hematite, and zircon occur sparingly. Quartz is thoroughly recrystallized and shows little strain. Quartz-muscovite schist containing abundant chloritoid crystals 2 to 7 mm long occurs within the Bremo Member 0.6 mile west of Bremo Bluff.

Figure 14. Bremo Member of the Arvonia Formation exposed in Bremo Bluff at the north end of the John H. Cocke Memorial Bridge over the James River. Note well-developed mullion structure in the quartzite.

The vertical, nearly massive quartzite unit, over 500 feet thick, that crops out in Bremo Bluff at the north end of the John H. Cocke Memorial Bridge over the James River, is part of a sequence of interbedded quartzites and Arvonia-type porphyroblastic slates and schists which has been interpreted as occurring in a syncline at the top of the Arvonia Formation (Stose and Stose, 1948, p. 396-398; Smith, Milici, and Greenberg, 1964, p. 14-15, Plate 1). Some features, including cross-bedding and dip of bedding do suggest that the large quartzite units just east and west of the John H. Cocke Memorial Bridge are opposite limbs of a syncline. It is certain that the top of the eastern unit is to the west. Problems with the hypothesis that Bremo quartzites lie at the top of the Arvonia Formation arise, however, when account is taken of the Buffards Formation to the west and southwest, which overlies the slate and appears to lie in the main trough are quartz, muscovite, and chlorite. Feldspar and carbonate minerals are common, and magnetite, hematite, and zircon occur sparingly. Quartz is thoroughly recrystallized and shows little strain. Quartz-muscovite schist containing abundant chloritoid crystals 2 to 7 mm long occurs within the Bremo Member 0.6 mile west of Bremo Bluff.



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Stratigraphic Relationships

Both the top and bottom of the Arvonia Formation appear to be marked by unconformity. The conglomeratic nature of the Buffards Formation, which in this area overlies Arvonia Formation from near the James River southwestward, and variations in the width of outcrop of the Arvonia on either side of the Buffards suggest an unconformable relationship. Arvonia Formation in the northwest limb of the Arvonia syncline overlies schists, phyllites, and metavolcanic rocks of the Evington Group(?); on the southeast limb of this syncline southwestward from near the James River it overlies what appear to be metavolcanic rocks of the Evington Group(?) and schists, gneisses, and quartzites of uncertain age. An exposure of actual contact was not observed, but foliation and bedding, where visible, in Arvonia Formation are approximately parallel with those in the nearby underlying rocks. When structural interpretations across the southern part of the Dillwyn quadrangle are attempted, however, it becomes apparent that at least here the Arvonia Formation almost certainly must rest upon underlying rocks with marked unconformity. This interpretation is based partly upon the assumption that garnet-amphibole-quartz rock near the north end and along the east side of the Whispering Creek anticline, associated in part with patches of Arvonia schist, is the same "key bed" that is found to the north in the Arvonia Formation in the Arvonia syncline.

The Arvonia Formation and the Hatcher Complex (mapped as "granodiorite unit" by Smith, Milici, and Greenberg, 1964, Plate 1) are in contact from about 0.5 mile northeast of Bremo Bluff northeastward to and around the end of the Arvonia syncline, thence southwestward along the west flank of the syncline to a place 1.5 miles southwest of Carysbrook (Plate 1). The almandine (garnet) isograd transects stratigraphic units from the Evington(?) west of the Arvonia syncline to Hatcher Complex on the east. South of the James River garnets are plentiful in the eastern part of the Arvonia syncline but are lacking in its terminus to the north where the isograd crosses the Arvonia-Hatcher contact about 2.5 miles south-southwest of Carysbrook. The occurrence and location of the garnets represent a product of regional metamorphism, and south of the James River the grade of metamorphism increases within the Arvonia eastward toward the Hatcher Complex. The lack of garnets in the terminus of the Arvonia syncline which is west of the garnet isograd is indicative that contact metamorphism was inoperative, thus supporting the idea that the Arvonia was deposited upon the Hatcher rather than having been intruded by it.

In most places north of the James River, where the Arvonia is in contact or near contact with Hatcher rocks, there is a distinctive conglomeratic quartz-mica schist at the base of the Arvonia Formation. This distinctive unit is not found elsewhere. It was upon the basis of this conglomeratic schist that Taber (1913, p. 41-42) and Stose and Stose (1948, p. 396-397) determined that the slate unconformably overlies the "granite" (Hatcher Complex), a conclusion to which the writer tends to subscribe. The presence of conglomeratic and pebbly schists in many parts of the Evington Group(?) complicates relationships where schists, immediately below the Arvonia Formation, were intruded by granitic rock (now metamorphosed) of the Hatcher. In many places it is difficult to determine whether these conglomeratic schists are part of the Evington(?) or the Arvonia.

In the southern part of the Dillwyn quadrangle, the prevailingly metasedimentary rocks of uncertain age in the Whispering Creek anticline on the southeast side of the Arvonia syncline appear to be structurally and compositionally distinct from the rocks of the Evington Group(?), just beyond this syncline to the northwest, and are interpreted to be older. They are folded in broad domal fashion quite unlike the tight elongate folding that has affected most of the Evington Group(?), as well as the Arvonia Formation. It would appear that the Arvonia Formation was deposited upon a deeply eroded "basement" of these older rocks. The granitic rocks (now metamorphosed) of the Hatcher Complex were so intimately intruded into the rocks of uncertain age in the Whispering Creek anticline and the older(?) part of the Evington Group(?), granitizing them in part, and at the same time not intruding the Arvonia Formation, that they appear to be a part of this older "basement".

BUFFARDS FORMATION

It is proposed that the name Buffards (pronounced Bŭ′fards) Formation be applied to those more or less conglomeratic, pyroclastic, quartz-mica schists that are typically exposed in Buffards Mountain 3.5 miles northeast of Dillwyn (Plate 1). The formation is estimated to be 1500 feet or more thick. These conglomeratic and pyroclastic schists crop out in a belt, 0.1 to 0.8 mile wide, extending from 1.5 miles northeast of Arvonia southwestward to and beyond the southwest portion of the Dillwyn quadrangle. The formation is well exposed over much of Buffards Mountain and especially at its summit in the vicinity of the fire tower. There are also many exposures adjacent to U. S. Highway 15 where it extends along the formation for about 9 miles between Arvonia and Dillwyn, and along the several secondary roads that extend northwestward from this highway across the strike of the Buffards. The formation is exposed along State Road 671, 2 miles south-southwest of Arvonia and 0.6 mile southeast of Penlan.

The Buffards includes the rocks that Stose and Stose (1948) identified as quartzose mica schist underlying the Arvonia slate in an anticline between two synclines of Arvonia Formation south of the James River. It is this writer's interpretation, however, that Buffards conglomeratic schist lies upon Arvonia in the approximate trough of the Arvonia syncline. The strongest evidence noted for the synclinal occurrence of the Buffards is the southwesterly plunge of from 15 to 45 degrees of elongate pebbles and bedding-cleavage lineations at the north end of the belt of Buffards Formation. Additionally the writer has recognized that the conglomeratic schist of the Buffards is lithologically different from the quartzose conglomerate at the base of the Arvonia reported by Stose and Stose (1948).

Attitudes of bedding and cleavage in Buffards Formation are approximately concordant with those in nearby Arvonia slate. The conglomeratic nature of the Buffards and the variation in width of outcrop of Arvonia slate (especially the narrowing of slate outcrop in the vicinity of Alpha) suggest that the Buffards rests with angular unconformity upon the Arvonia (Plate 1). The Buffards Formation is moderately resistant to weathering and tends to form ridges and hills; Buffards Mountain is a monadnock. In the vicinity of Arvonia and for several miles to the southwest, conglomeratic Buffards rocks crop out in a pair of low parallel ridges about 0.3 mile apart, presumably on opposite limbs of the Arvonia syncline. U. S. Highway 15 follows the crest of the eastern ridge for about 7 miles. The coarsest conglomeratic material is in the northwest ridge which suggests that the source area was to the northwest.

The formation west of the almandine isograd consists chiefly of light-gray silvery phyllite knotted in variable degree with pebbles of quartz and quartzite, a fraction of an inch to more than 7 inches long (Figures 15, 16); east of the almandine isograd the formation is

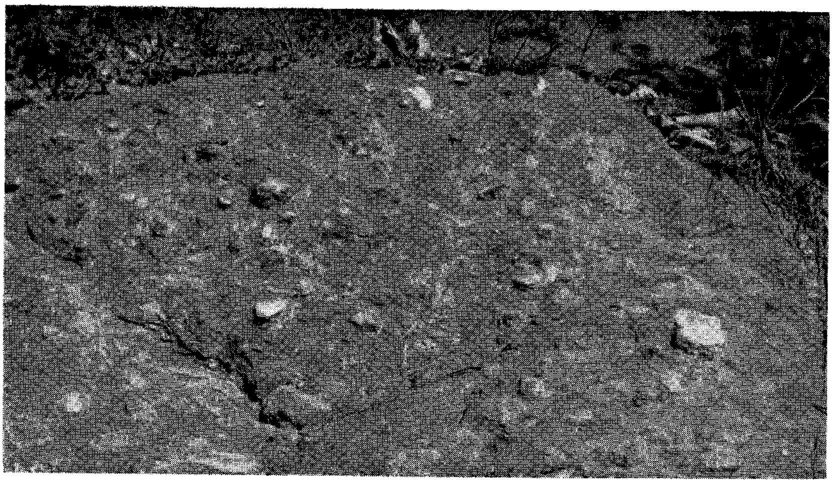

Figure 15. Conglomeratic pyroclastic Buffards schist 0.6 mile east-southeast of Penlan. Pebbles and cobbles are chiefly vein quartz; cobble on the right is 4.5 inches across.

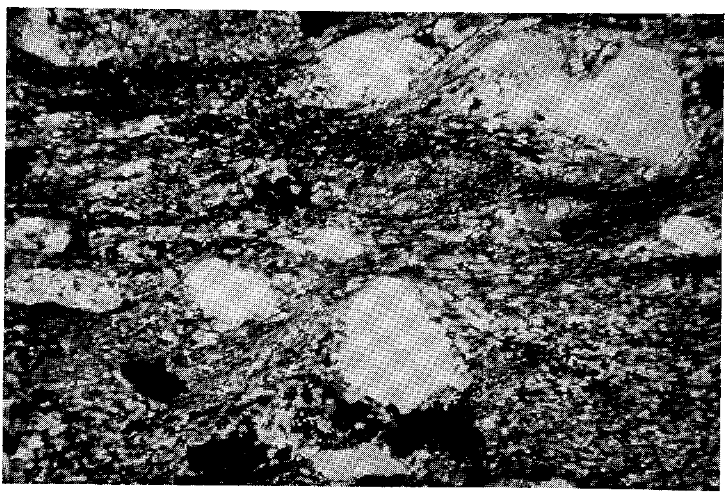

Figure 16. Photomicrograph of Buffards conglomeratic pyroclastic schist from along State Road 672, 0.6 mile north of Arvonia. Note fragments of schistose pyroclastic(?) material and corroded pebbles of quartz. Cross-polarized light, X 24.

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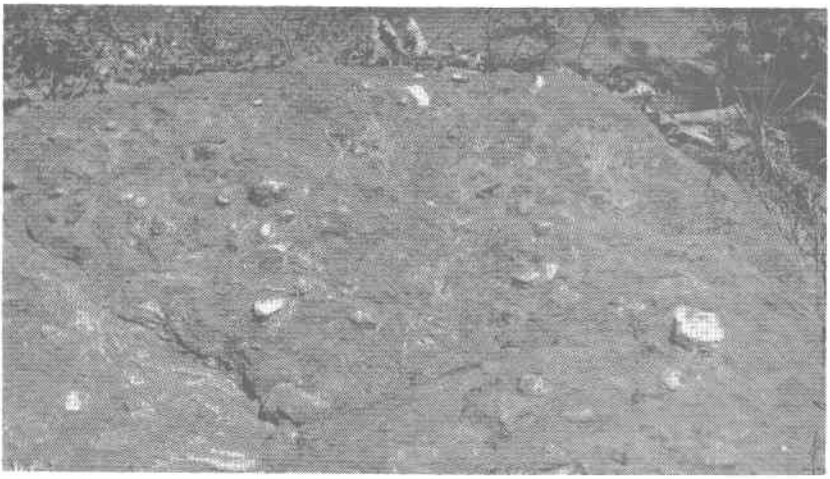

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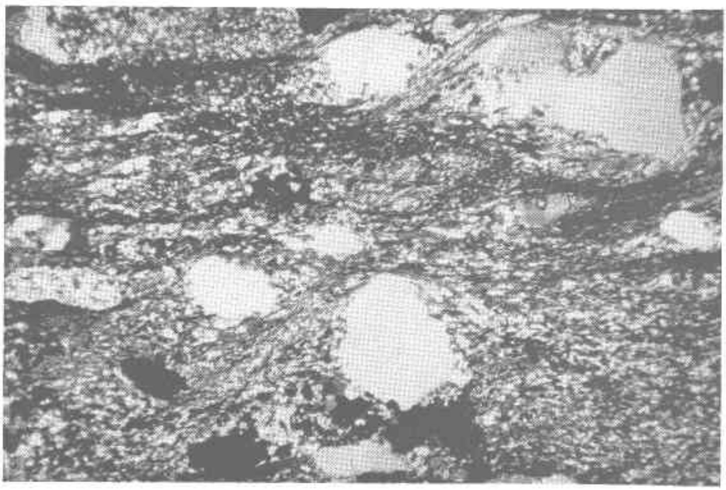

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chiefly lustrous conglomeratic quartz-muscovite schist. Most parts of the formation contain stretched and flattened pebbles of vein quartz. In places, notably where State Road 671 crosses a low ridge 2 miles south-southwest of Arvonia, the rock is markedly splotched with flattened fragments of white, gray, and green slaty and phyllitic material highly suggestive of a pyroclastic origin. These fragments are mostly less than 3 mm thick and are commonly 5 to 12.7 cm long and 2.5 to 5 cm wide. They have been metamorphosed into phyllitic masses of sericite, quartz, iron oxides, and chlorite. Green plates are predominantly quartz and chlorite; white plates are nearly pure sericite. No volcanic structures or textures have been recognized in the plates.

In thin section, matrix material in the phyllite and schist is mostly lepidoblastic muscovite and quartz, 0.03 to 0.1 mm in greatest dimension, spotted and dusted through with magnetite and hematite; in higher grade facies, grains average as much as 0.6 mm in length. Some muscovite flakes are more than 1 mm long, and tiny garnets are common. Chlorite, epidote, chloritoid, tourmaline, and zircon are locally present in the matrix. Minor amounts of kyanite were detected in specimens from just southeast of Dillwyn.

TRIASSIC ROCKS

Triassic sedimentary rocks in the northeastern part of the Farmville basin occupy a triangular area about 7.5 miles long and a maximum of 1.5 miles wide in the extreme southeastern part of the Dillwyn quadrangle (Plate 1). Much of the Triassic sedimentary rock is covered by alluvium from Willis River and its tributaries, but good outcrops occur along the Willis River Truck Trail and in the creeks near its junction with State Road 629; exposures are also present in and near the creek below Winston Lake and in a quarry 1.6 miles northeast of Trents Mill. Sedimentary rocks near the fault along the northwest side of the basin consist largely or entirely of cobble and boulder conglomerate. Fresh, thoroughly indurated, gray cobble conglomerate is well exposed in the quarry northeast of Trents Mill (Figure 17); the angular to subrounded cobbles are composed of granitic gneiss, pegmatitic rocks, impure quartzite, schist, vein quartz, feldspar, and mica. Particle size diminishes in a southeasterly direction away from the fault, and near the southeast side of the basin the rocks are chiefly conglomeratic arkoses. Pale-green, medium- to fine-grained feldspathic graywacke near the junction of the Willis River Truck Trail and State Road 629 contains quartz, sodic plagioclase, muscovite, chlorite, epidote, clinozoisite, biotite, garnet, and zircon.

Figure 17. Triassic conglomerate in quarry on the east side of Willis River, 1.7 miles northeast of Trents Mill.

Diabase dikes, presumably of Triassic age, are numerous in the area (Plate 1). Most dikes have nearly vertical dips and strikes of N. 20° W. to N. 25° W., across the regional structure; a few have northerly to north-northeasterly strikes. The alignment of mapped segments suggests that some dikes are more than 10 miles long; they range in width from 2 to 200 feet. A few bodies have columnar jointing, and spheroidal weathering is typical. Where dikes cut Arvonia slate in quarry areas, the nearby slate is unusable for roofing purposes (Figure 18).

The diabase is dark gray to black and fine to medium grained. Textures are typically subophitic, except in very fine-grained specimens where they are commonly intergranular and microporphyritic. Labradorite normally makes up 40 to 60 percent of the rock (Appendix, Part 6). Pyroxene, which is somewhat less abundant, is generally of two types: augite and pigeonite, or augite and orthopyroxene. Olivine is lacking in many specimens but makes up as much as 5 percent of others. Micropegmatite is almost invariably present in the olivine-free material. Magnetite-ilmenite and apatite occur as accessories; variable amounts of deuteric hornblende, chlorite, talc, serpentine, biotite, and carbonate minerals are present.

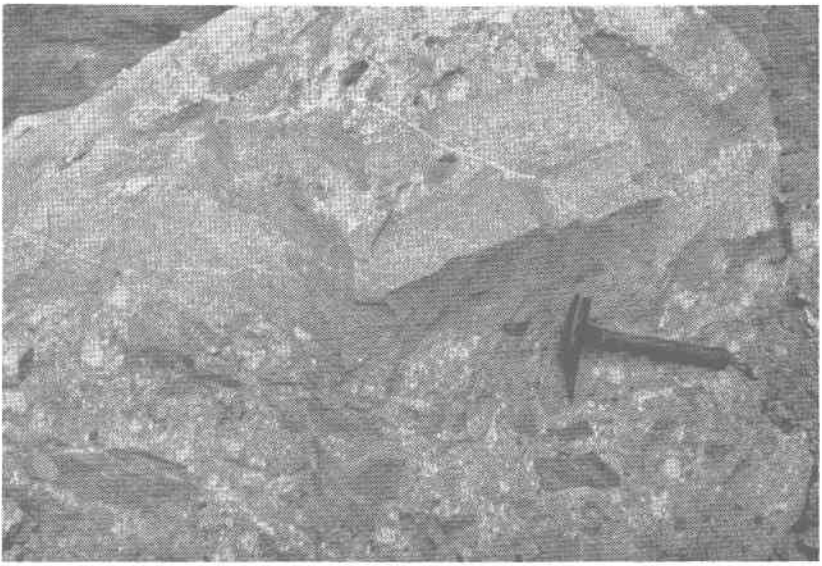

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Figure 18. Triassic diabase dike exposed in the Solite Corporation slate quarry 1.7 miles north of Arvonia.

STRUCTURE

Four major structural features are present in the Dillwyn quadrangle. These are from northwest to southeast: the large overturned Hardware anticline, the Arvonia syncline, the Whispering Creek anticline, and the Farmville basin (Plate 1). In addition to these, there are many lesser structures. Between the Hardware anticline and the Arvonia syncline there are at least two smaller anticlines and three smaller synclines, including the Long Island syncline with its long narrow infold of Arvonia(?) slate. There is probably a shear zone or fault zone along Bear Garden Creek south of New Canton in which sulfide mineralization is present. Also, drilling west of the Solite Corporation plant located about 1.5 miles west of New Canton has shown that Arvonia slate is in fault contact with underlying Evington(?) rocks (Dewey Kirstein, personal communication). In the same general area, small-scale folding and faulting have complicated the geology near the end of Buffards Formation outcrop. Several faults have been inferred near the north end and along the east side of the Whispering Creek anticline (Plate 1) where the main kyanite quartzite unit and the garnet-amphibole-quartz rock "key bed" appear to have been broken into segments.

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Arvonia slate in the Arvonia syncline appears to be separated from underlying rocks by large unconformity, so the structure of this syncline may not be duplicated in the underlying rocks. The Whispering Creek anticline is a broad, almost domal feature, quite unlike other major folds in the area. Although it was probably remobilized to some extent later, its initial development appears to have been pre-Arvonia; its form suggests that its age is different from that of the Hardware anticline. The youngest major structure in the Dillwyn quadrangle is the Farmville basin of Triassic age.

HARDWARE ANTICLINE

The Hardware anticline, a large north-northeastward-trending fold in Evington(?) rocks, is the dominant structural feature in

Figure 19. Drag folds in Evington(?) metagraywacke indicating that beds are overturned on west limb of the Hardware anticline 1 mile west of Hardware. Note thinning on limb of small anticline by hammer and start of shearing out of other limb.

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the northwestern part of the Dillwyn quadrangle (Plate 1). A body of hornblende metadiorite is present along its axial portion in the vicinity of Diana Mills. Elongate outcrop areas of greenstones and ultramafic rocks extend along both flanks of the fold and outline its form. Northward, these bands of outcrop diverge; south of the hornblende metadiorite in the vicinity of Diana Mills, they converge, and from there are nearly parallel to beyond the limits of the quadrangle. In this area of parallelism, the fold must be very steep, closely compressed, and essentially isoclinal.

The west flank of the anticline is marked by a zone of steeply southeastward-dipping overturned beds that are in contrast to more gently dipping upright beds immediately to the west. Drag folds and cleavage-bedding relations provide the best evidences for overturning and are most readily observed in the bluffs along the James River (Figure 19). Although flaring of the limbs, general disappearance of the greenstones, and the development of numerous subsidiary folds in the northern part of the anticline make it much less conspicuous to the north, the overturned west flank has been traced 10 miles north of the quadrangle to the vicinity of Palmyra (Smith, Milici, and Greenberg, 1964, p. 24, 25, Plate 1).

ARVONIA SYNCLINE

The Arvonia syncline, essentially defined by the extent of the Arvonia Formation that lies in its trough, extends north-northeastward diagonally through the central part of the Dillwyn quadrangle (Plate 1). The outcrop belt of Arvonia Formation in this quadrangle ranges in width from 1.2 to 2.6 miles; it terminates at the north end of the fold 4 miles north of the quadrangle, 0.3 mile southeast of Carysbrook (Smith, Milici, and Greenberg, 1964, Plate 1). The synclinal nature of the fold is well defined north of the James River where the Arvonia Formation has a basal conglomeratic schist that dips on both limbs toward the axis; it is recognizable in other places by attitudes of bedding and by cleavage-bedding relations (Figure 20). Broadly, however, folding has been essentially isoclinal. If the rocks in the Whispering Creek anticline on the southeast side of the Arvonia syncline are different in age from those beyond this syncline to the northwest, the base of the Arvonia Formation is marked by large unconformity, and folding in the underlying rocks does not necessarily match that in the Arvonia Formation.

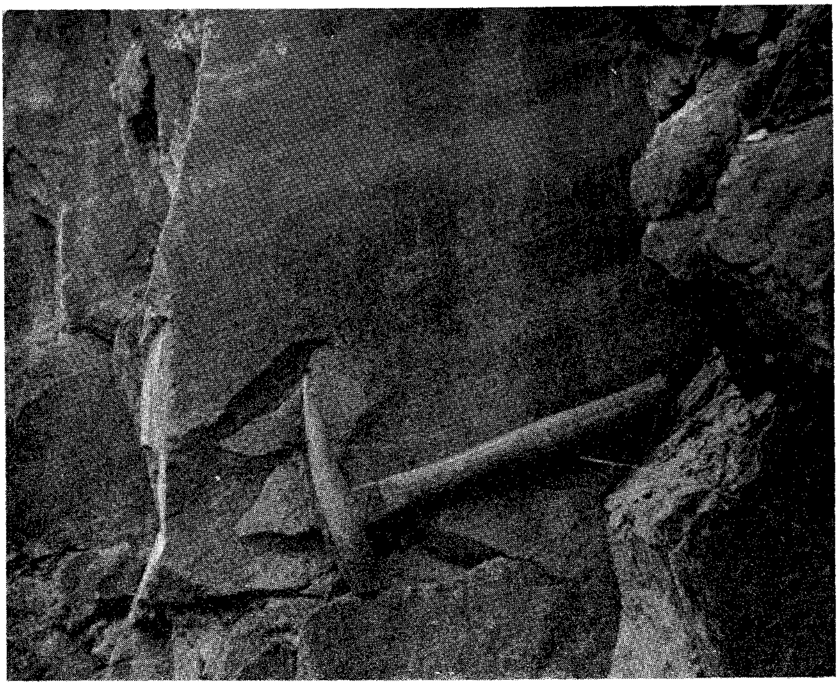
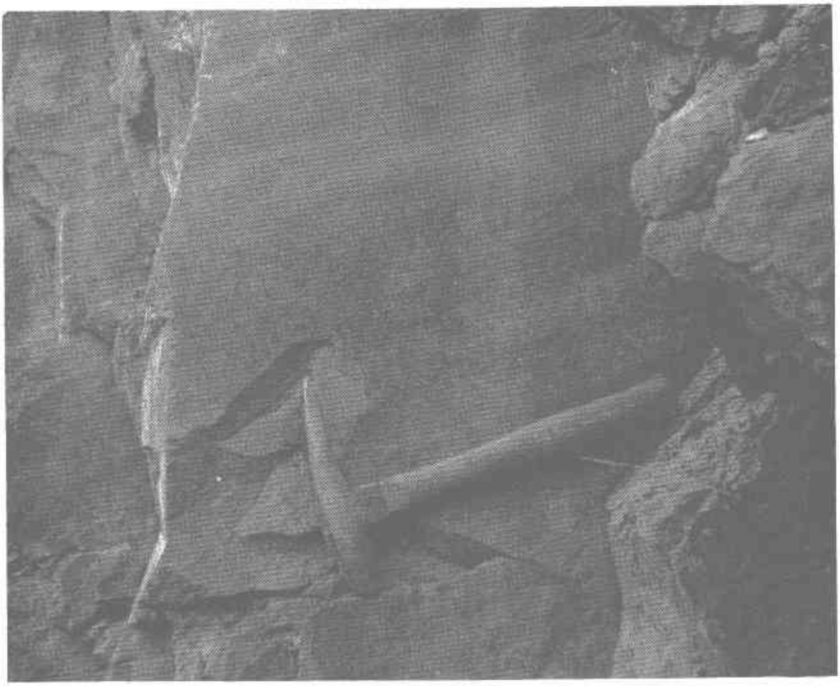


Figure 20. Bedding-cleavage lineations in Arvonia slate 1.5 miles north-northeast of Arvonia. Plunge is to the southwest.

Rocks mapped as Buffards Formation (Plate 1) were interpreted by Stose and Stose (1948, p. 401) as lying in an anticline between two synclines of Arvonia Formation. However, stretched-pebble and bedding-cleavage lineations at the north end of the belt of Buffards conglomeratic schist have a plunge of 15° to 45° SW., indicating that the structure is synclinal rather than anticlinal. In addition, the Buffards is lithologically unlike the basal Arvonia; it is much thicker, and it occurs within the belt of Arvonia outcrop only where little or no conglomerate is present at the outer limits of the Arvonia Formation.

The belt of Arvonia Formation outcrop on either side of the Buffards Formation in this quadrangle ranges in width from 0.15 to 1.4 miles. This variation is probably due partly to minor folding as indicated by Stose and Stose (1948, Figure 1), and possibly to faulting; but, in view of the conglomeratic nature of the Buffards and the inclusion of fragments of slate in the conglomerate, it appears also to be due in considerable part to angular unconformity between the Buffards and Arvonia formations. The Buffards, therefore, probably lies only in the approxi-



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The name Long Island syncline (Smith, Milici, and Greenberg, 1964, p. 24, Plate 1) has been given to the narrow belt of slate which extends just west of and nearly parallel to the Arvonia syncline from 2.5 miles east of Palmyra, 7.5 miles north of the Dillwyn quadrangle, southwestward entirely across this quadrangle (Plate 1). Very likely it is a tight deep infold of Arvonia slate. The best indications of the synclinal nature of this belt are probably found at its northeast end where lineations have a plunge of 21° to 35° SW. (Smith, Milici, and Greenberg, 1964, Plate 1). In the central part of the Dillwyn quadrangle there is another narrow belt of slate between the Long Island and Arvonia synclines which may be either a separate infold or a bifurcation of the Long Island syncline.

WHISPERING CREEK ANTICLINE

Espenshade and Potter (1960, p. 42, Plate 2) gave the name Whispering Creek to the large anticlinal structure that extends from the vicinity of Willis and Round mountains, 5 miles south of Dillwyn, northeastward about 10 miles into the southeast-central part of the Dillwyn quadrangle. The fold is asymmetric, with the northwest limb appreciably steeper than the southeast. At the northeast end of the fold, the metamorphosed surficial rocks of which it is composed merge into the hornblendic and granitic gneisses of the Hatcher Complex, and the dip of foliation in this complex continues for several miles to reflect the form of the anticline (Plate 1). At this place of merging rock types, lineations, dip of foliation, and the pattern of rock units show a saddle-like low in the structure. The "pinching effect" at this low along the crestal part of the anticline may have been responsible for the apparent infolds of Arvonia porphyroblastic schist and garnet-amphibole-quartz rock preserved at this place (Plate 1). The garnet-amphibole-quartz rock on the east flank of the anticline 5.5 miles east of Dillwyn is interpreted to be an infold of Arvonia Formation. The fact that these apparent infolded remnants of lower Arvonia Formation are not everywhere in contact with rocks of the same stratigraphic position in the Whispering Creek anticline, and nowhere appear to be in contact with the uppermost units, is probably an indication that the Whispering Creek anticline was raised and eroded before the Arvonia Formation was deposited. Furthermore, if there were no marked unconformity beneath the Arvonia Formation, structural relations would require that there be another area of Arvonia Formation on the southeast side of the Whispering Creek anticline. The rounded, nearly domal shape of the Whispering Creek anticline, so different from the tight elongate shape of other folds in the area, also suggests that this anticline developed at a different time and under different forces than these other folds.

FARMVILLE BASIN

A 7.5-mile-long segment of the northeast end of the Farmville basin extends across the southeast portion of the Dillwyn quadrangle (Plate 1). It is bounded on the west by a high-angle normal fault, which in Triassic time formed an appreciable fault scarp, as evidenced by the coarse fanglomerates deposited along the west side of the basin.

MINOR STRUCTURAL FEATURES

Bedding

Bedding is readily evident in parts of the metasedimentary rock units in the area. A possible exception is the biotite gneiss in the Whispering Creek anticline in which well-defined compositional banding is assumed to be more or less parallel to bedding. Bedding, including some layers that have crude grading, is well preserved in rocks of the Evington Group(?) in the northwestern part of the quadrangle; to the southeast, however, as the effects of shearing and recrystallization become progressively greater, and folds become more closely appressed, the attitudes of many minor compositional bands show that, in places, true bedding has been disrupted and more massive compositional bands are actually pseudobedding of the sort illustrated by Turner and Weiss (1963, p. 94-95), and Whitten (1966, p. 186-199).

On most large cleavage surfaces of Arvonia slate the position of bedding can generally be determined by close examination of bedding-cleavage lineations (Figure 9). In edge view, unless the edge is sawn or very smooth, it is difficult to detect bedding in the slate. This is due mainly to the sparsity of color variations, the gradational nature of grain-size variations, and the usual near-parallelism of bedding and cleavage. Where bedding is visible in edge view, much of it is attenuated and disrupted.

Drag Folds

Drag folds, in places greatly drawn out, are commonly well developed in most of the schistose rocks of the area. They are particularly useful in the delineation of small folds in Evington(?) rocks along the James River and in discerning the overturned west flank of the large Hardware anticline (Figure 19). Drag folds are evidence for the synclinal nature of the Arvonia syncline.

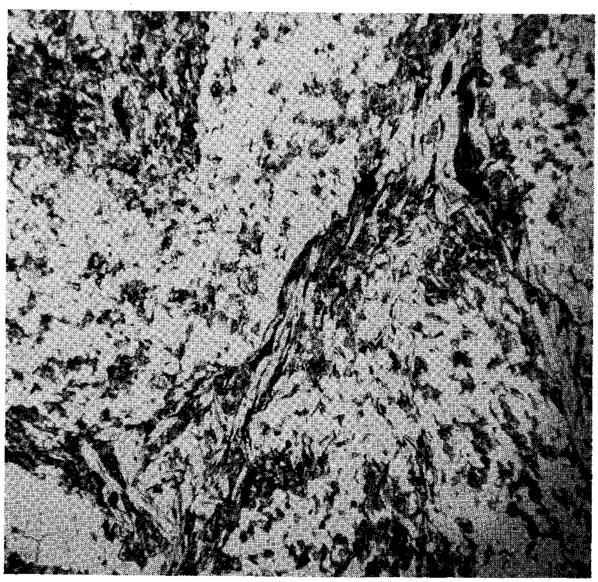

Figure 21. Photomicrograph of folded bedding in recrystallized Evington(?) metagraywacke from 0.8 mile southeast of Shores. Folding is later than early foliation that was either axial-plane or bedding foliation; the late folding is partly by shear, as shown by vertical mica grains in crest of anticlinal structure. Plane-polarized light, X 24.

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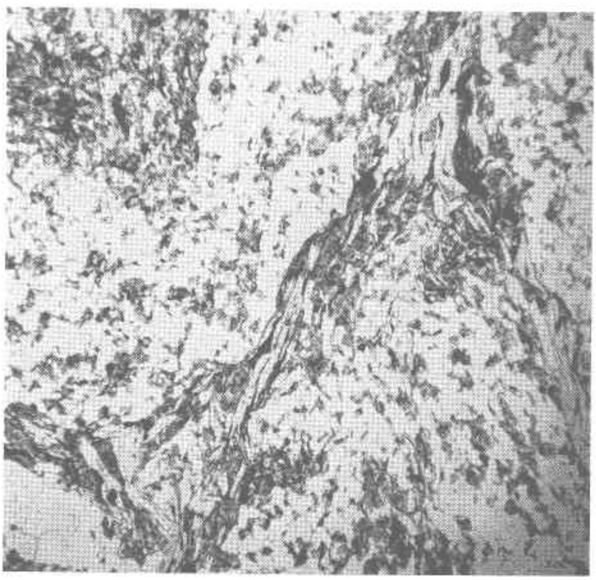

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Foliation

The term foliation as used here includes all planar structures (s-surfaces) of deformational or metamorphic origin such as slaty and slip cleavage, schistosity, and gneissic foliation due to metamorphic differentiation (Turner and Weiss, 1963, p. 91). With the exception of the rocks of Triassic age, virtually all lithologic units in the Dillwyn area are foliated, and all of the major classes of foliation are represented. Some rocks have had two or more foliations impressed upon them (Figures 21, 22). Basal Arvonia conglomerate contains fragments of schist which had foliation before they were eroded and incorporated in Arvonia Formation.

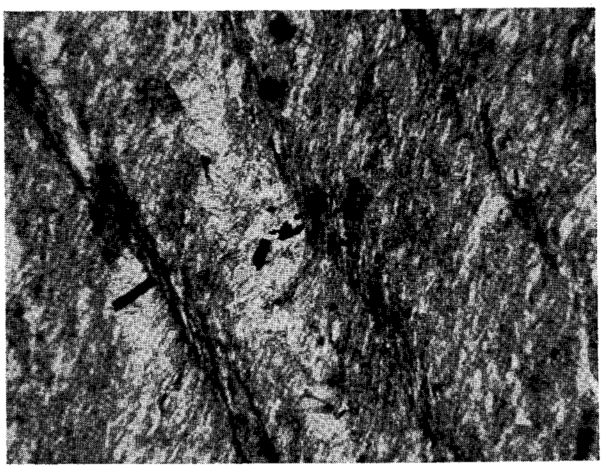

Figure 22. Photomicrograph of Arvonia slate showing slip cleavage (broad spaced) across slaty cleavage. Plane-polarized light, X 41.

Slip cleavage (crenulation foliation) is nowhere widespread in the Dillwyn area but is most common in small folds in Arvonia slate (Figure 22). The earlier foliation upon which it is imposed is generally axial-plane slaty cleavage or schistosity. Although the slip cleavage may be essentially parallel to axial planes of late folds, in this area it does not appear to be a reliable indicator of the relation of beds to early folding.

Gneissic foliation, probably due at least in part to metamorphic differentiation, occurs throughout most of the rocks of the Hatcher Complex. The compositional banding that characterizes the biotite gneiss in the Whispering Creek anticline may also be of this origin, but more likely it is related to bedding. For some distance northeast of this anticline, the dip of foliation in the Hatcher Complex continues to express anticlinal form.

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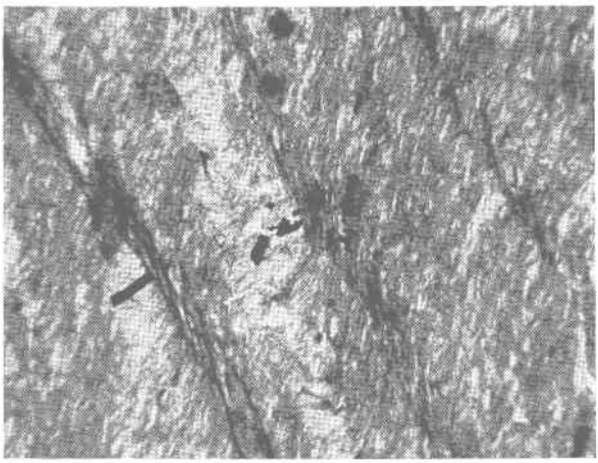

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Lineations

Lineations, including bedding-foliation intersections, stretched pebbles, mullion structure in quartzites, axes of crinkles and minor folds, and alignment of elongate mineral grains, provide important information concerning larger fold structures. The southwesterly plunge of stretched pebbles and of bedding-foliation intersections near the northeast end of the belt of Buffards Formation constitutes by far the best evidence that this belt is synclinal and not anti-

Figure 23. LeSueur-Richmond Slate Corporation quarry west of Arvonia (view to the west). Note large cleavage surfaces parallel to wall of quarry and joints, or "posts," approximately perpendicular to wall. Overhead cables used for raising blocks of slate can be seen at top of picture.

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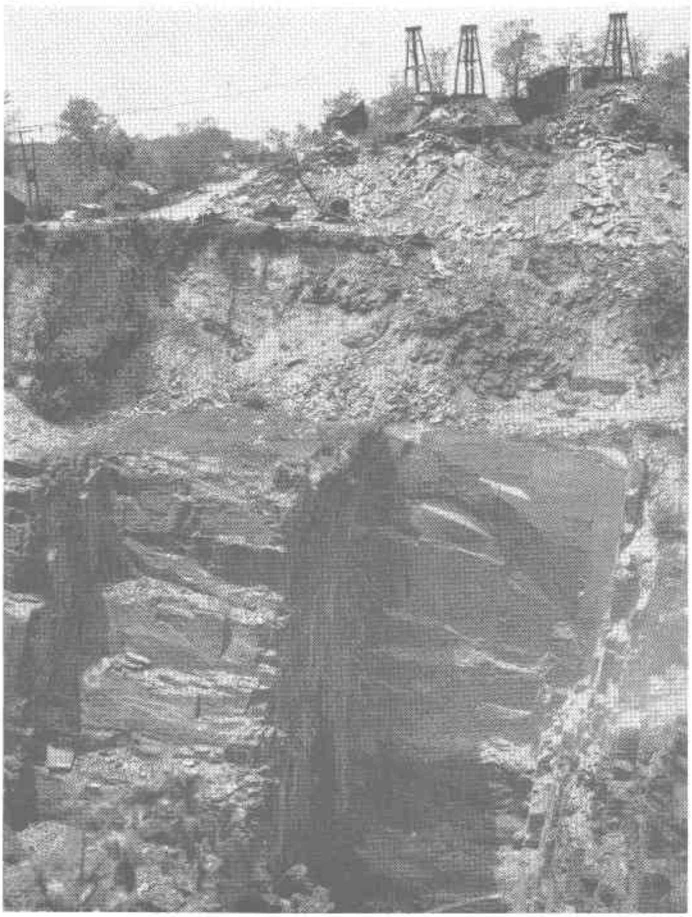

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clinal, and that the Buffards is younger rather than older than the Arvonia Formation. Well-developed mullion structure in Bremo quartzite at Bremo Bluff (Figure 14) has a northerly plunge of 10 degrees. This supports the interpretation that the disappearance of the quartzite a short distance south of Bremo Bluff is due at least in part to its occurrence in a synclinal structure with northerly plunge. The saddle-like low in the Whispering Creek anticline 6 miles east-northeast of Dillwyn, which may be responsible for the apparent infolds of Arvonia Formation within older rock at this place, is indicated, in part, by plunge of bedding-foliation intersections and elongate mineral grains. Crinkle axes and mineral streaks, known as "grain", as well as bedding-foliation lineations, in commercial Arvonia slate affect its preparation and use (Figure 9).

Joints

Joints are common and widespread throughout the area. Most of them are cross joints that dip steeply and strike northwestward across the prevailing northeasterly structural trend (Plate 1). They are particularly prominent in Arvonia slate and affect the manner in which the slate is quarried (Figure 23).

METAMORPHISM

All of the rocks in the area except those of Triassic and Quaternary age have been affected by regional metamorphism, essentially of Barrovian type. The presence of schist fragments in the conglomeratic schist at the base of the Arvonia Formation and of schistose xenoliths in the somewhat foliated plutonic rocks in the vicinity of Diana Mills indicates that at least the older rocks of the area have undergone two or more periods of dynamothermal metamorphism. The temperature-pressure conditions were such, however, that the metamorphism was predominantly progressive. In general, the metamorphic grade increases from northwest to southeast across the area. The assemblages of metamorphic minerals in the approximate northwestern half of the quadrangle are of the greenschist facies; those in the southeastern half are largely of the almandine-amphibolite facies.

In the Dillwyn quadrangle, northwest of the Paynes Mill vicinity, the mineral assemblages in the Evington(?) metagraywackes include chiefly quartz, muscovite, chlorite, and detrital plagioclase feldspar (Appendix, Part 1). Sparse stilpnomelane has been tentatively identified and has been reported by Ern

(1968, p. 34) in the adjacent quadrangle to the west. Just east of Paynes Mill, albite, biotite, epidote, and sphene are present, in addition to the preceding minerals. This albite is developed as overgrowths about detrital plagioclase and as irregular replacement masses, filled with sericite inclusions, along surfaces of shear. The ratio of new albite to detrital plagioclase generally increases southeastward, and in the vicinity of Shores on the James River most or all of the detrital plagioclase has become reconstituted.

Southeastward from Shores to the Arvonia Formation in the Arvonia syncline there is little noticable change in the metamorphic grade. In the northern half of the quadrangle, however, the increase in grade southeastward across the belt of Arvonia Formation is most evident. From northwest to southeast there is a gradual increase in grain size, followed by the appearance of biotite porphyroblasts, and accompanied in a short distance by almandine garnets that increase in size and number to the eastern limit of the formation. Chloritoid occurs locally just west of the garnet isograd and also with sparse staurolite in Arvonia conglomeratic schist 0.4 mile east of this isograd (Figure 13). Southwestward from the James River the almandine (garnet) isograd extends diagonally across the Arvonia syncline, and near the middle of the quadrangle it lies within rocks of the Evington Group(?) (Plate 1). Near Dillwyn some kyanite occurs in the Buffards Formation, and 2.5 miles farther eastward it becomes abundant in certain of the quartzites of unknown age in the Whispering Creek anticline. Staurolite occurs with kyanite in chloritic schist 2.2 miles east-southeast of Buffards Mountain, and Espenshade and Potter (1960, p. 48) reported the presence of sillimanite with kyanite in the garnet-amphibole-quartz rock, thought to be part of the Arvonia Formation, east of Tower Hill.

GEOLOGIC HISTORY

The oldest rocks in the area are the biotite and hornblende gneisses in the inner part of the Whispering Creek anticline and the metagraywackes in the inner part of the Hardware anticline. Although the latter are part of the unit designated Evington Group(?) on Plate 1, the fact that they occur beneath greenstones of possible Catoctin age and contain ultramafic bodies suggests that these graywackes are at least in part correlative with the late Precambrian Lynchburg Formation in the western Piedmont. It is also possible that the biotite gneiss in the Whispering Creek anticline, which resembles Lynchburg gneiss, and the hornblende gneisses that overlie and intertongue with it are partly correlative with the Lynchburg and Catoctin formations, respectively. The earliest records in the area, therefore, appear to be those of late Precambrian sedimentation and volcanism. In the Dillwyn area graywacke sedimentation, which began before the start of Catoctin(?) volcanism, continued without marked change after this volcanism, so that metagraywackes underlie the volcanic rocks, are interlayered with them, and overlie them. Along with or somewhat later than Catoctin volcanism, ultramafic rocks were intruded at shallow levels and/or extruded upon the sea floor (Brown, 1958, p. 45).

The hornblende diorite (now metamorphosed) near Diana Mills is younger than the foliation in the enclosing metagraywackes, so it is likely that burial and the tectonic unrest evident in the late Precambrian continued, bringing about broad folding and the development of foliation, perhaps largely parallel to bedding, by Early Cambrian time. Probably somewhat later than the intrusion of the hornblende diorite, the batholithic Hatcher Complex, by intrusion and granitization, came to occupy what is now the eastern part of the quadrangle and areas to the north and east. The region next was raised and the Hatcher Complex was exposed as a result of erosion.

In Late Ordovician time downwarping occurred, and pebbly arkosic sediments, quartz sands, and siliceous muds, later to become Arvonia Formation, accumulated in shallow waters upon the eroded surface of the Hatcher Complex and older rocks in the region. Fossil brachiopods, echinoderms, bryozoans, trilobites, and possible pelecypods that have been found in the Arvonia indicate shallow-water conditions. Quartzite in the Bremo Member of the Arvonia contains some cross-bedding and may be of deltaic origin. After deposition of the Arvonia Formation, there appears to have been another period of moderate folding and uplift, possibly part of the Taconic orogeny, which was followed by downwarping, volcanic activity, and deposition of the conglomeratic Buffards Formation upon the slightly eroded surface of the Arvonia. Sediment transport appears to have been chiefly from the north or northwest. The Buffards is interpreted to be the youngest Paleozoic sedimentary unit in the area.

After the Buffards was deposited, further burial took place, and less competent rocks in the area were tightly folded. The Arvonia syncline was formed and the Hardware anticline, which probably had been arched earlier, was tightly compressed and overturned westward. Rocks in the eastern part of the area were metamorphosed to kyanite and staurolite subfacies, a new pervasive foliation was imposed upon most of the rocks, and earlier foliates were transposed in part. These events preceded or accompanied in part a stage of thermal metamorphism that occurred between 287 and 324 m. y. ago (Smith, Milici, and Greenberg, 1964, p. 56).

No further Paleozoic events are recorded; in Late Triassic time, after long erosion, the region tended to be re-elevated, and was broken into a series of irregular fault blocks. Terrestrial sediments accumulated in great thicknesses on the downfaulted portions of the blocks. A remnant of one such fault basin is the Farmville basin, the northeast part of which extends across the southeast corner of the Dillwyn quadrangle. Faulting was accompanied, and followed to some extent, by the widespread intrusion of diabase sills and dikes. From Triassic time to the present, the history is largely one of periodic uplift and erosion. Alluvium along stream valleys accumulated during the Quaternary.

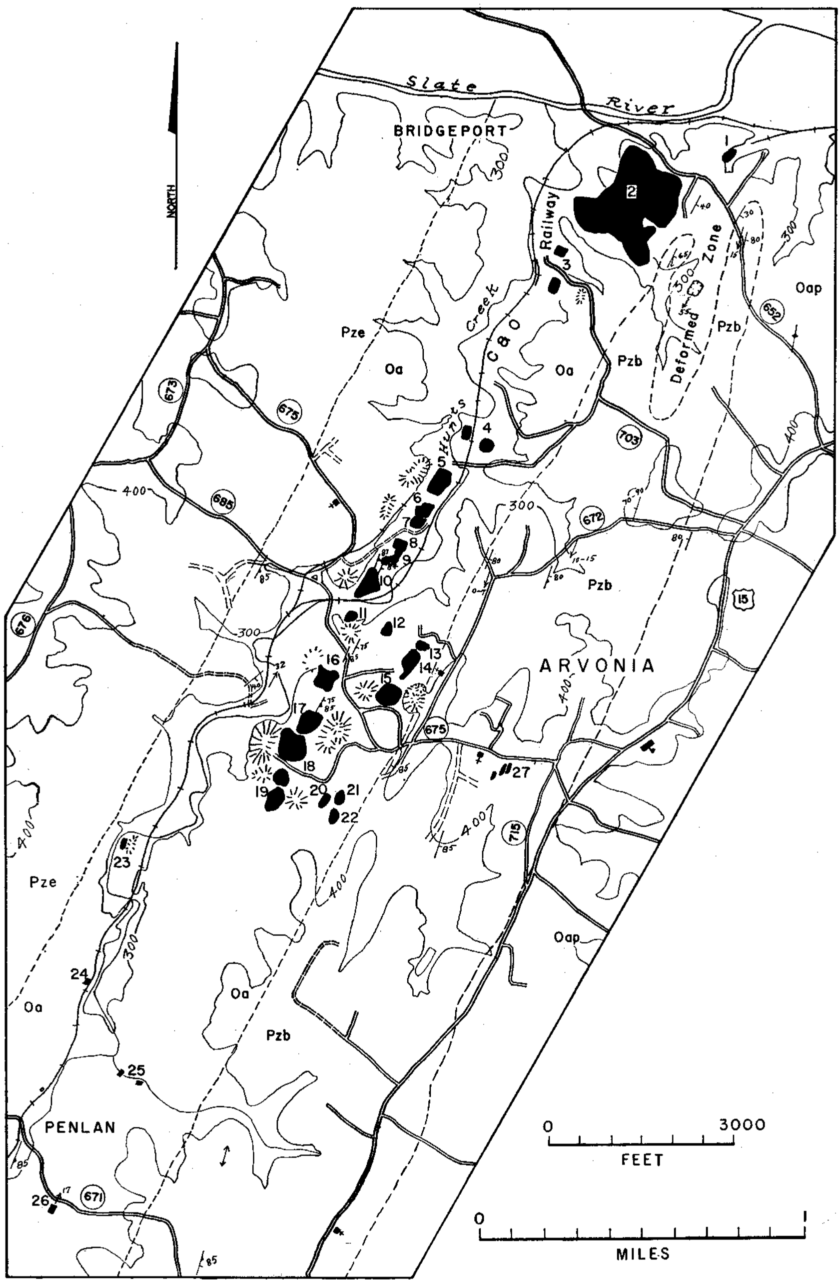
MINERAL RESOURCES

The production of slate has long been the dominant mineral industry in the Dillwyn area and has been the only one of importance in recent years. The area, however, does lie across the mineralized Piedmont gold belt of Virginia, and years ago it was a source of gold and ores of copper and iron. Crushed stone is produced sporadically for local use, and garnets and kyanite quartzite are of potential value.

SLATE

W. B. Rogers (1884, p. 79) stated that a quarry being worked in the neighborhood of New Canton on Slate River had been first opened to procure slate for roofing the capitol (presumably about 1787) and that buildings at the University would soon be furnished with a complete covering of slate from this quarry. According to McDowell (1964, p. 70-71), large-scale operations did not begin until 1869, when companies were organized, primarily by immigrants from the famous slate districts of Wales. The name "Arvon" was later given the community in honor of Carnarvon, the former home of many of these Welsh workmen.

In 1906, about the time of maximum production of roofing slate, eight companies were operating quarries in the Arvonia


NORTH
Slate River
BRIDGEPORT
ARVONIA
PENLAN
Hunts Creek
C & O Railway
Deformed Zone
Pze
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Pzb
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0 3000
FEET
0 1
MILES

district (Watson, 1907, p. 44). At present the only companies producing roofing shingles and millstock are the Arvonia-Buckingham Slate Company, Inc., and the LeSueur-Richmond Slate Corporation, which market their products jointly as "Buckingham Slate" through the Buckingham-Virginia Slate Corporation of Richmond. The Solite Corporation expands weathered slate for use as lightweight aggregate.

Slate constitutes a restricted portion of the Arvonia Formation of Late Ordovician age. This formation, which occurs mainly in the trough of the tight, elongate Arvonia syncline that extends diagonally northeastward through the Dillwyn quadrangle, consists chiefly of porphyroblastic schists, with lesser quartzites and metaconglomerates. Slate is largely confined to a less metamorphosed part of the formation along the west flank of the Arvonia syncline in a tapering belt about 12 miles long and 1 mile wide at its northern and widest part, extending from near Alpha, 8 miles southwest of Arvonia, northeastward to near the limit of the quadrangle. About 40 quarries of variable size have been opened within this belt, several just south of Penlan southwest of Arvonia and a few near Strathmore north of the James River, but most of the dimension slate produced has come from an area no more than 1.5 miles long by 1500 feet wide just west of Arvonia (Figure 24). Table 1, which outlines the generalized stratigraphy of this slate-producing area, shows further that a large part of the quarrying has been confined to a zone only about 400 feet thick.

Figure 24. Quarries in the vicinity of Arvonia (data in part from McDowell, 1964): 1, Ferncliff; 2, Solite Corporation; 3, Blue Ridge Slate Corporation; 4, Spessard; 5, Big; 6, New; 7, Catfish; 8, Jeffrey; 9, Present; 10, Upper Williams; 11, Old Nicholas; 12, Morgan; 13, Mud Hole; 14, New LeSueur; 15, Richmond; 16, Yancey; 17, Arvonia-Buckingham Slate Company, Inc.; 18, LeSueur-Richmond Slate Corporation; 19, Pitts; 20, Virginia; 21, Roberts; 22, Edwards; 23, Ordway; 24, Bullfrog; 25, Bucks Branch; 26, Pettit; 27, Ore Bank iron-ore pits. Explanation: Pzb, Buffards Formation; Oa, Arvonia slate; Oap, Arvonia porphyroblastic schist and slate; Pze, Evington Group(?). Quarries are represented by solid black areas; waste heaps are indicated by radiating hachures.

Table 1.—Generalized stratigraphic section of Arvonia Formation in the vicinity of Arvonia (modified after McDowell, 1964, p. 17).

	Thickness Feet
BUFFARDS FORMATION: pyroclastic, conglomeratic schist	
ARVONIA FORMATION:	
Slate, dark-gray, some commercial grade but not quarried; interbedded porphyroblastic ("speck") slate	400
Metagraywacke ("grindstone" of quarrymen), medium-gray, fine-grained, thick-bedded	20
Slate, dark-gray, commercial grade, smooth cleavage surface, quarried	200
Metagraywacke ("grindstone" of quarrymen), medium-gray, fine-grained, thick-bedded	20
Slate, dark-gray, main commercial unit, quarried predominantly in lower 400 feet; fossiliferous; zone of porphyroblastic ("big speck") slate near base	1000
Slate, dark-gray, finely porphyroblastic ("speck")	1500
Total	3140
EVINGTON GROUP(?): greenstone volcanics	

The most reliable and most used guide to the location of quarries in the past has been to locate them near, and along strike with, successful quarries. As pointed out by McDowell (1964, p. 79-80), in following this procedure it is important to project along the bedding strike rather than along the strike of the slaty cleavage, which is the natural tendency. In the vicinity of Arvonia the bedding strike is generally about 5 degrees more easterly than the cleavage strike. Use of metagraywacke ("grindstone") and porphyroblastic ("big speck") zones as markers can be very helpful, but these change character somewhat along strike, and zones of "speck" occur in numerous places.

Properties of Arvonia Slate

The unweathered slate is uniformly dark to very dark gray, rarely faintly greenish gray; its luster is bright. Even slate that has been in use for over a hundred years is not appreciably faded. Thin plates are markedly sonorous, emitting a clear ring when held by the end and struck with a hard object. The more or less rough surface texture of the natural cleft slate gives it a bold pleasing appearance when used in spandrels, panels, and facings. It has low electrical conductivity and is chemically inert.

Arvonia slate was originally a marine silty shale that developed a microcrystalline texture and more or less perfect slaty cleavage as a result of the compressive force and moderate heat imposed upon it during low-grade regional metamorphism which accompanied mountain building in this region. Like most other slates, it consists predominantly of muscovite and quartz with small percentages of biotite, chlorite, magnetite, plagioclase, pyrite, carbonate minerals, garnet, and hematite and occasional grains of tourmaline and zircon. The grain size of constituents is mostly between 0.02 and 0.06 mm (silt size). Detailed accounts of the petrography have been given by Dale and others (1914) and McDowell (1964).

The slaty cleavage, along which the commercial stone can be split into thin flat sheets of uniform thickness, is due to the nearly parallel arrangement of tiny flattened grains of quartz and highly cleavable plates of mica and chlorite. Slaty cleavage is so nearly parallel to bedding that some workers have stated that the two are parallel, but careful examination will virtually always disclose some angularity between them. This angularity is made obvious by the faint to very prominent bedding-cleavage lineations upon the surface of the slate (Figure 9). In the quarries the cleavage generally has a dip of 75° to 87° SE. and a strike of about N. 25° E.; dip of the bedding is about 5 degrees less and the strike is several degrees more easterly. Bedding-cleavage lineations in the quarries have a plunge of 20° to 30° SW. These lineations, called "strike" or "ribbon" by quarrymen, are often considered to be an attractive feature in the stone.

In addition to common bedding-cleavage lineations on the surface of the slate there is a less prominent, more pervasive lineation called "grain", which is due to minute crinkles and the alignment of elongate mineral grains. All splitting, or "sculping", of the slate across the cleavage is done parallel to the "grain" (Figure 9), and splitting parallel to the cleavage is done in the direction of the grain. In the Arvonia quarries the grain is nearly horizontal, unlike that in many slate districts where it plunges steeply in the direction of the cleavage dip (Dale and others, 1914, p. 41).

Structures that have been imposed, in part, upon the earlier structures, and which affect the commercial recovery and utilization of the slate, include joints, fracture or slip cleavage, small faults and folds, veins, and dikes. Dip joints, which are nearly vertical and strike northwestward almost at right angles to the cleavage strike, are prominent in most of the quarries (Figure 23). These are the quarrymen's "post" that tend to limit the length of blocks which can be recovered. Strike joints, dipping southeastward somewhat more gently than bedding, are common. Slip cleavage, which consists of closely spaced parallel fractures and/or the axial planes of minute tight crinkles imposed upon slaty cleavage, locally renders portions of the slate unusable. One place in the belt of commercial slate where slip cleavage was observed to be widespread is just south of the James River. Faults of small displacement and minor folds are present in the slate and are readily observable along the Chesapeake and Ohio Railway east of Bridgeport. Veins of quartz and calcite are locally common, and numerous Triassic diabase dikes are also present.

Measurements of less obvious properties of the slate which affect its use and durability have been made (Dale, 1906; Dale and others, 1914; Kessler and Sligh, 1932). Determinations of physical properties of slates from the Arvonia district have been compared with those for slates from various districts in the United States (Kessler and Sligh, 1932). These tests show Arvonia slate to have significantly greater hardness and modulus of elasticity, and lower porosity and absorption, than the average and to compare favorably in other respects with slates from other districts in this country.

High-quality slate like the Arvonia can generally be expected to outlast almost any structure upon which it is used. Kessler and Sligh (1932, p. 400-411) showed that the chief cause of deterioration in slate is the formation of gypsum from the interaction of the decay products of the minerals calcite and pyrite or marcasite in the rock. Measurements of decrease in flexural strength and increase in absorption (characteristics assumed to be indicative of deterioration) in slates which had been exposed to 20 years of weathering and in slates which had been subjected to wetting and drying tests showed Arvonia slate to be less affected, and presumably to be more durable, than slates from any of the other districts in the United States from which samples were taken (Kessler and Sligh, 1932, Figure 4).

Uses of Slate

Slate, one of the most durable roofing materials known, for many years was used almost solely in roofing shingles, but in less expensive and shorter term building it has been unable to compete with cheaper, lighter weight and more colorful and versatile materials. Output has been maintained or enlarged in recent years, however, because, through its remarkable form, high strength, resistance to weathering and chemical action, low absorption and electrical conductivity, and its beauty, it has found its way into a variety of other uses. In recent years the greatest tonnage of dimension slate produced in the United States has been in flagstones for walkways, stepping stones, porches, and terraces. The greatest value has been in millstock, chiefly electrical, structural, and sanitary slate; small quantities have gone into blackboards, bulletin boards, and billiard table and desk tops (Barton and Cotter, 1965, Table 13). Roofing slate has been second in value. Following this trend, less than half the dimension slate produced at Arvonia presently goes into roofing shingles; the larger part goes into structural and sanitary slate and flagging (Figures 25, 26). Figures 27 and 28 show some of the architectural effects recently achieved with Arvonia slate. Some slate is crushed for roadstone and other purposes.

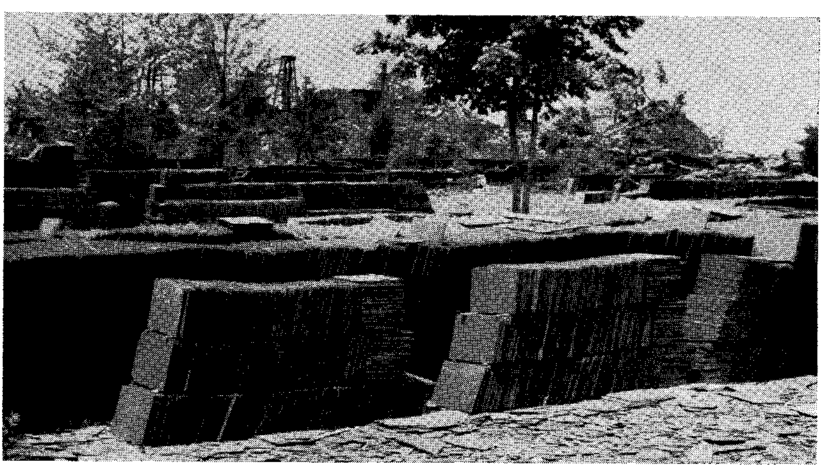

Figure 25. Stockpile of roofing slate that has been split along cleavage planes.

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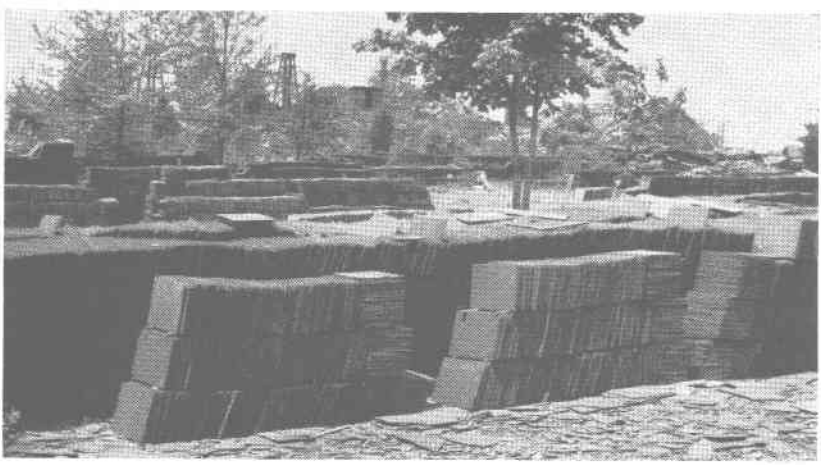

Figure 25. Stockpile of roofing slate that has been split along cleavage planes.

Figure 26. Stockpile of slate that has been sawn for various architectural applications.

Figure 27. Slate shingles used as roofing material on a residence in Portsmouth, Virginia. (Photograph courtesy of Buckingham-Virginia Slate Corporation.)

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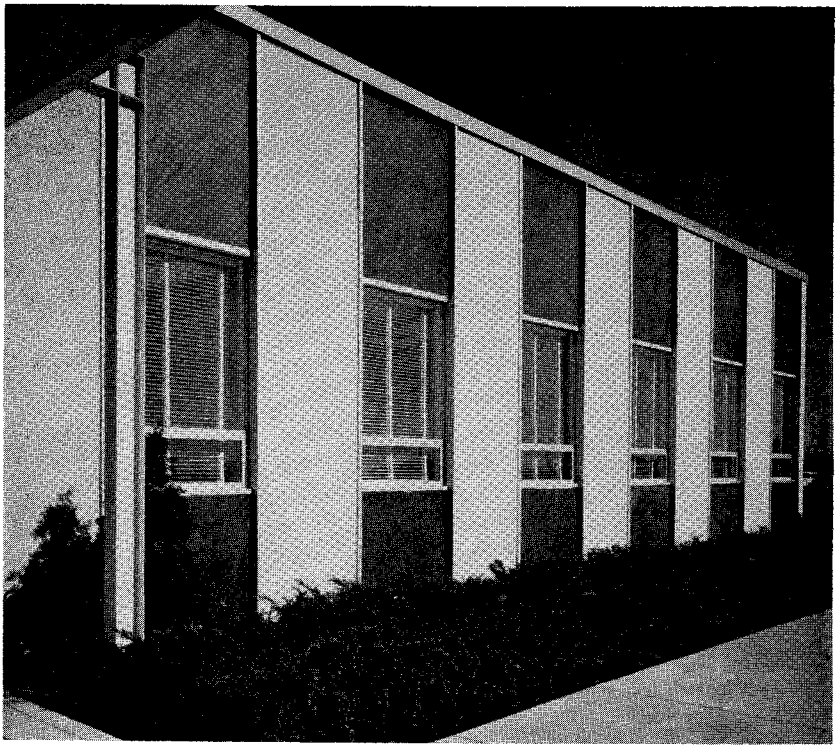

Figure 28. Panels of Arvonia slate used in curtain-wall application on office building of Libby, McNeill and Libby in Chicago, Illinois. (Photograph by Bill Engdahl, Hedrich-Blessing. Courtesy Buckingham-Virginia Slate Corporation.)

In 1947 the Solite Corporation of Richmond opened a plant in the slate belt just south of the James River at which it expands weathered slate in large rotary furnaces for use as lightweight aggregate (Figure 29). This product, which combines high strength with low specific gravity, has wide use in lightweight concrete for large buildings and bridges and is particularly useful in precast masonry units. Test determinations for a sample of Arvonia slate from an abandoned quarry on the southwest side of State Road 671, 0.3 mile southeast of Penlan (Plate 1, R-1728), indicated that it was potentially suitable for the production of lightweight aggregate by the rotary-kiln method (Calver, Smith, and Le Van, 1964, p. 118). From 1924 until the latter part of 1968 the Blue Ridge Slate Corporation operated a plant 1.5 miles north of Arvonia for grinding waste slate from other operations into granules and flour for use in asphalt-base roofing.

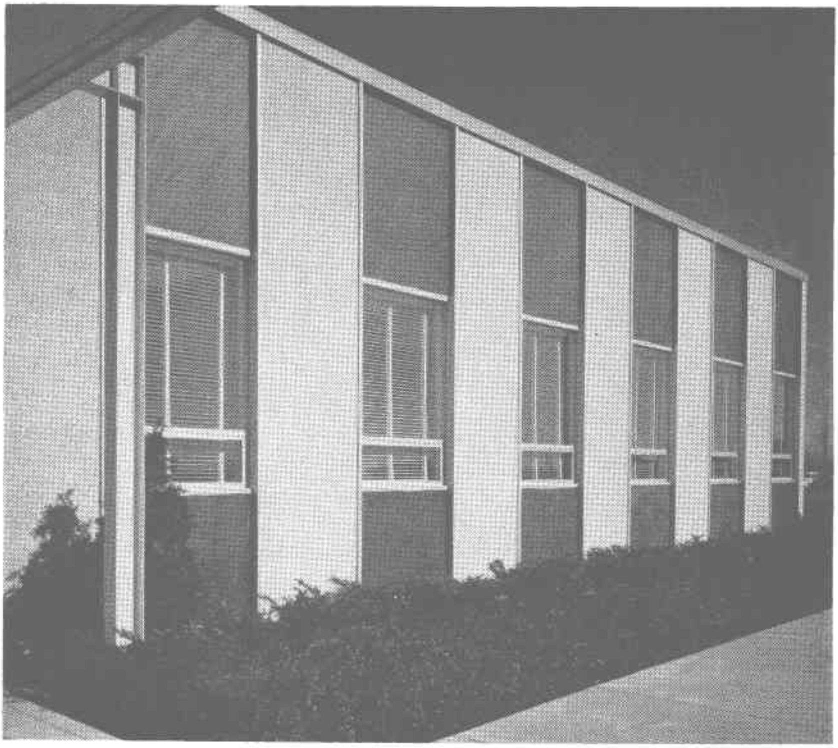

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Figure 29. Aerial view of Solite Corporation plant 1.7 miles north of Arvonia. Weathered Arvonia slate is expanded in large rotary furnaces for use as lightweight aggregate. (Photograph courtesy of the Solite Corporation.)

Quarrying and Processing of Slate

Nearly every step in the quarrying and processing of slate is a rather highly specialized operation. Methods used in the Arvonia district have been described by Redden (1961) and McDowell (1964). In the Arvonia district, where bedding and cleavage are nearly parallel and dip almost vertically to the southeast, quarries are steep walled and deep. The northwest wall generally consists of a series of large cleavage surfaces separated by short flats or inclines across the cleavage; the southeast wall has lower average steepness and consists of benches. The ends of the quarries are usually bounded by nearly vertical closely spaced dip joints, or "posts" (Figure 23). The walls are relatively stable, and many quarries extend below 200 feet and are reported to have reached depths of over 350 feet. The slate is removed by a benching operation in which blocks are "lifted" from each bench by drilling horizontal holes at the base of the bench and by the use of light explosive charges. Care is taken throughout to prevent excessive breakage. Blocks and slabs weighing 1 to 5 tons are hoisted from the quarry by overhead cableways (Figure 23). Because of im-

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Blocks not immediately discarded are first reduced to manageable sizes and shapes by splitting along the cleavage and "sculping" across the cleavage in the direction of the grain; they are then cut to desired lengths by diamond or carborundum saws. Sculping is assisted by driving wooden plugs in 1-inch holes drilled along the plane to be broken. In the final splitting, or rifting, slabs are successively halved along the cleavage with very long thin chisels until the desired thickness (about 3/16 inch in most roofing slate) is attained. Roofing slate is trimmed to size by chipping along the edge with large mechanically operated guillotine blades, care being taken to recover the largest possible shingle size.

CRUSHED STONE

Numerous rock types have been worked locally on a small scale for the production of crushed stone, mainly roadstone. Most of these rock types are more or less schistose or gneissose, and the better materials consist chiefly of hard minerals like quartz, feldspar, and hornblende. Greenstone has been quarried along the north side of the James River 0.5 mile southeast of Shores, and similar material from the dump at the Anaconda copper mine 5 miles north of Dillwyn has been used on county roads. For a time hornblende gneiss was produced from a quarry located 5 miles east-southeast of Dillwyn (Plate 1). Triassic arkosic boulder conglomerate was also quarried on a small scale 10.5 miles east-northeast of Dillwyn. Vein quartz has been produced at a site just east of State Road 721 about 2.25 miles northwest of Diana Mills. The quartz was marketed for use as ornamental exposed aggregate.

The best potentially workable stones in the area have received little or no use. These are the gneissic "granite" (compositionally, mostly quartz diorite) in the eastern fourth of the quadrangle and relatively massive hornblende metadiorite and related hornblendic rocks in the vicinity of Diana Mills in the northwest central part of the area (Plate 1). The gneissic "granite", essentially the same as that quarried at Columbia east of this area, is largely obscured by the zone of deep weathering but is well exposed along the James River and in some nearby small stream valleys. The zone of weathering appears generally to be shallower over the metadiorite near Diana Mills.

SOAPSTONE

Small areas of soapstone occur with other ultramafic rocks that crop out in several narrow bands from 2.5 to 8 miles west of Arvonia (Plate 1). All soapstone bodies observed are too small to be of any but very local use. A small quarry was opened years ago in a lens of soapstone and chlorite-actinolite schist within Hatcher granitic gneiss just north of the James River 1.6 miles east-southeast of Bremo Bluff.

GOLD

The Piedmont gold belt of Virginia extends southwestward diagonally through the central part of the Dillwyn quadrangle. As in other parts of this belt, mining was most active between about 1830 and 1861, and has been intermittent and sporadic since. Old records indicate that some of the deposits were fairly rich at and near the surface where the gold had become enriched by residual weathering, and in placers where the gold had been concentrated mechanically by running water. These enriched areas were worked out fairly rapidly and, in most cases, continued mining showed values at depth to be too low for profitable operation.

Taber (1913, p. 183-207) described the Greeley placer mine, 1 mile southwest of Gravel Hill; the Lightfoot gold-copper mine, 2.5 miles northwest of Arvonia; and the Morton, Burnett, London and Virginia, Buckingham, and Williams gold mines between Johnson Station and just northwest of Dillwyn. The five mines between Johnson Station and the Dillwyn vicinity are in rocks of the Evington Group(?), about 0.5 mile northwest of the main belt of Arvonia Formation, and all are along the same general trend. Taber (1913, p. 192, 198) reported that prospect pits and openings of various sorts had been made at short intervals between these mines, and also along the continuation of this trend southwestward from the London and Virginia mine to beyond the limits of the Dillwyn quadrangle. Taber (1913, p. 192) further stated: "The few written records of this early work confirm the data collected in the field, and indicate that the bed of quartzite, which where mineralized forms the greater part of the ore-body at the London and Virginia and Buckingham mines, is practically continuous throughout most of this distance." The London and Virginia and Buckingham properties have been the most important of the five along this trend in the Dillwyn quadrangle, and the geology of the ore deposits at these mines appears to be more or less typical for the trend.

London and Virginia and Buckingham Mines

The London and Virginia and Buckingham mines are located on adjoining properties just northwest of the town limit of Dillwyn (Plate 1), and the underground workings are continuous from one into the other. The London and Virginia property, to the northeast, was first worked by a Mr. Eldridge before being sold to the London and Virginia Gold and Copper Mining Company, which was formed in London, England, and incorporated in Virginia in 1853 (Taber, 1913, p. 183). It has been reported that pit mining was extended to a depth of 40 feet, and extensive underground mining was carried on from 5 shafts, the deepest of which was 150 feet. A mill was operated on a stream to the north for 15 years, and later another was erected just southeast of the mine. The operation was closed down prior to 1856.

The Buckingham mine to the southwest, first known as the Wiseman mine, began operation under the Buckingham Gold Mining Company in 1853. As on the adjoining property, first development was by open pit; then two shafts were sunk, one reported to be 180 feet deep. The greatest part of the ore is said to have come from the upper levels. According to Taber (1913, p. 191), "Austin writing in 1854 states that an average of 20 tons of ore were being crushed daily, yielding 130 dwt. of gold per day, and that during the previous year 1,500 ounces of gold were obtained from the mine." Mining ceased sometime prior to 1858.

As to the nature of the vein at the London and Virginia and Buckingham mines, Taber (1913, p. 187) quoted Henwood as follows:

> "The metalliferous bed, conforming to the dissimilar flexures of the rocks on opposite sides, varies in width from 3 to 20 feet on the northeast, but 4 to 5 only toward the southwest. The northeastern portion consists, near the surface, of granular, massive, and cellular quartz; sometimes embedded in, but frequently mingled with, earthy brown iron ore. Traces of galena occur at intervals. . . . The quartzose parts contain bodies of friable iron pyrites. . . . These . . . enclose isolated masses of copper-pyrites . . . with earthy black copper ore. The southwestern portions include many unconnected, angular blocks of slate . . . ."

The "dissimilar flexures of the rocks on opposite sides" and the "many unconnected, angular blocks of slate" suggest that the vein follows a fault fissure.

In 1939 a mass of residual clear granular quartz with fine muscovite was worked by drag bucket just north of the main pit. It was reported that this material was profitably milled at the Booker (Morrow) mine 4 miles southwest of Dillwyn. In 1944 the U. S. Bureau of Mines drove one diamond drill hole, inclined 45 degrees in a direction of N. 48° W., beneath the enlarged north end of the main pit to intersect the vein at about 180 feet. Veinlets and scattered grains of sulfides, chiefly pyrite, were encountered, but the tenor appeared to be too low to support underground mining. In 1953 and 1955, the London and Virginia and Buckingham properties were explored by diamond drilling by the Virginia Mining Corporation subsidiary of Belville Gold Mines, Ltd., under contracts with the Defense Minerals Exploration Administration (Espenshade and Potter, 1960, p. 54), and it was reported that 723,000 tons of ore containing 3.2 percent zinc, 20 percent pyrite, and fractional pecentages of gold, silver, copper, and lead were blocked out (Robert S. Young, personal communication).

COPPER ORE

Copper ore has been produced on a small scale at three localities in the Dillwyn quadrangle. These are the Lightfoot mine, 2.5 miles west-northwest of Arvonia; the Anaconda mine, 4.5 miles north of Dillwyn; and the New Canton mines, from 0.5 to 1.5 miles southwest of New Canton (Plate 1). The Lightfoot and Anaconda mines are in greenstone of the Evington Group(?), and the New Canton mines are in metasedimentary schists at the border zone of the Hatcher Complex. In all of them, pyrite, more or less auriferous, was the chief hypogene ore mineral and occurred with minor pyrrhotite, chalcopyrite, and magnetite. In the New Canton mines secondarily enriched chalcocite was the chief copper mineral.

Lightfoot Mine

The Lightfoot mine, consisting of two shafts, one 85 feet deep, and underground workings of unknown extent, is on the southeast side of the Slate River several hundred feet east-northeast of its crossing by State Road 676 and 2.5 miles west-northwest of Arvonia (Plate 1). It was first worked for gold, and later for copper ore. Only minor development work has been attempted since 1861. At present the shafts are caved, and the area is so overgrown that virtually nothing can be determined about the deposit. Credner (1869, p. 58) described the vein as having an iron oxide gossan 4 to

5 feet wide, beneath which there was pyrite, and at a depth of about 20 feet, chalcopyrite was present; in the lower workings the vein contained 11 percent copper. The crushed and fractured condition of the greenstone country rock suggests that the ore was localized along a zone of shearing.

Anaconda Mine

The Anaconda mine, formerly known as the Eldridge mine (Taber, 1913, p. 243), is on the south side of and immediately adjacent to State Road 617, 0.7 mile east of Eldridge Mill, and 4.5 miles north of Dillwyn (Plate 1). The Q. Q. Copper Company worked the mine about 1903, and the United States Mineral Company did some further work about 1905. During this time, 3300 pounds of ore containing 10.75 percent copper were shipped to the smelter in Norfolk (Taber, 1913, p. 243-244). The country rock is sheared, epidotized greenstone similar to that in which the Lightfoot mine is located. Just northwest of the shaft, there is a 3-foot-thick body of ultramafic igneous material which may be related to similar rock containing a small amount of amphibole asbestos about 400 yards to the northeast. The shaft was reported to have been 75 feet deep and to have had a short drift from it to the northeast. Much of the material in the dump has been used to surface the nearby road, but in the material that remains, streaks and scattered grains of chalcopyrite occur in greenish to white quartz, and malachite and azurite stains are common.

New Canton Mines

The New Canton mines, located from about 0.5 to 1.5 miles southwest of New Canton and aligned approximately N. 20° E., include from north to south the Margaret, McKenna, Johnson, and Hudgins mines (Plate 1). The first operations were for the recovery of iron ore from the limonite gossan. The mining of iron ore apparently began prior to 1784 (Rogers, 1884, p. 80) but was most active during the 1830's, after the building of the Bear Garden or Dean charcoal furnace 0.5 mile south of New Canton (Taber, 1913, p. 246-247). In the late 1800's, following a long period of idleness, mining of copper ore, chiefly supergene chalcocite at and just below the water table, was begun. Later still, the deposits were prospected for pyrite. The following notes on the history of the mining are taken largely from Taber (1913, p. 246-259).

The Johnson mine appears to have been the first to be worked for copper ore. A Mr. Staples reportedly sank a shaft 78 feet deep and shipped 780 tons of ore that averaged 8 percent copper before leasing the property to White and Walters who worked the mine 2 or 3 years beginning in 1891. About 1903 the Johnson Mining Company sank a 278-foot shaft near the top of a hill above a short ridge that projects southward into the valley of Bear Garden Creek, drove an adit from the creek northwestward to the shaft, and opened three levels in the mine. Prospecting for copper on the McKenna property just northeast of the Johnson mine was begun by J. P. McKenna in about 1895; in 1906 the Virginia Copper Company sank a 53-foot shaft at the foot of the hill just west of the creek, but the operation was short-lived. During the same general period the Hudgins mine, 1.5 miles southwest of New Canton, was opened with the sinking of a shaft about 70 feet deep, but there seems to have been no further work. The Margaret mine, consisting of one shaft 80 to 90 feet deep on the end of a low hill just northeast across Bear Garden Creek from the McKenna mine, was opened in 1910 in the search for a body of minable pyrite. According to Espenshade and Potter (1960, p. 54), "Deposits along Bear Garden Creek near New Canton were prospected by diamond drilling in 1951 to 1952. Some prospect drilling under contracts with the Defense Minerals Exploration Administration was done in the New Canton area in 1955 by the Virginia Mining Corporation and in 1956 by Roland F. Beers, Inc."

The New Canton mines appear to be largely or entirely in garnetiferous chlorite-quartz-sericite schists and related quartzites, metadacites, and hornblendic rocks, probably belonging to the Evington Group(?). To the east these units have been intruded and metamorphosed by rocks of the Hatcher Complex, and to the west they are overlain, probably unconformably, by the porphyroblastic portion of the Arvonia Formation. The description of "knotted schist" (Taber, 1913, p. 254) underground in the Johnson mine and east of the ore body, however, suggests that the ores, at least here, may be in porphyroblastic Arvonia Formation. If this is the case, the ores almost certainly are not contact deposits related to the emplacement of the "granite" (Hatcher Complex), as interpreted by Taber (1913, p. 257), but are appreciably younger. Localization of sulfides along planes of foliation and the apparently undeformed condition of the ores in the dump suggest further that the ores are not only younger than Arvonia Formation but are also later than the dynamic metamorphism that changed the Arvonia into slate. Taber (1913) stated that the ores, which were similar in all of the mines, occurred chiefly in white to light-gray, garnetiferous chlorite-quartz-sericite schists and had no definite boundaries. The hypogene part of the ore bodies consisted chiefly of more or less cupriferous pyrite, some pyrrhotite and magnetite, and very minor chalcopyrite disseminated through the schist or concentrated in irregular stringers and lenses parallel to the schistosity. The greatest part of the copper production seems to have come from secondary concentrations of chalcocite and bornite below the ground-water level.

IRON ORE

Iron ore has been mined locally on a small scale and prospected for in a number of places in the Dillwyn quadrangle. Activity was largely confined to the period of major gold mining, 1830 to 1861. Geologically the deposits are chiefly of three types: (1) the oxidized "gossan" capping of pyrite ore zones, (2) ferruginous quartzites, and (3) the oxidized portions of the garnet-amphibole-quartz rock "key bed" in the Arvonia Formation.

The New Canton mines in the valley of Bear Garden Creek from 0.5 to 1.5 miles southwest of New Canton (Plate 1) are best known as sources of supergene-sulfide copper ore, but the bodies were first worked for their limonite cappings. Iron ore was produced chiefly from the early 1830's, when the Bear Garden or Dean furnace was built 0.5 mile south of New Canton, until 1840; ore also was hauled from Ore Bank to this furnace (Taber, 1913, p. 246-247). At present the old pits at Arvonia give no hint as to the nature of the deposits. During the 1950's the Virginia Mining Corporation drilled beneath the pits in search of sulfides.

The chief occurrence of ferruginous quartzites in the area is in a narrow curving band near the northward-plunging end of the Whispering Creek anticline about 3.5 miles east of Dillwyn (Plate 1). Several pits and shafts, one 40 to 50 feet deep, were opened on the Ayre tract just south of State Road 650, 0.7 mile west of Cornerstone Church (Espenshade and Potter, 1960, p. 53). At this place the quartzite crops out in an area 100 feet wide and several hundred feet long. Black specular hematite and lesser amounts of medium-grained magnetite, accompanied in part by reddish-brown manganiferous garnet, occur in bands and irregular masses through much of the quartzite. Blades of kyanite, as much as 1 inch long, occur in the soil nearby. Several small openings also have been made in similar quartzite on both sides of State Road 628, 0.9 mile south of Cornerstone Church. Espenshade and Potter (1960, p. 40) suggested that these and similar iron-manganese-quartz rocks were originally "ferruginous and manganiferous chert beds of the type associated with basaltic lavas in many regions."

The garnet-amphibole-quartz rock, which has been shown to be an oolitic rock in Fluvanna County beyond the almandine isograd (Smith, Milici, and Greenberg, 1964, p. 15 and Figure 7), has been prospected for iron ore in a number of places, including the New Canton vicinity, but mainly just north of Tower Hill (Plate 1). It is likely that this rock was originally a chamositic oolite.

KYANITE

Kyanite, which has important use in the manufacture of high-alumina refractory linings for metallurgical and glass furnaces as well as various ceramic articles, is being produced on a large scale by the Kyanite Mining Corporation at Willis Mountain, 1.7 miles south of the Dillwyn quadrangle. This operation is in a very resistant elongate mass of kyanite quartzite on the west limb of the Whispering Creek anticline. Although the quartzite on this limb has been traced almost to the Dillwyn quadrangle (Espenshade and Potter, 1960, Plate 2), it has not been found in this quadrangle. The corresponding kyanite quartzite on the east limb of the anticline, which has not been worked, can be traced continuously northeastward to where it enters this quadrangle 4 miles southeast of Dillwyn; from there it can be traced northeastward for another 2.5 miles (Plate 1).

At U. S. Highway 60, at the southern boundary of the quadrangle, the quartzite is 15 to 20 feet thick and has a strike of N. 60° E. and a dip of 65° SE.; at Little Buffalo Creek, 1.6 miles to the northeast, it is about 50 feet thick and has a strike of N. 38° E. and a dip of 53° SE. At both places the quartzite is estimated to contain about 10 percent kyanite. North of Little Buffalo Creek the quartzite appears to be offset to the east, but it can be traced in segments to just east of Tower Hill. The quartzite tends everywhere to make low ridges and can be traced even across plowed fields by the abundant kyanite fragments in the soil. The occurrence of kyanite in this region has been discussed in detail by Espenshade and Potter (1960). It is their conclusion that the origin of the kyanite quartzite cannot be closely related to the influence of granitic intrusions, but can be explained in terms of regional metamorphism of alumina-rich sedimentary rocks (Espenshade and Potter, 1960, p. 53).

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APPENDIX

APPROXIMATE MINERAL COMPOSITION OF ROCKS IN THE DILLWYN QUADRANGLE*

PART 1: EVINGTON GROUP(?) METAGRAYWACKE (IN PERCENT).

	1	2	3	4	5
Quartz	60	58	28	32	32
Plagioclase	14	11	24	34	37
Potassic feldspar	—	8	—	—	—
Muscovite	12	12	32	18	12
Biotite	—	8	—	—	—
Chlorite	10	—	14	10	10
Epidote, Clinozoisite	2	2	2	5	8
Leucoxene	1	—	—	—	—
Anorthite content of plagioclase					
Detrital	23	27	—	—	20
Reconstituted	—	5	13	10	—

1. Chesapeake and Ohio Railway 0.3 mile southeast of Scottsville (Scottsville quadrangle).
2. North side of James River at north edge of Dillwyn quadrangle.
3. North side of James River 0.6 mile southeast of Shores.
4. North side of James River 0.8 mile southeast of Shores.
5. Turpin Creek 3 miles north-northwest of Dillwyn.

*Minerals present in amounts of less than 1 percent are not reported.

PART 2: DACITIC METAVOLCANIC ROCKS AND GREENSTONES (IN PERCENT).

	Dacitic Metavolcanic Rocks					Greenstones					
	1	2	3	4	5	6	7	8	9	10	11
Plagioclase	55	52	68	63	57	63	15	—	40	37	67
Quartz	32	40	25	25	30	25	10	40	30	—	3
Actinolite	—	—	—	—	—	—	40	20	—	15	25
Biotite	—	5	—	—	—	2	—	—	—	3	—
Muscovite	10	—	—	—	4	5	—	—	—	—	—
Magnetite and ilmenite	—	—	—	1	2	—	—	—	—	—	—
Hematite	—	—	1	—	—	—	—	—	—	—	—
Chlorite	2	—	4	6	2	—	10	—	20	20	—
Epidote	—	3	—	5	5	4	25	40	8	25	—
Clinozoisite	—	—	2	—	—	—	—	—	—	—	—
Garnet	1	—	—	—	—	—	—	—	—	—	—
Magnetite	—	—	—	—	—	—	—	—	2	—	5
Anorthite content of plagioclase	16	15	16	11	6	8	9	—	15	14	13

1. Holman Creek 0.5 mile northeast of Bremo Bluff.
2. Holman Creek 0.4 mile east-northeast of Bremo Bluff.
3. Bear Garden Creek 0.2 mile southeast of New Canton.
4. State Road 671, 0.3 mile west of Penlan.
5. Chesapeake and Ohio Railway 0.9 mile north-northeast of Fork Union Station (Scottsville quadrangle).
6. Creek 0.5 mile northeast of Little Mountain Hill (Scottsville quadrangle).
7. North side of James River at Shores.
8. 0.5 mile east of Diana Mills school.
9. Slate River 0.4 mile west of Bridgeport.
10. Anaconda mine 4.5 miles north of Dillwyn.
11. U. S. Highway 60, 0.5 mile southeast of Sprouses Corner.

PART 3: BIOTITE GNEISS IN THE WHISPERING CREEK ANTICLINE (IN PERCENT).

	1	2	3	4	5	6	7
Plagioclase	26	30	20	6	16	13	20
Quartz	46	60	62	90	61	67	54
Biotite	15	8	5	2	5	10	7
Muscovite	12	—	11	1	13	2	4
Chlorite	—	—	—	—	—	2	—
Clinozoisite / Epidote	—	2	—	—	4	—	12
Garnet	—	—	—	—	—	5	2
Anorthite content of plagioclase	15–18	26	15	16	44	39	77

1. Whispering Creek 1.3 miles south-southeast of Dillwyn.
2. 1.5 miles east-northeast of Rosney.
3. U. S. Highway 60, 2.5 miles east-southeast of Sprouses Corner.
4. Tower Branch 0.7 mile west-southwest of the crest of Tower Hill.
5. 1 mile north of the crest of Tower Hill.
6. State Road 699 at the north side of Tower Hill.
7. 0.7 mile northwest of the crest of Tower Hill.

PART 4: ROCKS OF THE HATCHER COMPLEX (IN PERCENT).

	"Granitic" Rocks									Augen Gneiss		
	1	2	3	4	5	6	7	8	9	10	11	12
Plagioclase	45	43	46	21	57	18	51	—	60	20	19	27
Microcline	—	—	—	23	—	—	5	60	—	5	28	—
Quartz	40	49	38	35	42	52	33	35	28	42	32	20
Biotite	8	4	—	10	—	9	5	1	—	28	11	43
Muscovite	—	4	16	6	—	7	3	2	10	1	7	1
Hornblende	4	—	—	—	—	—	—	—	—	—	—	—
Epidote / Clinozoisite	2	—	—	4	—	14	3	—	1	3	2	4
Sphene	—	—	—	—	—	—	—	—	—	1	—	4
Magnetite and ilmenite	—	—	—	—	—	—	—	1	—	—	—	—
Anorthite content of plagioclase	43	15-30	14	23	5	3–12	32	—	2	38	4	31

1. 0.5 mile north of Hatcher, 8.8 miles east-northeast of Dillwyn.
2. North side of James River 2.2 miles east-southeast of Bremo Bluff.
3. Along State Road 656, 0.4 mile east of Bremo Bluff.
4. 2.0 miles northeast of Bremo Bluff.
5. 0.2 mile southwest of Trents Mill 9 miles east of Dillwyn.
6. U. S. Highway 15, 1.0 mile south of Carysbrook (Columbia quadrangle).
7. Columbia (Columbia quadrangle).
8. 1.4 miles west-northwest of Slate Hill.
9. North side of James River 1 mile west-northwest of Shores.
10-12. Along Bear Creek south of Bear Creek Truck Trail, 10.5 miles east of Dillwyn.

PART 5: HORNBLENDE GNEISS (IN PERCENT).

	1	2	3	4	5	6	7	8	9
Plagioclase	65	1	39	7	48	53	45	52	68
Hornblende	33	58	53	15	37	30	25	27	8
Quartz	1	—	8	54	8	—	20	20	22
Chlorite	—	—	—	2	5	5	7	—	—
Carbonate	1	—	—	—	—	—	—	—	—
Epidote } Clinozoisite	—	—	—	2	2	—	1	—	3
Zoisite	—	41	—	—	—	—	—	—	—
Garnet	—	—	—	—	—	8	1	—	—
Muscovite	—	—	—	5	—	—	—	—	—
Biotite	—	—	—	4	—	2	—	—	—
Kyanite	—	—	—	—	—	2	—	—	—
Scapolite (Mizzonite)	—	—	—	10	—	—	—	—	—
Sphene	—	—	—	1	—	—	—	—	—
Anorthite content of plagioclase	15	—	37	40	41	45	41	20	45

1. Quarry south side of Little Buffalo Creek, 6 miles east of Sprouses Corner.
2. State Road 696, 0.7 mile southwest of Lawford, 10 miles east-northeast of Dillwyn.
3. State Road 626 at crossing of Buffalo Creek 6.4 miles east-southeast of Dillwyn.
4. 0.2 mile east of Rosney, 2.8 miles southeast of Dillwyn.
5. Gneiss with pattern 1.8 miles southeast of Dillwyn.
6. Gneiss with pattern 1.6 miles south-southeast of Dillwyn.
7. Gneiss with pattern 1.3 miles south of Dillwyn.
8. 0.5 mile east of Bremo Bluff.
9. 1.0 mile northeast of Hatcher.

PART 6: ULTRAMAFIC ROCKS AND TRIASSIC DIABASE (IN PERCENT).

	Ultramafic Rocks								Triassic Diabase		
	1	2	3	4	5	6	7	8	9	10	11
Plagioclase	—	—	—	—	—	4	—	—	61	57	45
Pyroxene	—	—	—	—	—	—	—	—	28	38	43
Olivine	—	—	—	—	—	—	—	—	—	—	5
Hornblende	—	—	—	—	—	15	—	—	5	—	—
Tremolite-actinolite	39	12	20	—	—	35	18	70	—	—	—
Magnetite-ilmenite	1	—	2	1	—	—	2	—	1	1	—
Chlorite	40	—	33	69	84	26	20	26	2	1	6
Serpentine	—	—	—	—	—	—	60	—	—	—	—
Talc	20	88	45	—	—	—	—	—	—	—	—
Quartz	—	—	—	10	5	—	—	—	—	—	—
Muscovite	—	—	—	20	10	—	—	—	—	—	—
Epidote-clinozoisite	—	—	—	—	—	20	—	3	—	—	—
Micropegmatite	—	—	—	—	—	—	—	—	2	3	—
Anorthite content of plagioclase	—	—	—	—	—	—	—	—	57	67	70

1. Soapstone at the crossing of Stouts Creek by State Road 622, 2.5 miles southwest of Diana Mills.
2. Soapstone along State Road 617, 0.5 mile east of Eldridge Mill.
3. Soapstone in small quarry on north side of James River 1.8 miles east-southeast of Bremo Bluff.

4-5. Chloritic schist by State Road 671, 0.6 mile east of Diana Mills.

6. Chlorite-amphibole schist by State Road 733 just east of Rocky Creek, 2.5 miles west of Arvonia.
7. Serpentinite along State Road 733 just east of Rocky Creek, 2.5 miles west of Arvonia.
8. Chlorite-actinolite schist in small quarry on north side of James River 1.8 miles east-southeast of Bremo Bluff.
9. By State Road 667, 2.5 miles west-southwest of Hatcher.
10. By State Road 650, 1.5 miles east of Dillwyn.
11. By Chesapeake and Ohio Railway, south side of James River, 0.5 mile west of Cocke Memorial Bridge.

PART 7: METADIORITE AND ASSOCIATED ROCKS IN THE VICINITY OF DIANA MILLS (IN PERCENT).

	Metadiorite 1	2	3	Horn-blendite 4	Peg-matite 5	Aplite 6	Orbicular Serpentinite 7	8	9
Plagioclase	42	62	15	—	85	57	—	—	—
Quartz	—	5	—	—	—	30	—	—	—
Hornblende	37	13	—	78	10	—	—	—	—
Tremolite-actinolite	—	—	8	12	—	—	—	—	30
Pyroxene	—	—	—	3	—	—	—	—	1
Biotite	—	17	—	—	—	—	—	—	—
Muscovite	2	—	3	—	2	10	—	—	—
Epidote } Clinozoisite	15	2	50	—	3	3	—	—	—
Pyrrhotite	—	—	1	—	—	—	—	—	—
Magnetite	—	—	—	2	—	—	2	2	2
Chlorite	3	—	22	—	—	—	—	7	1
Antigorite Serpentine	—	—	—	5	—	—	98	88	66
Talc	—	—	—	—	—	—	—	3	—
Anorthite content of plagioclase	15-42	39	8	—	7	12	—	—	—

1. State Road 611, 0.3 mile south of Mt. Tabor Church.
2. Dry Creek 0.5 mile southwest of Diana Mills.
3. State Road 671, 0.2 mile east of Diana Mills.
4. 1.5 miles west-southwest of Taggart.
5. State Road 671 at Diana Mills.
6. 1.6 miles southwest of Diana Mills.
7-9. State Road 611, 1.3 miles north of Diana Mills.

PART 8: COMMERCIAL SLATE AND PORPHYROBLASTIC SLATE OF THE ARVONIA FORMATION (IN PERCENT).

	Commercial Slate	Porphyroblastic ("knotted") Slate			
	1	2	3	4	5
Muscovite	44	35	42	33	30
Quartz*	35	48	40	43	50
Plagioclase*	9	8	10	7	10
Chlorite	6	—	—	3	—
Biotite	4	6	6	8	8
Magnetite	1	—	1	—	—
Garnet	—	2	1	5	1

1. Average of 8 point-count analyses of commercial slate from Arvonia vicinity.
2. Chesapeake and Ohio Railway 0.8 mile north of New Canton.
3. 100 feet east of location number 2.
4. State Road 672, 200 feet west of Bear Garden Creek, 1.3 miles east of Arvonia.
5. 1 mile north-northeast of Gravel Hill.

*Relative proportions of quartz to plagioclase are not considered accurate because of the difficulty of distinguishing untwinned plagioclase from quartz in such fine-grained aggregate.

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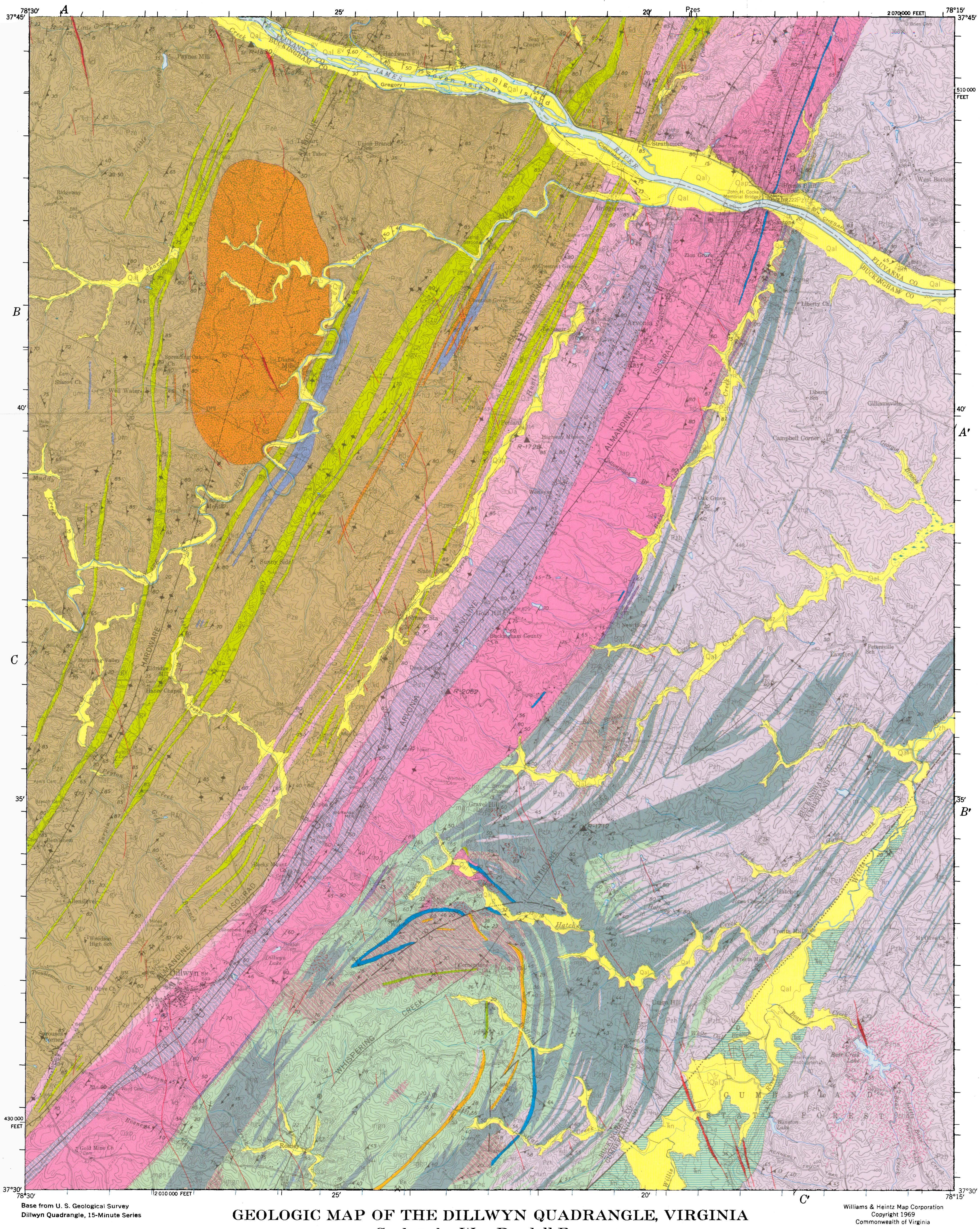
COMMONWEALTH OF VIRGINIA
DEPARTMENT OF CONSERVATION AND ECONOMIC DEVELOPMENT
DIVISION OF MINERAL RESOURCES
James L. Calver
Commissioner of Mineral Resources and State Geologist



Base from U. S. Geological Survey
Dillwyn Quadrangle, 15-Minute Series

GEOLOGIC MAP OF THE DILLWYN QUADRANGLE, VIRGINIA

Geology by Wm. Randall Brown

SCALE 1:62500

CONTOUR INTERVAL 20 FEET
DATUM IS MEAN SEA LEVEL

1969

APPROXIMATE MEAN DECLINATION, 1958

EXPLANATION

CENOZOIC — QUATERNARY

Qal — **Alluvium**

MESOZOIC — TRIASSIC

Ŧd — **Diabase**

Ŧn — Boulder conglomerate, arkosic sandstone, graywacke.

PALEOZOIC — ORDOVICIAN

Pzb — **Buffards Formation**
Light-gray phyllite west of the almandine isograd; quartz-muscovite schist east of the almandine isograd; generally conglomeratic and pyroclastic.

Arvonia Formation
Oa, slate; Oap, porphyroblastic biotite and biotite-garnet schist and slate; Obr, Bremo Member, chiefly quartzite, some schist and slate; g, garnet-amphibole-quartz rock; c, conglomeratic quartz-sericite schist, chloritoid common.

Hatcher Complex
Pzh, gneissic quartz diorite, granodiorite, and some granite; Pzhg, hornblende gneiss; p, hornblende gneiss with pattern; m, migmatite of hornblendic and granodioritic gneisses; Pzha, augen gneiss.

hd — **Hornblende metadiorite**
Includes hornblendite, amphibolite, metaperidotite, orbicular serpentinite, and pegmatitic and apolitic bodies.

um — **Ultramafic rocks**
Soapstone, chlorite-actinolite schist, and related rocks.

Evington Group(?)
Pze, arkosic chlorite-quartz-muscovite schist and phyllite, commonly with pebbles (metagraywacke); gv, greenstone volcanic rocks (metamorphosed mafic igneous rocks); Pzes, altered silicic to intermediate volcanic rocks and tuffs and interbedded fine-grained arkosic schists, phyllites, and quartzites.

Rocks of uncertain age: both equivalent to and older than the Evington Group(?); mgn, biotite gneiss; hg, hornblende gneiss; p, hornblende gneiss with pattern; s, mica schist; k, kyanite quartzite; f, ferruginous quartzite; q, micaceous quartzite.

CONTACTS

- exposed
- approximate
- covered

FOLDS

- Anticline-trace of axial plane
- Syncline-trace of axial plane
- Overturned anticline-trace of axial plane
- Overturned syncline-trace of axial plane

FAULTS

- exposed
- approximate
- covered
- U – upthrown side
- D – downthrown side

ATTITUDE OF ROCKS

- Strike and dip of beds
- Strike and dip of overturned beds
- Strike of vertical beds
- Horizontal beds

FOLIATION AND CLEAVAGE

- Strike and dip of foliation
- Strike of vertical foliation

BEARING AND PLUNGE OF LINEATIONS

- Bedding-foliation intersections
- Horizontal bedding-foliation intersections
- Axes of crinkles or minor folds
- Stretched pebbles
- Mineral streaks
- Horizontal mineral streaks

JOINTS

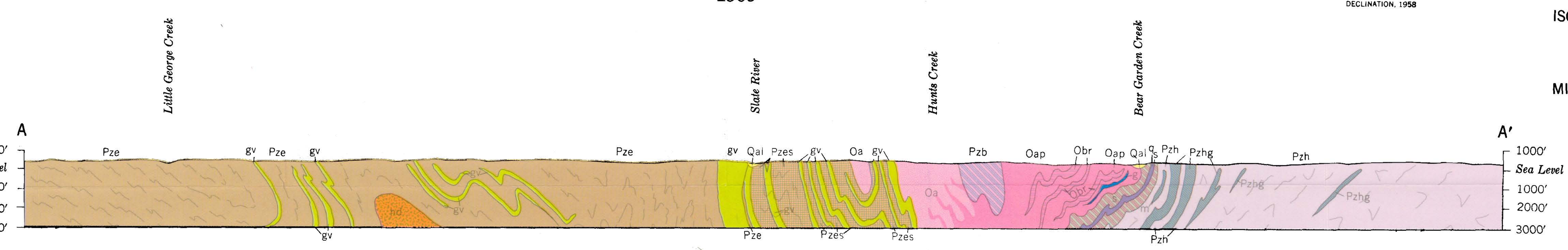
- Strike and dip of joints
- Strike of vertical joints

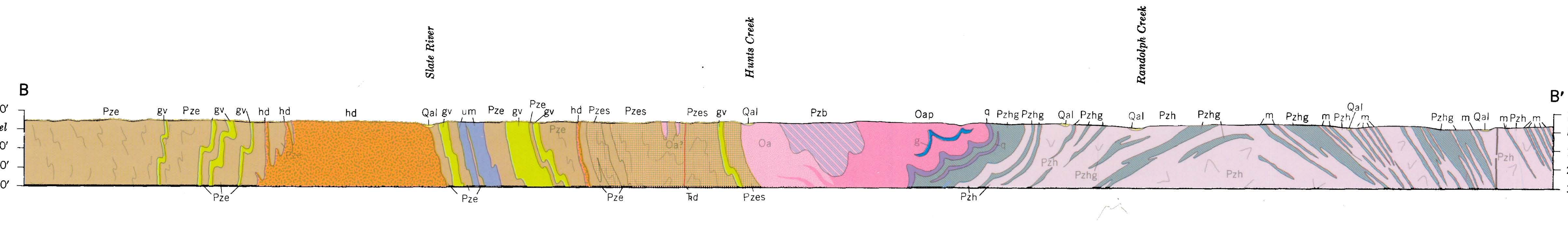
ISOGRAD

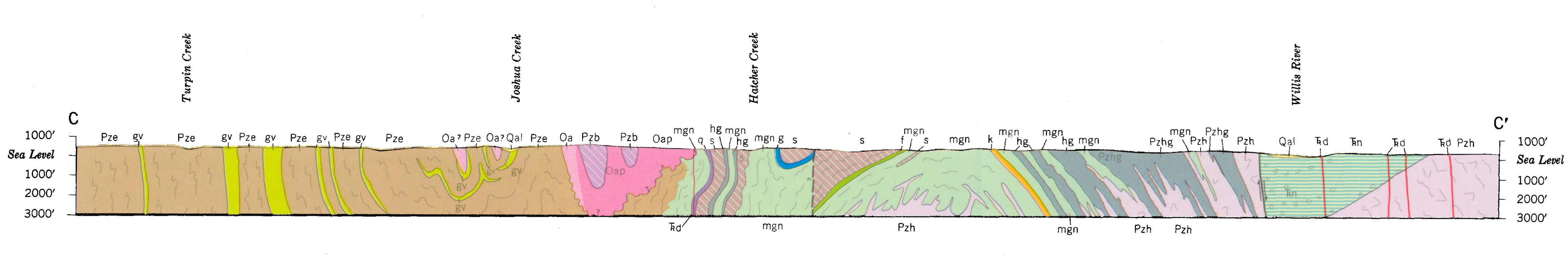
- Almandine present on hachured side of isograd

MINES, PROSPECTS, AND SAMPLE LOCATIONS

- Abandoned mine or prospect with symbol indicating gold (Au), copper (Cu), or iron (Fe)
- Location of sample for ceramic and light-weight-aggregate tests







No Vertical Exaggeration