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

GEOLOGY OF THE LEESBURG QUADRANGLE VIRGINIA

E. CLAYTON TOEWE

REPORT OF INVESTIGATIONS 11

VIRGINIA DIVISION OF MINERAL RESOURCES

James L. Calver
Commissioner of Mineral Resources and State Geologist

CHARLOTTESVILLE, VIRGINIA
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Commonwealth of Virginia
Department of Purchases and Supply
Richmond
1966

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GEOLOGY OF THE LEESBURG QUADRANGLE, VIRGINIA

by

E. Clayton Toewe

ABSTRACT

The Leesburg quadrangle is located in Loudoun County in northern Virginia. Cambrian or Precambrian chlorite schists of the Catoctin Formation are overlain by banded quartzites of the Weverton Formation. A local Catoctin-Weverton discontinuity is suggested by the varying dips of the Catoctin and Weverton formations and the absence of the Loudoun Formation. Triassic rocks in the Culpeper basin, including shales, sandstones, conglomerates, pyroclastic rocks, basalts, and diabases, are separated from the Catoctin and Weverton formations by the Bull Run fault, a high angle, eastward-dipping normal fault that truncates the Triassic rocks. The truncation can be explained by a combination of fan-like sedimentation and post-Triassic faulting.

Three periods of Triassic or post-Triassic igneous activity are recognized. A sequence of interbedded basalts and pyroclastic rocks, including intermediate, mafic, and felsic crystal tuffs, represents the oldest Triassic igneous activity. A vesicular basalt flow is younger than the pyroclastic unit, and older than the diabase that intrudes most of the Triassic units in the quadrangle.

Diabase is crushed for road material at quarries in the area; several other rock types have been, or could be, utilized in this manner. Limestone conglomerate has been used for the production of lime and agricultural stone, and clay and shale of Triassic age may have some economic potential.

INTRODUCTION

The Leesburg quadrangle is in east-central Loudoun County in northern Virginia (Figure 1). It covers an area of 57.97 square miles and is bounded by parallels 39°00′00″ and 39°07′30″ and meridians 77°30′00″ and 77°37′30″. Leesburg, the only major town, has a population of 2869 (1960 census).

The Leesburg quadrangle is within both the Piedmont and Blue Ridge physiographic provinces as defined by Fenneman (1938, p. 121-

194), and the boundary between the two provinces lies just west of Leesburg and Oatlands. Maximum relief is about 520 feet. The highest elevations, between 700 and 720 feet, are on the east flank of Catoctin Mountain in the northwestern portion of the quadrangle; the lowest elevation, slightly below 200 feet, is in the northeastern portion of the quadrangle at the Potomac River. Triassic rocks occur in the Culpeper basin (Cohee, 1961), and are characterized by gently rolling topography, averaging 300 to 500 feet in elevation. West of the Culpeper basin in the foothills of the Blue Ridge, the Weverton and Catoctin formations form northeast-southwest trending ridges with elevations between 500 and 700 feet.

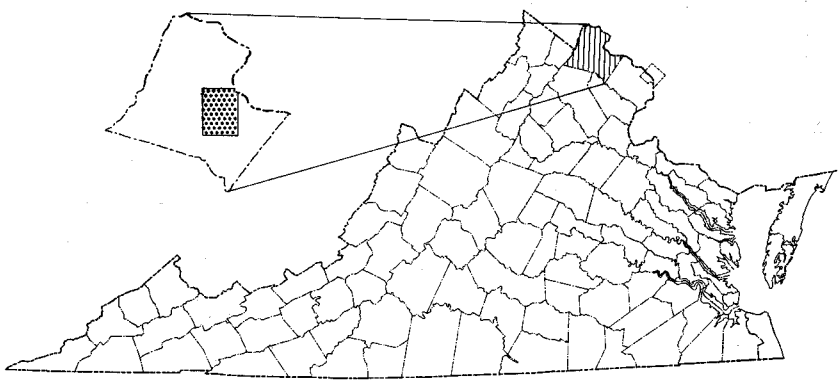


Figure 1. Index map showing location of Loudoun County and Leesburg quadrangle.

The earliest investigation in the Leesburg area was a general reconnaissance by Rogers (1884, p. 133-134). The first detailed maps were prepared by Keith (1893, 1894). Roberts (1928) and Whitaker (1955) also mapped portions of the Leesburg quadrangle. The portion of the geologic map of Virginia (Virginia Division of Mineral Resources, 1963) illustrating the area of the Leesburg quadrangle was compiled from the work of the above authors. Shannon (1924) made a petrographic study of diabase southeast of Leesburg. Hotchkiss (1884), Keith (1894), Watson (1907, p. 37-39, 58-59, 73, 227-228, 518), and Roberts (1928, p. 117-134) wrote on various phases of economic geology in the area.

The writer would like to acknowledge the assistance of the following members of the Virginia Division of Mineral Resources: Dr. James L. Calver, State Geologist, for editing the map and text; James F. Conley for making several trips into the field with the writer and

contributing much to the identification and classification of the pyroclastic rocks; D. C. LeVan for working with the writer on several magnetic surveys; and T. M. Gathright for preparing most of the photographs used in the report. Herman Conner, superintendent of the Virginia Trap Rock, Inc., quarry, provided the writer with mineral samples, and the residents of the Leesburg area were most cooperative in allowing access to their property.

STRATIGRAPHY

The rocks of the area include Precambrian or Cambrian metamorphosed basalt, Cambrian quartzite, and Triassic conglomerate, sandstone, shale, pyroclastic rock, diabase, and basalt. A Catoctin-Weverton discontinuity is suggested by a marked change in the lithologies of the Catoctin and Weverton formations. The Triassic sequence contains mostly coarse-grained clastic sedimentary rocks that generally become finer grained toward the east. The presence of intrusive diabase, extrusive basalt, and pyroclastic rocks suggests extensive igneous activity during Triassic time. Some of the intrusive diabase may be post-Triassic in age.

CAMBRIAN-PRECAMBRIAN ROCKS

Catoctin Formation

The Catoctin Formation is the oldest unit present in the Leesburg quadrangle. It is exposed on the southeast flank of Catoctin Mountain in the northwestern portion of the quadrangle. Catoctin lithologies include chlorite schist, metamorphosed basalt, and epidosite, a rock containing mainly epidote and quartz. The base of the Catoctin Formation is not exposed and no diagnostic stratigraphic intervals were found. The formation may have repetitive folds as evidenced by the variation of the easterly dips.

The principal lithology of the Catoctin Formation is a medium-grained, well-foliated chlorite schist (R-3020, R-3021). (Numbers in parentheses correspond to sample localities on Plate 1; samples are on file in the rock and mineral repository of the Division of Mineral Resources at Charlottesville.) Thin sections contain chlorite and albite, with accessory epidote, quartz, actinolite, sericite, and magnetite. Portions of the formation that contain from 8 to 15 percent epidote should probably be termed saussuritized basalt schist. Within the Catoctin Formation a gray-green, very fine-grained metabasalt is present at a few localities. This rock type is composed of albite, saussurite,

chlorite, actinolite, and opaque minerals as shown by thin-section analyses. One sample had elongated amygdules containing epidote and quartz. Epidosite (R-3022) occurs in several locations but is not confined to any particular stratigraphic interval. Epidote and quartz are the major constituents; plagioclase, zircon, biotite, and magnetite are accessory. These rocks could have been developed by the concentration of epidote formed during albitization, or possibly by hydrothermal processes.

CAMBRIAN ROCKS

Loudoun Formation

The Loudoun Formation is not present as a mappable unit. In two localities, small outcrops of light-purple tuffaceous phyllites were found, but in general, the chlorite schists of the upper Catoctin Formation appear to be directly overlain by banded quartzites of the Weverton Formation. Thin sections of the phyllites contain sericite, chlorite, hematite, and quartz. The purple phyllites occupy a stratigraphic interval formerly designated as Loudoun (Keith, 1893, p. 324-329), but may be interbedded with the metabasalt and grade upward into the Chilhowee Group (Whitaker, 1955, p. 440). No gradation of the Catoctin into the Weverton was found in the Leesburg quadrangle.

Weverton Formation

The Weverton Formation is present in the northwestern part of the Leesburg quadrangle and occurs as a low ridge along the east flank of Catoctin Mountain. The Weverton is well exposed in most of the gaps in this ridge, and outcrops are numerous on the northwest flank of the ridge. The strike of the Weverton Formation closely approximates the strike of the west edge of the Culpeper basin. Only the basal beds of the Weverton are present at the surface; a greater thickness was probably downfaulted into the basin and covered by Triassic sedimentary rocks. The Weverton is about 300 feet thick just north of Leesburg (Keith, 1894, Plate 26) where it is not in contact with the Bull Run fault, and roughly 500 feet thick west of Leesburg (Nickelsen, 1956, p. 248-250).

The Weverton is a light-gray, vitreous, fine-grained, finely laminated or banded quartzite. A few feet of greenish-gray micaceous phyllitic quartzite are present near the top of the formation in the Leesburg quadrangle. A typical section was measured at Mountain Gap, about 6 miles southwest of Leesburg:

	Thickness Feet
WEVERTON FORMATION (71.0 feet)	
Phyllitic quartzite, white to light-gray, medium-grained, friable, weathers darker gray; this unit is highly fractured. Quartz and sericite or muscovite are identifiable megascopically. Thin section (R-3016) contains: quartz, 80 percent; sericite, 19 percent; magnetite, 1 percent	8.0
Quartzite, light-gray, medium-grained, weathers darker gray, mostly massive, but with occasional thin blue to gray bands, vitreous, cross-bedded. Thin section (R-3017) contains: quartz, 80 percent; sericite, 15 percent; magnetite, 2 percent; staurolite, 2 percent; tourmaline, 1 percent	51.0
Quartzite, light-gray to light bluish-gray, medium-grained, weathers darker gray, massive, vitreous. Thin section (R-3018) contains: quartz, 90 percent; sericite, 6 percent; magnetite, 2 percent; staurolite, 1 percent; rutile, 1 percent. X-ray diffraction shows quartz and mica present	12.0

A discontinuity below the Weverton Formation has not been proven in the Leesburg quadrangle, but the transition beds of the Loudoun Formation are not present and a sharp nonmarine-marine change exists between the Catoctin and the Weverton formations. These facts suggest a local discontinuity in the Leesburg area.

TRIASSIC ROCKS

The sedimentary rocks of the Newark Group are separated into four units on the basis of their dominant lithology: conglomerate, including both limestone conglomerate and quartz conglomerate; sandstone; shale; and pyroclastic rock. The interfingering relationship of shale, sandstone, and conglomerate members can be seen in a measured section south of Leesburg along State Road 650 (Appendix I).

Limestone Conglomerate

The limestone conglomerate crops out for a distance of 1 mile west of Leesburg to the Bull Run fault; good exposures of this unit can be seen along U. S. Highway 15 north of Leesburg, and in an abandoned quarry (Plate 1, No. 1) south of Leesburg. Limestone conglomerate interfingers with standstone (Figure 2), shale, and pyroclastic rock south and east of Leesburg. The conglomerate consists of pebbles ranging in size from 0.25 inch to several feet in diameter in a red matrix composed of quartz, feldspar, calcite, mica, chlorite, and clay. About 60 percent of the pebbles are limestone or

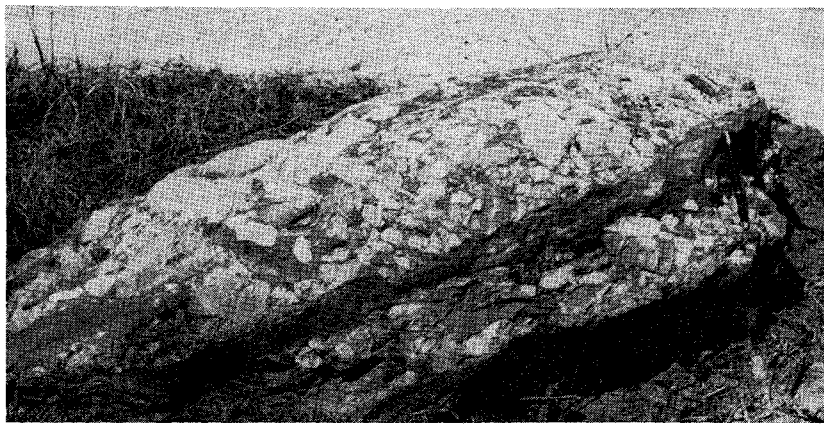
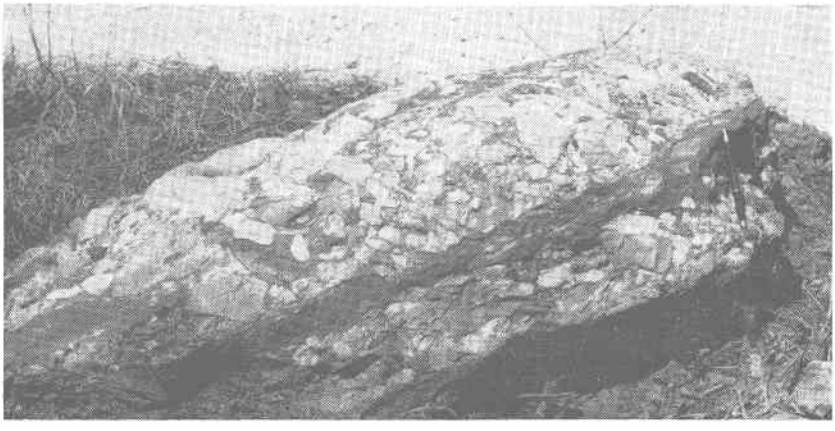


Figure 2. Triassic limestone conglomerate with interbedded dark, coarse-grained sandstone just south of Leesburg. There is a complete lack of sorting in the conglomerate.

Figure 3. Triassic limestone conglomerate in abandoned quarry (Plate 1, No. 1) north of State Road 654, south of Leesburg. Lack of sorting or orientation and the range in pebble size can be seen.



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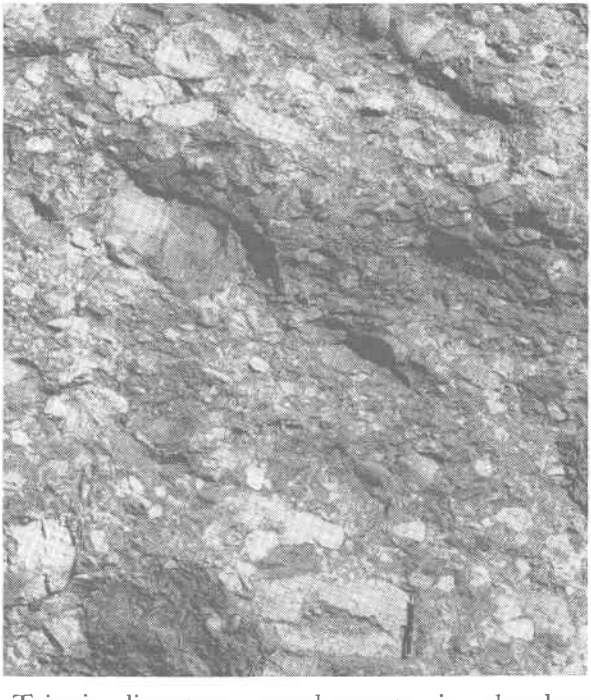

Figure 3. Triassic limestone conglomerate in abandoned quarry (Plate 1, No. 1) north of State Road 654, south of Leesburg. Lack of sorting or orientation and the range in pebble size can be seen.

dolomite; 25 percent are quartz and quartzite, and the remainder are metamorphosed basalt, chlorite schist, feldspar, phyllite, and shale pebbles. This conglomerate is an unsorted mass (Figure 3); in a few instances there is an alignment of flat pebbles. Outcrops of the limestone conglomerate are not continuous enough to obtain a measured section, but 338 feet of this unit is present in a water well in Leesburg which was drilled to a depth of 360 feet. The limestone conglomerate dips to the west 20° in the vicinity of the well.

Quartz Conglomerate

Good exposures of the quartz conglomerate are located along the south bank of Goose Creek, from the junction of Little River eastward for a distance of 0.25 mile. In this area, the quartz conglomerate is interbedded with coarse-grained sandstones. The strike of this sequence is approximately north-south, and the westerly dip is at angles ranging from 32° west of Evergreen Mills to 42° at the confluence of Goose Creek and Little River. Quartz conglomerate, composed of rounded quartz fragments that range from 0.25 to 6 inches in diameter in a light- to medium-brown matrix of coarse-grained sandstone and coarse-grained arkosic sandstone, interbedded with coarse-grained sandstone, is exposed over much of the southern portion of the Leesburg quadrangle. Thin sections (R-3019) of the quartz conglomerate contain pebbles of quartz, 25 to 30 percent; quartzite, 20 to 25 percent; metamorphosed basalt, 3 to 5 percent; and schist, 2 to 3 percent; the matrix consists of quartz, 15 to 17 percent; calcite, 10 to 12 percent; plagioclase, 8 to 10 percent; chlorite, 2 to 3 percent; and epidote, 1 to 2 percent. The presence of normal faults in the area makes it difficult to determine the thickness of the unit; even so, an estimate of 500 to 600 feet for this unit would not be excessive. The quartz conglomerate is the most resistant of the Triassic sedimentary rocks, and forms a low ridge that decreases in elevation toward the north where the quartz conglomerate interfingers with less resistant sandstones.

Sandstone

Exposures of coarse-grained sandstone are present north of Little River about 0.25 mile west of U. S. Highway 15, and in a trench silo which is 1.7 miles south of Leesburg, 0.3 mile southeast of the intersection of State Roads 621 and 654. Sandstone with interbedded conglomerate crops out along Cattail Branch 0.5 mile south of, and parallel to, the Potomac River, and along State Road 650, 6.37 miles

south-southwest of Leesburg, 0.2 mile east of U. S. Highway 15. Sandstone units are maroon, red, pink, gray, brown, and green, and medium to coarse grained. Some of the sandstone units are arkosic; subgraywackes and pure sandstones are also present. All sandstone exposures contain interbeds of conglomerate and/or shale. Thin sections of graywackes (R-3014) contain quartz, 30 to 35 percent; plagioclase, 20 to 25 percent; muscovite, 7 to 10 percent; rock fragments, 8 to 12 percent; calcite, 7 to 10 percent; matrix, 8 to 10 percent; and magnetite, 2 to 4 percent. Quartz and plagioclase are the main minerals present in most of the sandstones; mica, mainly muscovite, is present in all samples. Potassium feldspar, magnetite, chlorite, epidote, chalcopyrite, and calcite are present in varying amounts as accessory minerals. The red color, dominant in most of the sandstones, is due to the presence of ferric iron, both in the matrix and as clay coatings on the sand grains.

Shale

Shale is exposed along the south bank of the Potomac River in the northeastern portion of the quadrangle, and in a trench silo 4.3 miles south of Leesburg and 0.2 mile southeast of the intersection of State Roads 621 and 653. A shale sequence containing sandstone interbeds is exposed along State Road 653, 4.0 miles south of Leesburg. The shale is various shades of pink, red, and maroon; the color variation is due to the type and amount of iron oxide present in the rock. Most of the shales are thin bedded and range from fairly soft to extremely brittle. Quartz, plagioclase, and mica are the dominant minerals; secondary minerals include chlorite, epidote, chalcopyrite, pyrite, malachite, calcite, and magnetite.

Pyroclastic Rocks

A sequence of pyroclastic rocks is present in the upper part of the Newark Group, and is interbedded with red shales, sandstones, arkoses, and conglomerates (Toewe, 1966). The pyroclastic unit is best exposed in an abandoned quarry (Figure 4) west of Goose Creek 3.5 miles southeast of Leesburg, and 0.1 mile north of State Highway 7; exposures of this unit are also present along State Road 659 and along small creeks which join Goose Creek west of State Road 659. Another small abandoned quarry in the pyroclastic unit is located 8.5 miles south of Leesburg at Evergreen Mills. The pyroclastic rocks

are uniformly very fine grained, and range from pinkish gray to dark gray or black. The pyroclastic rocks are the most resistant rocks in the Culpeper basin within the Leesburg quadrangle; they are dense and very hard, and have a conchoidal fracture. The dominant lithology is an intermediate crystal tuff of andesitic or trachytic composition. Felsic crystal tuffs of dacitic composition and mafic crystal tuffs of basaltic composition are also present. Thin basalt flows are interbedded within the pyroclastic sequence. A welded tuff sampled

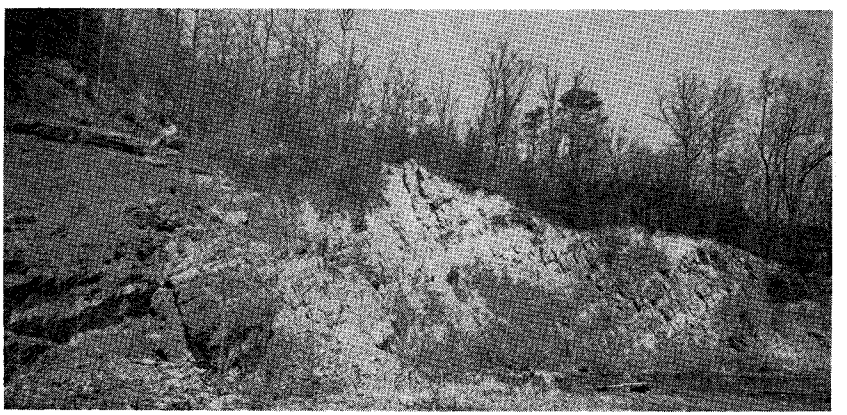

Figure 4. Faulted lower beds of the Triassic pyroclastic sequence in an abandoned quarry (Plate 1, No. 5) 3.5 miles southeast of Leesburg. A stratigraphic section that was measured in this quarry is described in Appendix II.

at one locality (Plate 1, R-2815) is essentially a crystal tuff of trachytic composition containing lithic fragments, spherulites, relict glass shards, and flow lines. Most of the contacts between individual units within the pyroclastic sequence are sharp and definitive, but in some areas felsic material is included in a predominantly mafic or intermediate sequence. Figure 5 shows the upper portion of a felsic tuff in contact with an overlying mafic tuff; small stringers of felsic material, 0.25 inch wide and ranging from 8 to 14 inches in length, are included in the lower portion of the mafic unit. Figure 6 is a photomicrograph of this contact zone. Flow lines are quite evident, and arcuate structures, most probably collapsed glass shards, are present. The felsic material contains amygdules of calcite and prehnite. Chemical and normative analyses of these pyroclastic rocks are included in Appendix III.

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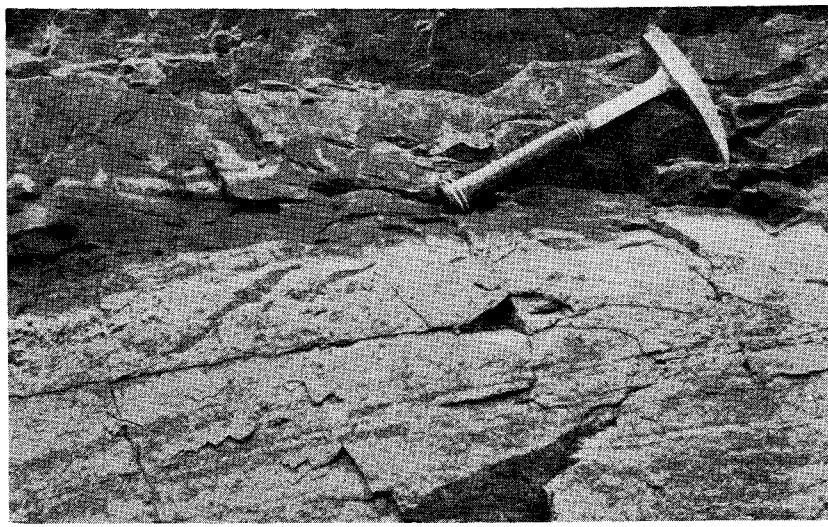
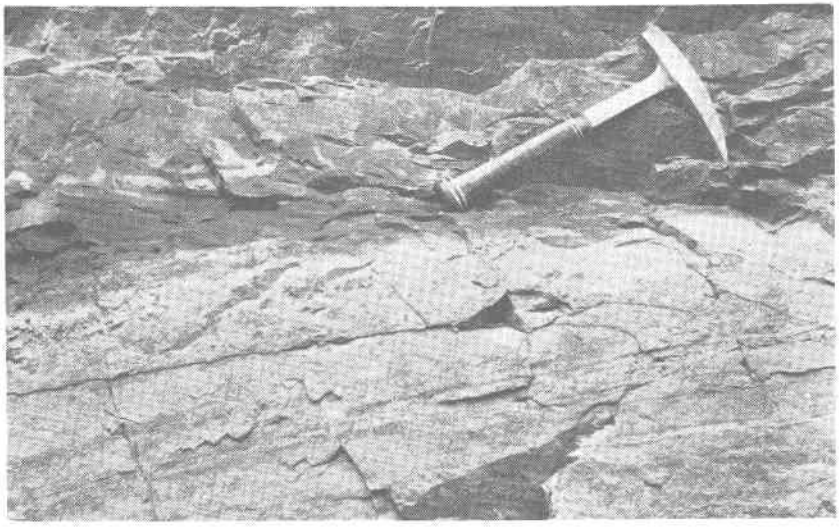


Figure 5. Contact between a felsic tuff and an overlying mafic tuff in the abandoned quarry shown in Figure 4. The contact line is sharp, but irregular; inclusions of the felsic tuff are present in the lower portion of the mafic tuff.

Figure 6. Photomicrograph of contact between the felsic and mafic tuffs shown in Figure 5. Flow lines are present in the mafic unit (left); amygdules in the felsic tuff are filled with calcite and prehnite. Plain light, X 3.8.



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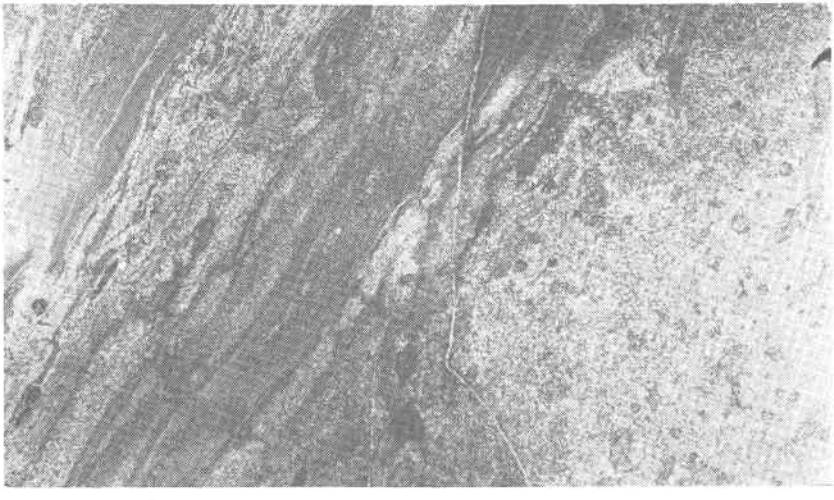

Figure 6. Photomicrograph of contact between the felsic and mafic tuffs shown in Figure 5. Flow lines are present in the mafic unit (left); amygdules in the felsic tuff are filled with calcite and prehnite. Plain light, X 3.8.

A thickness of 170 feet was measured in the section of pyroclastic rocks exposed in an abandoned quarry east of Leesburg (Figure 4). These rocks are described in Appendix II. Although no other continuous exposures of the pyroclastic sequence are present in the Leesburg quadrangle, a total thickness of 500 to 700 feet is estimated.

X-ray diffraction analyses of approximately 400 samples collected from outcrops of the pyroclastic unit show that the lower portion of the sequence is more mafic than the upper beds. In the lower 200-300 feet the pyroclastic sequence has the following mineralogic characteristics:

1. Pyroxene is the most abundant mineral in 25 percent of the samples examined, is second in 40 percent, and is absent in 6 percent.
2. Quartz is the most abundant mineral in 11 percent of the samples examined, is second in 32 percent, and is absent in 17.5 percent.

In the upper 300-400 feet the pyroclastic sequence has the following characteristics:

1. Pyroxene is the most abundant mineral in 17 percent of the samples examined, is second in 14 percent, and is absent in 14 percent.
2. Quartz is the most abundant mineral in 37 percent of the samples examined, is second in 40 percent, and is absent in 3 percent.

A cyclic repetition, ranging from a mafic tuff upward into a more felsic unit, is repeated several times (Appendix III). Eaton and Murata (1960, p. 936), in studies of Mauna Loa and Kilawea in Hawaii, noted a change from an original tholeiitic basalt to an alkalic basalt as a result of fractional crystallization of pyroxene. This change, which was evident during the course of a series of eruptions throughout a period of several weeks, is also applicable to the composition of the lavas from these volcanos throughout history. The pyroclastic sequence in the Leesburg quadrangle seems to be similar. In addition to the mafic through felsic trend of the entire pyroclastic sequence, smaller scale gradations, possibly representing differentiation during individual eruptions, are present throughout. Toward the end of the volcanic activity that gave rise to the pyroclastic rocks, clastic sediments were again introduced into the basin, and sandstones and shales were interbedded with the upper pyroclastic units. These uppermost pyroclastic units are highest in silica percentage and are the coarsest grained

strata in the pyroclastic sequence, possibly due to the simultaneous deposition of clastic sediments and pyroclastic debris, a feature not present in the lower mafic units.

Diabase and Basalt

Diabase is best exposed in two active quarries (Plate 1, Nos. 6, 7) in the eastern portion of the quadrangle; fresh diabase outcrops are nearly continuous from Evergreen Mills for 1.1 miles eastward along Goose Creek. The presence of large rounded diabase boulders marks the areas underlain by diabase. Diabase occurs in large masses that are generally conformable with, but in some areas truncate, the enclosing sedimentary rocks. Most of the dark-gray to black diabase is medium grained, but some coarse-grained varieties are present in the Virginia Trap Rock, Inc. quarry. Thin sections of diabase have a characteristic subophitic texture. Plagioclase and pyroxene are the essential constituents. The main plagioclase present is labradorite (An_{50-60}), but some slightly more sodic varieties were identified, generally andesine (An_{40-50}). Much of the plagioclase has albite twinning; some grains have both Carlsbad and albite twinning. In thin sections from all wells (Appendix III) plagioclase has been partially or completely altered to saussurite, probably by hydrothermal solutions moving along joint or other fracture surfaces. Small amounts of sulfide mineralization are present in these altered areas. The dominant pyroxene is augite; some pigeonite was identified. Amphibole has been formed from pyroxene by hydrothermal alteration in some cases (Appendix III). Micropegmatitic intergrowths of quartz and potassium feldspar constitute from 3 to 5 percent of the rock. Skeletal crystals of magnetite are present in all samples, and make up from 2 to 5 percent of the diabase. Secondary minerals include sericite, chlorite, prehnite, zeolites, hornblende, calcite, pyrite, chalcopyrite, and biotite. Open joints in the diabase have been filled by prehnite (R-2701), calcite, and various zeolites. In addition, aplite dikes (R-2702) transect the diabase masses (Figure 7); xenotime was identified by X-ray diffraction analysis (X-474) in one of these aplite dikes. Thin-section analyses of the diabase from the Leesburg area are included in logs of cores taken from several prospect holes drilled by Bear Creek Mining Company (Appendix III). One chemical analysis of diabase collected from the Arlington Stone Company quarry is shown in Appendix IV.

A basalt flow is present near the top of the Triassic sedimentary sequence. The upper portion is vesicular (R-2703); some of the vesi-

cules are filled with prehnite. Less common vesicule fillings include quartz, calcite, and various zeolites. The basalt is essentially composed of labradorite and pyroxene; some magnetite and quartz are also present.

Diabase, the youngest rock in the Culpeper basin, transects all the units of the sedimentary and pyroclastic sequence. The diabase

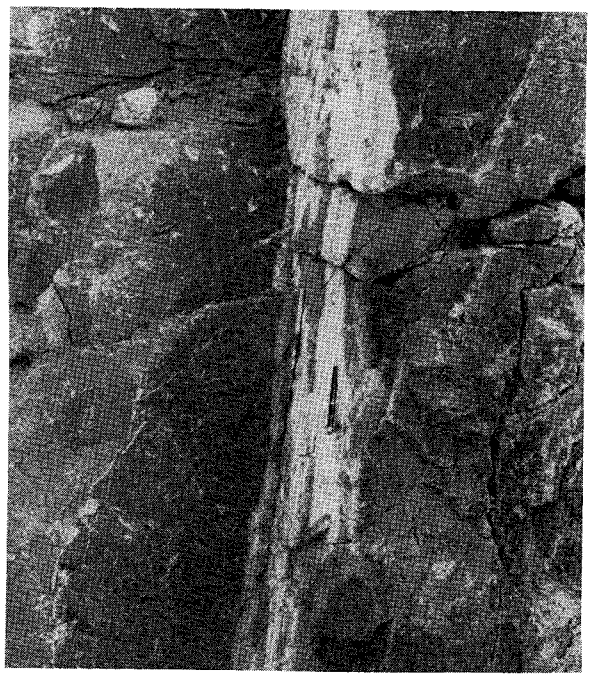

Figure 7. Aplite dike transecting Triassic diabase in the upper level of the Virginia Trap Rock, Inc. quarry, west of State Road 653, 3.5 miles east of Leesburg (Plate 1, No. 6).

probably rose toward the surface along fault planes, and then was forced into the sedimentary and pyroclastic rocks along bedding and joint surfaces. The lower contact of the easternmost intrusive body is generally conformable with the rocks into which it was intruded. In at least two areas, east of Leesburg at Goose Creek and near Waxpool, diabase has been emplaced at several stratigraphic horizons. Two diabase sills are present in the southwestern portion of the quadrangle; the arcuate outcrop pattern of these sills reflects that of the enclosing sedimentary rocks of the Newark Group. A narrow diabase dike intersects conglomerates and sandstones southwest of Leesburg. The strike of this dike closely approximates that of the

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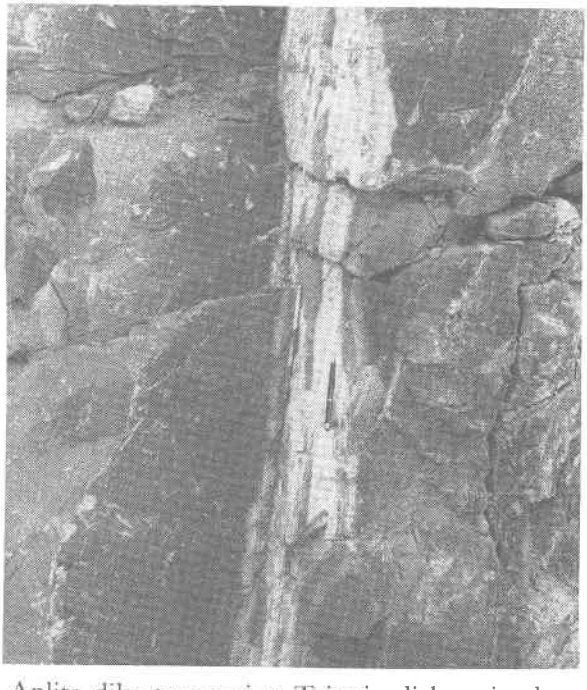

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Bull Run fault; it is probable that the diabase came to the surface along a parallel fault plane.

Contact Metamorphism

The effects of metamorphism are evident at the contact of the diabase and basalt with the sedimentary rocks. Alteration, or "baking," is minor and extends no more than 20 to 30 feet from the contact. The limestone conglomerate has the most evident alterations. The diabase-limestone conglomerate contact is exposed along the Washington and Old Dominion Railway in the southern part of Leesburg, and along State Road T1020 east of an abandoned water-filled quarry (Plate 1, No. 2) in the limestone conglomerate. Thin sections of the limestone conglomerate from the diabase contact along State Road T1020 have large amounts of pyroxene and magnetite in a calcareous matrix. Wollastonite was identified in one thin section. The metamorphism of limestone conglomerate and the formation of diopside vesuvianite, magnetite, colerainite, garnet, serpentine, xonotlite, thusmanite, and wollastonite have been described elsewhere (Shannon, 1925a, p. 12-13; 1925b). Pyroclastic rocks have been only slightly affected by metamorphism, although in some places pods of epidote and chlorite are present near the contact area.

A contact between diabase and red shale is exposed 6.8 miles southwest of Leesburg along Goose Creek east of U. S. Highway 15 (Figure 8). The diabase is slightly finer grained at the contact; this "chilled zone" ranges from 2 to 3 inches in thickness. The shale is only slightly affected by contact metamorphism. The "baked zone" extends from 6 to 10 inches below the diabase, and is slightly hardened. No color change or mineralization is present; study of a series of thin sections from the "baked" shale and the unaltered shale zone has shown no change in mineralogy. In some contact areas, "baked" shale contains a greater percentage of chlorite than is normally present, possibly caused by a metamorphic influence.

TERTIARY(?) TERRACE GRAVELS

Several of the higher hills in the southwestern portion of the Leesburg quadrangle with elevations of 440 to 480 feet are capped by gravels (Plate 1) which consist of quartz and quartzite pebbles in a brownish quartz sand matrix. The surface on which the gravels were deposited has a low dip toward the east or southeast. The actual contact of the gravels with the underlying rocks was not observed, and their thickness is difficult to estimate because of downslope move-

ments of the sand and pebbles. The age of the gravels has not been determined; similar gravels have been described as Tertiary (Keith, 1893, p. 366-369; 1894), and as Pliocene and Pleistocene (Darton, 1947).

Figure 8. Contact between Triassic diabase sill and underlying red shale 0.25 mile east of U. S. Highway 15, south of Goose Creek. Several well-developed joints in the diabase result in blocky weathering. Note variance of attitude of joints in shale from those in the diabase.

STRUCTURE

BULL RUN FAULT

The high-angle normal fault that truncates the regional trend of the Triassic strata was named the Bull Run fault by Keith (1893, p. 356). It is easily traced by examining topographic expression and lithology in the northwestern portion of the Leesburg quadrangle (Plate 1). The Weverton quartzite lies west of this fault and has an easterly dip ranging from 29° to 45°. The trace of the fault is relatively straight in the Leesburg area, trending approximately N. 20°E. The dip of the Bull Run fault was not measured within the Leesburg quadrangle during the present study, but southeasterly dips of 30° to 50° were measured by Keith (1893, p. 356).

The arcuate outcrop pattern of the Triassic strata could be explained by localized sedimentation, such as development of fan-like

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The arcuate outcrop pattern of the Triassic strata could be explained by localized sedimentation, such as development of fan-like

deposits from the fault scarp. The source for local sediments may have been located southwest of the limits of the Leesburg quadrangle. Cross-bedding indicates that the source area for most of the Triassic sedimentary rocks in the Leesburg quadrangle was to the west or southwest. It is probable that a combination of post-Triassic faulting and fan-like sedimentation gave rise to the present map pattern. The apparent bending of the strata to the northwest is probably due largely to features caused by sedimentation, modified by differential movement along faults, and it seems virtually certain that post-depositional movements occurred along or in the area of the Bull Run fault. Erosion of overlying material has exposed the strata in the present configuration.

MINOR NORMAL FAULTS

Normal faults are quite common within the Culpeper basin. Most of them are small scale, with displacements ranging from several inches to a few feet. Many of the mappable minor faults in the Leesburg quadrangle strike in a northwesterly direction and are roughly normal to the Bull Run fault. A few cross faults having minor displacements offset the Bull Run fault; most of them are parallel to a major direction of jointing. Many minor faults are recognized in the field but are not mapped. Most of the northwestward-trending faults within the Culpeper basin must have occurred after intrusion of the diabase because the diabase-pyroclastic rock contacts are offset. Downthrown blocks of pyroclastic and sedimentary rocks are present in the diabase outcrop area.

JOINTS

Joint systems are well developed in most of the rocks in the Leesburg quadrangle. In order to graphically illustrate the attitude of the joints, contour diagrams (lower hemisphere) that represent joint systems in the pre-Triassic rocks and in the Triassic sedimentary, pyroclastic, and diabasic rocks were prepared (Figures 9-12). One hundred joint attitudes were taken and plotted for each diagram.

The diagram showing the distribution of joints within the pre-Triassic rocks, the Catoctin and Weverton formations (Figure 9), exhibits three prominent joint sets: N. 10° W., N. 80° E., and N. 45° W. Dips are nearly vertical in all three sets. Three prominent joint sets are evident on the diagram prepared from joint attitudes of the Triassic sedimentary rocks (Figure 10). The prevalent attitudes of the joint sets in these rocks are: east-west, nearly vertical to vertical;

N. 60° W., vertical; and N. 15° E., with dips ranging from about 70° SE. to vertical. The pyroclastic rocks have a similar pattern as shown in Figure 11: east-west, vertical; N. 45° W., vertical; and

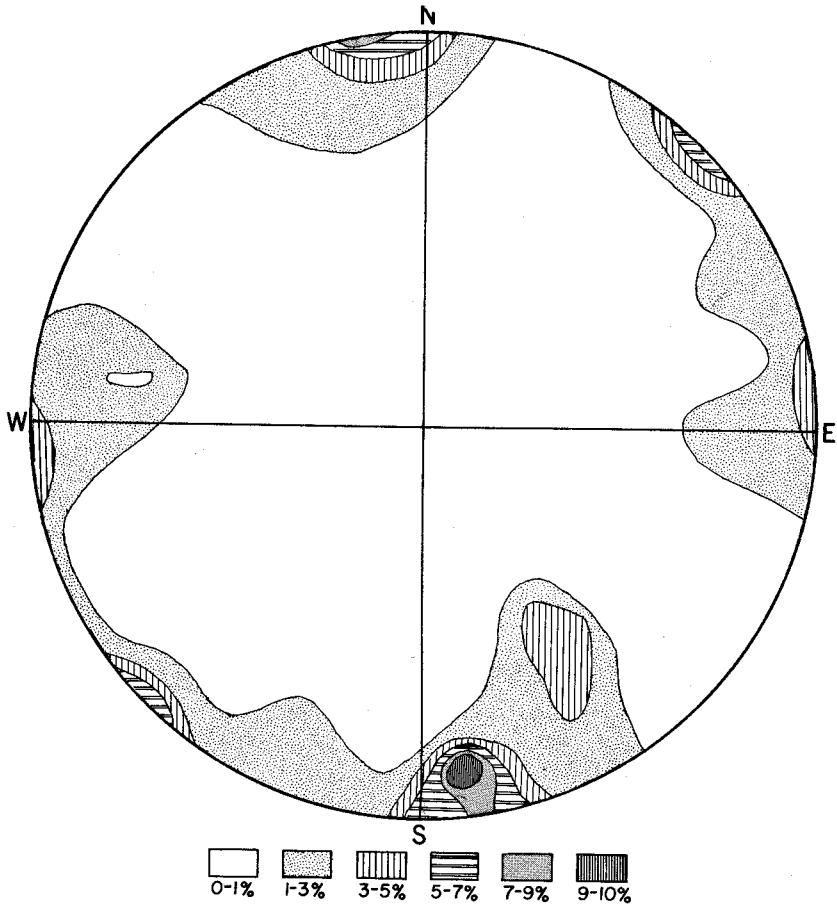


Figure 9. Contour diagram illustrating the attitude of joints in the Catoctin and Weverton formations. Lower hemisphere plot based on 100 attitudes.

N. 50° E., with dips ranging from about 70° SE. to vertical. The diabase has five main joint directions: N. 10° E., dipping 65° to 80° SE; N. 30° E., dipping 85° SE. to vertical; N. 40° W., dipping 80° NE.; N. 50° W., dipping 85° SW. to vertical; and N. 80° E., dip-

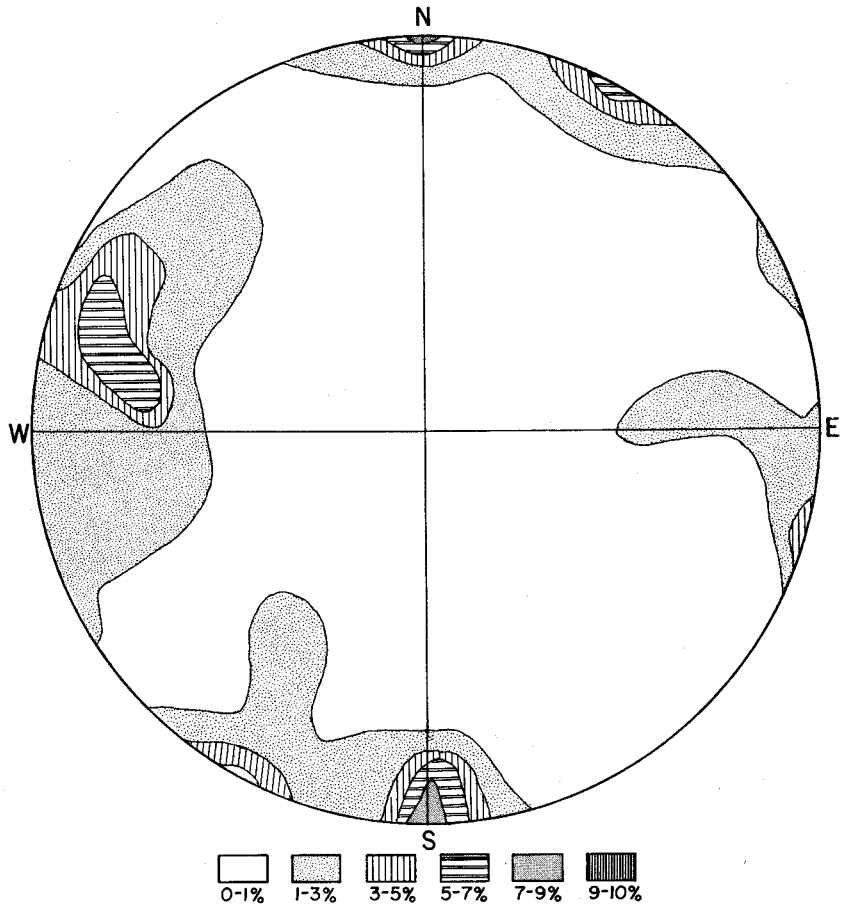


Figure 10. Contour diagram illustrating the attitude of joints in Triassic sedimentary rocks. Lower hemisphere plot based on 100 attitudes.

ping from 80° NW. to 85° SE (Figure 12). Figure 13 shows several directions of jointing in the diabase. One location (Figure 14) was found which has polygonal jointing formed on the upper surface of a fine-grained diabase or basalt sill.

The attitudes of some joints in the Catoctin and Weverton formations are similar to attitudes of joints in Triassic rocks and may be Triassic or post-Triassic in age. Other joint systems were probably caused by pre-Triassic deformation. The joint patterns in the Triassic sedimentary and pyroclastic rocks are quite similar; the joint

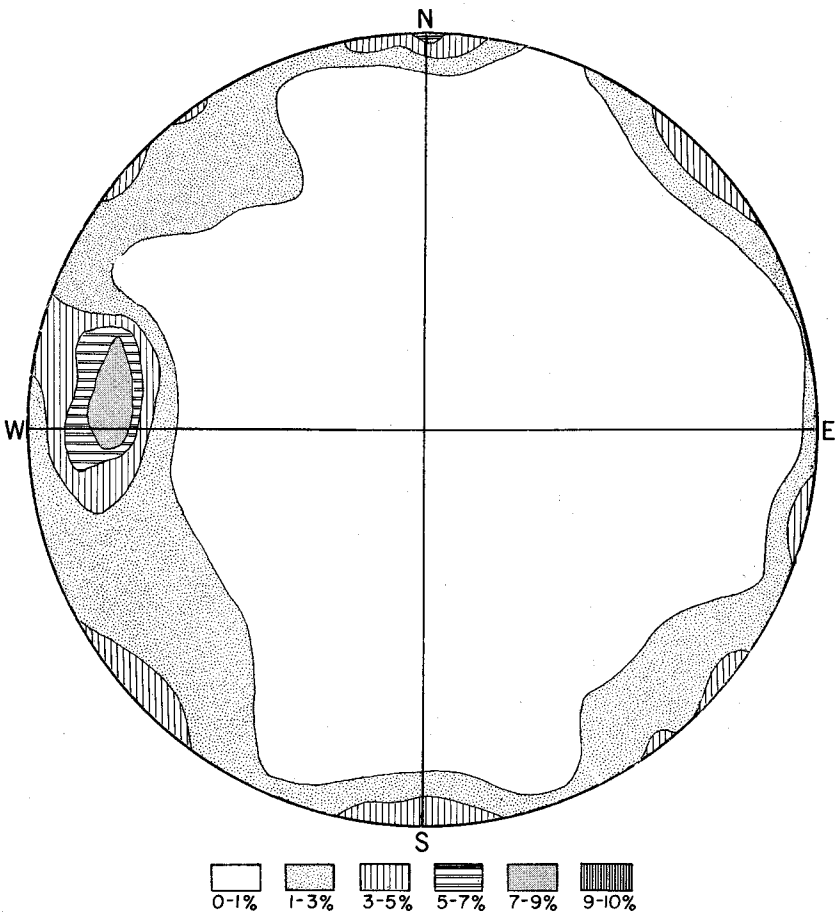


Figure 11. Contour diagram illustrating the attitude of joints in Triassic pyroclastic rocks. Lower hemisphere plot based on 100 attitudes.

directions in the diabase include those present in the other Triassic rocks, as well as other joint sets, possibly due to cooling after intrusion, which are unique to the diabase.

Joints play a major role in the control of topographic features in the Leesburg quadrangle. Goose Creek has several right-angle bends that correspond to major directions of jointing. Many of the minor faults within the Culpeper basin parallel a direction of jointing.

A slight amount of intrusive doming is evident in some areas within the Culpeper basin where the Triassic sedimentary and pyro-

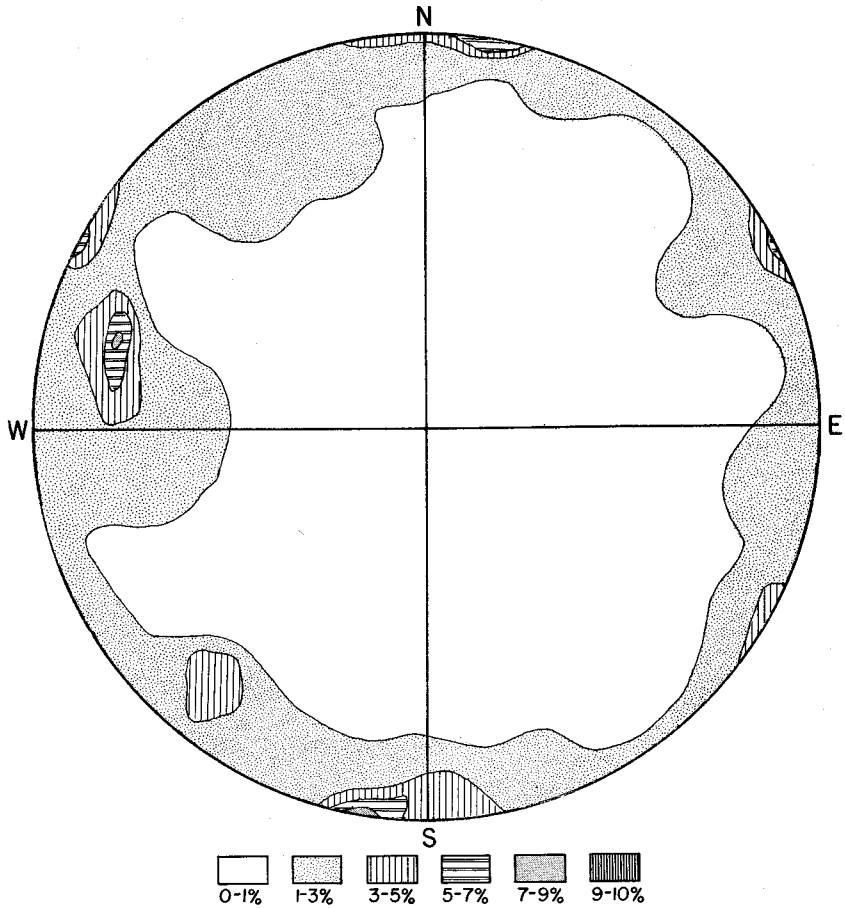


Figure 12. Contour diagram illustrating the attitude of joints in Triassic diabase. Lower hemisphere plot based on 100 attitudes.

clastic rocks have been bowed up at the diabase contact. This effect is minor, amounting to only a few degrees of steepening of dip. Another structural feature affecting the dip of the Triassic strata is movement along normal faults parallel to the Bull Run fault. This movement resulted in westerly dips for the entire Triassic section, even though the coarser material derived from a source area to the west of the Culpeper basin would have had an initial easterly dip. These "fault blocks" are not particularly apparent, but could be postulated in areas where a sharp change in the westerly dip of the rocks is evident.

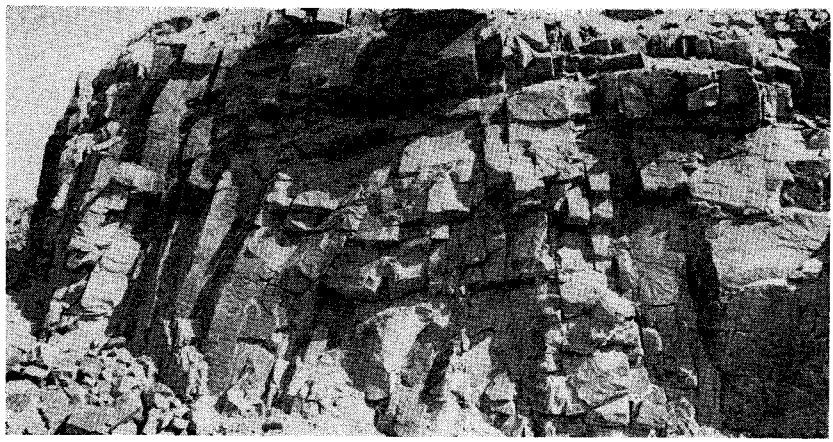
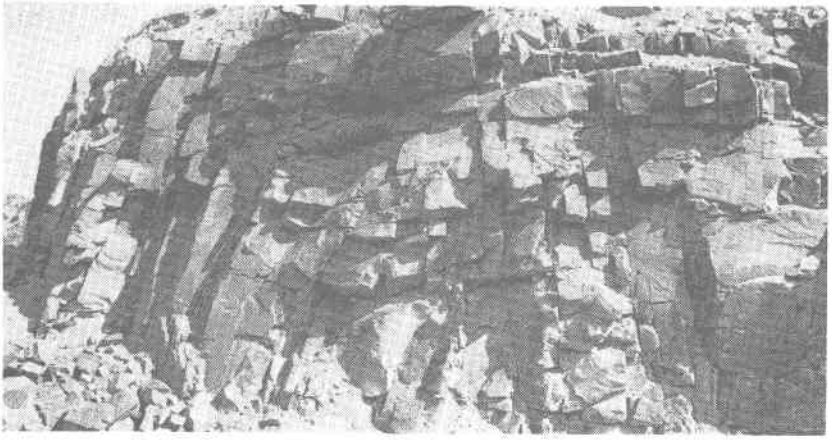


Figure 13. Jointed Triassic diabase in the upper level of the Virginia Trap Rock, Inc. quarry west of State Road 653, 3.5 miles east of Leesburg (Plate 1, No. 6). Four joint directions can be seen.

Figure 14. Polygonal jointing on the upper surface of a fine-grained Triassic diabase sill near Oatlands, just east of U. S. Highway 15.

GEOLOGIC HISTORY

The Catoctin Formation, composed of basic or intermediate lava flows and pyroclastic rocks, represents a period of vulcanism at the beginning of deposition in the late Precambrian-Early Cambrian geosyncline. The Weverton Formation was deposited on this volcanic sequence, and may indicate a change from eugeosynclinal to mio-



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geosynclinal environment. During succeeding Paleozoic time, the area was subjected to the processes of tectonism, and the Catoctin Formation was regionally metamorphosed to the greenschist facies.

Most of the Triassic rocks in the Leesburg quadrangle were derived from a source area to the west, as evidenced by cross-bedding and the size, shape, and lithology of the pebbles in the conglomerates. Though the environment was one primarily of sedimentation, pyroclastic materials and basalt flows were alternately introduced in some areas covered by water during the cessation of sand and clay deposition. These water-laid materials are stratified. As volcanic activity abated, clastic sediments were deposited with pyroclastic debris. A later period of deposition was interrupted by a thin flow of vesicular basalt. Movement along a normal fault located at the western margin of the basin was more or less active throughout the period of deposition. Intrusion of diabase along faults, joints, and bedding planes followed sedimentation. Secondary normal faults occurred after the intrusion of the diabase, as shown by truncation of the sedimentary units and the diabase. The Bull Run fault may be a subsequent fault which raised the former limit of Triassic sedimentation to the west above base level where it was stripped off by erosion. Regional uplift established the post-Triassic drainage across the basin, and Tertiary gravels were deposited locally. Most of these gravels were removed by later erosion, which is active at the present time.

ECONOMIC GEOLOGY

BUILDING STONE

Several rocks in the Leesburg quadrangle have potential use as a building stone: limestone conglomerate, diabase, and sandstone. Small quantities of limestone conglomerate have been quarried for building stone near Leesburg. A small quarry (Plate 1, No. 4) was operated in 1948, 0.5 mile east of town on State Road 643. It was recently filled in during the construction of the U.S. Highway 15 bypass east of Leesburg. Large tonnages of similar rock have been quarried in Maryland, and marketed under the trade name "Potomac marble" or "calico marble." The limestone conglomerate is attractive when cut and polished, and should be considered a potential ornamental stone.

Very little of the diabase presently being produced in the Leesburg area is used for dimension or ornamental purposes, but its uniform coloration and grain size would make the rock an attractive

facing material. Similar diabase is quarried for dimension stone in Culpeper County, Virginia. Sandstones have been quarried extensively for dimension stone (Watson, 1907, p. 59), but no operations were found in the Leesburg quadrangle during the present study.

CRUSHED STONE

Two companies, The Arlington Stone Company and Virginia Trap Rock, Inc., both of Leesburg, are presently quarrying and crushing diabase. The Arlington Stone Company quarry (Plate 1, No. 7) is about 4 miles southeast of Leesburg on the west side of State Road 659. It was first opened about 1880, as the Belmont Trap Rock quarry (Roberts, 1928, p. 121), with sporadic production until 1928. Since that date the quarry has been in continuous operation. Physical test data (Gooch and others, 1960, p. 29) are as follows: Los Angeles loss (500 rev), 22.5; absorption, 0.10; specific gravity, 3.04. Earlier tests on the diabase from this quarry (Parrott, 1947b) give the following data: Los Angeles loss, Grade A—17.8, Grade B—19.2, Grade C—27.2, Grade D—24.0; specific gravity, 2.92.

The Virginia Trap Rock, Inc. quarry (Plate 1, No. 6) is located about 3.5 miles southeast of Leesburg on the northwest side of State Road 653 (Figures 7, 13). This quarry was first opened in September 1957 (Gooch and others, 1960, p. 47), and has been in continuous production since that time. Physical test data are as follows: Los Angeles loss (500 rev), 24.7-30.7; absorption, 0.67; specific gravity, 3.01 (Gooch and others, 1960, p. 47).

Several small pits have been operated in the diabase for local road material. Most of these are abandoned, but one pit (Plate 1, No. 9), located about 6.5 miles southwest of Leesburg near Oatlands, east of U. S. Highway 15, is still in use. Weathered diabase from this pit is used locally for driveway stone. Physical test data are as follows: Los Angeles loss (500 rev), 14.6; absorption, 0.66; specific gravity, 2.88; soundness, OK (Parrott, 1954, p. 67).

The pyroclastic unit has been quarried for use as crushed road material. One quarry (Plate 1, No. 5) is located about 3 miles southeast of Leesburg, west of Goose Creek and just north of State Highway 7. This quarry was operated by the Commonwealth of Virginia for highway aggregate from 1946 to 1957. The following physical test data have been reported: Los Angeles loss (500 rev), Grade A—11.6, Grade B—16.0, Grade C—12.2; absorption, 1.02; specific gravity, 2.74-2.75 (Parrott, 1947a).

A second abandoned quarry (Plate 1, No. 10) in the pyroclastic

unit is located about 6 miles south of Leesburg near Evergreen Mills, south of Goose Creek and east of the intersection of State Roads 621 and 625. Physical test data from the Evergreen quarry are as follows: Los Angeles loss (500 rev), 19.6; absorption, 2.34; specific gravity, 2.63; soundness, 0.50 (Parrott, 1954, p. 67).

The Triassic limestone conglomerate has been quarried for use as crushed aggregate, and there are three abandoned quarries in this rock in the Leesburg quadrangle. One of these (Plate 1, No. 3) was opened in 1884 (Roberts, 1928, p. 128) in the southeastern part of the town of Leesburg, but was apparently abandoned shortly after operations had commenced. A second, and larger quarry (Plate 1, No. 2), located just west of the site of the small pit, was opened in 1888 (Roberts, 1928, p. 128), under the name of Leesburg Lime Quarry Company and was operated until 1945. Another quarry (Plate 1, No. 1) in the limestone conglomerate which was worked for road metal is located east of State Road 621, about 0.6 mile south of Leesburg.

A small abandoned quarry in an arkosic conglomerate is present about 6.5 miles southwest of Leesburg near Oatlands, about 0.5 mile west of U. S. Highway 15. Roberts (1928, p. 126) mentioned slight activity at the site from which good road metal might be obtained. Physical test data were reported by Parrott (1954, p. 67) as follows: Los Angeles loss, Grade A—14.6; absorption, 1.6; specific gravity, 2.75.

The epidote-quartz phase of the Catoctin Formation has some potential as crushed aggregate, but the dominant lithology is a chlorite schist that is too soft to make an acceptable crushed stone. A small abandoned quarry in the Catoctin Formation is located about 7 miles southwest of Leesburg near Oatlands, 1 mile west of the intersection of U. S. Highway 15 and State Road 733. Physical test data are as follows: Los Angeles loss (500 rev), Grade A—21.9; specific gravity, 3.00 (Parrott, 1947c).

Rock from the Weverton Formation has been crushed for road metal. A pit (Plate 1, No. 8), located 5.2 miles southwest of Leesburg west of U. S. Highway 15, was operated from about 1920 to 1930 and was eventually abandoned because the rock was too soft. This quarry was in the upper phyllitic beds of the Weverton; the lower quartzites are quite hard and should make an adequate road metal.

AGRICULTURAL LIME

Limestone conglomerate was quarried from 1888 (Roberts, 1928, p. 128) until about 1945 by the Leesburg Lime Company, Inc., at

their quarry (Plate 1, No. 2) in Leesburg. Following are two chemical analyses of the rock (Roberts, 1928, p. 13, 129):

(1)	CaO	37.75%	(2)	$CaCO_3$	65%
	MgO	19.43%		$MgCO_3$	20%
	SiO_2	13.55%		SiO_2	10%
	Fe_2O_3 and Al_2O_3	6.97%		Al_2O_3	5%
	CO_2	21.17%			
	Moisture	1.00%			

This material was used as agricultural limestone, burned agricultural lime, and aggregate for concrete.

COPPER-BEARING MINERALS

Copper-bearing minerals are fairly common in many of the rock units in the Leesburg quadrangle. Chalcopyrite occurs in diabase, basalt, and pyroclastic rocks; traces of chalcopyrite are present in drill cores from the diabase (Appendix III). Malachite has been found along bedding and fracture surfaces in sandstones, shales, and pyroclastic rocks. None of these occurrences of copper mineralization shows any economic potential. A copper prospect, located about 4 miles east of Leesburg near Goose Creek (Plate 1), was opened in about 1880 (Roberts, 1928, p. 135), but little or no actual copper production resulted. This prospect was visited by the writer and only a few elongate depressions that may have been prospect trenches were found.

CLAY AND SHALE

Triassic shales have been tested and evaluated for potential commercial use in Loudoun County (Calver and others, 1961, p. 79-89). These results indicate that some of the Triassic shales are potentially suitable for brick, sintered aggregate, tile, and low-grade pottery. None of the sample localities are in the Leesburg quadrangle, but the clay and shale of the Leesburg quadrangle may be of comparable quality. A sample (R-2883) of light-brown silty clay was collected 2 miles north of Leesburg, east of U. S. Highway 15. Tests by the U. S. Bureau of Mines indicate that this material is suitable for face brick and quarry tile.

SURFACE WATER

The Leesburg quadrangle is in the Potomac River drainage basin. Goose Creek is a main tributary to the Potomac River, and empties into the Potomac about 4.7 miles east of Leesburg. Little River, Sycoline Creek, and Tuscarora Creek are main tributaries to Goose Creek. A stream gage is located in Goose Creek at Evergreen Mills, and large variations in the flow are indicated by the following data (Holmes, 1957, p. 37):

Drainage area: 338 square miles
Record for the period July 1909 to December 1912 and January 1930 to September 1955
Average discharge (27 years): 308 cubic feet per second
Maximum of 45,000 cubic feet per second on August 26, 1937 and October 16, 1942
Minimum of 0.4 cubic feet per second on September 27, 1941

Quality of the surface water in the area is given in Table 1.

Table 1.—Chemical analyses of waters from Goose Creek near Evergreen Mills. Values are expressed in parts per million where applicable.

	1932 (1)	1932 (1)	1947 (2)	8/15/58 (3)	1/9/59 (3)	5/8/59 (3)	9/1 /59 (3)
SiO_2	13.0	16.0	9.8	34.0	12.0	7.4	8.8
Fe	0.03	0.09	0.07	0.07	0.0	0.05	0.0
Ca	25.0	9.3	7.8	16.0	11.0	9.9	18.0
Mg	7.1	3.4	2.8	9.5	3.3	0.0	2.2
Na	3.0	4.5	3.4	3.7	11.0	5.6	5.2
K	1.7	1.5		3.0	2.5	4.0	5.8
HCO_3	116.0	20.0	32.0	34.0	38.0	37.0	47.0
SO_4	4.0	13.0	7.2	7.4	11.0	1.3	11.0
Cl	2.2	4.8	2.4	4.5	7.4	5.5	6.8
F	—	—	0.0	0.0	0.1	0.0	0.1
NO_3	0.3	17.0	1.6	4.0	7.1	2.2	1.8
Dissolved solids	202	90	57	368	102	101	106
pH	—	—	—	6.9	6.9	7.0	7.0
Color	1	19	12	35	3	7	10
Temp. (°F)	—	—	—	—	32	64	78
Ignition loss	—	—	—	280	29	27	43
Total hardness	92	37	31	79	41	23	54
Discharge (cu ft/sec)	1.8	150	214	210	49	116	10

(1) Collins and others (1932, p. 65).
(2) Lamar and Whetstone (1947, p. 32).
(3) Holmes (1960, p. 34).

GROUND WATER

Tables 2-6 are compilations of data from 111 drilled wells in the Leesburg quadrangle; four municipal wells from the town of Leesburg and 107 domestic wells are included. Most of the domestic wells have a diameter of 6 inches; one municipal well has a diameter of 6 inches, two have diameters of 8 inches, and one is 10 inches. No record could be found of the diameter of some of the domestic wells, but it is assumed that these have a diameter of 6 or 8 inches. The yields recorded for domestic wells do not necessarily represent their maximum potentials.

Wells in the Catoctin Formation have an average yield of 12 gallons per minute in the Leesburg area, with no marked increase or decrease with depth (Table 2). The Catoctin Formation is generally considered a poor aquifer (Cady, 1938, p. 24, 39-40), but higher yields from wells in this formation in the Leesburg area are probably due to the well-foliated nature of the Catoctin and the presence of weathered zones and fractures.

Table 2.—Average yield of wells in the Catoctin Formation.

Total Depth (feet)	Number of Wells	Yield (gallons per minute)	
		Range	Average
0-100	10	3-30	11+
101-200	7	3-25	9+
201-300	8	5-75	15+
	25	3-75	12+

No records could be found of wells drilled into either the Weverton or Loudoun formations. The Loudoun Formation is very sparsely, if at all, represented in the Leesburg quadrangle, and the Weverton is rather thin and forms a narrow strike ridge; homes built on this ridge are generally supplied by wells drilled in areas underlain by either the Catoctin Formation or Triassic rocks.

The limestone conglomerate of Triassic age is a good source of ground water where it is highly fractured, and fairly shallow wells yield sufficient quantities of water for domestic purposes. Yields of 11 to 12 gallons per minute are obtained from wells less than 100 feet deep (Table 3). The four producing deep wells in the limestone conglomerate are Leesburg municipal wells.

Water obtained from the limestone conglomerate may be very hard. Total hardness reported as $CaCO_3$ in a chemical analysis of water obtained from a 360-foot-deep Leesburg municipal well (Cady, 1938, p. 116) was 248 parts per million.

Table 3.—Average yield of wells in Triassic limestone conglomerate.

Total Depth (feet)	Number of Wells	Yield (gallons per minute) Range	Average
0-100	20	0.5-25	11.5
101-200	13	0-55	16+
201-400	5	60-480	153
	38	0-480	35+

The quartz conglomerate is also a good source of water; the poor sorting and incomplete cementation of the conglomerate make it an excellent aquifer. Eight wells drilled to depths of 50 to 100 feet yielded from 7 to 25 gallons per minute, with an average yield of 20.5 gallons per minute.

Interbedded sandstones and shales provide ample amounts of water for domestic use. In general, the yield from these rocks increases with depth as more water-bearing horizons are encountered (Table 4). The sandstones and arkoses are poorly cemented, and connecting joints and other fractures allow easy passage of water.

Table 4.—Average yield of wells in Triassic shale and sandstone.

Total Depth (feet)	Number of Wells	Yield (gallons per minute) Range	Average
0-100	17	0.5-60	14+
101-300	3	—	17+
	20	0.5-60	15+

Diabase and basalt are relatively poor aquifers in the Leesburg area (Table 5). Most wells in these rocks yield less than 5 gallons per minute; the depth of a well has little influence on the quantity of water obtained. An 803-foot-deep well in diabase yielded only 3 gallons per minute (Johnston, 1960, p. 3). The best chance for obtaining adequate quantities of water from diabase or basalt would be from shallow wells in deeply weathered material, or in areas where the diabase or basalt is highly fractured.

Table 5.—Average yield of wells in Triassic diabase and basalt.

Total Depth (feet)	Number of Wells	Yield (gallons per minute) Range	Average
0-100	16	1-6	3.5
101-200	6	0.5-20	8
	22	0.5-20	4.5+

The pyroclastic unit is a very poor source of water except where it is highly fractured. Contacts between this unit and the diabase or

shale and sandstone would probably offer the best potential for ample water supplies.

Table 6.—Average yield of wells in Triassic pyroclastic rocks.

Total Depth (feet)	Number of Wells	Yield (gallons per minute)	
		Range	Average
0-100	3	8-10	8+
101-200	3	—	2.5
	6	2.5-10	5+

Wells drilled into the fault zone at the west margin of the Culpeper basin should provide sufficient water for most domestic requirements. The recharge conditions are ideal, both topographically and structurally. The Weverton Formation forms a prominent ridge and has an easterly dip into the fault; the Triassic rocks have a westerly dip into the fault plane. The rocks within this zone are highly fractured, and allow easy passage of water.

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APPENDIX I

Stratigraphic section of Triassic sedimentary rocks, measured along State Road 650, 6.37 miles south-southeast of Leesburg, and 0.2 mile east of U. S. Highway 15.

	Thickness Feet
Diabase, dark-gray, medium-grained; plagioclase laths intergrown with pyroxene to form subophitic texture	10.0
"Baked" shale, gray, fine-grained, laminated; in places the laminae are severely contorted, probably due to deformation caused by the intrusion of diabase	1.9
Shale, pink, fine-grained, thin-bedded, fissile; muscovite and quartz identifiable megascopically; muscovite is oriented along bedding planes	0.6
Covered interval; red sandstone and shale float	16.3
Sandstone, gray to red, fine- to medium-grained, irregularly bedded (1 to 4 inches thick), 0.5-inch interbeds of sandy shale, weathers buff; grains mostly angular to subangular	6.5
Shale, red, thin-bedded, calcareous, weathers reddish-brown	3.1
Sandstone, gray, medium-grained, 1- to 2-foot-thick beds, somewhat friable, weathers pinkish-gray; grains are subangular to subrounded	4.5
Arkose, red, medium-grained, thin-bedded, slightly calcareous, weathers reddish-brown; quartz grains angular to subangular; feldspar grains angular	1.1
Covered interval	35.0
Sandstone, gray, medium-grained, thin-bedded, very friable, weathers light-gray; poorly defined cross-bedding; grains angular to subangular	0.5
Sandstone, maroon, thin-bedded, calcareous, slightly friable, weathers reddish-brown; grains angular to subrounded	0.4
Arkose, red, medium-grained with some coarse quartz grains, thin-bedded, slightly calcareous, weathers dull reddish-brown; grains mostly angular	2.1
Conglomerate, brown to red, bedding not readily discernible but about 1 to 1.5 feet thick, friable, weathers brown. Matrix is arkosic, medium-grained; grains angular to subangular. Pebbles (quartz) are up to 1.5 inches in diameter and are subangular to subrounded; most pebbles sound, but some contain incipient fractures filled with reddish-brown clay	10.0
Shale, red, sandy, thin-bedded, cross-bedded	3.5
Covered interval	19.6
Shale, red to brown, quite fissile, very slightly calcareous, weathers gray-brown; mud cracks on bedding planes; several 1- to 3-inch-thick sandy shale interbeds	3.5
Covered interval	6.0
Arkose, red to gray, medium-grained, beds 2 to 6 inches thick, weathers reddish-gray; grains mostly angular; interbeds of sandy shale 1 to 2 inches thick give "flaggy" appearance	5.8

	Thickness Feet
Shale, red, sandy, thin-bedded, somewhat fissile, calcareous, weathers red-brown; thin interbeds of green shale	10.0
Sandstone, olive, medium-grained, beds 10 to 12 inches thick, fairly friable, weathers buff; grains angular to subangular	2.1
Shale, olive, thin-bedded, calcareous, weathers gray	0.1
Shale, red, thin-bedded, fissile, calcareous, weathers brown	0.6
Sandstone, red-brown, medium-grained, flaggy, 0.5- to 3.5-inch beds, weathers reddish-gray; grains subangular	3.0
Shale, gray, very thin-bedded, fissile, weathers gray	0.1
Sandstone and shale, interlayered; sandstone brown, slightly calcareous, medium-grained, weathers rust-brown; shale green to red, thin-bedded, slightly calcareous, weathers pinkish-green. Several small normal faults are present	7.0
Shale, green, thin-bedded, calcareous, weathers gray-green	1.2
Sandstone, red-brown, medium-grained, weathers brown; grains angular; contains interbeds of olive, thin-bedded shale	5.5
Sandstone, pink to brown, medium-grained, slightly friable, weathers pale-brown; grains angular to subangular	1.6
Shale, brown, thin-bedded, fissile; weathers dark-brown	8.9
Sandstone, gray to pink, medium-grained; 0.5- to 1.2-foot-thick beds, weathers gray	2.3
Siltstone, pink to red-brown, thin-bedded, slightly fissile, weathers brown; interbeds of sandstone and shale	8.0
Shale, green, very thin-bedded, fissile, weathers gray-green	0.6
Sandstone, gray-green, medium-grained, massively bedded at base, thinner bedded near top, weathers gray; grains angular to subangular; interbeds of gray-green shale near top	3.7
Shale, dark-red to maroon, thin-bedded, fairly fissile, weathers dark-red; sandstone interbeds 0.5 to 0.75 inch thick	5.8
Shale, green, fissile, weathers gray-green	0.5
Sandstone, pinkish-gray, fine-grained, fairly thin-bedded, weathers gray; grains angular to subrounded; few interbeds of pink fissle shale	6.8
Shale, red, thin-bedded, very slightly calcareous, weathers pink	1.8
Sandstone, pink to brown, medium-grained, thin-bedded, weathers pinkish-gray; grains angular to subangular	4.2
Shale, red, thin-bedded, weathers pink; few interbeds of green shale	4.5
Sandstone, green to gray, medium- to coarse-grained, thin-bedded, weathers gray; grains subangular to subrounded	3.2
Sandstone, red, medium-grained, very friable, weathers pink; grains angular; interbeds of pink siltstone	5.1
Arkose, red, coarse-grained, slightly conglomeratic with some 0.5-inch quartz pebbles, very friable, weathers red; grains angular	1.2
Sandstone, red, medium-grained, thin-bedded, weathers pink; grains angular to subrounded	2.1
Shale, dark-red, thin-bedded, fissile, some beds slightly calcareous, weathers dull-red; grades down section into green shale (11 inches)	3.0

	Thickness Feet
Sandstone, gray to olive, medium-grained, thin-bedded, weathers gray-green; grains subangular	0.6
Arkose, red, coarse-grained, slightly conglomeratic, no discernible bedding, weathers red-brown; grains angular	1.3
Sandstone, red, medium- to coarse-grained, weathers brown; grains subangular to subrounded	0.5
Conglomerate, brown, friable. Matrix is sandstone, brown, medium-grained. Pebbles (quartz) average 1 inch in diameter and are subangular to subrounded	1.2
Covered interval	45.0
Sandstone, olive, medium-grained, weathers gray-green; grains angular	5.0
Shale, green, fissile, weathers gray-green	0.8
Sandstone, green, coarse-grained, very friable, weathers gray	12.5
Conglomerate, red to brown, completely weathered to quartz pebbles and brown sand	10.9
Sandstone, brown, medium-grained, very friable, weathers brown; grains angular to subangular	1.1
Shale, olive to brown, thin-bedded, soft, slightly calcareous, weathers gray-brown	2.3
Sandstone, brown, medium-grained, very friable, massive, weathers brown; grains subangular	1.3
Shale, olive to gray, thin-bedded, soft, weathers gray; 0.5-foot-thick sandstone bed in middle of sequence	5.2
Sandstone, arkosic, gray to brown, medium- to coarse-grained, friable, massive, slightly calcareous, weathers buff; grains angular	1.8
Shale and sandstone, interlayered: shale, olive, soft; sandstone, brown, medium-grained, slightly calcareous, weathers olive-brown; "flaggy" appearance	9.2
Shale, dark-gray, soft, weathers light-gray; contains *Unio* sp., *Estheria* (*Isaura*) *ovata*, fish scales, wood fragments, and possibly some ostracodes (R-2704)	4.6
Shale, olive to gray, thin-bedded, friable; and sandstone, brown to gray, medium-grained, weathers gray; contains fossil remains as above (R-2705)	10.5
Shale, dark-gray, thin-bedded, soft, slightly calcareous, weathers light-gray; plant fossils (R-2706)	2.0
Siltstone, brown; and sandstone, brown, medium-grained, beds 0.25 to 0.5 inch thick, weathers rust-brown	11.0
Sandstone, light-brown, fine- to medium-grained, massive, weathers light rust-brown; grains angular to subangular	1.9
Shale, light-pink to pinkish-green, soft, thin-bedded, calcareous	1.7
Shale, pink to green, interbedded with siltstone and sandstone	3.9
Conglomerate, brown, friable. Matrix is sandstone, brown, medium-grained. Pebbles (quartz) average 1 inch in diameter and are subangular to subrounded	1.2
Sandstone, red, medium- to coarse-grained, 2- to 4-inch-thick beds, slightly friable, weathers reddish-brown; grains are subangular	2.2

	Thickness Feet
Conglomerate, brown to red, bedding not discernible, friable, weathers brown. Matrix is arkosic, medium-grained; grains subangular. Pebbles (quartz) average 0.5 inch in diameter and are subangular to subrounded	1.0
Sandstone, red, medium- to coarse-grained, beds range from 1 to 5 inches in thickness, cross-bedded, friable, weathers red-brown; grains subangular	7.6
Covered interval	24.2
Sandstone, arkosic, red, medium- to coarse-grained, irregularly bedded (some cross-bedding), weathers red; grains angular to subangular	3.5
Sandstone, arkosic, gray, coarse-grained, weathers gray; grains angular	1.1
Sandstone, red, coarse-grained, weathers red-brown; grains angular to subangular	8.9
Conglomerate, brown, very friable, weathers brown; quartz pebbles average 0.5 inch in diameter, and most are subangular but some are subrounded	1.8
Sandstone, arkosic, red, coarse-grained, 0.5- to 4-inch-thick beds, cross-bedded, weathers brown; grains angular to subangular	13.0
Conglomerate, red to brown, very friable, weathers brown; quartz pebbles average 0.75 to 1 inch in diameter	5.7
Sandstone, arkosic, red, coarse-grained, cross-bedded, very friable, weathers brown; grains angular	1.8
Conglomerate, buff to brown, massive, weathers brown; quartz pebbles average 2.5 inches in diameter and range from 0.25 to 6 inches	4.5
Sandstone, red, coarse-grained, cross-bedded, somewhat arkosic, weathers red-brown; slightly conglomeratic; grains angular	12.6
Covered interval	20.6
Sandstone, arkosic, gray to red, medium- to coarse-grained, cross-bedded, weathers pinkish-gray; beds range from 2 to 7 inches in thickness; grains angular to subangular	101.8
Siltstone, red; and shale, dark-red, fissile, calcareous, weathers red; "flaggy"	15.1
Sandstone, arkosic, red, medium- to coarse-grained, weathers light-red; grains subangular	4.2
Conglomerate, red to brown, very friable, weathers brown. Quartz pebbles average 0.25 inch in diameter. Matrix is arkosic, coarse-grained; grains angular	1.0
Sandstone, red, medium- to coarse-grained, weathers red; grains angular to subangular	0.6
Shale, red, fissile, calcareous, thin-bedded, weathers red-brown	1.4
Total	591.4

APPENDIX II

Stratigraphic section of Triassic pyroclastic rocks, measured in abandoned quarry (Plate 1, No. 5) 3.5 miles east-southeast of Leesburg.

	Thickness Feet
Crystal tuff, gray, very fine-grained, mafic to intermediate, weathers dark-gray, slightly laminated but laminae not continuous, could represent flow lines. Thin section (R-2823) contains quartz, 25 percent; plagioclase, 15 percent; biotite, 10 percent; opaque minerals, 9 percent; rutile, 1 percent; and a fine-grained groundmass of pyroxene and plagioclase, 40 percent. X-ray diffraction (X-452) shows the following minerals in order of relative abundance: pyroxene, plagioclase, mica, quartz, and epidote(?)	35.0
Basalt, black, very fine-grained, weathers dark-gray. X-ray diffraction (X-458) indicates that pyroxene and plagioclase are the main minerals	12.0
Crystal tuff, gray-green, very fine-grained, intermediate to felsic, weathers gray-brown; beds are from 0.7 to 1.0 foot thick. Thin section (R-2826) contains quartz, 35 percent; plagioclase, 10 percent; pyroxene, 8 percent; opaque minerals, 7 percent; biotite, 3 percent; zircon, 1 percent; rutile, 1 percent; and a fine-grained groundmass, 35 percent. X-ray diffraction (X-455) shows the following minerals in order of relative abundance: plagioclase, quartz, pyroxene, and epidote	12.4
Crystal tuff, light-tan, very fine-grained, intermediate, weathers gray-brown; concentrations of magnetite give rock a spotted appearance; beds range from 1 to 2 feet in thickness. Thin section (R-2822) contains pyroxene, 35 percent; plagioclase, 30 percent; quartz, 20 percent; calcite, 5 percent; opaque minerals, 3 percent; hornblende, 2 percent; zircon, 2 percent; biotite, 2 percent; chlorite, 1 percent; and epidote and rutile in trace amounts. X-ray diffraction (X-451) shows the following minerals in order of relative abundance: plagioclase, pyroxene, quartz, amphibole, chlorite, and epidote	8.6
Crystal tuff, gray, very fine-grained, intermediate, weathers light-gray; "blebs" in rock are more resistent to weathering and produce a "knobby" appearance. In thin section (R-2824), the "blebs" are due to concentrations of opaque minerals, and are possibly accretionary lapilli. The rock contains quartz, 35 percent; plagioclase, 25 percent; hornblende, 5 percent; opaque minerals, 3 percent; epidote, 2 percent; and a fine-grained groundmass, probably pyroxene, 30 percent. X-ray diffraction (X-453) shows the following minerals in order of relative abundance: pyroxene, quartz, plagioclase, amphibole, and epidote	12.0
Crystal tuff, gray, very fine-grained, intermediate to mafic, weathers dark-gray to black. Thin section (R-2821) contains quartz, 20 percent; chlorite, 5 percent; calcite, 5 percent; opaque minerals, 3 percent; prehnite, 1 percent; zircon, 1 percent; and a dark, fine-grained	

Thickness
Feet

groundmass, probably pyroxene and plagioclase, 65 percent. X-ray diffraction (X-450) shows the following minerals in order of relative abundance: pyroxene, plagioclase, quartz, calcite, mica and epidote(?) 27.0

Basalt, dark-gray to black, very fine-grained, weathers dark-gray. X-ray diffraction (X-447) shows pyroxene and plagioclase to be the main minerals present 8.0

Crystal tuff, mottled pink and light gray-green, very fine-grained, felsic, weathers mottled pinkish-gray and greenish-gray; no discernible bedding. Thin section (R-2817) contains quartz, 60 percent; calcite, 20 percent; pyroxene, 10 percent; chlorite, 5 percent; opaque minerals, 3 percent; and plagioclase, 2 percent. X-ray diffraction (X-446) shows the following minerals in order of relative abundance: quartz, calcite, chlorite, pyroxene, and plagioclase..... 1.0

Interbedded felsic and intermediate crystal tuffs. Felsic tuffs are dominant in the top 4.5 feet, and are pinkish-gray, very fine-grained, and weather pink to gray-green; some thin (0.1- to 0.2-inch) bands of intermediate tuff are included in the upper 4.5 feet. Intermediate tuffs make up the middle 6.9 feet; they are light-gray to dark-gray, very fine-grained, and weather gray. The lower 2.6 feet is mainly felsic tuffs. Two 0.2-inch-thick, discontinuous bands of intermediate tuff are present as 14- to 20-inch-long "stringers" within the felsic section. A thin section (R-2820) of the contact area between the felsic and intermediate units contains flow lines and amygdules, and shows the sinuous nature of the contact. X-ray diffraction analyses were run on both units. The analysis of the felsic unit (X-449) shows the following minerals in order of relative abundance: plagioclase, quartz, pyroxene, calcite, and possibly epidote. The analysis of the intermediate unit (X-449-A) shows the following minerals in order of relative abundance: pyroxene, plagioclase, quartz, and amphibole..... 14.0

Crystal tuff, mottled pinkish-gray and gray-green, very fine-grained, intermediate to felsic, weathers brown to buff; gray-green amygdules are present in a pinkish-gray groundmass. Thin section (R-2819) contains plagioclase, 35 percent; quartz, 25 percent; calcite, 20 percent; pyroxene, 15 percent; opaque minerals, 2 percent; chlorite, 2 percent; biotite, 1 percent. The pinkish-gray groundmass is composed of plagioclase, quartz, calcite, and some pyroxene; the gray-green amygdules contain pyroxene, chlorite, biotite, opaque minerals, and some quartz and calcite. X-ray diffraction analysis (X-448 of the groundmass shows the following minerals in order of relative abundance: plagioclase, quartz, calcite, and pyroxene; analysis (X-448-A) shows that the gray-green amygdules contain pyroxene and chlorite, with some calcite and quartz..... 4.0

Crystal tuff, dark-gray, very fine-grained, intermediate, weathers light-gray, massive, with no discernible bedding. Thin section (R-2816) contains quartz and pyroxene in a very fine-grained matrix of pla-

	Thickness Feet
gioclase and pyroxene. There is an apparent concentration of mafic and opaque minerals in spherulite-like masses. The mineralogy is: quartz, 30 percent; plagioclase, 10 percent; pyroxene, 7 percent; opaque minerals, 3 percent; and groundmass (plagioclase and probably pyroxene), 40 to 50 percent. X-ray diffraction (X-445) shows the following minerals in order of relative abundance: plagioclase, pyroxene, quartz, and possibly epidote	1.0
Crystal tuff, pinkish to pink-green, fine-grained, felsic, weathers pinkish-tan. Thin section (R-2818) contains: quartz, 50 percent; plagioclase (mainly labradorite, where identifiable), 30 percent; pyroxene, 10 percent; opaque minerals, 3 percent; zircon, 3 percent; calcite, 2 percent; and hornblende, 2 percent. X-ray diffraction analysis (X-447) indicates the following minerals in order of abundance: plagioclase, quartz, and pyroxene	4.5
Crystal tuff, medium-gray with light-gray blebs, very fine-grained, felsic to intermediate, weathers brown to brownish-gray. Thin section (R-2827) shows that the blebs are spherical bodies which have coarser cores of pyroxene, quartz, feldspar, prehnite(?), and possibly nearly completely devitrified glass; these cores are surrounded by very fine-grained opaque minerals. The minerology is: quartz, 30 percent; pyroxene, 20 percent; plagioclase, 10 percent; opaque minerals, 5 percent; biotite, 2 percent; amphibole, 2 percent; prehnite, 1 percent; and a dark unidentifiable groundmass, 30 percent. X-ray diffraction (X-456) indicates the following minerals in order of relative abundance: quartz, plagioclase, pyroxene, and prehnite(?)	4.0
Crystal tuff, dark gray-green, very fine-grained, intermediate to mafic, weathers brownish-gray; beds from 2 to 4 feet thick; some manganese dendrites and hematite spots on joint and bedding surfaces. Thin section (R-2825) is in general too fine grained to identify individual minerals. Identifiable minerals are: plagioclase, 15 percent; pyroxene, 15 percent; quartz, 10 percent; opaque minerals, 6 percent; zircon, 2 percent; rutile(?), 2 percent; dark unidentifiable groundmass, 50 percent. X-ray diffraction analysis (X-454) indicates the following minerals in order of abundance: pyroxene, plagioclase, quartz, and chlorite	27.0
Total	170.5

APPENDIX III

Geologic logs of cores of Triassic diabase from Leesburg quadrangle.

Well W-886

Depth Feet	Thickness Feet	Description
0-27.0	27.0	No recovery.
27.0-47.2	20.2	Diabase, dark-gray, medium-grained. Plagioclase, 55 to 60 percent; pyroxene, 40 to 45 percent; and magnetite, 2 to 5 percent. Shear planes with black slickensides cut entire core in this interval. Thin section (R-2375), from 35.0 feet, contains: plagioclase (An_{50-70}), 55 percent; augite, 30 percent; magnetite, 7 percent; and biotite, 3 percent.
47.2-68.4	21.2	Diabase, dark-gray to black, medium-grained. Plagioclase, 50 to 60 percent; pyroxene, 45 to 50 percent; and magnetite, 5 to 8 percent. Shear planes and dark veins are common in this interval. Thin section (R-2376), from 63.7 feet, contains: plagioclase (retaining crystal outlines for the most part, but almost entirely altered to saussurite), 50 percent; uralite-hornblende, 25 percent; augite, 15 percent; magnetite, 5 percent; biotite, 3 percent; and quartz, 2 percent. Poor core recovery from 48.0 to 52.0 feet.
68.4-80.3	11.9	Diabase, same as above, except dark veins absent.
80.3-157.2	76.9	Diabase, dark-gray, medium-grained. Plagioclase, 50 to 60 percent; pyroxene, 45 to 50 percent; and magnetite, 2 to 5 percent. Shear planes with black slickensides cut the core from 80.3 to 81.7 feet, 91.8 to 92.7 feet, 109.6 to 113.2 feet, 121.5 to 122.6 feet, 125.9 to 126.1 feet, 130.7 to 131.2 feet, 140.7 to 140.8 feet, and 140.8 to 149.9 feet. Thin section (R-2377), from 140.0 feet, contains: labradorite (An_{50-70}), 55 percent; augite, 30 percent; magnetite, 6 percent; hornblende, 5 percent; biotite, 3 percent; and quartz, 1 percent.
157.2-161.2	4.0	Diabase, same as above, having shear planes with black slickensides throughout.
161.2-188.4	27.2	Diabase, dark-gray to black, medium-grained. Plagioclase, 50 to 60 percent; pyroxene, 45 to 55 percent; magnetite, 2 to 5 percent; and biotite, 1 to 2 percent.
188.4-191.4	3.0	Diabase, same as above, except shear planes with black slickensides cut the core.
191.4-223.5	32.1	Diabase, same as above, except shear planes absent.
223.5-224.5	1.0	Diabase, dark-gray to black, slightly finer grained than above. Mineralogy same as above.

Depth Feet	Thickness Feet	Description
224.5-233.0	8.5	Diabase, light- to medium-gray, medium-grained. Plagioclase, 55 to 60 percent; pyroxene, 40 to 45 percent; and magnetite, 5 to 8 percent. Shear planes with black slickensides cut the core from 228.0 to 232.8 feet. Light-colored veins, cut the core from 228.1 to 229.6 feet, 230.8 to 230.9 feet, 231.7 to 232.2 feet, and 232.5 to 232.7 feet. Thin section (R-2378), from 230.5 feet, contains: labradorite (An_{50-70}), 55 percent; augite, 35 percent; magnetite, 5 percent; biotite, 3 percent; and quartz, 2 percent.
233.0-240.0	7.0	Diabase, dark-gray to black, medium-grained. Plagioclase, 50 to 55 percent; pyroxene, 35 to 40 percent; and magnetite, 5 to 8 percent.

Well W-887

0-27.0	27.0	No recovery.
27.0-38.6	11.6	Diabase, light green-brown to red-brown, medium-grained, weathered; core recovery in the form of small rounded fragments.
38.6-49.7	11.1	Diabase, dark-gray, medium-grained. Plagioclase, 55 to 60 percent; pyroxene, 40 to 45 percent; magnetite, 2 to 5 percent; and pyrite, 1 to 2 percent. Shear planes with black shiny slickensides cut the core from 38.0 to 38.2 feet, 39.8 to 40.2 feet, and 44.6 to 45.0 feet.
49.7-93.8	44.1	Diabase, same as above, except lighter in color. A dull greenish-black vein (stilpnomelane) is present from 94.3 to 94.5 feet. Thin section (R-2389), from 68.5 feet, contains: labradorite (An_{50-70}), 60 percent; augite, 30 percent; magnetite, 5 percent; biotite, 5 percent; and quartz, more than 1 percent.
93.8-96.9	3.1	Diabase, same as above, except cut by many small shear planes.
96.9-100.3	3.4	Diabase, medium-gray, medium-grained. Plagioclase, 55 to 60 percent; pyroxene 35 to 45 percent, magnetite, 2 to 5 percent; biotite, 2 to 5 percent; and pyrite, 1 percent.
100.3-108.6	8.3	Diabase, same as above, except 5 to 10 percent of the plagioclase is apparently altered. Shear planes with black slickensides cut the core from 100.3 to 100.9 feet and from 108.2 to 108.6 feet. Thin section (R-2390), from 106.5 feet, contains: plagioclase altered to saussurite, 45 percent; augite, 25 percent; pyroxene altered to hornblende-uralite, 6 percent; labradorite (An_{50-70}), 7 percent; biotite, 8 percent; magnetite, 7 percent; and quartz, 2 percent.

Depth Feet	Thickness Feet	Description
108.6-140.0	31.4	Diabase, medium- to dark-gray, medium-grained. Plagioclase, 55 to 65 percent; pyroxene, 45 to 50 percent; magnetite, 2 to 5 percent; and pyrite, 1 to 2 percent. A shear plane with black slickensides cuts the core from 116.4 to 116.7 feet.
140.0-144.9	4.9	Diabase, pinkish-green to gray, medium-grained; altered interval. Plagioclase(?), 60 to 70 percent; pyroxene/amphibole, 35 to 40 percent; magnetite, 1 to 2 percent; and pyrite, more than 1 percent. Shear plane with black slickensides cuts core from 144.0 to 144.6 feet.
144.9-162.8	17.9	Diabase, medium-gray, medium-grained. Plagioclase, 55 to 60 percent; pyroxene, 40 to 45 percent; and magnetite, 2 to 5 percent. Shear planes with black slickensides cut core from 145.7 to 145.9 feet and from 159.0 to 159.2 feet.
162.8-164.8	2.0	Diabase, pinkish-green to gray, medium-grained. Plagioclase, 45 to 50 percent; pyroxene, 40 to 45 percent; pink altered feldspar, 10 to 15 percent; and magnetite, 2 to 5 percent.
164.8-173.4	8.6	Diabase, dark-gray, medium-grained. Plagioclase, 55 to 65 percent and pyroxene, 45 to 50 percent.
173.4-174.9	1.5	Diabase, light-gray, medium-grained. White plagioclase, 50 to 55 percent; pyroxene, 35 to 40 percent; pink altered feldspar, 15 to 20 percent; chalcopyrite, 2 to 4 percent; and magnetite, 1 to 2 percent. Thin section (R-2391), from 174.2 feet, contains: saussurite, 65 percent; augite, 28 percent; chalcopyrite, 5 percent; and magnetite, 2 percent.
174.9-211.8	36.9	Diabase, dark-gray to black, medium-grained. Plagioclase, 50 to 60 percent; pyroxene, 40 to 45 percent; and magnetite, 2 to 5 percent. Shear planes with black slickensides cut the core at 184.4 feet and from 198.5 to 198.7 feet.
211.8-220.8	9.0	Diabase, medium-gray, medium-grained. Plagioclase, 55 to 60 percent; pyroxene, 40 to 45 percent; and magnetite, 3 to 5 percent. A black vein (chlorite) containing small fragments of plagioclase cuts the core from 211.7 to 212.3 feet; chalcopyrite is associated with this vein.
220.8-222.5	1.7	Diabase, same as above, except about 4 to 8 percent of the white feldspars have been altered to pink (saussurite ?).
222.5-223.3	0.8	Diabase, same as above, except cut by light-colored veins (prehnite); some alteration associated with veins.
223.3-243.7	20.4	Diabase, medium-gray, medium-grained. Plagioclase,

Depth Feet	Thickness Feet	Description
		50 to 60 percent; pyroxene, 40 to 45 percent; and magnetite, 3 to 8 percent. A shear plane with black slickensides cuts the core from 237.8 to 237.9 feet. A dark vein (chlorite) cuts the core from 231.2 to 231.4 feet.
243.7-261.9	18.2	Diabase, dark-gray to black, medium-grained. Plagioclase, 50 to 55 percent; pyroxene, 45 to 50 percent; and magnetite, 2 to 5 percent.
261.9-263.7	1.8	Diabase, medium- to dark-gray, medium-grained. Plagioclase, 55 to 65 percent; pyroxene, 40 to 45 percent; and magnetite, 2 to 5 percent.
263.7-268.1	4.4	Diabase, light-gray, medium-grained. White plagioclase, 45 to 50 percent; pyroxene, 30 to 35 percent; pink altered feldspar, 15 to 20 percent; and magnetite, 1 to 3 percent. Light veins (prehnite) cut the core from 267.5 to 263.4 feet. A shear plane with black slickensides cuts the core from 264.4 to 264.9 feet.
268.1-275.5	7.4	Diabase, medium- to dark-gray, medium-grained. Plagioclase, 55 to 65 percent; pyroxene, 40 to 45 percent; and magnetite, 3 to 8 percent. A shear plane with black slickensides cuts the core from 268.6 to 269.1 feet.
275.8-279.0	3.2	Diabase, light- to medium-gray, medium-grained. Plagioclase, 60 to 65 percent; pyroxene, 35 to 40 percent; and magnetite, 1 to 2 percent.
279.0-286.5	7.5	Diabase, medium- to dark-gray, medium-grained. Plagioclase, 60 to 70 percent; pyroxene, 30 to 35 percent; and magnetite, 5 to 8 percent. Prehnite veins cut the core from 279.9 to 280.9 feet.
286.5-300.0	13.5	Diabase, dark-gray, medium-grained. Plagioclase, 50 to 55 percent; pyroxene, 45 to 50 percent; and magnetite, 5 to 9 percent. A light vein (zeolite ?) cuts the core from 289.6 to 289.9 feet.

Well W-888

0-40.0	40.0	Diabase, medium-brown, medium-grained, weathered. Yellow to brown iron-stained plagioclase, 60 to 65 percent; black to dark-green pyroxene, 35 to 40 percent; magnetite, 2 to 5 percent; biotite, 1 to 2 percent; pyrite, more than 1 percent; and chlorite, more than 1 percent. Only 1.7 feet of this core interval was recovered.
40.0-78.8	38.8	Diabase, dark-gray to black, medium-grained. Plagioclass, 50 to 60 percent; pyroxene, 35 to 45 percent; magnetite, 2 to 5 percent; pyrite, 1 to 2 percent;

Depth Feet	Thickness Feet	Description
		and biotite(?), more than 1 percent. Shear planes lined with black slickensides cut the core at 48.2 to 49.9 feet, 53.6 to 54.2 feet, and 72.0 to 73.2 feet. Thin section (R-2379), from 69.0 feet, contains: plagioclase (An_{50-70}), 60 percent; augite, 33 percent; magnetite, 5 percent; biotite, 1 to 2 percent; and quartz, more than 1 percent.
78.8-99.0	20.2	Diabase, same as above, except shear planes are more abundant. Poor core recovery from 90.1 to 90.8 feet, 92.0 to 92.3 feet, and 98.0 to 99.0 feet. Thin section (R-2380), from 92.0 feet, contains: plagioclase (An_{50-70}), much of which has been altered to saussurite, 55 percent; augite, some of which has been altered to uralite-hornblende, 35 percent; pyrite, 4 percent; biotite, slightly altered to chlorite, 3 percent; magnetite, 2 percent; and quartz, 1 percent.
99.0-103.2	4.2	Diabase, pinkish-green to gray, medium-grained, altered. Altered feldspar, 60 to 65 percent; pyroxene/amphibole, 20 to 25 percent; magnetite, 5 percent; and quartz-feldspar intergrowths, 2 to 5 percent. Shear planes lined with black and dark greenish-black slickensides cut this entire section of core. Thin section (R-2381), from 102.0 feet, contains: plagioclase (An_{30-70}), nearly completely altered to saussurite, 70 percent; hornblende (uralite), 20 percent; magnetite, 5 percent; and quartz-feldspar, 5 percent.
103.2-159.6	56.4	Diabase, gray to black, medium-grained. Plagioclase, 55 to 60 percent; amphibole/pyroxene, 35 to 45 percent; and magnetite, 1 to 2 percent. Shear planes lined with black slickensides cut the core at 110.8 to 112.2 feet, 123.6 to 124.0 feet, and 147.2 to 150.0 feet. Thin section (R-2382), from 103.8 feet, contains: plagioclase (An_{50-70}), partially altered to saussurite along margin of grains, 55 percent; amphibole (uralite-hornblende), 30 percent; augite, partially altered, 10 percent; magnetite, 3 percent; and quartz, 2 percent. Thin section (R-2383), from 111.0 feet, contains: plagioclase (An_{50-70}), slightly altered to saussurite, 60 percent; augite, 35 percent; magnetite, 4 percent; and quartz, 1 percent.
159.6-166.5	6.9	Diabase, same as above, except lighter in color. Shear planes, present throughout this interval, contain pyrite, magnetite, and chlorite. Core recovery from this interval is in the form of small rounded fragments.
166.5-171.9	5.4	Diabase, medium- to dark-gray, medium-grained. Pla-

Depth Feet	Thickness Feet	Description
		gioclase, 55 to 65 percent; pyroxene, 30 to 35 percent; pink altered feldspar, 1 to 5 percent; and magnetite, 2 to 4 percent. A thin white vein of prehnite/datolite cuts the core from 168.1 to 168.9 feet; slight alteration is visible along margins of the vein.
171.9-172.8	0.9	Diabase, same as above, except the ratio of pink to white feldspar is greater.
172.8-181.6	8.8	Diabase, gray, medium-grained. Plagioclase, 35 to 40 percent; pink altered feldspar, 30 to 35 percent; pyroxene, 30 to 35 percent; and magnetite, 2 to 5 percent. A white vein of barite cuts the core from 178.5 to 178.9 feet.
181.6-184.8	3.2	Diabase, same as above, except mineralization has occurred along open fractures, and pyrite, magnetite, prehnite, and colorless zeolites(?) are present.
184.8-192.6	7.8	Diabase, gray, medium-grained. White plagioclase, 50 to 60 percent; pink altered feldspar, 10 to 15 percent; pyroxene, 30 to 35 percent; pyrite, 1 to 2 percent; and magnetite, 1 to 2 percent.
192.6-200.0	7.4	Diabase, gray, medium-grained. Prehnite present in fracture fillings. Shear planes lined with black slickensides cut the core from 198.2 to 199.4 feet. Thin section (R-2384), from 198.0 feet, contains: plagioclase, so highly altered to saussurite that no determination of composition could be made, 55 percent; hornblende-uralite, 40 percent; magnetite, 2 percent; quartz, 2 percent; and biotite, 1 percent.
200.0-217.4	17.4	Diabase, same as above, except cut by several "gouge" areas .01 to .05 foot thick. This "gouge" is gray green, fine grained to very fine grained, and contains fragments of pyroxene, altered plagioclase, prehnite, and chlorite.
217.4-230.0	12.6	Diabase, gray, medium-grained. White plagioclase, 40 to 45 percent; pyroxene, 30 to 35 percent; pink altered feldspar, 5 to 10 percent; magnetite, 2 to 5 percent; and pyrite, 1 to 3 percent. Shear planes lined with black slickensides cut the core from 219.2 to 219.6 feet and 228.0 to 228.7 feet.
230.0-269.6	39.6	Diabase, same as above, except pink altered feldspar is absent.
269.6-273.3	3.7	Diabase, same as above, except entire section is cut by shear planes lined with black slickensides.
273.3-323.5	50.2	Diabase, gray to drak-gray, medium-grained. Plagioclase, 60 to 65 percent; pyroxene, 40 to 45 percent; and magnetite, 2 to 5 percent. No recovery from 304.0 to 305.5 feet and poor recovery at 307.4 and 316.9 feet.

Depth Feet	Thickness Feet	Description
323.5-328.3	4.8	Diabase, same as above, except 5 to 10 percent pink altered feldspar is present, pyrite and chlorite are present (more than 1 percent), and shear planes lined with black and dark greenish-black slickensides cut this entire interval.
328.3-349.0	20.7	Diabase, dark-gray, medium-grained. Plagioclase, 60 to 65 percent; pyroxene, 40 to 45 percent; magnetite, 2 to 5 percent; pyrite, 1 percent; and chlorite, more than 1 percent.
349.0-353.2	4.2	Diabase, green-gray, medium-grained, altered. Pink altered feldspar, 45 to 50 percent; pyroxene (amphibole?), 40 to 45 percent; white feldspar, 10 to 15 percent; magnetite, 2 to 5 percent; pyrite, 1 percent; chlorite, more than 1 percent; olivine(?), more than 1 percent; and quartz, more than 1 percent. Some mineralization (zeolites?) evident along shear planes that cut the core throughout this interval.
353.2-355.0	1.8	Diabase, same as above, except no mineralization associated with shear planes.
355.0-361.2	6.2	Diabase, same as above, except cut by light-gray to white veins of barite; possible contact alteration along margin of vein.
361.2-371.9	10.7	Diabase, dark-gray to dark gray-green, medium-grained. Plagioclase, 55 to 65 percent; pyroxene, 40 to 45 percent; and magnetite, 5 to 7 percent.
371.9-376.8	4.9	Diabase, pinkish-green, medium-grained. Pink altered feldspar, 50 to 60 percent; pyroxene, 35 to 40 percent; plagioclase, 10 to 15 percent; chalcopyrite, 2 to 5 percent; magnetite, 2 to 5 percent; and chlorite. more than 1 percent.
376.8-383.1	6.3	Diabase, gray, medium-grained. White plagioclase, 45 to 50 percent; pyroxene, 40 to 45 percent; pink altered feldspar, 5 to 10 percent; magnetite, 2 to 5 percent; prehnite, more than 1 percent; quartz, more than 1 percent; and pyrite, more than 1 percent. A vein of prehnite cuts the core from 382.4 to 383.1 feet.
383.1-429.2	46.1	Diabase, dark-gray, medium-grained. Plagioclase, 55 to 65 percent; pyroxene, 35 to 40 percent; and magnetite, 2 to 5 percent. Some large (0.1 to 0.4 inch) pyroxene crystals are present. Shear planes lined with black slickensides cut the core at 390.1 to 391.4 feet, 399.1 to 401.2 feet, 417.0 to 418.2 feet, and 428.1 to 428.4 feet.
429.2-435.3	6.1	Diabase, same as above, except lighter gray and shear planes absent.
435.3-435.7	0.4	Diabase, pinkish-green to gray-green, medium-grained.

Depth Feet	Thickness Feet	Description
		Pink altered feldspar, 50 to 55 percent; pyroxene (amphibole?), 45 to 50 percent; and white plagioclase, 15 to 20 percent.
435.7-444.9	9.2	Diabase, light- to medium-gray, medium-grained. Plagioclase, 60 to 65 percent; pyroxene, 35 to 40 percent; and magnetite, 5 percent. Shear planes lined with black slickensides cut the core throughout this interval.
444.9-490.6	45.7	Diabase, same as above, except shear planes present only at 452.0 to 454.6 feet and 487.9 to 490.2 feet. A black vein of chlorite at 488.3 to 489.9 feet is offset slightly by a shear plane at 489.0 feet.
490.6-496.0	5.4	Diabase, dark-gray, medium-grained. Plagioclase, 60 to 65 per cent; pyroxene, 35 to 40 percent; and magnetite, 5 to 10 percent.
		Well W-889
0-40.0	40.0	No recovery.
40.0-51.0	11.0	Diabase, light-brown, medium-grained, weathered.
51.0-63.1	12.1	Diabase, dark-gray to black, medium-grained. Plagioclase, 50 to 60 percent and pyroxene, 40 to 50 percent.
63.1-65.3	2.2	Diabase, pinkish-green to gray-green, medium-grained, altered. White plagioclase, 35 to 40 percent; pink altered feldspar, 30 to 35 percent; altered pyroxene, 30 to 35 percent; and magnetite, 5 to 8 percent. Shear planes with black slickensides cut the core from 63.5 to 64.6 feet. Thin section (R-2392), from 64.9 feet, contains: saussurite, 60 percent; plagioclase (An_{50-70}), 10 percent; augite, 15 percent; altered pyroxene, 10 percent; magnetite, 5 percent; and quartz, more than 1 percent.
65.3-79.3	14.0	Diabase, dark-gray to black, medium-grained. Plagioclase, 50 to 60 percent; pyroxene, 45 to 55 percent. Shear planes with black slickensides cut the core from 66.2 to 66.8 feet and from 67.6 to 68.0 feet.
79.3-79.6	0.3	Diabase, pinkish-gray, medium-grained. Plagioclase, 40 to 50 percent; pyroxene, 35 to 45 percent; and pink altered feldspar, 15 to 25 percent.
79.6-94.7	15.1	Diabase, dark-gray, medium-grained. Plagioclase, 35 to 65 percent; pyroxene, 35 to 45 percent; magnetite, 2 to 5 percent; and biotite(?), 1 to 2 percent.
94.7-95.9	1.2	Diabase, same as above, except 10 to 20 percent of the plagioclase is altered to a pink color.
95.9-124.2	28.3	Diabase, dark-gray, medium-grained. Plagioclase, 55 to 65 percent; pyroxene, 40 to 50 percent; and magnetite, 1 to 3 percent. Shear planes with black slick-

Depth Feet	Thickness Feet	Description
		ensides cut the core from 97.2 to 98.1 feet and from 101.3 to 101.5 feet.
124.2-124.9	0.7	Diabase, same as above, except 5 to 15 percent of the plagioclase is altered to a pink color.
124.9-149.8	24.9	Diabase, dark-gray to black, medium-grained. Plagioclase, 55 to 65 percent; pyroxene, 35 to 45 percent; and magnetite, 1 to 4 percent. Shear planes with black slickensides cut the core from 128.8 to 130.0 feet, 130.4 to 130.7 feet, and 141.9 to 142.4 feet. Poor core recovery from 141.0 to 152.5 feet.
149.8-151.3	1.5	Diabase, same as above, except veins containing chalcopyrite are present; pink altered feldspars are present along these veins.
151.3-166.0	14.7	Diabase, dark-gray to black, medium-grained (but slightly finer grained than above). Plagioclase, 55 to 65 percent and pyroxene, 40 to 50 percent. Shear planes with black slickensides cut the core from 157.6 to 157.9 feet.
166.0-177.7	11.7	Diabase, medium- to dark greenish-gray, medium-grained. Altered white plagioclase, 45 to 55 percent; pyroxene/amphibole, 35 to 45 percent; and pink altered feldspar, 5 to 15 percent. Shear planes with black slickensides cut the core from 167.9 to 168.1 feet and 173.0 to 174.5 feet. Thin section (R-2393), from 174.3 feet, contains saussurite, 60 percent; augite, 20 percent; hornblende (uralite ?), 10 percent; magnetite, 5 percent; biotite, 2 percent; chlorite (?), 2 percent; and quartz, 1 percent.
177.7-212.7	35.0	Diabase, medium- to dark-gray, medium-grained. Plagioclase, 50 to 60 percent and pyroxene, 45 to 50 percent. Shear planes cut the core from 179.2 to 179.8 feet, 194.2 to 194.5 feet, and 200.4 to 200.5 feet.
212.7-226.0	13.3	Diabase, same as above, except lighter in color; a prehnite vein is present at 216.1 feet; a shear plane with black slickensides cuts the core from 224.0 to 224.7 feet.
		Well W-890
0-24.2	24.2	Diabase, light-brown, medium-grained, weathered.
24.2-47.5	23.3	Diabase, medium- to dark-gray, medium-grained. Plagioclase, 55 to 65 percent; pyroxene, 30 to 35 percent; magnetite, 2 to 5 percent; biotite, 2 to 5 percent; and pyrite, 2 to 4 percent.
47.5-48.9	1.4	Diabase, light-gray, medium-grained. Plagioclase, 60 to 70 percent; pyroxene, 30 to 35 percent; magne-

Depth Feet	Thickness Feet	Description
		tite, 3 to 8 percent; pyrite, 2 to 5 percent; biotite, 1 to 2 percent; and quartz(?), more than 1 percent.
48.9-73.0	24.1	Diabase, medium-gray, medium-grained. Shear planes with black slickensides cut the core from 49.6 to 50.9 feet, 52.6 to 56.8 feet, 64.0 to 65.0 feet, and 71.2 to 73.0 feet. Plagioclase, 55 to 65 percent; pyroxene, 35 to 40 percent; biotite, 5 to 10 percent; magnetite, 2 to 4 percent; and pyrite, more than 1 percent. Thin section (R-2417), from 68.2 feet, contains: saussurite, 30 percent; pyroxene, 30 percent; plagioclase (An_{30-70}), 25 percent; hornblende, 10 percent; and magnetite, 5 percent.
73.0-76.8	3.8	Diabase, same as above, except in a shear zone; poor core recovery.
76.8-98.0	21.2	Diabase, dark-gray, medium-grained. Plagioclase, 50 to 55 percent; pyroxene, 40 to 50 percent; and magnetite, 2 to 5 percent. Shear planes with shiny black slickensides cut the core from 87.0 to 87.3 feet, 89.0 to 90.3 feet, and 96.9 to 98.0 feet.
98.0-99.4	1.4	Diabase, same as above, except 25 to 30 percent of the plagioclase has been altered to pink sericite.
99.4-130.0	30.6	Diabase, medium- to dark-gray, medium-grained. Plagioclase, 50 to 60 percent and pyroxene, 45 to 55 percent. This entire section of core is cut by shear planes with black slickensides. Thin section (R-2418), from 118.0 feet, contains: plagioclase (An_{30-50}), 45 percent; hornblende, 30 percent; saussurite, 20 percent; magnetite, 4 percent; quartz(?), 1 percent; and pyroxene(?), more than 1 percent.
130.0-154.3	24.3	Diabase, same as above, except dark-gray to black. Shear planes with black slickensides cut the core from 120.0 to 130.4 feet, 134.8 to 137.2 feet, 140.0 to 142.0 feet, and 152.4 to 153.6 feet.
154.3-181.4	27.1	Diabase, light-gray, medium-grained. Plagioclase, 60 to 70 percent; pyroxene, 35 to 40 percent; magnetite, 2 to 5 percent; and pyrite, 1 to 2 percent. Shear planes with black slickensides cut the core from 162.8 to 168.3 feet and 168.2 to 171.4 feet.
181.4-185.3	3.9	Diabase, pink-green to gray-green, medium-grained, altered. Plagioclase, 45 to 55 percent; pyroxene, 40 to 50 percent; feldspar, 5 to 10 percent; and chalcopyrite, 3 to 10 percent. A white vein (barite) cuts the core from 184.5 to 184.7 feet. Shear planes with black slickensides cut the core. Both the feldspar and pyroxene are highly altered in this interval. Thin section (R-2419), from 184.3 feet, contains: plagioclase (An_{40-70}), 50 percent; pyroxene,

Depth Feet	Thickness Feet	Description
		40 percent; saussurite, 5 percent; magnetite, 3 percent; hornblende(?), 2 percent; and quartz(?), more than 1 percent.
185.3-200.0	14.7	Diabase, medium-gray, medium-grained. Plagioclase, 55 to 65 percent and pyroxene, 35 to 45 percent. Shear planes with slickensides cut the core from 190.0 to 191.2 feet and 198.0 to 199.1 feet. Green-gray altered diabase is present from 194.6 to 195.1 feet.

APPENDIX IV

Chemical and normative analyses of rocks from the Leesburg quadrangle.

Chemical Analyses (%)

	R-2815	R-2816	R-2817	Diabase
SiO_2	66.81	60.43	61.52	51.56
Al_2O_3	11.00	15.00	6.20	13.81
FeO	1.03	1.40	1.60	11.32
Fe_2O_3	3.62	3.96	1.59	0.96
TiO_2	0.94	0.97	0.60	1.48
CaO	3.09	4.66	12.80	10.08
MgO	4.05	4.19	5.42	7.40
Na_2O	5.15	4.50	1.27	2.08
K_2O	3.25	3.95	2.89	0.96
MnO_2	0.016	0.047	0.079	0.19
P_2O_5	0.07	0.11	0.11	0.16
SO_4	0.018	0.027	0.018	N.A.
CO_3	0.690	0.409	5.45	—
	99.734	99.653	99.547	100.00

Normative Analyses (%)

	R-2815	R-2816	R-2817	Diabase
Orthoclase	17.97	21.80	15.00	5.0
Plagioclase	37.48 (An_0)	46.19 (An_{18})	12.30 (An_{15})	40.7 (An_{70})
Quartz	19.06	7.91	26.40	0.1
Diopside	6.93	11.42	31.40	21.10
Hypersthene	9.49	7.91	1.70	29.90
Acmite	3.85	—	—	—
Calcite	1.41	0.90	10.80	—
Magnetite	0.25	0.90	1.20	0.60
Ilmenite	1.54	1.55	0.90	2.40
Hematite	0.70	1.16	—	—
Apatite	1.28	0.20	0.20	0.20
	99.96	99.94	99.90	100.0

LOCALITIES

R-2815: "Welded" felsic tuff, 3.2 miles south of Leesburg, along Sycoline Creek south of State Road 653.

R-2816: Intermediate crystal tuff from abandoned quarry 3.5 miles east-southeast of Leesburg, northwest of Goose Creek.

R-2817: Felsic crystal tuff from abandoned quarry 3.5 miles east-southeast of Leesburg, northwest of Goose Creek.

Diabase: Arlington Stone Company quarry, 4.0 miles southeast of Leesburg, on the west side of State Road 659. Analysis from Shannon (1924, p. 13).

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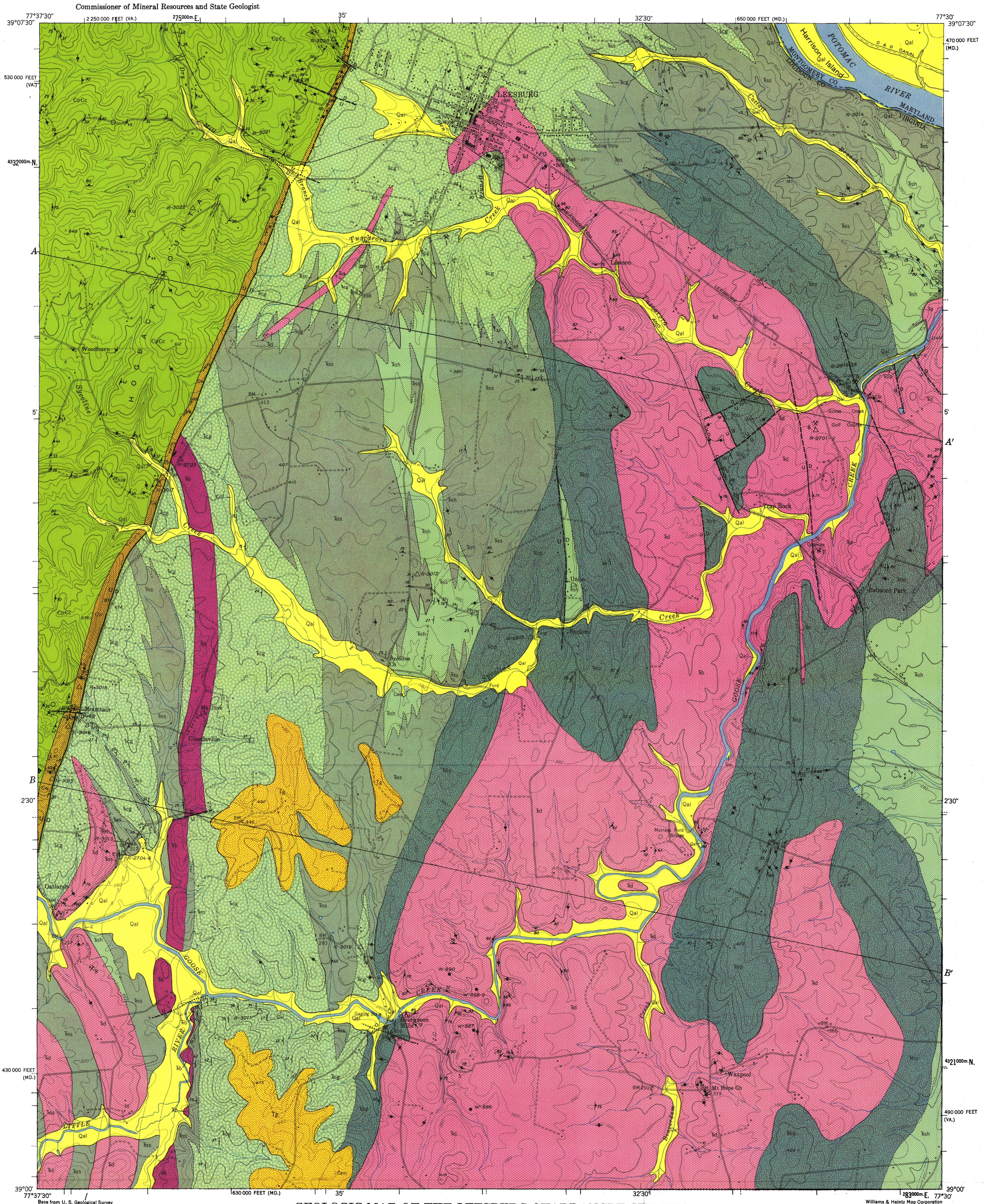
COMMONWEALTH OF VIRGINIA
DEPARTMENT OF CONSERVATION AND ECONOMIC DEVELOPMENT
DIVISION OF MINERAL RESOURCES
James L. Calver
Commissioner of Mineral Resources and State Geologist



Base from U. S. Geological Survey
Leesburg Quadrangle 7½-Minute Series

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GEOLOGIC MAP OF THE LEESBURG QUADRANGLE, VIRGINIA

Geology by E. Clayton Toewe

SCALE 1:24 000

1 ½ 0 1 MILE

1000 0 1000 2000 3000 4000 5000 6000 7000 FEET

1 .5 0 1 KILOMETER

CONTOUR INTERVAL 20 FEET
DATUM IS MEAN SEA LEVEL

1966

6½°
TRUE NORTH
MAGNETIC NORTH
APPROXIMATE MEAN DECLINATION, 1952

VIRGINIA
QUADRANGLE LOCATION

EXPLANATION

TERTIARY QUATERNARY

Qal — Alluvium

Tg — Terrace gravels

TRIASSIC

Ꞧd — Diabase
Sills and dikes: diabase, fine- to coarse-grained.

Newark Group
Ꞧcg, conglomerate; Ꞧss, sandstone; Ꞧsh shale; Ꞧb, basalt; Ꞧbp, basalt and pyroclastic unit, mafic and intermediate crystal tuffs with thin interbedded basalt; c, zones of contact metamorphism.

CAMBRIAN

Ꞓw — Weverton Formation
Quartzite, banded, dense, vitreous, and phyllitic quartzite.

PRECAMBRIAN

ꞒpꞒc — Catoctin Formation
Chlorite phyllite, metabasalt, and epidosite.

CONTACTS

exposed
approximate
covered

FAULTS

U D exposed
U D approximate
U D covered

U–upthrown side
D–downthrown side

SHEAR ZONE

ATTITUDE OF ROCKS

20 Strike and dip of beds
Horizontal beds

FOLIATION AND CLEAVAGE

20 Strike and dip of foliation
25 Average strike and dip of contorted foliation
40 Strike and dip of cleavage

JOINTS

75 Strike and dip of joints
Strike of vertical joints

SAMPLE LOCATIONS

R-2815 Locations of samples representative of different lithologies mapped; chemical analyses were made from samples R-2815, R-2816, and R-2817

W-887 Location of drill holes

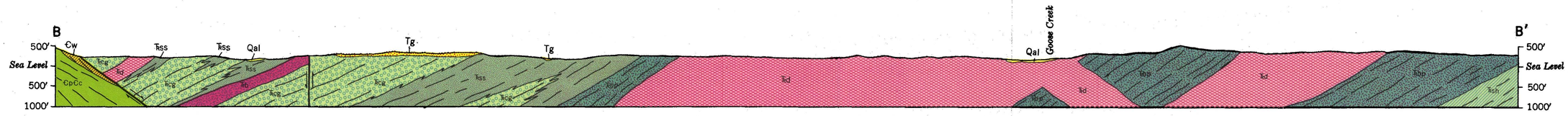
QUARRIES AND PROSPECTS

Active quarry
6. Virginia Trap Rock, Incorporated: diabase
7. Arlington Stone Company: diabase
9. Husted quarry: diabase

Abandoned quarry
1. Limestone conglomerate quarry
2. Leesburg Lime Company, Incorporated: limestone conglomerate
3. White quarry: limestone conglomerate
4. Pyroclastic rock quarry
5. Pyroclastic rock quarry
8. Quartzite quarry
10. Evergreen quarry: pyroclastic rock

Prospect with symbol to indicate copper (Cu) and ocher (Oc)

Quartz veins



No Vertical Exaggeration