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ARTHUR BEVAN, *State Geologist*

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Geology and Mineral Resources of the Warrenton Quadrangle, Virginia

By

A. S. FURCRON

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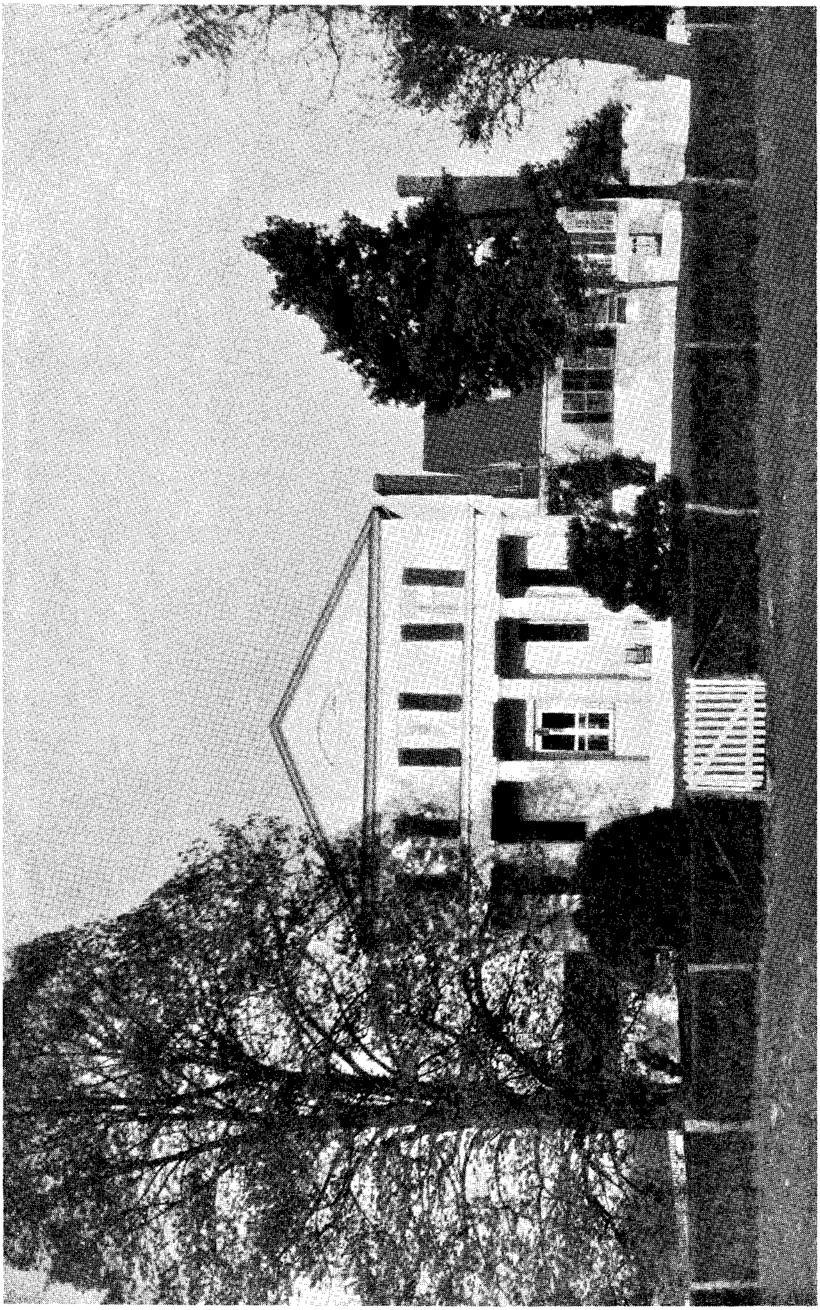
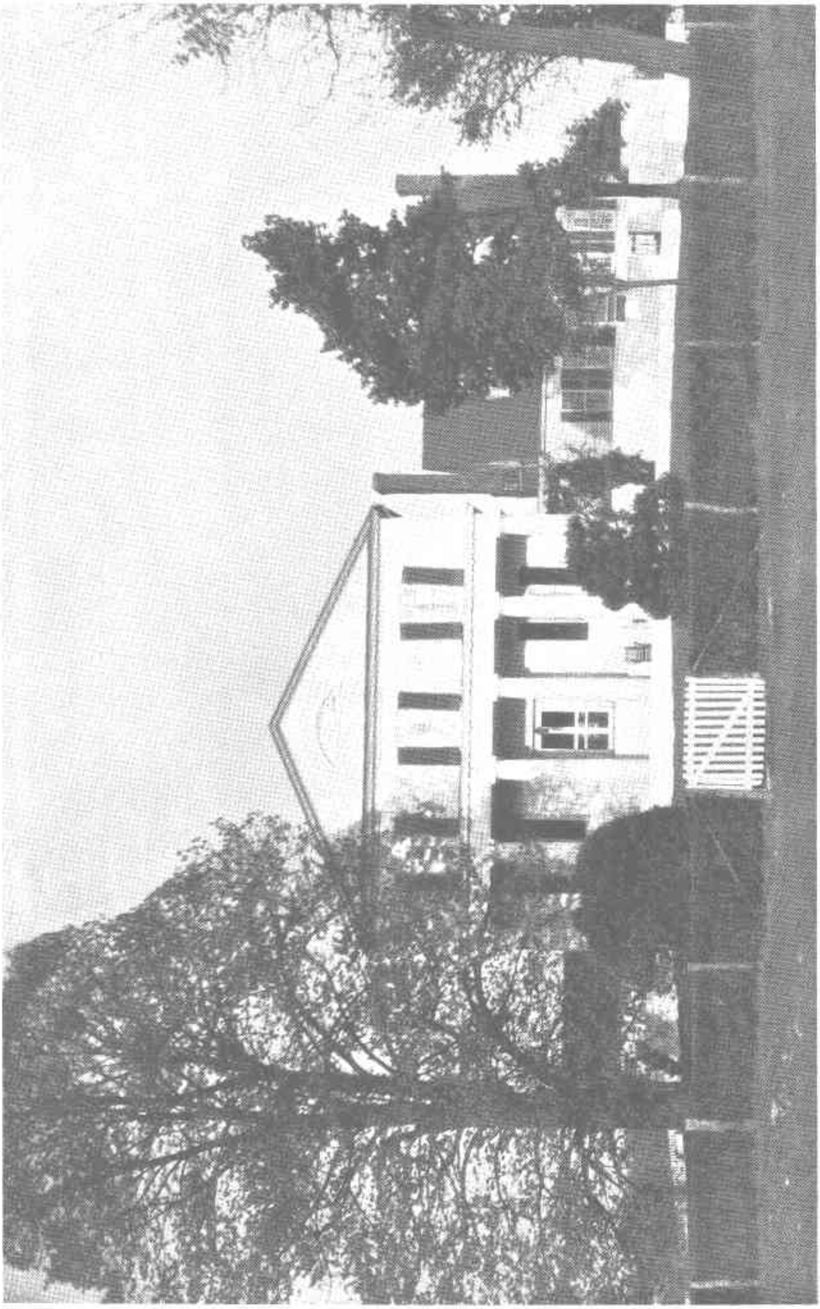


Oak Hill near Marshall, Fauquier County, Virginia. The home of former Chief Justice John Marshall of the United States Supreme Court.



Oak Hill near Marshall, Fauquier County, Virginia. The home of former Chief Justice John Marshall of the United States Supreme Court.

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LETTER OF TRANSMITTAL

COMMONWEALTH OF VIRGINIA
VIRGINIA GEOLOGICAL SURVEY
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CHARLOTTESVILLE, VA., May 15, 1939.

To the Virginia Conservation Commission:

GENTLEMEN:

I have the honor to transmit and to recommend for publication as Bulletin 54 of the Virginia Geological Survey series of reports the manuscript and illustrations of the *Geology and Mineral Resources of the Warrenton Quadrangle, Virginia,* by Dr. A. S. Furcron.

This project was undertaken by the Virginia Geological Survey because of the need of detailed investigations of the geology and mineral resources of the northern part of the Piedmont province. Lack of modern topographic base maps in other parts of the region made the Warrenton quadrangle the logical area in which to begin these investigations.

It will be noted from the geological map accompanying this report and from the discussions in the text that the author has made important contributions to the understanding of the geologic relations of the rocks and resources of the Warrenton area and, by analogy, of the rocks in adjacent areas.

This report should be of value to geologists and others interested in this part of Virginia. The author has attempted to make the report of interest, so far as the technical nature of the data would permit, to residents and teachers in the Warrenton and adjacent areas.

Respectfully submitted,

ARTHUR BEVAN,
State Geologist.

Approved for publication:

Virginia Conservation Commission,
Richmond, Virginia, May 16, 1939.
R. A. GILLIAM, *Executive Secretary and Treasurer.*

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Geology and Mineral Resources of the Warrenton Quadrangle, Virginia

By A. S. Furcron

ABSTRACT

The Warrenton quadrangle includes parts of Fauquier, Culpeper, and Rappahannock counties in the Piedmont province of north-central Virginia. The Piedmont province in this area includes parts of the Piedmont upland and of the Piedmont lowland. The boundary between these sections is here a long normal fault which is the most prominent structural feature of the area. It has been locally termed the Bull Run fault, or the Catoctin Mountain Border fault for the area of northern Virginia and Maryland. It separates Triassic rocks in the southeast part of the area from pre-Cambrian and Cambrian rocks on the northwest.

The oldest rocks of sedimentary origin in the area are a series of marbles, graphitic slates and graphitic schists, mica schists, and biotite-garnet gneisses herein named the Fauquier formation, which underlies the pre-Cambrian Catoctin volcanic series. The Fauquier formation enters the Warrenton quadrangle from the north where it follows the west side of Watery Mountain. It extends southwestward through the quadrangle in the area between the Catoctin series and the Loudoun formation. It is well exposed in the vicinity of Fauquier White Sulphur Springs and west of Piney Mountain. In this area it is extensively intruded by dikes of greenstone and amphibolite or metagabbro of Catoctin age. The rocks of the Fauquier formation were formerly classified with the Loudoun formation of Cambrian age.

The Catoctin series is believed by the writer to consist of the oldest igneous rocks of the area. In the Warrenton quadrangle this volcanic series is divisible into two facies. At the base there is an extensive accumulation of volcanic agglomerate (Warrenton agglomerate member), composed of rounded fragments of vesicular greenstone in a matrix of fine-grained green chlorite which resembles a metamorphosed ash of similar composition. Thin flows occur locally in the agglomerate. Flow breccias are not uncommon. Most of the Warrenton agglomerate is confined to the western border of the Catoctin series where it overlies the Fauquier formation. Above the Warrenton agglomerate are thick basalt flows, now altered to metabasalt composed chiefly of epidote and chlorite. The flows are vesicular, generally amygdaloidal, locally scoriaceous and contain tuff in the upper part. Amygdules are filled with epidote, quartz or calcite. A granite complex crops out over the northwestern part of the quadrangle. This complex is com-

posed mostly of granodiorite and Old Rag granite types common as intrusive rocks in the Shenandoah National Park area to the west. The Old Rag granite, named from Old Rag Mountain in Madison County, intrudes the granodiorite. Several varieties of the granite phase occur in the area. These rocks also include bands and stringers of an older biotite gneiss, possibly from the Fauquier formation. The intrusive rocks are believed to be younger than the Catoctin series.

The Loudoun formation was deposited in early Cambrian time upon the eroded surfaces of the above mentioned rocks. It occupies a belt between the Fauquier formation and granite and granodiorite. It consists almost entirely of arkose derived from the intrusive rocks. It is intruded by Triassic diabase dikes. It makes gray, sandy, uncultivated land which is easily recognized as being underlain by the Loudoun formation. Some anticlinal areas of granite occur in this belt.

Triassic rocks crop out east and southeast of the Border fault, thus occupying the entire southeast part of the quadrangle where they form a low flat plain. They are mainly red and green shales into which have been intruded thick diabase sills. Narrow dikes of diabase occur locally. Shales near the contact of the sill have been baked black by the intrusive body. Outcropping edges of the sills or dikes form low, piney ridges.

Normal faulting took place on a large scale during the Triassic period. Movement along the Catoctin Mountain Border fault at the close of the period produced an escarpment and increased the westward dip of the sediments deposited in the Triassic basin. Thick deposits of conglomerate, consisting mostly of greenstone fragments, accumulated at the base of the escarpment. Several cross-faults cut the Triassic sediments, diabase sill and Border fault. They show a decided tendency to intersect the Border fault at angles of less than 90°, thus producing a characteristic pattern.

High-rank metamorphism is generally absent in this quadrangle, except in the rocks of the Fauquier formation. North, east, and south of Warrenton, the rocks have been mashed and altered to mica schists and the volcanic rocks have been converted to chlorite schists. West of Warrenton, the rocks are generally massive. Granite has been mashed and is schistose locally. Slaty cleavage is pronounced in the phyllites of the Loudoun formation.

The mineral resources of the quadrangle include diabase, granite, greenstone, quartzite, slate, and other rocks suitable for local building stone and road construction. Clays derived from weathered greenstone and Triassic shales have been used for the manufacture of bricks. Among the mineral springs of the area, the Fauquier White Sulphur Springs and the Berry Hill Mineral Spring are the best known.

INTRODUCTION

LOCATION OF THE AREA

The Warrenton quadrangle lies between parallels 38° 30′ and 38° 45′ and meridians 77° 45′ and 78°. It occupies parts of Fauquier, Culpeper and Rappahannock counties in the north-central part of the State. About half of the area is in Fauquier County, north and east of Rappahannock River. The western part of the quadrangle is in Culpeper County. The eastern corner of Rappahannock County extends to a point 3 miles east of Amissville. (See Fig. 1.) The area of the quadrangle is about 234 square miles. The main line of the Southern Railway from Washington southward passes through the southeastern corner of the quadrangle. A branch line from Calverton connects that place with Warrenton. The town of Culpeper lies just beyond the southwestern limits of the area. All parts of the area are accessible by good roads which converge at Warrenton.

PURPOSE AND SCOPE OF THE REPORT

This report discusses the geology and mineral resources of the Warrenton quadrangle. Occurrences of mineral and nonmetallic resources of economic importance are discussed. Ground-water conditions in the different types of rocks are discussed and information given on local wells and springs. The main geographical and physical features of the quadrangle are described and information given on the soils, climate, and local history. The relationship of the geology or geologic history of the area to the development of the present surface features, geologic resources, and to the local history and development is discussed. The stratigraphy and petrology of the various rock formations are discussed in detail. The distribution and occurrence of the geologic formations are shown on the geologic map (Pl. 1), which accompanies this report.

FIELD WORK AND ACKNOWLEDGMENTS

The field work upon which this report is based was done mainly in the summer of 1931. Additional field work was done during August 1933 and June 1937. Several days were spent in the field with Dr. J. D. Burfoot, Jr., who was investigating the slate resources. Two days were spent in the area with Professor E. S. Larsen and Dr. L. R. Thiesmeyer of Harvard University, who were studying the granites.

The work was done under the direction of Dr. Arthur Bevan, State Geologist, to whom the writer is indebted for suggestions regarding the field work and preparation of the report, as well as for editorial

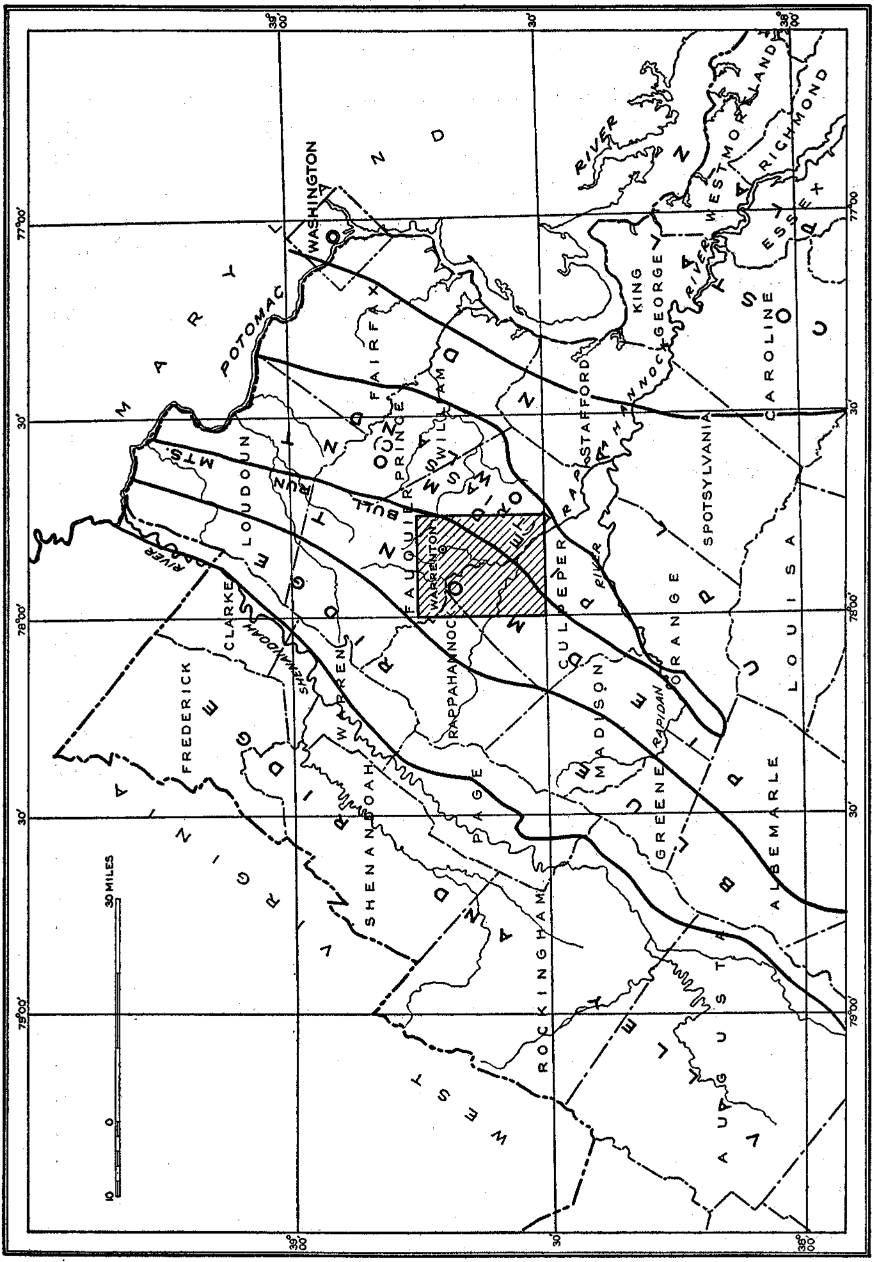


FIGURE 1.—Sketch map of northern Virginia showing location of the Warrenton quadrangle in regard to the physical divisions of the State.

criticism. The writer is indebted to Mr. William M. McGill, Assistant State Geologist, who has read the report, making valuable criticisms and suggestions. Dr. Anna I. Jonas has made numerous suggestions in regard to the field work and has read the manuscript.

The Culpeper Chamber of Commerce and Mr. F. D. Gaskins of the Warrenton Chamber of Commerce, supplied printed material on the area. Mr. W. W. Saunders, County Engineer at Warrenton, furnished information about the construction of hard-surfaced roads. Several photographs of Warrenton and vicinity were supplied by Mr. D. C. Fewell of Warrenton. Mr. H. P. Maddox of Marshall supplied useful information on local ground-water conditions and on some of the mineral resources of the area. Mr. A. N. Thomas of Cleveland, Ohio, assisted in the preparation of the microphotographs.

PREVIOUS GEOLOGIC WORK

The first recorded observations upon the geology of this area are found in the writings of W. B. Rogers, which were collected and published in 1884 in "The Geology of the Virginias." At that time all of the rocks, except those of Triassic age, were classified as Archean. The Catoctin volcanic rocks were believed to be of igneous origin. Rogers[1] described the Triassic rocks as of the "Middle Secondary Formation" and recognized the intrusive character of the trap. Keith, who worked in the Blue Ridge province of Virginia from the vicinity of Warrenton to the Maryland line, demonstrated the existence of Lower Cambrian sediments. He[2] named the Catoctin schist and described it as consisting of metamorphosed lava flows. Watson and Cline[3] discussed some phases of faulting in the Fauquier White Sulphur Springs district.

A generalized map of the pre-Cambrian, Cambrian, and Triassic rocks was made by Jonas[4] during the reconnaissance of Virginia for the State geologic map. Normal faults were recognized in the area and the name Catoctin Mountain Border fault was given to the fault between the Triassic sediments and crystalline rocks. The granite was separated from the other intrusive rocks of this area, and named the Marshall granite from its occurrence near Marshall in Fauquier County. The preliminary results and sketch map of northern Virginia were published in 1927.[5]

[1] Rogers, W. B., A reprint of annual reports and other papers on the geology of the Virginias, pp. 471-480, New York, D. Appleton and Co., 1884.

[2] Keith, Arthur, and Geiger, H. R., The structure of the Blue Ridge near Harpers Ferry: Geol. Soc. America Bull., vol. 2, pp. 155-164, 1891.

Keith, Arthur, Geology of the Catoctin belt: U. S. Geol. Survey 14th Ann. Rept., pt. 2, pp. 285-395, 1894; Description of the Harpers Ferry sheet: U. S. Geol. Survey Geol. Atlas, Harpers Ferry folio (no. 10), p. 2, 1894.

[3] Watson, T. L., and Cline, J. H., Normal faulting in the Cambrian of northern Piedmont, Virginia: Univ. Virginia Philos. Soc. Bull., Sci. ser., vol. 1, pp. 341-347, map, 1913.

[4] Geologic map of Virginia, Virginia Geol. Survey, 1928.

[5] Jonas, A. I., Geologic reconnaissance in the Piedmont of Virginia: Geol. Soc. America Bull., vol. 38, pp. 837-846, 1927.

GEOGRAPHY

TOPOGRAPHY

GENERAL STATEMENT

The Warrenton quadrangle lies in the Piedmont province in the north-central part of the State. (See Pl. 1 and Fig. 1.) The province is separated in this part of Virginia into the Piedmont upland or plateau (northwestern) and the Piedmont lowland (southeastern) by the Catoctin Mountain Border fault, which extends along the east side of Bull Run Mountain. West of this fault the country is rolling, hilly, and locally mountainous, with areas 500 to 600 feet above sea level, whereas east of it, the country is a low, flat plain about 300 feet in altitude.

The country west of the Border fault is a stream-dissected upland. Several short mountainous ridges rise above the upland level and generally trend northeast with the rock structure. They mark the location of more resistant rocks.

Along the Border fault the weaker Triassic rocks on the east were dropped down in respect to the more resistant crystalline rocks on the west, which rise above the Triassic rocks in a prominent escarpment. This scarp, although now dissected, is a prominent topographic feature of the area and has been termed the Bull Run escarpment since it extends along the east side of Bull Run Mountain. The weak rocks have been worn down to a plain which now stands about 300 to 400 feet above sea level. Stream channels are only a few feet below the bottoms of the valleys, and the channel walls slope very gently upward to the level of the plain. Low ridges occur where resistant diabase sills, baked shale, and dikes crop out.

PIEDMONT PROVINCE

The stage of erosion that produced the upland level in the Piedmont province in the Warrenton quadrangle was rather thorough, for there are few mountains standing above it. The area between Warrenton and Waterloo was less thoroughly reduced, so that where Catoctin metabasalt or greenstone occurs, mountainous ridges were left. Some of these, such as Piney Mountain, Viewtree Mountain and Watery Mountain stand 400 to 600 feet above the upland level. This is the roughest land of the quadrangle and thus has the greatest relief. The upland level west of the Border fault is much dissected. Remnants of it occur as stream divides at altitudes of 500 to 550 feet.

West of the Border fault there are four sets of surfaces: old flat or rolling divides of the upland level; steeply sloping sides of monadnock hills rising above the upland level; flood plains along the larger streams; and recent steep valley slopes.

The oldest surfaces are the flat or rolling remnants of the upland level that are now found on the divides. The older highways generally follow them. The slopes of the mountains that rise above the undissected upland surfaces have undergone only a slight change, as for example, Warrenton Mountain. In other instances erosion has been more rapid on these slopes since the uplift of the old plain; thus the slopes have been steepened. Their surfaces are steep and wooded.

In the northern part of the quadrangle, hills standing above the upland level considerably increase both the relief and the roughness. Warrenton is situated upon one of the lower hills. The town is practically surrounded by the old, partially dissected plain. To the west one obtains a view across this surface to View Tree Mountain and other hills which rise above its level.

The extensive erosion at the time of the formation of the upland level considerably dismembered mountain ridges and formed isolated peaks. Many of the peaks are conical, as for example Oven Top, near Hume (Pl. 3A.) Westward towards the Blue Ridge, these separated peaks are not so far apart and the area becomes a confused mass of ragged peaks. The unusual prominence of Bull Run Mouutain, beyond the limits of the Warrenton quadrangle, is due mainly to two factors. On the east it is bounded by the Catoctin Mountain Border fault, and the great differences in rock resistance on either side of this fault causes the eastern slope to descend abruptly to the plain. The eastern side of the ridge contains hard quartzite which rests upon massive greenstone.

In general, the character and distribution of the hills above the upland level indicate that they exist because they are at the headwaters of streams, and not because they are composed of more resistant rock. The area between Little River and the Bull Run escarpment is really a much dissected mountainous area to which Watery and View Tree mountains, farther south, also belong. Streams west of the Bull Run escarpment long ago reduced their valleys to a grade which was determined by the level of the Triassic plain. As far up as the headwaters of such streams as Little River, Goose Creek, and Carter Run the streams flow in wide valleys or meadows which distinctly lie below the surface of the upland plain. The streams are now rapid and are developing channels with high, steep banks in the meadows, thus indicating that a period of reintrenchment has begun. This condition is illustrated near Rappahannock River west of Waterloo, where renewed stream activity is progressing up the valleys of its tributaries making their lower courses steep and V-shaped. Kirby Run and Thumb Run are examples.

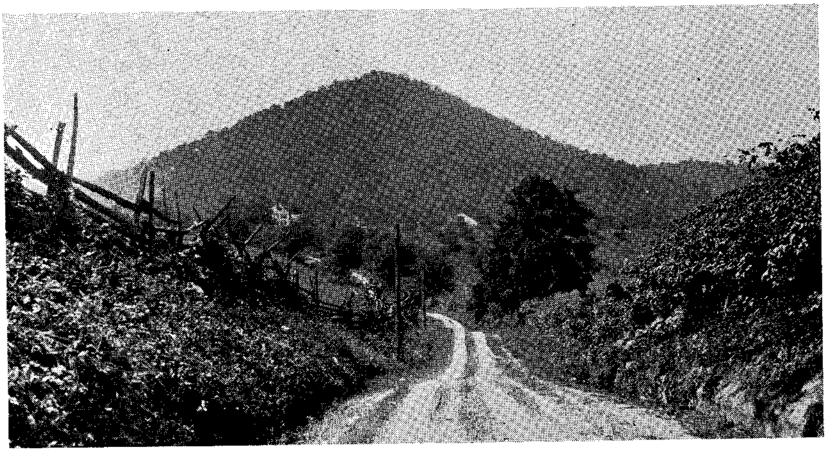
BULL RUN ESCARPMENT

Between the Triassic lowlands on the east and the Piedmont upland on the west there is a dissected escarpment which follows a normal fault—the Bull Run or Catoctin Mountain Border fault. From Aldie to Warrenton the Piedmont upland begins on the east as a mountainous ridge (Bull Run Mountain), but south of Warrenton the change from the lowland to the upland area is less pronounced. In the southwestern corner of the Warrenton quadrangle the boundary between the Triassic plain and the Piedmont upland is obscure because the Triassic fanglomerate is nearly as resistant to erosion as are the rocks of the upland area. The rise from the Triassic lowland to the dissected Piedmont upland is sudden but very variable in elevation. This change in topography is more noticeable in traveling from west to east. It may be clearly noticed on the James Madison Highway (U. S. 15), between Remington and Warrenton, about a mile north of Opal. (See Pl. 3B.) Stose[6] has suggested that after the formation of the Piedmont peneplain there was renewed movement along the Border fault and that that part of the peneplain to the east was dropped, thus explaining the discordance in levels. The part of the plain at the lower level would remain practically undissected, but that part of the plain west of the Border fault would be dissected by streams cutting headward from the fault escarpment. As the streams are now as well graded west of the Border fault as they are to the east, there has been little or no noticeable movement along this fault in recent times.

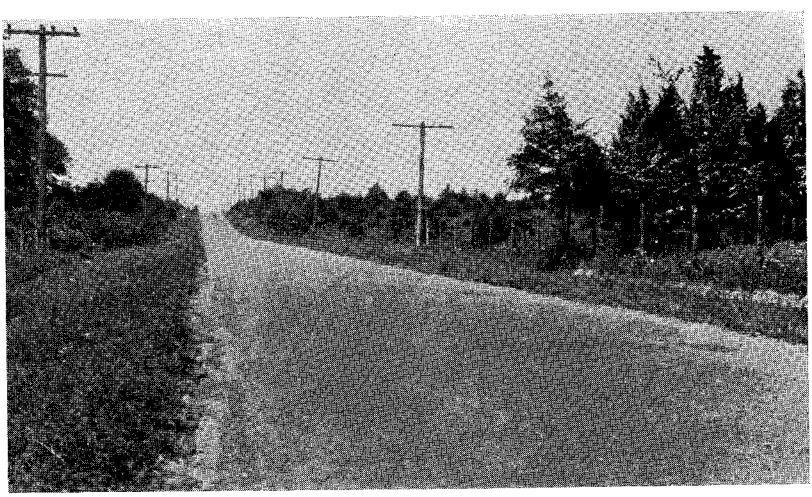
TRIASSIC PLAIN

The Triassic plain slopes gently southeastward from an altitude of 400 feet near the Border fault to 300 feet at Remington. Low ridges and hills occur where the edges of diabase sills crop out. The ridges are short and end abruptly since they are offset by cross faults. They rise to a height of 40 or 50 feet above the plain. U. S. Highway 15-29, from Remington nearly to Elkwood, follows one of these low ridges. Piney Ridge southeast of Remington ends abruptly to the northeast at Marsh Run. The offset sill shows again in Lucky Hill and in an unnamed ridge on the east side of the run. A narrow dike of resistant diabase extending northeast from Oak Shade Church forms a small ridge that may be traced for several miles (Pl. 12B). Fleetwood Hill between Brandy and Elkwood is composed of Catoctin greenstone that was brought to the surface between two normal faults that intersect to form a "V" where the hill occurs. (See Pl. 1.) The courses of streams

[6] Stose, G. W., Possible post-Cretaceous faulting in the Appalachians: Geol. Soc. America Bull., vol. 38, p. 495, 1927.



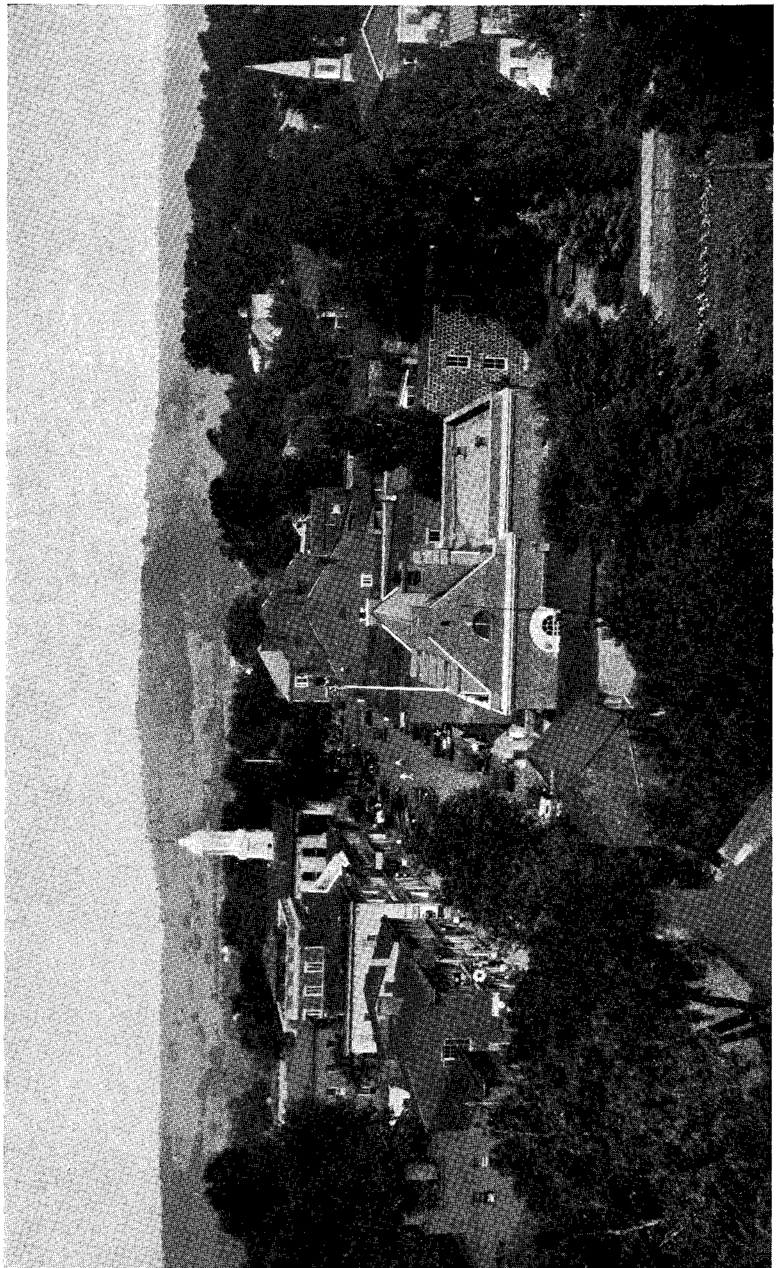
A. Oven Top Mountain near Hume, Fauquier County, Virginia.



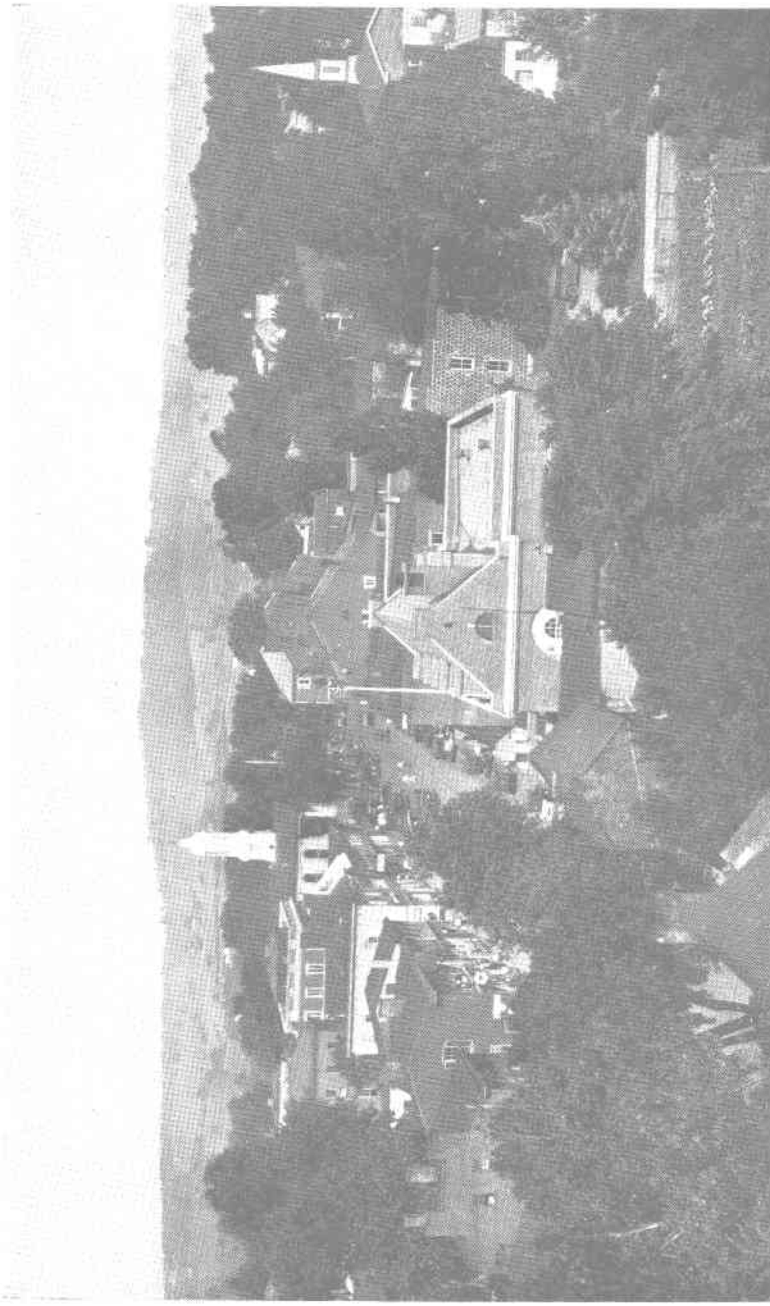
B. Change in topography along the Bull Run escarpment near Opal, Fauquier County, Virginia. The foreground is underlain by Triassic shales. The distant evergreens are growing upon Catoctin greenstone.

A. Oven Top Mountain near Hume, Fauquier County, Virginia.

B. Change in topography along the Bull Run escarpment near Opal, Fauquier County, Virginia. The foreground is underlain by Triassic shales. The distant evergreens are growing upon Catoctin greenstone.



A view of Warrenton, Virginia, looking west along Main Street towards the Blue Ridge. Viewtree Mountain is the background.



A view of Warrenton, Virginia, looking west along Main Street towards the Blue Ridge. Viewtree Mountain is the background.

on the Triassic plain, which have developed a dendritic drainage pattern, have been but slightly affected by the hills and ridges. The streams show little or no entrenchment since the uplift of the plain.

SCENIC ATTRACTIONS

Picturesque homes, beautiful estates, and a wide variety of scenic views are found in the Warrenton quadrangle. From Warrenton may be had excellent scenic vistas in all directions, especially towards the west. (See Pls. 2 and 4.) Good roads radiating from Warrenton afford ready access to sections and places of historic interest and offer good opportunities to study the interesting geologic and topographic features of the areas.

An excellent view of the Piedmont upland and Blue Ridge may be obtained from the road along Lee Ridge south of Warrenton. U. S. Highway 15, from Warrenton south to Culpeper, offers a sharp contrast in scenery where it crosses the Catoctin Mountain Border fault and enters the flat Triassic plain east of Opal. There are picturesque rapids in Rappahannock River at Kellys Ford, where the river crosses the gently dipping edges of Triassic shale. The Lee Highway (U. S. 211) leads from Warrenton west across the Piedmont upland, through Sperryville, and across the Blue Ridge at Thornton Gap, where it crosses the Skyline Drive in Shenandoah National Park.

DRAINAGE

The Warrenton area is drained by rivers which rise in the Blue Ridge, cut through Bull Run Mountain, and flow southeastward across the Triassic lowland. (See Fig. 1.) Rappahannock River rises on the east slope of the Blue Ridge and drains the southern part of the area as well as most of that part of the Piedmont upland within the quadrangle. The northern part of the area is drained by Goose Creek, which rises along the east flank of the Blue Ridge near Manassas Gap and crosses Bull Run Mountain near Oatlands. That part of the area from The Plains south to Warrenton is drained by Broad Run and Cedar Run, which rise east of Watery and View Tree mountains, respectively. All of these streams have branching, treelike drainage patterns on the rather uniformly resistant rocks east of the Border Fault. West of the fault most of the streams except the largest ones, flow parallel to the ridges, forming a more or less trellis-like drainage pattern.

On Rappahannock River, the largest stream in the area, there is a gaging station at the highway bridge at Kellys Ford, 5 miles south of Remington. The drainage area of Rappahannock River above this point is 641 square miles. The following extremes of discharge were recorded (1925-1927); maximum stage recorded 18.00 feet at 9 A. M., November 17, 1926 (discharge, 15,200 second-feet); minimum stage 1.5 feet at 6 P. M., September 9, 1925 (discharge, 15 second-feet.)[7]

CLIMATE

The climate of the Warrenton area is pleasant and agreeable. The range in monthly and seasonal mean temperatures, as well as the daily range of temperature is due largely to the fact that the western Piedmont and the Blue Ridge provinces are higher, have greater relief, and are farther from the sea than are areas to the east. Monthly mean temperatures average lower in the Blue Ridge because of its greater altitude. Variations in topography may produce temperature differences at relatively closely spaced stations. The cold air of the Blue Ridge descends to the east and west and displaces the warm air of the valleys which rises towards the mountain tops where the temperature at times becomes higher than in the valleys. These inversions of temperature delay the frost action on the higher slopes of the mountains and thus influence the location of orchards.

Winters are rigorous but not severe, and normally there is a relatively heavy annual fall of snow. In summer the days are warm, but nights are cool and pleasant, and the growing season is long. The country between Bull Run Mountain and the Blue Ridge is slightly warmer on the average than that in the Valley of Virginia.

Precipitation is abundant but not excessive throughout the year. Precipitation (in excess of a trace) occurs on an average of 107 days in the year and is well distributed. The average annual precipitation of northern Virginia is 38.69 inches with an average of 44 inches in the northeastern part of the Piedmont and Blue Ridge provinces. Precipitation is somewhat greater west of the Bull Run escarpment because of increased altitude.

In the higher part of the quadrangle the prevailing winds are from the northwest throughout the year. In the lowlands the prevailing wind direction is southerly during the summer. There are no government weather stations within the quadrangle. The nearest one to the northeast is at Arcola in Loudoun County; to the east, at Nokesville in Fauquier County; to the south, at Culpeper in Culpeper County, and to the west, at Shenandoah on the west side of the Blue Ridge. Others are located at Barboursville, Hawfield and Orange in Orange County; at Lincoln and Middleburg in Loudoun County; and at Stanardsville in Greene County. The records of the station at Mount Weather, near

[7] Dirzulaitis, J. J., and Stevens, G. C., Water resources of Virginia: Virginia Geol. Survey Bull. 31, p. 123, 1927.

Bluemont in Loudoun County, are typical of conditions in the Blue Ridge province to the west.[8] Data regarding weather conditions at these and other near-by stations, indicating reflecting weather conditions in the Warrenton quadrangle, may be obtained from reports of the U. S. Government Weather Bureau.[9]

Conditions at the stations at Arcola, Nokesville and Culpeper are more representative of conditions in the Warrenton quadrangle than are those of other stations. The mean annual temperature at Arcola during a period of 9 years ending in December 1930, was 54.8° F. The coldest month was January with an average temperature of 32.9° F., and the warmest month was July with an average temperature of 75.6° F. At Nokesville, over a period of 16 years ending in December 1930, the average annual temperature was 54.5° F., and at Culpeper, over a period of 23 years, ending at the same date, the average annual temperature was 54.4° F. The warmest month at Nokesville, for the 16 year period, was July with an average temperature of 76.4° F., and at Culpeper, over a period of 23 years, also July, with an average of 75.1° F. The coldest month was January which averaged 32.9° F., at Nokesville, over the 16 year period, and 33.9° F., at Culpeper, over a period of 23 years.

The average annual precipitation at Arcola, from January 1915 through December 1923, was 38.03 inches; at Nokesville, intermittently from November 1869 to December 1908, 37.97 inches; and at Culpeper, over a period of 23 years ending in December 1930, 39.31 inches. The driest months of all three stations were October and November; heaviest precipitation occurred in June and August, at Arcola and Nokesville, and in August and June, at Culpeper. The average length of the growing season—from the last killing frost in spring to the first killing frost in autumn—over a period of 9 years at Arcola, was 198 days; at Nokesville, over a period of 5 years, 181 days; and, at Culpeper, over a period of 24 years, 192 days. The average date of the last killing frost in spring, at Arcola, is April 11; at Nokesville, April 23, and at Culpeper, April 15. The average date of the earliest killing frost in autumn, at Arcola is October 26; at Nokesville, October 21; and, at Culpeper, October 24.

The mean annual temperature at the Mount Weather Observatory, during a period of 27 years, ending in December 1930, was 50.5° F.

[8] Some of these stations have recently been abandoned.

[9] Henry, A. J., The temperature of Mount Weather and adjacent valley stations: Bull. Mt. Weather Observatory, vol. 4, pp. 310-341, 1912.

............, Climatology of the United States: U. S. Dept. Agr., Weather Bur. Bull. Q, p. 256, 1906.

Martin, R. J., Climatic summary of the United States [Central Virginia]: U. S. Dept. Agr., Weather Bur. Sec. 93, 1933.

Marvin, Charles, Climatic summary of the United States [Potomac River basin]: U. S. Dept. Agr., Weather Bur. Sec. 91, 1932.

Hibbard, F. N., Climatological data [Virginia Section]: U. S. Dept. Agr., Weather Bur., monthly reports, Richmond, Va., 1931-1938.

The coldest month was January with an average temperature of 30.2° F., and the warmest month was July with an average temperature of 71.1° F. The average annual precipitation at Mount Weather, from January 1904 through December 1930, was 40.03 inches. The driest months were February and November; heaviest precipitation occurred in June and August, also in late winter and early spring. The average length of the growing season—from the last killing frost in spring to the first killing frost in autumn—over a period of 24 years was 193 days. The average date of the last killing frost in spring is April 18, and the average date of the first killing frost in autumn is October 28.

At Arcola during a period of 9 years, the average annual snowfall was reported as being 20.1 inches; snow falling in the months of January, February, March, April, November and December. At Nokesville, during a period of 5 years, the average annual snowfall was 19.5, snow falling in the same months as at Arcola. Culpeper had an average annual snowfall of 24.1 inches during a period of 24 years, snow falling in the same six months as at Arcola and Nokesville. Mount Weather records over a period of 34 years show an average annual snowfall of 31.0 inches, snow falling in the same 6 months as recorded for the stations at Arcola, Culpeper, and Nokesville.

POLITICAL DIVISIONS

Fauquier County.—Fauquier County, the fifty-first county of the State, was formed May 1, 1759, from Prince William County. It was named after Francis Fauquier, Lieutenant Governor of Virginia, 1758-1767. According to tradition the first court was held May 24 of that year, near the present village of Morrisville. The first courthouse and prison were built at Warrenton, the county seat, in 1760. Salem, now Marshall, was established in 1796. Upperville was incorporated in 1852, and The Plains in 1910.

The county is 45 miles long and contains 676 square miles. It is divided into five civil districts. Agriculture is the chief occupation. In 1930, there were 344,941 acres of farm land and 57,942 acres in woodland not used for pasture. In 1929, 32,352 acres were in corn, the leading crop. Fauquier County has been famous for its fine horses since earliest times.

The population of the county in 1790 was 17,892 including 6,642 slaves. The population in 1840 was 21,897. Since that time the population has remained essentially stationary. In 1930 the rural population was 12,473. Most of the residents are native born and most of the white inhabitants are descendants of the original settlers.

Culpeper County.—Culpeper County was formed from Orange County in 1748 and named for Lord Culpeper, Royal Governor of Virginia, 1680-1683. It was the forty-second county of the State to be formed. The county has an area of 399 square miles which is divided into five civil districts. In 1930 there were 188,774 acres in farms and 31,780 acres in woodland not used for pasture.

The county in 1930 had a population of 13,306, including a rural population of 7,401. Very few of the inhabitants are foreign born. Culpeper, the county seat, is the center of an agricultural community.

Rappahannock County.—Rappahannock County, created as the eighty-sixth county of Virginia, was formed in 1831 from Culpeper County. Its 264 square miles are divided into six civil districts. In 1930 there were 140,561 acres of land in farms, and 30,020 acres in woodland exclusive of pasture land. The total population in 1930 was 7,717, of which the rural population was 6,047. Washington, the county seat, located on the Lee Highway at the eastern foot of the Blue Ridge, is the center of a rich agricultural district in which apple orchards are important. In 1930, it had a population of 250.

TOWNS

Warrenton, the county seat of Fauquier County, is the largest town in the quadrangle. (See Pl. 4.) A line of towns occurs along the main line of the Southern Railway in the southeastern corner of the area, among which are Brandy, Elkwood, Remington, and Bealeton. Remington, the largest, is an important town in a dairying region. West of the Border fault Catalpa, Jeffersonton, Orlean, White Sulphur Springs, and Turnbull are the largest villages. In the northern part of the area are the towns or villages of Bethel, Delaplane, Gainesville, Buckland, The Plains, Middleburg, and Upperville. Horse raising is an important activity in the vicinity of the three last mentioned towns and each supports active hunt clubs. The Upperville Horse Show is the oldest one in the country.

Geology of the Warrenton Quadrangle

HISTORY OF THE WARRENTON AREA

GENERAL STATEMENT

The control which topography exercises upon the course of settlement and the history of a region has long been recognized. The trends of mountains and rivers determine first, the location and direction of pioneer trails and later, the location of established roads, railways, and towns. Mountains and streams serve also as political and social barriers; they frequently separate peoples of different nationalities, races and sects. The distribution of mountains and streams often determines the military policies of commanding officers in war and thus the topography of the region will influence or affect the type of warfare that is waged. The location and character of topographic features are determined in large part by the nature of the underlying rock, which also determines the quality of the soil and influences conditions of local human and industrial development. (See Pl. 1.)

Westward up the rivers and through mountain passes came the first pioneers to northern and northwestern Virginia. First were early explorers who found a well-watered country abounding in game. Later came adventurous hunters and Indian fighters, but the peaceful pursuits of agriculture offered no inducements to such men; they soon passed through gaps in the Blue Ridge to trap and hunt in the Great Valley, later moving southwestward and westward, breaking the first trails to the salt licks of Kentucky and Ohio. These men extended the frontier, and pushed the Indians back to the western wilderness. They blazed trails for the early settlers, who brought the civilization of the east to western Virginia. Thus adventurous explorers following Indian trails were followed by the early settlers, who converted their trails into wagon roads and their camp sites into villages.

Because of its probable interest to residents and visitors, the writer includes here a brief account of some of the important facts of the human history of the Warrenton area. Several historical sources on the general region have been consulted in the preparation of this account.

INDIAN INHABITANTS

The first white man to follow Rappahannock River into Culpeper and Fauquier counties was the German physician, John Lederer, who visited this area in the summer of 1670. He found the "Savanae" or low lands at the foot of the mountains to be pleasant country, well watered, and abounding in game.

Very little is recorded about the Indians of the Warrenton area. The Indian tribes of the western Piedmont were warlike hunters not inclined to agriculture, although Lederer reports that they raised some maize. They probably shifted from place to place with no permanent abode. The powerful and still more warlike Iroquois, their mortal enemies, sometimes came into this area through gaps in the Blue Ridge, so that the area was from earliest times a "Debatable Land." The general lack of permanent camp sites and the character of stone relics found in the soils of Fauquier County, reflect the uncultured and restless nature of its Indian inhabitants.

Miss Annie Lee Peyton[10] mentions an ancient Indian settlement, cemetery, and workshop near The Plains. This has been supposed to represent a camp of the Piscataway tribe. These Indians[11] moved into this area from Maryland about 1697, and in 1699 moved again to the Point of Rocks on the Potomac.

COLONIAL AND REVOLUTIONARY PERIODS

Bull Run Mountain was a natural barrier in early times and the first settlers in the Warrenton area came by way of Rappahannock Valley, Broad Run Valley, Thorofare Gap, and up Goose Creek Valley around the north end of Bull Run Mountain. Early in the eighteenth century they passed "the falls," at the frontier town of Fredericksburg, and reached the south fork of Rappahannock River, which at about that time Lieutenant Governor Spotswood renamed the Rapid Anne (Rapidan).

Colonel William Byrd visited the area in 1736 and described in his own amusing manner the conditions obtaining therein in early Colonial times[12]. In 1714 Governor Spotswood established a colony of Germans on the Rapidan near its confluence with the Rappahannock. The Knights of the Golden Horseshoe assembled here and departing September 24, 1716, are generally believed to have crossed the Blue Ridge at Swift Run Gap between Stanardsville and Elkton. At Germanna, as the colony of Germans was called, Spotswood built a private residence and near by established an iron furnace. This furnace in Spotsylvania County was, outside of New England and New Jersey, the first successful iron furnace in America. The near-by iron mines of Governor Spotswood became famous and in the early days gentlemen travelers from England who got as far as Fredericksburg, often made "a journey to the mines." The colonists who operated the mines

[10] Peyton, Annie L., Smithsonian Report, p. 447, 1879.
[11] Fauquier Hist. Soc. Bull. 2, p. 114, 1932.
[12] Byrd, William, The Proceedings of the Commissioners appointed to lay out the bounds of the Northern Neck, lying between the rivers Potomack and Rappahannock, Anno. 1736.

and the furnace came from near Siegen, the capital of the old principality of Nassau Siegen, which district had been the center of iron and silver production in Europe for more than a thousand years. The ruins of Spotswood's Castle and the old blast furnace still exist about 9 miles southeast of Germantown.

The German colonists became dissatisfied with the poverty of the soil around Germanna, and many of them moved to Madison County. In 1721 on a grant of land on Licking Run, supposed to have been near the site of the present village of Midland, was established a new settlement named Germantown. Other German settlers, who were always highly respected citizens, located in Fauquier County. Today their descendants are scattered widely over the area west of Bull Run Mountain. Some English settlers moved into Fauquier County and mingled with the Germans; others passed on along the old Falmouth trail to Winchester. Shortly after the founding of Germantown, settlers of both nationalities reached the vicinity of Warrenton.

The town of Warrenton was laid off under the direction of Richard Henry Lee, by the surveyor James Routt, December 4, 1790.[13] It was then known as Fauquier Court House, but before 1800 was renamed Warrenton in honor of General Warren, the hero of Bunker Hill. Settlement having progressed most rapidly in the Rappahannock Valley, Warrenton eventually became the county seat. In 1835 Warrenton contained two hundred dwellings and a population of 1,300. The population in 1930 was 1,450.

About 1725, English pioneers first came through Thorofare Gap in Bull Run Mountain and up Cedar Run and settled around Pignut (Mast) Mountain and in Broad Run Valley. By 1741 these settlers had pushed as far west as Rectortown, occupied also Little River Valley, and had moved as far north as Goose Creek Valley. Middleburg was founded in 1787 by Colonel Leven Powell. The first settlement at White Plains (later known as The Plains) must have been made shortly after the first settlers came through the thorofare of Bull Run.

Between 1750 and Revolutionary times, the district north of Warrenton became thinly settled by the colonists of Rappahannock and Broad Run valleys. Settlement in the Warrenton area developed as an offshoot of the Fredericksburg settlement, whereas the settlers of White Plains and other localities to the north came from Prince William County which was linked by roads with Alexandria. Settlers in these two areas differed in economic interests and to a considerable extent in political and religious thought.

The original inhabitants of the Warrenton area belonged to a hardy and vigorous stock. They were at home in the wilderness, self-

[13] Fauquier Hist. Soc. Bull. 1, p. 74, 1921.

reliant, and self-sufficient. Pioneer trails were only tracks through the forest and much of the country was unsettled as late as Revolutionary times. The map of 1751 by Fry and Jefferson shows a main road through Stafford and Prince William counties from Falmouth near Fredericksburg to Ashby Gap and thence to Winchester. Important settlements including Germantown and Watt's Ordinary (supposed to have been located at the present site of Delaplane) were on this road.[14] Many early settlers in the valley at Winchester came by way of this trail from Fredericksburg and Norfolk. A second road led to Ashby Gap from West's Ordinary. It is likely that about the same time a trail from Thorofare Gap up Broad Run Valley connected with the Falmouth-Winchester road somewhere near Marshall (formerly Salem). Near Marshall is Oak Hill, the picturesque home of former Chief Justice John Marshall of the United States Supreme Court. (See Pl. 2.) These roads, the locations of which were predetermined in position by topography, controlled the course of settlement and the location of towns. Warrenton grew up at the intersection of the lower Dumfries and the Falmouth-Winchester roads.

Good natural. northwest-southeast highways were important and difficult to find in this area because the rocks, and consequently the ridges, trend northeast. The Manassas branch of the Southern Railway now passes through Bull Run Mountain in Thorofare Gap, and follows Broad Run and the headwaters of Goose Creek, passing through the Blue Ridge at Manassas Gap. This is the easiest crossing of the Blue Ridge, and a traveler by night cannot tell by the grade when he is crossing it. The Plains, Marshall, Rectortown (formerly called Madstone), Delaplane, Markham, and Linden are along the route of this railway.

About 7 miles to the north a second line of towns—Aldie, Middleburg, Upperville, and Paris—have grown up along the trail which follows Goose Creek to Ashby Gap in the Blue Ridge. Middleburg was half way between Alexandria and Winchester on the old coach road.

The rough country between Warrenton and Marshall is still called locally "The Free State." According to Chappalear,[15] the "Free State" proper comprised an area of about 12 square miles between Marshall and Orlean. It occupies the roughest and most inaccessible section of the area which is also the watershed between Rappahannock River and Broad Run. The "Free State" which existed in the days of early wagon roads has nearly disappeared. In the district south of Marshall

[14] Fry, Joshua, and Jefferson, Peter: A map of the most inhabited part of Virginia containing the whole province of Maryland, with part of Pennsylvania, New Jersey, and North Carolina. Published in 1751. The part of this map covering the district between the Potomac and Rappahannock rivers is republished in Fauquier Hist. Soc. Bull. 1, and on it places are relocated with reference to present geography.

[15] Chappalear, Curtis, Notes on the town of Marshall and vicinage, Fauquier Hist. Soc. Bull. 3, p. 303, 1923.

its area is reduced to rugged, isolated ridges that are poor and scrubby, and which are surrounded by fertile valleys.

WAR BETWEEN THE STATES

During the War between the States, because of its geographic position and topographic character, this part of the State was overrun by troops of both armies. West of the Catoctin Mountain Border fault, the hilly Piedmont upland and the Blue Ridge regions were suited to cavalry warfare, whereas major engagements involving the movement of large masses of troops and supplies took place upon the Triassic plain east of the fault. Throughout the war the Valley of Virginia was used as a highway by troops of both armies. The Manassas Gap branch of the Southern Railway was completed in 1852. By means of the gaps in the Blue Ridge and the east-west roads and railroads, General Lee could send troops to the Valley to threaten the city of Washington, thus diverting attention from the important field of warfare in eastern Virginia. Troops could also be as rapidly recalled. Rappahannock River with its headwaters in Manassas Gap served for a long time as a natural line of defense between Federal and Confederate troops. For this reason much of the area of this quadrangle was often occupied by Federal troops throughout the War. Warrenton, strategically located on a high hill, was the largest town, and was frequently occupied by both armies.

The scars of this conflict have disappeared. Rapid transportation and good roads have welded together diverse interests and broken down many physiographic and geologic barriers, but the best and the most romantic features of the "old times" still linger in this picturesque rural region of Virginia.

STRATIGRAPHY AND PETROLOGY

IGNEOUS ROCKS

PRE-CAMBRIAN

CATOCTIN SERIES

GENERAL STATEMENT

The oldest extrusive rocks in the Warrenton area are metamorphosed basaltic lava flows and agglomerates. (See Pl. 1.) Rogers[16] recognized as early as 1836 the existence of two belts of old lava flows in the upland area which he called "epidotic rocks." He noted their amygdaloidal character but believed that they were intrusive, and he plotted their distribution on the first geologic map to be prepared for Virginia.[17] He examined the Warrenton area in 1840 and recognized sedimentary and volcanic rock types, which he described as follows:[18]

> "At the western base of Watery mountain, four miles west of *Warrenton*, a range of these rocks, consisting of a grey sandstone occurs adjacent to Chloritic slate. The bed has the usual northeastern direction and steep dip towards the southeast, and furnishes an excellent stone which is quarried for building purposes and for flagging. The rocks of Watery mountain, and most of the space thence to *Warrenton*, are more or less of an Epidotic composition. Similar Epidotic and Chloritic rocks extend westward of the belt of sandstone, so as to form the mass of Carter's mountain and Rappahannock mountain, along the western flank of which, on Carter's Run, we find another and quite extensive belt of the Gneissoid sandstone, grey, hard and very siliceous, in strata several feet thick and associated with a Chloritic slate."

Fontaine[19] also studied these volcanic rocks of the Blue Ridge and in 1875 he applied the name "Catoctin" to the entire eastern mountain chain which is partly composed of these rocks. They were described in northern Virginia and Maryland by Keith,[20] and named "Catoctin schist." On the geologic map of Virginia published in 1928, these rocks were mapped by Jonas as "Catoctin greenstone" and their relations to various intrusive rocks were suggested.

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[16] Rogers, W. B., A reprint of annual reports and other papers on the geology of the Virginias, pp. 461-462, New York, D. Appleton and Co., 1884.

[17] Rogers, W. B., op. cit., geological map.

[18] Rogers, W. B., op. cit., pp. 465-466.

[19] Fontaine, W. M., On some points in the geology of the Blue Ridge in Virginia: Am. Jour. Sci., 3d ser., vol. 9, pp. 15-22, 93-101, 1875.

[20] Keith, Arthur, Geology of the Catoctin Belt: U. S. Geol. Survey, 14th Ann. Rept., pt. 2, pp. 293-394, 1894.

In this area the Catoctin series is divided into two distinct parts. At the base and overlying the Fauquier formation is the Warrenton agglomerate member; above that are the basalt flows now altered to metabasalt or "greenstone" schist. Although flows of the Catoctin series of this area closely resemble those of the Shenandoah National Park area in the Blue Ridge, they are less massive and the original minerals show more alteration to chlorite, epidote, and quartz. There is, on the whole, less variation in the flows of this area, but the agglomerate member, so widespread near Warrenton, is rare and unimportant in the Park area.

Quartz veins and stringers are especially common in the Catoctin series and hence are abundant in the soils formed from the weathering of those rocks. Massive metabasalt flows of the Catoctin series are more resistant than other facies of the agglomerate and therefore usually occupy mountainous areas.

DISTRIBUTION

The eastern belt of the Catoctin series in Virginia passes through the middle part of the Warrenton quadrangle. Its area is interrupted and offset by several normal faults. (See Pl. 1.)

WARRENTON AGGLOMERATE MEMBER

General statement.—An agglomerate composed of metabasalt and greenstone schist fragments, here named Warrenton agglomerate, is widespread in the Warrenton area. It is difficult to separate from the lava flows because locally the two types of volcanic rocks so closely resemble each other that exact boundaries cannot be determined. Thin flows occur locally in the agglomerate. The agglomerate was mentioned in one locality by Keith,[21] in his report on the Catoctin belt, as a possible, though doubtful, occurrence of tuff along Bull Run Mountain near The Plains, in Fauquier County.

Occurrence.—The agglomerate member is exposed along the west side of Bull Run Mountain from Aldie to The Plains in Fauquier County. Southwest of The Plains the belt of volcanic rocks widens, but the agglomerate is generally confined to the western side of the area. It enters the northern part of the Warrenton quadrangle on the west and east sides of Watery Mountain where it surrounds a large area of massive metabasalt. From the west side of Watery Mountain near The Plains, it extends southwest along Piney Mountain to the vicinity of Blue Hill School. The belt is interrupted by faulting around Fauquier White Sulphur Springs but south of the Springs it is from

[21] Keith, Arthur, op. cit., p. 307.

1 to 3 miles wide. It extends southwest along the west side of a large area of greenstone which narrows near Culpeper.

Good exposures of the agglomerate are found along the west side of Bull Run Mountain. From The Plains to Bethel (Thorofare Gap sheet) the agglomerate is thick and well exposed in the fields. East of the road fork to Marshall the exposures are unusually good. From this point the agglomerate extends southwest along the west side of Rappahannock Mountain. About one mile west of the store at Bethel, agglomerate and interlayered arkose are exposed in cuts on the north side of U. S. Highway 15 (Pl. 7A). There are other good exposures in Piney Mountain. Along the Lee Highway (U. S. 211), west of Warrenton, different facies of the agglomerate are exposed in numerous cuts and field ledges. (See Pls. 5A and 5B.) Excellent exposures are found at Shiloh School (Pls. 5C and 7B), and along Muddy Run near Catalpa.

Lithologic character.—The agglomerate member is composed of boulders, cobbles and pebbles of greenstone imbedded in a finer matrix of similar material. The largest boulders are several feet in diameter. The pebbles and cobbles are more commonly scoriaceous or amygdaloidal than are the flows. In places they are of altered metadiabase and not vesicular.

In some places the agglomerate is composed almost entirely of greenstone fragments; in other places greenstone fragments are sparingly scattered through a fine matrix. Where large fragments are absent the agglomerate is difficult to distinguish from the flows because both rocks have essentially the same composition. In one exposure, the fragmental character may not be evident, yet in another exposure a short distance away the rock is distinctly an agglomerate. The fragmental character is the best criterion for the identification of this rock in the field.

Most of the fragments are of epidosite—the yellow-green variety of the metabasalt containing much secondary epidote and quartz. In the southwestern part of the quadrangle, south of Shiloh School, fragments of chlorite schist and of the dark-green, chloritic schistose variety are common. They are often held in a matrix of fine epidosite fragments which enhances the contrast on weathered surfaces. The reverse may also occur. On the west side of the Lee Highway (U. S. 211), at the Carhart estate west of Warrenton, epidosite fragments are generally contained in a chloritic matrix.

Locally the agglomerate contains visible feldspar fragments, as along the road extending north from Greenwood Church near Shiloh School. In many places the matrix of the agglomerate weathers to whitish clay derived from feldspar. (See Pl. 7B.) Sandy beds included in the agglomerate are described later. Rock resembling flow breccia occurs on the west side of the Lee Highway just west of Warrenton and also about a mile south of Muddy Run School.

The agglomerate member is more schistose than the metabasalt which, unless sheared, is massive. The degree of schistosity depends upon the quantity of fine material present. In places the agglomerate appears to have a crude stratification.

Microscopic character.—The fragmental pattern of the agglomerate member is readily observed in thin sections examined under low power. The grains and pebbles are separated by a finer, granular matrix. If the rock is weathered the pebbles are surrounded by a film of iron oxide. (See Pls. 7A and 7B.)

Thickness.—The thickness of the agglomerate member is variable and cannot be accurately determined. At Shiloh School and in Piney Mountain the agglomerate is at least 1,500 to 2,000 feet thick. In the southwestern corner of the quadrangle it is thin.

Origin.—The Catoctin-Blue Ridge region of Maryland and Pennsylvania contains volcanic rocks which extend southward into Virginia. The eastern belt of these rocks extends from Maryland into the Warrenton quadrangle. Williams[22] was the first to describe these rocks as volcanic flows in Maryland and Pennsylvania. Fuller descriptions and maps have been given by Keith,[23] Bascom,[24] and Stose.[25] One should expect pyroclastic materials to be abundant in the Catoctin-Blue Ridge region of Virginia, especially since investigators in other areas find that locally such materials occur in greater quantity than lava flows.

Many of the fragments of the agglomerate are rounded. Boulders and cobbles in a certain type of volcanic agglomerate may be rounded. This rounding is attributed by Shand[26] to the fact that the fragments have been tossed up and down in the throat of a volcano before they are finally ejected. He says: "The matrix is composed entirely of dust of the same composition as the balls. A volcanic conglomerate may look like an ordinary conglomerate, but instead of being stratified it typically occupies a volcanic neck. The rock is generally a very basic one—basalt, melilite-basalt, lamprophyre, or peridotite."[27]

[22] Williams, G. H., The volcanic rocks of South Mountain in Pennsylvania and Maryland: Am. Jour. Sci., 3d ser., vol. 44, pp. 482-496, 1892.

[23] Keith, Arthur, Geology of the Catoctin Belt: U. S. Geol. Survey, 14th Ann. Rept., pt. 2, pp. 293-394, 1894; Descriptions of the Harpers Ferry sheet: U. S. Geol. Survey Geol. Atlas, Harpers Ferry folio (no. 10), 1894.

[24] Bascom, Florence, The ancient volcanic rocks of South Mountain, Pennsylvania: U. S. Geol. Survey Bull. 136, 124 pp., 1896.

[25] Stose, G. W., and Bascom, Florence, Descriptions of the Fairfield and Gettysburg quadrangle: U. S. Geol. Survey Geol. Atlas, Fairfield-Gettysburg folio (no. 225), 1929.

[26] Shand, S. J., The study of rocks, p. 169, London, Thomas Murby and Co., 1931.

[27] Idem.

INTERBEDDED SANDSTONES

Beds of sandstone or quartzite appear to occur interlayered with the agglomerate and greenstone flows in places. (See Pl. 6A.) These rocks are similar to beds in the Loudoun formation which unquestionably is unconformable over the Catoctin series. Sedimentary rocks of the Loudoun formation are also infolded in many places with the flows so that it is hazardous to assume that a few occurrences of similar sediments which do not appear to be infolded are of a different age.

METABASALT

Occurrence.—The distribution of lava flows of the Catoctin in this quadrangle is shown on Plate 1. Flows are well exposed in the Viewtree Mountain district along the road to the mountain. The rock is a massive epidosite, generally vesicular, and some of the gas cavities are filled with quartz and epidote. Ledges exposed on the old Waterloo road about a mile east of Shade School contain amygdules filled with quartz and calcite or quartz with a calcite center some of which are an inch or more in greatest diameter. (See Pl. 6B.)

Near Warrenton the best exposures are found along the road which follows Lee Ridge a short distance south of town. Sheared, chloritized varieties may be seen along State Highway 29 where the rocks are greatly mashed. Southwest of Warrenton massive and schistose flows are well exposed locally. At Mount Zion Church near Alanthus, the rock is mottled yellow green and bluish green; the first type containing considerable secondary epidote. West of Muddy Run in Culpeper County, Catoctin lava flows are associated with hornblende metagabbro.

Talc and chlorite schists have been produced from metabasalt. Exposures occur along the roads southeast of Warrenton. Along the James Madison Highway (U. S. 15), south of Warrenton, from Turkey Run to the Catoctin Mountain Border fault, metabasalt or greenstone has been reduced to a chlorite schist and phyllite by shearing. Overthrusting has probably taken place in this area, but it has not exposed the underlying rocks. A characteristic feature is the occurrence of unsheared masses of greenstone of variable size enclosed in the schist. (See Pl. 11A.) This sheared rock with unsheared boulders of greenstone may be seen also south of Warrenton on the road to Fauquier White Sulphur Springs, just east of Jordan Run, or in other near-by places. Slabs of schistose greenstone are used in the construction of stone fences along the road, where the rock is quarried in places between Warrenton and Turnbull.

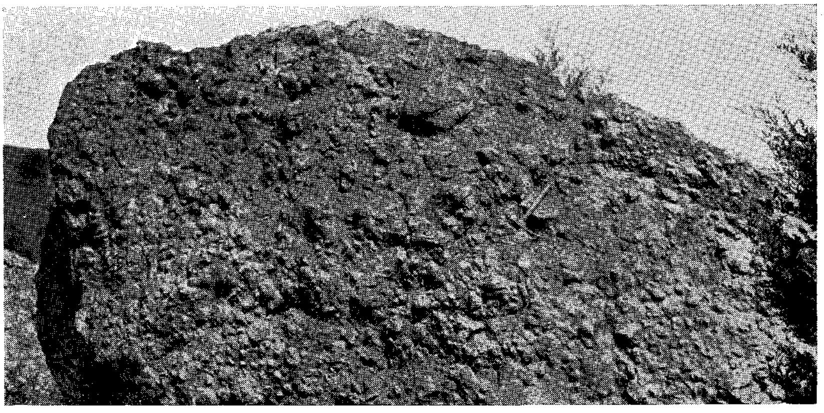
Lithologic character.—The lava flows of the Catoctin series are generally massive but they are schistose in the vicinity of Warrenton. Several different flows probably exist but the number has not been determined. No columnar jointing or "pillar structures" have been observed in this area similar to those occurring in the Shenandoah National Park area to the west. The vesicular and locally scoriaceous texture of the rock is characteristic. The cavities range from microscopic to several inches across, although the larger ones are rare. In the large cavities, extensive replacement of the rock has taken place. The average vesicle is perhaps a quarter of an inch in greatest diameter and some are filled with quartz and epidote occurring together or separately, and less commonly with calcite. In places the dominant filling is milky quartz containing prisms of epidote. The epidote crystals are radially arranged around the margin of the quartz-filled cavity; or the outside shell may be quartz surrounding epidote in the center.

Amygdaloidal and scoriaceous rock occurs in a road quarry about a mile west of Turnbull. One variety is dark gray with calcite in the amygdules (Pl. 7C). In places the rock is nearly half calcite. Large replacements about the size of a walnut or cocoanut also occur. These often contain a center of coarsely cleavable calcite with a rim of milky quartz which is pierced by numerous prismatic crystals of epidote. Irregular stringers of quartz and epidote occupy small fractures in the rock which they have also partly replaced (Pl. 8A).

The color of the lava flows is due to the minerals epidote and chlorite. Epidotic varieties are massive and yellowish green, whereas chloritic varieties are dark green and schistose. Epidotic varieties are called epidosite but the degree of alteration to epidote varies with the locality. There is nothing in this area to indicate that epidotization is due to the presence of intrusive rocks. Deuteric changes best explain the fillings and accompanying rock replacements.

Microscopic character.—The Catoctin was originally a series of basaltic flows with a prevailing ophitic texture. Thin sections of less altered rock show numerous lath-shaped rods of plagioclase with interstitial fillings of secondary chlorite and epidote. No original pyroxene has been observed. In later stages of alteration plagioclase is absent and the rock consists mostly of epidote and equidimensional quartz grains which fill spaces between the epidote crystals. Epidote is abundant and characteristic of massive varieties whereas chlorite predominates in the schistose varieties. Epidote occurs in the form of rods and grains; generally both epidote and zoisite occur in thin sections. Chlorite may have been produced from the other constituents by hydrothermal changes during shearing. (See Pl. 8B.) Magnetite is a common accessory mineral.

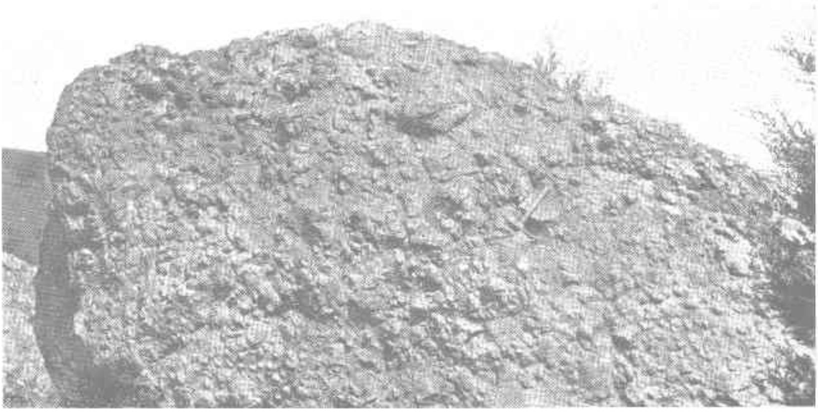
A. Ledges of Warrenton agglomerate 2 miles west of Viewtree Mountain, showing exfoliation. The ledges dip southeastward.



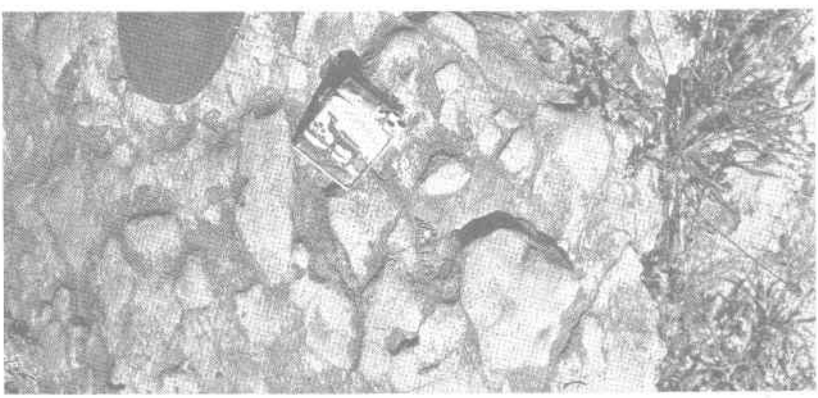
B. Detail of the ledge near the cedar tree in the left foreground of (A).

C. Detail of the Warrenton agglomerate at Shiloh School, Culpeper County, Virginia.

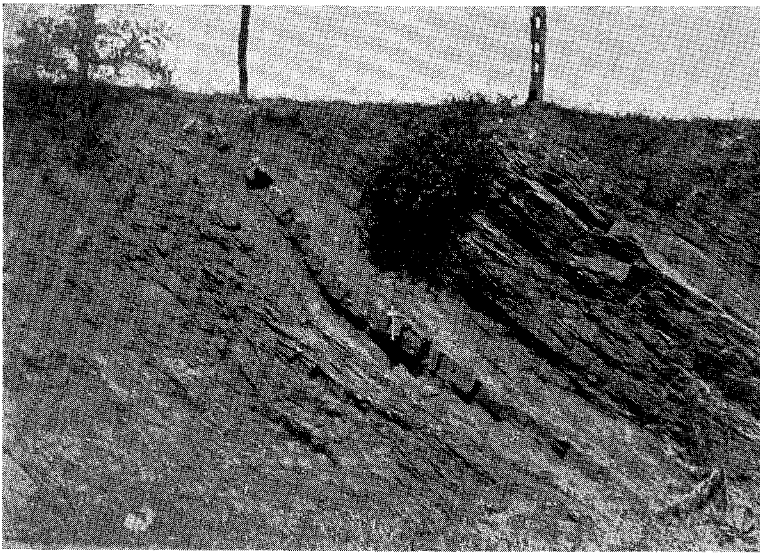
A. Ledges of Warrenton agglomerate 2 miles west of Viewtree Mountain, showing exfoliation. The ledges dip southeastward.



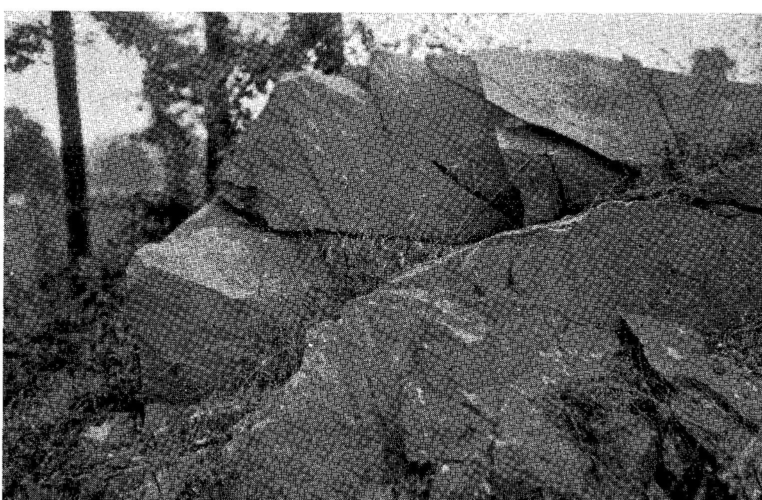
B. Detail of the ledge near the cedar tree in the left foreground of (A).



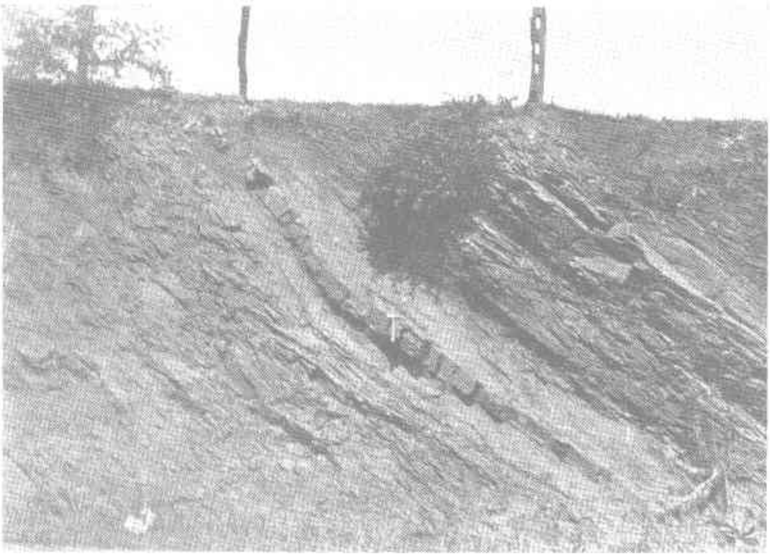
C. Detail of the Warrenton agglomerate at Shiloh School, Culpeper County, Virginia.



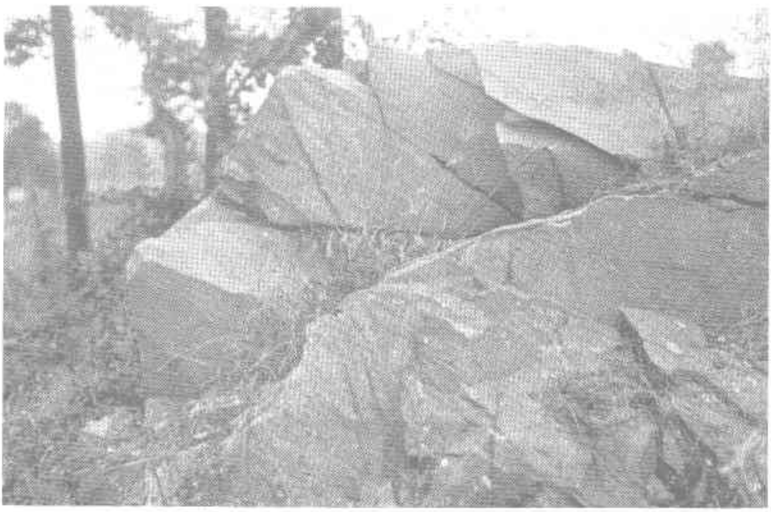
A. A sandstone bed (marked by hammer) in schistose greenstone near Culpeper, Culpeper County, Virginia.



B. Catoctin greenstone flow showing large gas cavities filled with calcite. Along the old Warrenton-Waterloo road at the southern end of Viewtree Mountain.



A. A sandstone bed (marked by hammer) in schistose greenstone near Culpeper, Culpeper County, Virginia.



B. Catoctin greenstone flow showing large gas cavities filled with calcite. Along the old Warrenton-Waterloo road at the southern end of Viewtree Mountain.

Of twenty thin sections selected at random, twelve are amygdaloidal. In some the vesicles are perfectly circular but more generally they are oval in outline. Often they coalesce; in many cases the fillings also replace the enclosing rock. Quartz, epidote, and zoisite generally fill the vesicular cavities. Calcite and chlorite are less common. When present, calcite is the dominant filling (Pl. 7C). Chlorite fillings after brown biotite have been found in thin sections from several parts of the quadrangle.

In places epidote forms the center of the amygdule and is surrounded by grains of quartz (Pl. 8A), although often the reverse is true. In many instances the two minerals are mixed in nearly equal proportions, and in other cases the cavity is filled almost entirely by one mineral. In some specimens epidote prisms occur radiating from a center to form circular or fanlike structures that may show circular polarization. Tiny grains of magnetite may line the borders of a cavity.

In a quarry about a mile west of Turnbull, greenstone is intruded by a fine-grained, gray biotite granite (Pl. 11B), thin sections of which show plagioclase, orthoclase, quartz, and considerable biotite. Plagioclase is considerably altered to prismatic or granular, faintly pleochroic, yellow to transparent epidote, which is relatively abundant. Biotite is generally green, in places brown, always pleochroic. The rock is dark and scoriaceous, resembling a recent lava. Around the granite the amygdules are of calcite with considerable calcite in the granite also. In thin sections, the feldspar of the granite has the appearance of being intergrown with the calcite. Farther from the granite, amygdules are of epidote and quartz. This occurrence suggests the possibility that calcite amygdules may indicate proximity to an intrusive. (See Pls. 7C and 8A.)

The amygdules may be of the same age as the epidote and quartz lenses that are common in schistose Catoctin flows. Epidotization probably took place in pre-Cambrian times because amygdules and epidosite fragments are found in otherwise unaltered Lower Cambrian sediments.

TUFF

Occurrence.—A tuffaceous rock is exposed on Barrs Run about a mile west of Turnbull. (See Pl. 8C.) Good outcrops occur on the west side of the run and on both sides of the local road. This rock is underlain by vesicular greenstone flows and overlain by arkose of the Loudoun formation.

A metamorphosed tuffaceous rock is well exposed where it crosses the county road about half a mile northwest of Jeffersonton and again on the banks of Rappahannock River on the Pierce estate, where it has been quarried. The rock is gray green, slaty and characterized by porphyroblasts of biotite and magnetite.

Lithologic character.—Blue-gray, very fine-grained, angular fragments compose the larger part of the rock near Turnbull. Some are 2 inches in diameter. Fragments of greenstone, mica schist and vein quartz also occur. Grains of blue quartz associated with or surrounded by biotite flakes are common.

Microscopic character.—Under the microscope most of the constituents are angular and shard shaped (Pl. 8C). They appear to be recrystallized volcanic glass and differ in appearance from any other rock materials in this area known to the writer. In some thin sections the products of recrystallization are arranged in bands. Such structures disappear when examined between crossed nicols. The most frequent type of alteration is to a fine mosaic of quartz and feldspar (?). Epidote grains, magnetite, and shreds of biotite or chlorite are common. Some of the fragments are thickly studded with small octahedra of magnetite. Feldspar fragments are very common. Lath-shaped plagioclase of a type characteristic of Catoctin lava flows occurs sparingly, but large, ragged crytals of plagioclase and orthoclase, which are more or less equidimensional, are more or less abundant. Plagioclase is often considerably altered to epidote. Grains of microperthite are numerous. Grains of clear quartz in part surrounded or associated with biotite are present. The rock is not mashed or schistose.

The metamorphosed tuff on the Pierce estate is composed of quartz, some plagioclase, chlorite, epidote, muscovite and magnetite; quartz being the most abundant. At Jeffersonton the rock contains numerous prisms of epidote.

AMPHIBOLITE OR HORNBLENDE METAGABBRO

Occurrence and character.—Along the southeastern border of the Catoctin-Blue Ridge uplift in Virginia, basic igneous rocks ranging in composition from metagabbro to metaperidotite occur in close association with basic lava flows of Catoctin age which range between andesite and olivine basalt. Other workers[28] in this part of the State have generally assumed that the original ferromagnesian silicate of the metagabbro was pyroxene although it was not found by the author in thin sections studied by him. In the Warrenton quadrangle this rock

[28] Keith, Arthur, Geology of the Catoctin belt: U. S. Geol. Survey, 14th Ann. Rept., pt. 2, pp. 285-395, 1894.

............, Description of the Harpers Ferry sheet: U. S. Geol. Survey Geol. Atlas, Harpers Ferry folio (no. 10), 1894.

Jonas, A. I., Geologic reconnaissance in the Piedmont of Virginia: Geol. Soc. America Bull., vol. 38, no. 4, pp. 837-846, 1927.

............, Structure of the metamorphic belt of the central Appalachians: Geol. Soc. America Bull., vol. 40, no. 2, pp. 503-513, 1929.

may be properly referred to as metagabbro; in places plagioclase is nearly completely absent and the rock becomes a metapyroxenite or an amphibolite. The rock is so infolded with the flows of the Catoctin series that it is impossible to separate them in some places on the geologic map.

Metagabbro covers but a small portion of this area, the principal outcrops occurring in the southwest corner of the quadrangle. From Rixeyville south, the metagabbro occurs associated with Catoctin greenstone. Other occurrences are found along Great Run south and southeast of Fauquier White Sulphur Springs, and on Beaverdam Creek about 2 miles southwest of the Springs. About 4 miles south of Marshall (Thorofare Gap sheet) the metagabbro occurs directly beneath the Warrenton agglomerate member.

Metapyroxenite often underlies or is interlayered with black slate of the Fauquier formation. Metapyroxenite and greenstone are exposed along State Highway 29 south of Catalpa in such a manner as to indicate a genetic relationship. West of Catalpa metapyroxenite is underlain by the Fauquier formation. Another prominent outcrop of metapyroxenite occurs east of Fauquier White Sulphur Springs, where this rock intrudes slate of the Fauquier formation.

The best exposures in the area occur along the south banks of Great Run where the rock in places stands up in distinct ledges. In texture the rock is subject to great variations, ranging from coarse to fine grained within short distances. It may be nearly pure metapyroxenite with pale green hornblende or a typical metagabbro with abundant plagioclase and a diabasic texture. In all cases both minerals are considerably altered. Locally the rock is sheared. In a sample collected at this locality the amphibole was mashed out into flattened disclike patches of chlorite; the rock is generally gray in color and effervesces freely in dilute acid. The specimen might easily be mistaken for a metamorphosed calcareous sediment. About a third of this thin section is composed of large calcite grains; there is considerable quartz in small grains; some plagioclase and shreds of chlorite are moderately abundant. In places, patches of pale green, unchloritized amphibole occur.

The small outcrop found near Beaverdam Run, south of Fauquier White Sulphur Springs, is the least altered of all exposures. It is a medium fine-grained diabase constituting a sill or the basal part of a flow. It is composed of green hornblende and lath-shaped plagioclase. The former is slightly altered to biotite and chlorite.

Mineral composition.—In general the metagabbro is a green rock, fine to coarse grained composed in large part of light-green amphibole which may be recognized in the medium-grained and coarser varieties without a hand lens. The grayer the rock, the more altered the amphibole content. Coarse-grained varieties are often more altered than fine-grained types, which are locally dark green. Sheared varieties are chloritized. In places lath-shaped plagioclases may be observed in the fine-grained rock without the aid of a hand lens and such rocks are typical diabases.

Thin sections show the rock to be composed of amphibole, plagioclase feldspar, and alteration products of those minerals. Variations from nearly pure amphibole is generally pale green with slight pleochroism, but in less altered rock, probably a variety of hornblende, it has a deep green color. The feldspar corresponds to albite or oligoclase, but probably neither mineral was original in the rock. The hornblende is probably derived from original pyroxene, whereas the original feldspar may have been more basic; however no pyroxene has been found in this rock. Epidote and zoisite are common alteration products of both hornblende and feldspar, and indicate that the rock has passed through the same history as the Catoctin flows. They occur typically in grains that may cover feldspars or be arranged along cleavage planes or occasionally replace hornblende crystals. Hornblende also alters to chlorite, especially where the rock has been subjected to shearing. Irregular areas of brown titanite or leucoxene, that are white in reflected light, occur frequently.

Age and relations.—The mode of occurrence, texture, and composition of the metagabbro suggest that, in part at least, it may represent the basal portions of the flows. Metagabbro also occurs in the Fauquier formation as dikes, which were intruded during the Catoctin epoch of vulcanism. The metagabbro is infolded with the Catoctin volcanic series, but has never been found to cut the lava flows. In places, as for example west of Rixeyville, the metagabbro is so fine grained that it is difficult to distinguish it from the flows of the Catoctin series.

GRANITE COMPLEX

OCCURRENCE

Occurrences of granite are found in the northwest corner of the Warrenton quadrangle. This is in a part of the main granite belt which extends southwestward to Franklin County and northeastward through Marshall, Rectortown and Middleburg into southern Maryland.[29] Amissville and Orlean are the only towns in the quadrangle

[29] This belt of intrusive rocks extends as far south as Georgia, where granodiorite and granite similar to that of this area intrude the Pine Log sedimentary formation. This formation appears to be even less metamorphosed than the Fauquier formation of Virginia.

that are situated upon granite. Excellent exposures occur in the vicinity of Amissville where the rock has been quarried recently.

LITHOLOGIC CHARACTER

The granite occurs throughout the area in two facies which cannot be separated because of lack of outcrops. An older granodiorite or granite gneiss, and a later granite which is granulated, and in places schistose, occur. The granodiorite predominates in this area and is locally intruded and soaked by pegmatite of a later age. It is characteristically composed of purple or lilac-colored quartz and greenish-gray potash feldspar. The latter mineral is in places pink or flesh-colored. Biotite occurs usually in small amounts. The granodiorite contains orthoclase phenocrysts added during the stage of pegmatite injection.

Pegmatite consists entirely of coarse gray, cream or flesh-colored potash feldspar and purple quartz. This rock is the Old Rag granite of the Shenandoah National Park area[30] to the west. The older facies is frequently so soaked with pegmatite as to form a hybrid rock. The pegmatite facies is well exposed in quarries near Amissville. Locally, however, the pegmatite occurs in zones and stringers which may grade laterally into the other type. The proportions of quartz and feldspar in the pegmatite vary considerably; in places stringers and sheets of nearly pure purple quartz occur, showing the relation of this intrusive to occasional occurrences of purple quartz veins.

Variations in the color and texture of the rock from place to place appear to be due to variations in the degree of mashing and alteration of the original minerals, and to the presence or absence of the pegmatitic facies. Shear planes along which the feldspars have been altered to mica are common. In texture the rock ranges from medium to coarse, even grained, or porphyritic. Large unmashed feldspars are usually pink or gray. In places the feldspars are granulated to a fine greenish-gray mass. In hand specimens, the pegmatite does not show the effects of mashing and the minerals appear to be quite fresh and unaltered.

Porphyritic granite is common in this area. It may be conveniently studied along the road to Hinsons Mill[31] which intersects the Lee Highway (U. S. 211), about a mile north of Amissville. This variety consists of large, oval, pink potash feldspars and lavender-colored quartz. The large feldspars which contain some quartz grains average three-fourths of an inch by an inch and a half in dimensions. The largest

[30] Furcron, A. S., Igneous rocks of the Shenandoah National Park area: Jour. Geology, vol. 42, no. 4, pp. 400-410, 1934.
[31] Henson Ford on Warrenton topographic map.

grains measure three inches or more in greatest dimension. In places the feldspars are mashed to a fine bluish-gray, granular saussuritic mass.

Other granitic types or variations of the Old Rag granite found in this area are also probably younger than the granodiorite.

MICROSCOPIC CHARACTER

According to thin sections, the older facies, which is largely granodiorite, consists of potash feldspar, plagioclase, and quartz. Other minerals, occurring in small quantities, are generally secondary. The rock always shows cataclastic effects. In the Shenandoah National Park area to the west the granodiorite usually is massive. Except in sheared facies, the rock, petrographically, is generally similar to the granodiorite of the Park area.

The principal feldspars are microcline and orthoclase. Plagioclase (albite) or oligioclase always occurs, in some thin sections as an important constituent ranking in abundance with potash feldspars, but usually occurring in subordinate amounts. Perthite, in stringers and veins, believed to be deuteritic in origin, is common. The host of the perthite is orthoclase, and the other feldspar is albite. No twinning lines were found in the spindles and veins.

Other minerals are generally unimportant except where the rock is much mashed. Hypersthene, hornblende and biotite are the dominant iron minerals. For the most part, other minerals are secondary and were produced during the period of fracturing and mashing. Sericite is always present as an alteration product of feldspar. In places the plagioclase is altered to sericite and the potash feldspars much less so. Biotite occurs sparingly and, in many cases at least, is secondary after some unknown primary mineral. Rings of leucoxene surrounding cores of magnetite or ilmenite are found in practically all sections. In some sections patches of biotite, leucoxene, and calcite occur with small garnets.

Cataclastic structures occur in all thin sections. The minerals are strained and show wavy extinction or they may be completely granulated. The feldspars are the first affected; early effects consists of a rim of granules around the margins of the larger grains. Also in thin sections showing the early stage of alteration, belts of granulated feldspar cut through the larger grains and in these belts or zones sericite may have been formed. In places biotite of undoubted secondary origin also occurs in such positions.

The younger facies consists of quartz, microcline and orthoclase with little sericite, and with but little evidence of mashing and granulation.

AGE AND RELATIONS

The pre-Cambrian age of the granite of this belt is evident in this area. The granite underlies the Lower Cambrian Loudoun formation. Locally short, narrow anticlines of granite occur within areas of the Loudoun; likewise where the contact between the two rocks is irregular, infolded fingers of granite extend out into the Loudoun area. The arkosic quartzite of the Loudoun formation is composed largely of granite fragments which are usually comminuted to single mineral grains or fragments of individual minerals.

The relation of the granite to the Catoctin greenstone series in this area is more difficult to ascertain. The main line of contact between the two rocks is separated by the Fauquier formation. The writer has found few occurrences of granite associated with the Catoctin greenstone belt that extends through the central part of the quadrangle, although granite and granodiorite intrude the Catoctin series in the Shenandoah National Park area.

Jonas points out that the Fauquier formation is not found between the Catoctin series and the granite complex in the western Blue Ridge belt. She states that the evidence for her conclusion that the granite complex is older than the Catotcin volcanic series is as follows[32]: "In Maryland where the granitic complex is exposed in the Middletown anticline between areas of Catoctin metabasalt lying on the two sides of this anticline, metadiabase dikes cut across injection gneiss and granitic rocks. They do not enter the Lower Cambrian rocks and are related to the Catoctin metabasalt in composition. No intrusive rocks cut the metabasalt or aporhyolite in Maryland. In southwestern Virginia, metadiabase dikes and porphyry dikes, traceable into areas of metabasalt and aporhyolite flows, cross cut metamorphosed sediments, metadiorite, granite, pegmatite, and injection gneiss. No intrusive rocks have been found with cross cutting relations to these dikes.

"The pegmatite which cuts the Catoctin[33] series in the Stony Man area may represent a late pre-Cambrian intrusion younger than the granitic complex. Since the age of the pegmatite in Nelson and Amherst counties, Virginia, which is related to the granite that intrudes the diorite and granodiorite has been determined[34] as 800 million years it cannot be the same pegmatite as that cutting the Catoctin metabasalt farther north for, from evidence found in southwestern Virginia, and which I will publish later, the Catoctin metabasalt and associated rhyolite flows were extruded in the late part of the pre-Cambrian."

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[32] Jonas, A. I., personal communication, May 11, 1938.

[33] Furcron, A. S., Igneous rocks of the Shenandoah National Park area, Virginia: Jour. Geology, vol. 52, pp. 408-410, 1934.

[34] Marble, J. P., Age of allanite from Amherst County, Virginia: American Jour. Sci., 5th ser., vol. 30, p. 351, 1935.

After a study of such relationships in the Shenandoah National Park area the writer believes that the burden of evidence indicates that the granodiorite and Old Rag granite members of the complex intrude the Catoctin volcanic rocks, and are therefore younger than that series of rocks.[35]

Both facies of granite are exposed along State Highway 50 between Middleburg and Paris. The rock is often mashed and schistose. Stringers and bands of greenstone are included in the granite on the western outskirts of Upperville. Between Upperville and Middleburg in Fauquier County, are numerous alternations of granite and greenstone layers. Because of the relations described above, it is assumed that the granite intrudes the greenstone, but no granite has yet been found to cross-cut the greenstone in this area.

PALEOZOIC (?) DIKES

OCCURRENCE AND CHARACTER

Greenstone dikes of Paleozoic age have not been found in the Loudoun formation of the Warrenton quadrangle. In the Shenandoah National Park area greenstone dikes intrude pre-Cambrian granite and granodiorite. A lava flow of Lower Cambrian age has been described from the Park area on the west side of the Blue Ridge.[36] Several greenstone dikes cut the pre-Cambrian granite complex in the northwestern part of the Warrenton quadrangle. Greenstone dikes intrude the Loudoun formation on the farm of A. W. C. Furcron, about a mile west of The Plains, several miles north of the Warrenton quadrangle. These dikes may be of Early Cambrian or later age. Jonas believes that the metadiabase ("greenstone") dikes she has seen in the granite complex in Maryland and Virginia belong to the Catoctin period of intrusion. She states[37] that "The metadiabase dikes which I have seen in the Catoctin-Blue Ridge anticlinorium in southern Maryland and in the same region in Virginia, west of the Fauquier formation and the Lynchburg gneiss, are cogenetic with Catoctin metabasalt and cut the older rocks of the intrusive complex which underlies Catoctin metabasalt."

[35] Bevan, Arthur, and others, Guidebook Field Conference of Pennsylvania Geologists: Virginia Geol. Survey Guide Leaflet 1, Pl. 9, 1938.
[36] Furcron, A. S., and Woodward, H. P., A basal Cambrian lava flow in northern Virginia: Jour. Geology, vol. 44, no. 1, pp. 45-51, 1936.
[37] Jonas, A. I., personal communication, May 11, 1938.

TRIASSIC DIABASE

GENERAL STATEMENT

The Triassic areas of Virginia have been described by Roberts[38] and others.[39] The southwestern portion of the Potomac Triassic basin extends into the southeastern part of the Warrenton quadrangle, southeast of the Bull Run or Catoctin Mountain Border fault.

The deposition of Triassic sediments in eastern North America was accompanied by the intrusion of dikes, sills, and stocks of diabase, and by lava flows. The writer knows of no flows having been recorded from Virginia. In the Triassic rocks of the Potomac basin in the State, however, intrusions in the form of large sills are characteristic. There are also several stocks or locally thickened portions of a sill east of Leesburg in Loudoun County, at Buzzard Mountain north of Rapidan station in Culpeper County, and at several other localities. Narrow dikes also occur, cutting the gently dipping sediments at steep angles. Diabase dikes also intrude sedimentary rocks of the smaller areas of Triassic rocks in the same manner and also cut the Cambrian and pre-Cambrian sediments of the Piedmont province.

These trap or diabase intrusives (dikes) are composed for the most part of plagioclase and augite. Some varieties are more basic and carry olivene, whereas the common and more acid varieties contain micropegmatitic areas of quartz and feldspar. From Nova Scotia to Alabama there is slight variation in the diabase dikes of Triassic age.

CRITERIA FOR DIKES AND SILLS

Only dikes have been found outside the boundaries of the Triassic sedimentary basins; they cut across the schistosity or bedding of the enclosing rock. They are the only intrusive bodies to cut the Loudoun sediments in this area. Dikes thin out and disappear along the line of strike, whereas sills are offset by faults or split and enclose island areas of shale. In this area the dikes and sills show no difference in mineral composition, but the dikes generally have a finer grained texture. The outer part of a sill may be also fine grained due to chilling. Thick dikes may be coarse grained.

Fine-grained diabase of small, narrow dikes is so tough that the rock cannot be readily crushed, but large, wide, coarse-grained dikes have been quarried and used successfully for various purposes in other parts of the Piedmont region. Diabase in the sills is of commercial

[38] Roberts, J. K., The geology of the Virginia Triassic: Virginia Geol. Survey Bull. 29, 205 pp., 1928.

[39] Jonas, A. I., Geological reconnaissance in the Piedmont of Virginia: Geol. Soc. America Bull., vol. 38, no. 4, pp. 837-846, 1927.

Lonsdale, J. T., Geology of the gold-pyrite belt of the northeastern Piedmont Virginia: Virginia Geol. Survey Bull. 30, 110 pp., 1927.

value since generally it can be crushed with comparative ease. The sill rock tends to break with a smooth fracture, and the dike rock with an irregular, hackly fracture; the latter is finer grained and hence tough. Abundant joints[40] in the sill greatly aid quarrying operations, whereas large rounded boulders, characteristic of weathered dikes, indicate fewer joints in the dikes.

DIKES

OCCURRENCE

A few small diabase dikes occur in the Warrenton quadrangle. They appear to be more abundant near or within belts that correspond to the general trend of the Triassic basins. West of the Border fault the dikes generally trend a little east of north or more generally west of north. Only one dikelike body was found in the Triassic rocks east of the Bull Run escarpment. It is north of Bealeton, and extends northeast and southwest as do the outcropping edges of the large diabase sill which occurs in the east-central portion of the quadrangle.

Dikes west of the escarpment have little or no topographic expression; they are generally short and difficult to trace, although a line of rounded boulders generally marks their course. It is often impossible to determine accurately their width or strike. Just beyond the northeast corner of the quadrangle a large dike is exposed on the eastern side of Baldwin Ridge, and on the road to New Baltimore near its junction with the road across the ridge. Its strike is northwest, thus, diabase on the road just west of Cattail Run and about a mile west of Lee Highway (U. S. 211), may be a continuation of this dike. This is the widest dike and the coarsest in grain found in the area, and it has a medium coarse-grained texture. In the Warrenton quadrangle, a dike extending eastward from a point near Little Fork Church forms a low, narrow ridge that is locally topped with conical hills. It has a finer texture than the other dikes and has apparently produced no contact effects upon the rocks which it intrudes.

In the Blue Ridge section of the quadrangle there is a small dike which cuts arkosic Loudoun quartzite about a mile west of Blue Hill School. This dike is fine grained and about 40 feet wide. It strikes about S. 30° W. It lies next to a quartz vein which follows its course. Another occurs about a mile southwest of Little Fork Church. Neither of these can be traced for any considerable distance. A third dike, which is at least 2 miles long, occurs just west of Muddy Run School.

[40] Roberts, J. K., and Ward, R. V., Prismatic jointing in the Virginia diabase [abstract]: Geol. Soc. America Proc., 1936-1937, p. 111, 1937.

PETROLOGY

In general the dikes of the quadrangle are thin, fine grained and dark gray in color. The ophitic texture may be seen without a hand lens and with a hand lens the white feldspar and dark, nearly black augite may be recognized.

All the dikes are similar in composition and may therefore be described as a group. No olivine diabase has been found. Thin sections show that the dike rock consists of about 60 per cent plagioclase, of a composition generally that of labradorite, and 40 per cent iron-rich augite. The feldspar is in typical lath-shaped crystals that extend in all directions through the rock. The augite is nearly colorless and shows good cleavage. Some shows twinned crystals. It occupies the space between the feldspars and generally crystallized later, although the periods of crystallization have somewhat overlapped. All sections contain irregular-shaped grains of magnetite. Small patches of micrographic intergrowths of quartz and orthoclase not infrequently occur. The rock is fresh and unaltered as a rule, but slight alterations of the augite, especially to yellow serpentine or to green, iron-rich serpentine, occur in practically all thin sections. The character of the enclosing rocks has had no appreciable effect upon the composition of the dikes.

SILL

OCCURRENCE

Outcrops of a large diabase sill cover about half of the territory of the quadrangle southeast of the Catoctin Mountain Border fault. The sill was intruded into the shales which are metamorphosed above and below the intrusive contact. The belt or zone of "baked shale" is shown on the geologic map (Pl. 1). Outcrops of the sill are broken by normal faults. Since the sill is harder than the shales, low ridges are formed where its edges crop out at the surface. The sill dips westward with the sediments and varies in thickness; it may be as much as 500 feet thick in places.

Variations in texture are characteristic. The sill being thicker than the dikes, is generally coarser grained, but the borders of the sill are frequently fine grained because of rapid cooling. Where a conspicuous belt of altered shale occurs near the border of the intrusive, as for example along Marsh Run and in the southeastern corner of the quadrangle, the diabase may be coarse grained.

In contrast with dike rock, the sill rock is well jointed. Normally the joints extend in two directions which intersect to form rhombohedral blocks, with one joint usually better developed than the other. Along the best developed joint the rock is often slickensided. Locally, abundant jointing facilitates quarrying operations.

PETROLOGY

Exposures of the large diabase sill near the Border fault are fine grained because they belong to the more quickly chilled top of the sill from which the sediments have been removed but recently. This rock is in places amygdaloidal. The outcropping edges of the sill farther east may expose fine-grained borders with coarse interiors, although the former may be absent. The fine-grained rock is dark gray whereas the coarser varieties are light gray.

The sill has the same original mineral composition as the dikes. Augite is in places altered to chlorite and leucoxene, and these minerals may be accompanied by grains of calcite. (See Pl. 9A.) Slickensided joint surfaces are covered with chlorite. Small micrographic intergrowths of quartz and feldspar may occur as they do in the dikes. In one thin section a large square orthoclase crystal composed of micropegmatite was observed.

PEGMATITE

Cross-cutting veins of coarse diabase pegmatite, similar to that described by Shannon,[41] occur in the quarry along Rappahannock River at the crossing of U. S. Highway 15-29 at Remington.

The diabase of the quarry is of a normal gray color and is medium coarse. Hand specimens effervesce with dilute hydrochloric acid. The pegmatite, composed of coarse plagioclase with augite, cross-cuts the diabase, or fills and replaces joint planes. The minerals of both the diabase near the pegmatite and the pegmatite have been considerably altered by hydrothermal action and the augite is partly changed to brown hornblende, or completely altered to green hornblende. The feldspars are partially altered to a kaolinlike substance. The alteration is believed to have occurred during the epoch of intrusion. Two thin sections of this rock examined, suggest that micrographic intergrowths of quartz and feldspar are more common in the pegmatite and associated altered diabase than in the normal, unaffected diabase. The writer believes, as does Shannon, that the coarse variety is a late differentiation of the magma into a pegmatitic facies.

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[41] Shannon, E. V., The mineralogy and petrology of intrusive diabase at Goose Creek, Loudoun County, Virginia: U. S. Nat. Mus. Proc., vol. 66, art. 2, 86 pp., 1924.

SEDIMENTARY ROCKS

PRE-CAMBRIAN

GENERAL STATEMENT

The oldest sedimentary rocks of the area lie west of Bull Run and Watery mountains, extending through the central part of the quadrangle. They consist of slate, schist, gneiss, and marble which formerly were included[42] in the Loudoun formation of Early Cambrian age. They are here classified as of pre-Cambrian age.

FAUQUIER FORMATION

OCCURRENCE AND GENERAL CHARACTER

The Fauquier formation in the quadrangle includes blue and white marble east of Marshall. On the Horner property and on the farm of Dr. Reginald J. Vickers, the marble occurs at the top of the formation where it dips under the Catoctin at an angle of from 15° to 25°. Under the marble are slate, schist, and biotite gneiss (Pl. 9B). The slate of the Fauquier slate belt is a part of this formation.

In the Warrenton quadrangle, the Fauquier formation embraces a variety of metamorphosed sedimentary rocks which crop out on the west side of the area of the Catoctin series. The formation enters the northern part of the quadrangle at Dudie where dark-colored slates lie immediately under the Catoctin. It crops out over a wide area in the central part of the quadrangle, where it has been brought up to the surface by normal faulting. The presence of this formation may be recognized by its poor outcrops, deeply weathered red clay soil which contains abundant fragments of vein quartz, and by numerous local amphibolite and greenstone dikes of the Catoctin series. The rocks of the formation are quite variable in composition.

MARBLE

No definite deposits of marble were discovered in the Warrenton quadrangle although highly calcareous rocks, possibly altered limestones, occur between Cliff Mills and the bridge over Carter Run, and also along the west side of the greenstone belt between Dudie and Cliff Mills, where marble might be expected. An occurrence of actinolite schist at the Loudoun contact at Dudie probably represents altered marble at that locality.

[42] Keith, Arthur, Geology of the Catoctin belt: U. S. Geol. Survey 14th Ann. Rept., pt. 2, pp. 285-395, 1894; Description of the Harpers Ferry sheet: U. S. Geol. Survey Geol. Atlas, Harpers Ferry folio (no. 10), 1894.

At the western base of Watery Mountain, southeast of Marshall, marble and schist occur under Catoctin lava flows and dip under the overlying extrusive rocks at the base of the mountain. This occurrence was mentioned by Rogers[43] in 1834. Marble has been quarried and burned at this locality at several different periods since 1838. The rock is white, gray, blue; massive to slaty. Marble deposits are common along the west side of Bull Run Mountain northeast of this area.

A more detailed and extensive examination of these calcareous rocks of the Fauquier formation may reveal definitely mappable subdivisions. The marble which crops out west of Marshall occurs at the top of the formation. Below that is a great thickness of slate and also water-laid silts, now altered to argillites. Biotite gneiss, biotite-bearing quartzite, and quartz-muscovite schists are also common rocks in the Fauquier formation. The black graphitic slate and graphite schist of this belt are closely associated with amphibolite. Southeast of Fauquier White Sulphur Springs they are interlayered with narrow amphibolite bodies in such a manner that an intrusive contact is inferred.

SLATE

Occurrence and relations.—Rocks ranging from black slate to graphite slate and schist underlie the Warrenton agglomerate member in this quadrangle; in the southwestern part of the quadrangle south of Fauquier White Sulphur Springs, they also lie directly beneath Catoctin flows and hornblende metagabbro. There is, however, generally some schist between the slate and the base of the Catoctin series, and in places, slate occurs infolded or interbedded in the schist. This slate was formerly regarded as Lower Cambrian.[44] West of Rixeyville and at the slate quarry about a mile southeast of Waterloo, loose surface blocks of Loudoun arkosic quartzite contain fragments of black slate. The relation of these loose surface fragments to the slate in place could not be determined, but their presence near the slate suggests the existence of an unconformity between the slate and the Loudoun formation.

There are two main belts of slate in the quadrangle; both are narrow and vary in thickness and length from place to place. The slate also varies in quality and composition. This fact supports the theory that proper conditions for deposition of high-grade slate existed only in certain localities. One belt of slate north of Fauquier White Sulphur Springs loops southward from Turnbull and then strikes northwestward to Rappahannock River. (See Pl. 1.) The average width of this belt

[43] Rogers, W. B., A reprint of annual reports and other papers on the geology of the Virginias, pp. 465-466, 467-469, New York, D. Appleton and Co., 1884.

[44] Watson, T. L., and Powell, S. L., Fossil evidence of the age of the Virginia Piedmont slates: Am. Jour. Sci., 4th ser., vol. 31, pp. 33-44, 1911.

is about 500 feet and its length about three miles. The second or southern belt extends from the bend in Rappahannock River a mile below the highway bridge at the Springs, northeastward for about 2½ miles to a point just south of Great Run. The width of this belt is about 300 feet. Layers of schist are included in the slate and the slate is, in places, intruded by amphibolite.

Lithologic character.—The slate of the Fauquier formation is bluish black to black, dull with very little luster, and has a rough, speckled cleavage surface due to the development of pyrite or other secondary constituents, or to the presence of coarse mineral grains. In places the cleavage planes have a decidedly knotty or wrinkly surface. The texture ranges from moderately fine to coarsely crystalline. The slate contains considerable pyrite, and near the surface the cleavage planes are stained with ferric oxide. Bands of muscovite occur locally. There are generally two sets of joints. According to Dale,[45] the slate is very carbonaceous or graphitic, shows considerable pyrite on sawn edges, has very little magnetite, does not effervesce in cold dilute hydrochloric acid, has an argillaceous odor, and is very sonorous. Its pyritiferous character is a marked feature. Where used for roofing in this area, the slate has given non-fading service.

Microscopic character.—The mineral composition and grain size of the slate varies locally. Several thin sections examined contain much black carbonaceous matter, probably graphite. Quartz is next in abundance and with the graphitic material composes most of the rock. Thin sections of some of the slate exhibit a knotty appearance, due to the growth of secondary minerals, especially pyrite, and the local occurrence of large ungranulated fragments of quartz or plagioclase. (See Pl. 10A.) The secondary minerals contain much included quartz and graphite. Coarse-grained slate may be practically a graphitic arkose. Muscovite, chlorite, feldspar, and pyrite are generally found in small amounts.

QUARTZ-MICA SCHIST

Occurrence and character.—Beneath the black slate is a considerable thickness of thinly laminated silts, for the most part altered to mica schist or slate. These rocks occur over the central part of the quadrangle where they dip at gentle angles, and contain numerous minor folds and normal faults of little displacement or extent. They are well exposed on the Seven Hills Road between Fauquier White Sulphur Springs and Jeffersonton. (See Pl. 10B.) On Indian Run, west of

[45] Dale, T. N., Slate deposits and slate industry of the United States: U. S. Geol. Survey Bull. 275, pp. 117-119, 1906.

Jeffersonton, there is a large quarry in this rock. Here it is a blue-gray, thinly laminated rock somewhat past the slate stage. It may be designated as a very fine-grained quartz-mica schist in which small biotite porphyroblasts frequently occur. A similar rock is well exposed in large cliffs at Monumental Mills about 2½ miles west of Rixeyville.

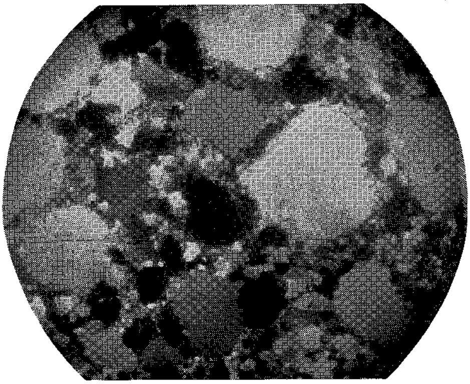
GEOLOGIC AGE

The series of rocks comprising the Fauquier formation is pre-Cambrian in age because it dips under the Catoctin volcanic series, and is intruded by amphibolite and greenstone dikes of Catoctin age. On the geologic map of Virginia published in 1928, the marbles were shown as underlying the Catoctin series. This interpretation for the marbles should include the other associated rocks of the Fauquier formation.

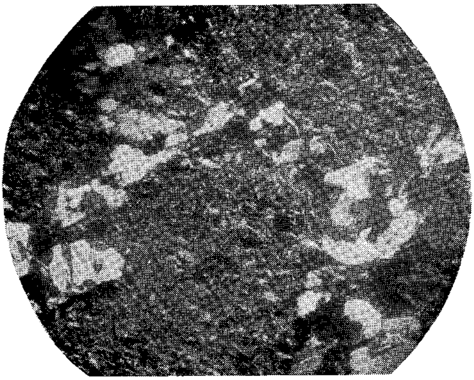
Fragments of slate and schist from the Fauquier formation occur in the Loudoun arkosic quartzite. The rocks of the Fauquier formation are more metamorphosed than those of the Loudoun formation which overlie them to the west.

In many places slate lies under the Catoctin series which indicates an unconformity at the base of the Catoctin series or else that the Catoctin series is thrust over the Fauquier formation. If the latter relation is correct, the Warrenton agglomerate member would in all probability be broken by the movement so that its outcrop would not be as continuous as it is. The writer believes, therefore, that the evidence indicates a widespread unconformity of pre-Cambrian age between the Catoctin series and the Fauquier formation and that the Catoctin flows were poured out on the much folded and eroded surface of the Fauquier formation; that the greenstone and amphibolite dikes cogenetic with the Catoctin series intruded the Fauquier formation; that these old sediments now crop out at the crest of an extensive anticline; that, before the deposition of the Loudoun, the Catoctin series was removed by erosion, leaving to the west the underlying Fauquier formation; and that, at the time of Loudoun deposition, both the Catoctin series and the Fauquier formation had nearly equal topographic expression. Since fragments of the latter are found in the arkosic sediments of the Loudoun whereas the occurrence of greenstone fragments is very rare, it is supposed that the Fauquier formation originally outcropped more boldly than did the greenstone. The arkose of the Loudoun is composed almost entirely of granitic waste.

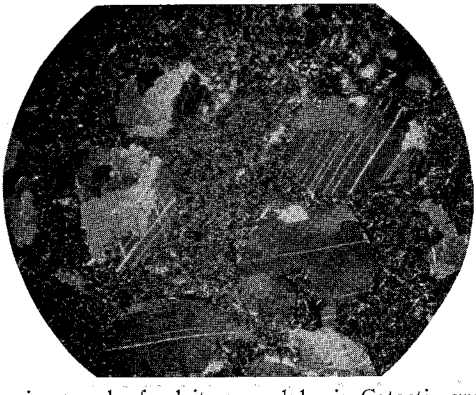
The relation of the Fauquier formation to the granite and granodiorite is not known. Inclusions of biotite gneiss and schist in the granites may belong to this formation. So far no granitic intrusions have been found in the Fauquier formation, but they may be expected for it



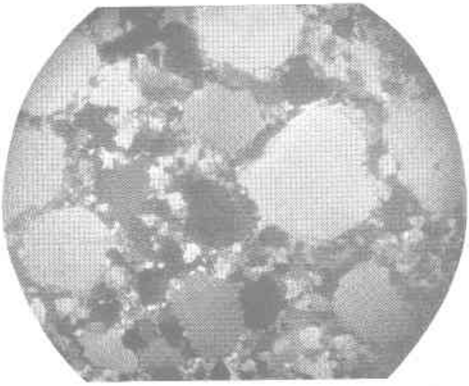
A. Photomicrograph showing granulated quartz and feldspar grains in arkosic beds that are interbedded with greenstone agglomerate near Bethel, Fauquier County, Virginia. Crossed nicols. X 12.



B. Photomicrograph of Warrenton agglomerate about three-fourths of a mile east of Shiloh School, Fauquier County, showing feldspar grains (light) filling interstices in fragments of greenstone. Crossed nicols. X 12.



C. Photomicrograph of calcite amygdules in Catoctin greenstone flow, 1 mile west of Turnbull, Fauquier County. Crossed nicols. X 12.



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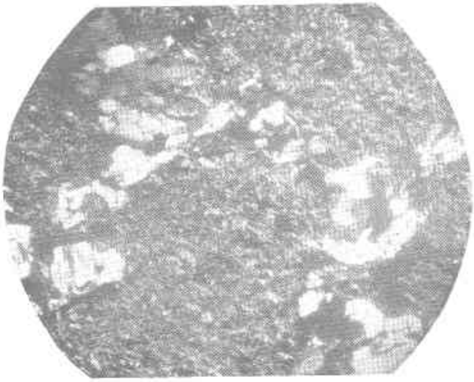
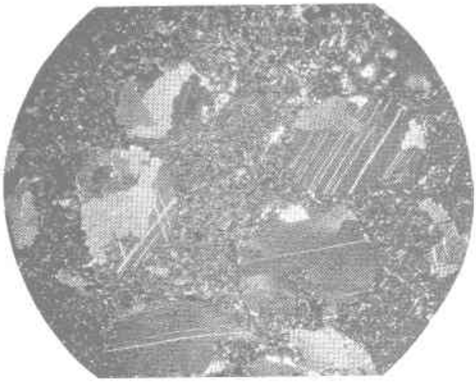


B. Photomicrograph of Warrenton agglomerate about three-fourths of a mile east of Shiloh School, Fauquier County, showing feldspar grains (light) filling interstices in fragments of greenstone. Crossed nicols. X 12.



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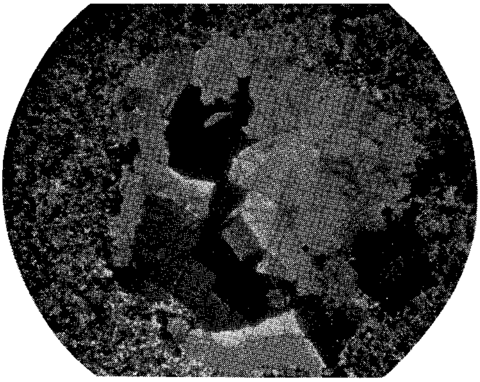
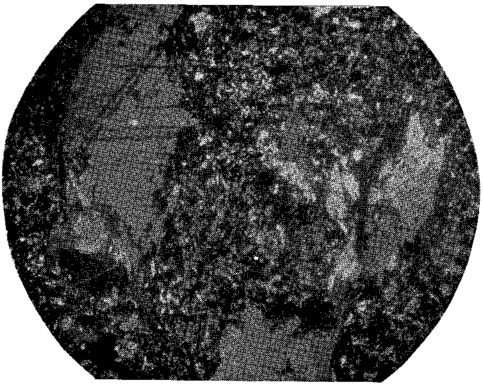
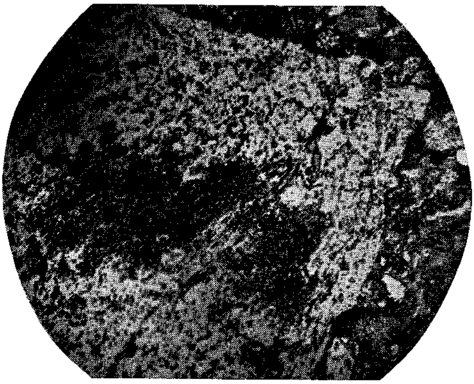


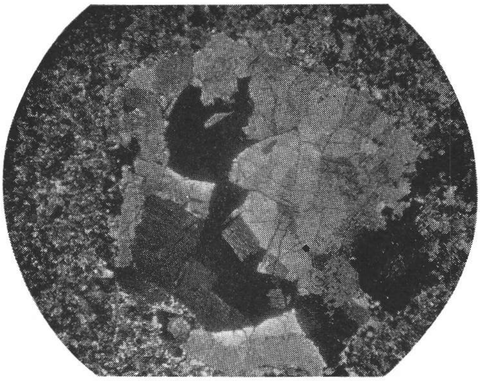
A. Photomicrograph of epidote amygdule in Catoctin greenstone flow 1 mile west of Turnbull, Fauquier County. The cavity filling has replaced the greenstone. Cross nicols. X 12.



B. Photomicrograph of sheared Catoctin greenstone. The large areas are calcite; the groundmass is plagioclase, quartz, chlorite, and some epidote. Crossed nicols. X 12.



C. Photomicrograph of part of a devitrified glass shard in tuff on Barrs Run west of Turnbull, Fauquier County. Plane polarized light. X 12.



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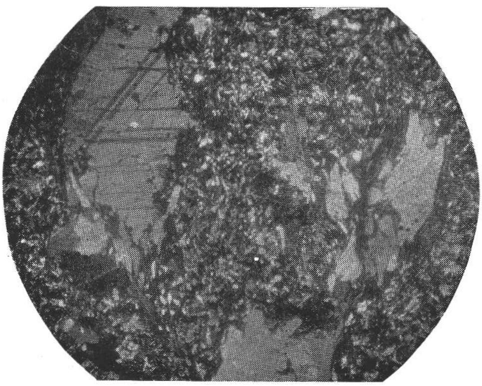

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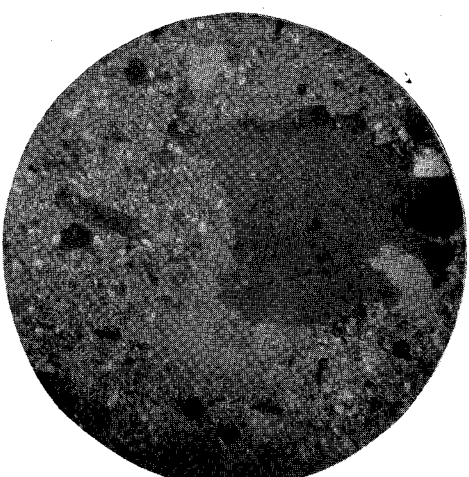
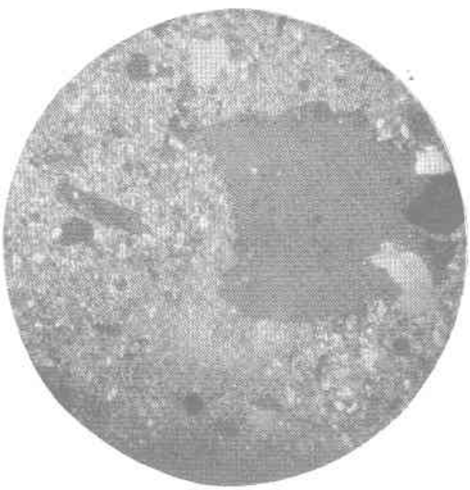
C. Photomicrograph of part of a devitrified glass shard in tuff on Barrs Run west of Turnbull, Fauquier County. Plane polarized light. X 12.

A. Photomicrograph of Triassic diabase sill in the southeastern corner of the Warrenton quadrangle, showing augite and labradorite. Crossed nicols. X 13.

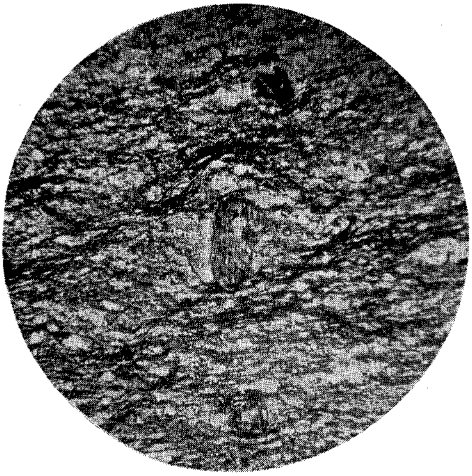


B. Photomicrograph of biotite-epidote gneiss of the Fauquier formation at Cliff Mills, Fauquier County. The groundmass is quartz, plagioclase, and epidote. The prismatic crystal in the lower center is epidote and the large porphyroblast is biotite. Crossed nicols. X 36.

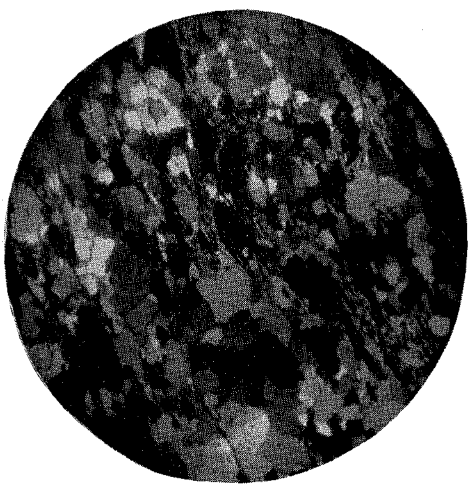
A. Photomicrograph of Triassic diabase sill in the southeastern corner of the Warrenton quadrangle, showing augite and labradorite. Crossed nicols. X 13.



B. Photomicrograph of biotite-epidote gneiss of the Fauquier formation at Cliff Mills, Fauquier County. The groundmass is quartz, plagioclase, and epidote. The prismatic crystal in the lower center is epidote and the large porphyroblast is biotite. Crossed nicols. X 36.

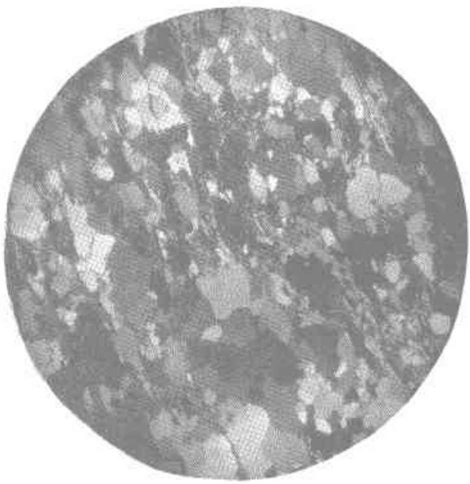


A. Photomicrograph of black slate of the Fauquier formation, about half a mile east of the bridge on the Lee Highway over Rappahannock River. The dark material is mostly graphite; the light material, quartz and feldspar. Plane polarized light. X 13.



B. Photomicrograph of granulated quartz-mica schist of the Fauquier formation associated with slate, about three-fourths of a mile south of Fauquier White Sulphur Springs. Shreds of muscovite and fragments of granulated quartz are shown. Crossed nicols. X 12.

A. Photomicrograph of black slate of the Fauquier formation, about half a mile east of the bridge on the Lee Highway over Rappahannock River. The dark material is mostly graphite; the light material, quartz and feldspar. Plane polarized light. X 13.



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is believed by the author that the granite intrudes the Catoctin volcanics. The writer has not traced these rocks beyond the limits of this quadrangle; further geologic work should be done southwest of the Warrenton quadrangle in order to separate this belt of rocks from the Loudoun formation. The graphitic schists and associated amphibolite rocks of the University quadrangle are probably a southwestward continuation of this belt of pre-Cambrian rocks.

When the Fauquier formation is traced southward it may be possible to establish its relationship with the Lynchburg gneiss and the Wissahickon schist. The Lynchburg gneiss is lithologically unlike the rocks of the Fauquier formation. The Cockeysville marble of the James River belt[46] in central Virginia also shows a sequence which differs from that of the Fauquier formation. In the James River belt the marble is overlain by Wissahickon schist, and underlain by the Mount Athos quartzite, beneath which is a thick series of greenstone flows.[47]

In the case of the Fauquier formation slates underlie the marble, and the Catoctin series overlies it. Present knowledge seems insufficient to justify a correlation of the rocks of the Fauquier formation with those of the James River belt.

In conclusion it should be said that the marble of the Fauquier formation, where it crops out on the Horner and Vickers properties, appears to be less metamorphosed than other pre-Cambrian rocks of the area. Unless Paleozoic fossils are found in this marble, the evidence given above indicates a pre-Cambrian age for these rocks of the Fauquier formation.

LOWER CAMBRIAN

LOUDOUN FORMATION

OCCURRENCE

The name Loudoun formation was given by Keith[48] to arkosic sandstones, slates, and marbles in Loudoun County, Virginia. The term is here applied only to coarse arkose and conglomerate which lie at the base of the Cambrian system. On the west side of the Blue Ridge and in the Great Valley region these rocks grade upward into beds which contain Lower Cambrian fossils. On the crest and western flank of the Blue Ridge, and for about 20 miles east of the mountain in this section of the State, arkose occurs locally. These arkosic rocks, although unfossiliferous, are generally considered to be Lower Cambrian

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[46] Furcron, A. S., James River iron and marble belt, Virginia: Virginia Geol. Survey Bull. 39, pp. 27-31, 1935.
[47] Furcron, A. S., op. cit., pp. 47, 48-49, 1935.
[48] Keith, Arthur, Geology of the Catoctin belt: U. S. Geol. Survey 14th Ann. Rept., pt. 2, pp. 293-294, 1894; Description of the Harpers Ferry sheet: U. S. Geol. Survey Geol. Atlas, Harpers Ferry folio (no. 10), p. 2, 1894.

sediments. They are unconformable upon the crystalline rocks, and are referred to as the Loudoun formation.

Rogers[49] first described these rocks in Virginia and called them Pseudo Gneiss or Gneissoid Sandstone. He says of their occurrence in the Warrenton region:

> "At the western base of Watery mountain, four miles west of *Warrenton*, a range of these rocks, consisting of a grey sandstone occurs adjacent to Chloritic slate. The bed has the usual northeastern direction and steep dip towards the southeast, and furnishes an excellent stone which is quarried for building purposes and for flagging."

He also called attention to an occurrence of similar rocks along the western flank of Rappahannock Mountain on Carter Run which is described as "grey, hard, and very siliceous, in strata several feet thick and associated with Chloritic slate."[50] The sediments in Bull Run Mountains he describes as "Quartz Slate or Quartzite."[51]

In the Warrenton quadrangle the Loudoun formation consists mainly of arkosic sandstones deposited over a much eroded surface of crystalline rocks at the beginning of Paleozoic time. The sediments were derived locally from the weathering of pre-Cambrian granite. The formation is variable in composition, texture, and thickness from place to place. In the northeast part of the quadrangle the rocks of the Loudoun formation are in places schistose.

ARKOSIC SEDIMENTS

Occurrence.—The arkosic rocks are generally fine to coarse-grained quartzites composed of feldspar and quartz. The coarser beds are massive and resistant to erosion. They form low monadnocks such as Sheads Mountain and its unnamed northeastward extension to the vicinity of Blue Hill School.

The arkosic beds in this area overlie greenstone, the Fauquier formation, and granite, but are derived from granite. Fragments do not show chemical weathering. Disintegration, transportation, and deposition must have taken place rapidly, therefore the deposits, although thick, probably represent but a short period of time. On the western side of the quadrangle they lie directly upon granite, whereas to the east they occur above other pre-Cambrian rocks. Even where the underlying rock is greenstone, the sediments are of granite waste and bear practically no resemblance to any other type of rock.

49 Rogers, W. B., op. cit., p. 465.
50 Rogers, W. B., op. cit., p. 466.
51 Rogers, W. B., op. cit., p. 464.

The coarser layers form the best, less weathered exposures, thus one is inclined to overemphasize the relative abundance of coarse material. The quartzite weathers readily by mechanical weathering to sand which is composed almost entirely of quartz and fresh feldspar. Freezing and thawing of water in the pores of the rock lead to its rapid disruption. Small boulders of this rock are in places completely reduced to piles of sand within the course of a single winter. After hard rains black streaks of magnetite are common along dirt roads; garnet and zircon are also present in small quantities.

The line of contact between the granite and the arkose of the Loudoun formation is difficult to draw because the Loudoun is rarely a conglomerate in this area and exposures of it are so fresh and composed of particles so angular that it closely resembles the granite rock from which it was derived. A short distance above the granite on which it lies the clastic character of the arkose, especially if weathered, is apparent.

Lithologic character.—Typical arkose of the Loudoun is blue-gray in color when fresh because of the high content of blue quartz and blue-gray feldspar. It weathers to a chalky gray color. Massive, coarse layers occur with thinner slaty or schistose beds. (See Pl. 12A.) Pink feldspar occurs locally and milky quartz is quite common. The minerals are subangular to angular but occasional rounded pebbles occur. Both rock cleavage and original bedding may be found in the same outcrop depending upon the resistance of the rock. Northeast of Warrenton the rock locally shows the effects of mashing and shearing.

Sand grains in the coarser facies of the arkose are about the average size of the same minerals in the granite. No true conglomerate is found in the Warrenton quadrangle, although occasional small pebbles occur among the sand grains. They are locally of milky or blue quartz as may be seen in the arkose on the south bank of Hazel River about 1½ miles southeast of Little Fork Church. Just west of the highway bridge over Carter Run at Dudie, are good fresh exposures of medium-coarse gray arkose containing occasional round flat pieces of slate about one-half an inch by three-fourths an inch. These slate fragments resemble rocks in the Fauquier formation. Such examples are common throughout the region, but rarely is the basal Loudoun really conglomeratic. However, conglomerate occurs near the headwaters of Little River in the old Thorofare Gap quadrangle, between The Plains and Rectortown, on the farm known as "Texas," about 2 miles northwest of The Plains.

West of the Catoctin Mountain Border fault, numerous detached areas of arkose occur upon Catoctin "greenstone" or agglomerate. They are fine grained and of even texture. East and south of Warrenton these sediments are mashed. The effects of mashing are discussed under "Structure and Metamorphism."

Microscopic character.—The Loudoun arkose is composed of rounded or angular grains of quartz, orthoclase, microcline, perthite, and some plagioclase. Fine grains of quartz and muscovite fill interstices between the larger grains. The minerals are fresh and unchanged except where affected seriously by dynamic forces. In some thin sections quartz, potash feldspars, and plagioclase are practically the only minerals present. Near the granite the arkose has essentially the same composition as that of the granite except that the Loudoun may contain more muscovite. Feldspars were derived from the Old Rag granite and granodiorite. The clastic character of the arkose is evident in plane polarized light where the outlines of subrounded grains may be seen. Thin sections of some of the arkosic lenses, which occur above Catoctin volcanic rocks, contain mostly rounded quartz grains with some plagioclase and in places calcite grains.

SCHISTOSE ROCKS

In the northeast and east-central portions of the quadrangle and in Baldwin Ridge in the vicinity of Warrenton, occur muscovite and biotite schists containing quartzite beds. It is difficult to separate the Loudoun from the Fauquier formation in this part of the quadrangle since the rocks of both formations are much sheared and deeply weathered. Many of the quartzite layers, which are very fine grained, white, and mashed, do not closely resemble Cambrian quartzite found in other parts of the quadrangle. About three-fourths of a mile north of Cedar Run at the north edge of the quadrangle, the schist is arkosic and graphitic. These schistose beds lie above the Catoctin series, but they are more metamorphosed than typical Loudoun sediments. However, as they seem to be related in stratigraphic position and strike with the Lower Cambrian quartzites in Bull Run Mountain, they are here tentatively classified as being of Loudoun age.

A ridge of quartzite, that to the northeast is continuous into Bull Run Mountain, trends northeast and southwest through Meetze. It may be traced for a mile southeast of Meetze where it is cut out by the Border fault. Where it is crossed at Meetze by the Meetze-Calverton road, is exposed about 40 feet of fine white quartzite enclosed by chlorite schist or phyllite. Although petrologically this rock is unlike the Loudoun in the Warrenton quadrangle, it is mapped as Loudoun on the basis of present structural interpretation.

One mile north of Meetze along a road at the top of a hill are good exposures of a phyllite which strikes about N. 15° E., with a nearly vertical dip of the schistosity. The rock weathers to a white sericitic schist. Another exposure about three-fourths of a mile east of the forks in the road at Alwington may be a sheared volcanic rock. It contains about 60 per cent chlorite in large shreds and considerable muscovite, magnetite, and quartz. This rock has been extensively sheared during thrusting.

TRIASSIC ROCKS

GENERAL STATEMENT

The Triassic in Virginia is part of the Newark group. It is represented by conglomerates, sandstones, and shales of nonmarine origin which were deposited in long troughlike basins in the central and eastern portions of the Piedmont region. These disconnected areas of Triassic rocks extend from Nova Scotia to South Carolina. Red or brown colors predominate in these rocks; brown conglomerate, brown sandstones or brownstones, and red shales being the predominating rocks. The brownstones have been used for building purposes. Locally coal beds occur, as in the Richmond basin, where coal was first discovered by a French Huguenot settler, and where it was mined as early as 1750.

The eastern part of the Warrenton quadrangle lies in the southwestern part of the Potomac basin area of Triassic rocks, which is the largest and longest continuous area of the series. It extends from the vicinity of Orange, Virginia, through Maryland, southeastern Pennsylvania, northern New Jersey, into the southeastern corner of New York. In northern Virginia thick beds of brownstone, known as the Manassas sandstone, occur at the base and above the red Bull Run shale with the Border conglomerate on the western side. In this quadrangle the Bull Run shale occupies most of the area for the sandstone is unimportant. Near the Catoctin Mountain Border fault occur fans of conglomerate which were deposited locally and, for the most part, are composed of fragments of Catoctin metabasalt.

Triassic rocks are well exposed along the roads, for although cuts are shallow due to the flat character of the region, bedrock lies within a foot or so of the surface. There are good exposures along U. S. Highway 15-29 north of Remington, around Liberty Church, and between Liberty Church and Bealeton. (See Pl. 12B.)

The most prominent sandstone horizon in the shale, and the only one worthy of mention, occurs along the eastern outcropping edge of the diabase sill between Liberty Church and Rappahannock River. At

Liberty Church a gray micaceous sandstone lies just beneath the sill. It is about 30 feet thick, is underlain by red shale, and dips about 15° NW. The color of the sandstone is darker within a few feet of the sill, but otherwise it does not appear to have been affected by the intrusive body. This sandstone is exposed again near Tinpot Run, where it appears to lie just above the diabase. A short distance east of Rappahannock River it occurs at the base of the sill.

A few nonmarine fossils—generally fragmentary plant remains—have been reported from the Triassic rocks of this part of the Potomac area. Dinosaur tracks have been found in sandstone and shale beds near Aldie in Loudoun County, Virginia.[52]

BULL RUN SHALE

OCCURRENCE

As is shown on the geologic map accompanying this report (Pl. 1), the Bull Run shale covers about a third of the Warrenton quadrangle; or that part east of the Catoctin Mountain Border fault. The formation was named from exposures along Bull Run between Prince William and Fairfax counties, Virginia.[53]

Outcrops are not continuous; they are broken by normal faults, and are intruded by a thick diabase sill. The shale occurs on the downthrown side of faults and in shallow synclinal basins. Dips are normally less than 20 degrees, and generally to the northwest. Southwest of Elkwood the shale dips nearly west; in other parts of the quadrangle dips are often nearly north of northwest. The variations in strike are due to faulting. South of Brandy the rocks are nearly horizontal. Although shales cover considerable territory, the total thickness of the exposed beds in this quadrangle is probably less than 1,000 feet.

COMPOSITION AND FACIES

In this quadrangle the Bull Run shale is nearly all shale with unimportant sandstone beds occurring at several horizons. Most of the shale is bright or dull red in color due to the presence of ferric oxide. Some beds are blue green, olive, or greenish-gray.

All variations in composition occur, from typical soft clay shales to shaly sandstones and hard sandstones.[54] Red clay shale is the most characteristic rock type. In addition to kaolin and iron oxides, con-

[52] Roberts, J. K., The geology of the Virginia Triassic: Virginia Geol. Survey Bull. 29, p. 147, Pl. 31A, 1928.

[53] Roberts, J. K., Triassic basins of northern Virginia: Pan-Am. Geologist, vol. 39, no. 3, pp. 185-200, 1923; The geology of the Virginia Triassic: Virginia Geol. Survey Bull. 29, pp. 38-43, 1928.

[54] Roberts, J. K., The geology of the Virginia Triassic: Virginia Geol. Survey Bull. 29, p. 40, 1928.

siderable quartz and feldspar are present in the shales. The sandstones are arkosic and micaceous; feldspar, quartz, and sedimentary mica (mostly muscovite) are the important minerals.

IGNEOUS METAMORPHISM

The shale is baked or otherwise changed in the vicinity of the sill. The baked zones are shown on the geologic map (Pl. 1), although it is difficult to be certain of their width and importance. In general, where the diabase is in contact with shale, metamorphic effects may be expected. Where sandy beds rest against the sill the baked zone may be only a few inches or a few feet wide. Evidently the kaolin and ferruginous constituents of the shale were more easily affected than the quartz and feldspar of the sandstone. Near the intrusive body, the shales are altered to a black or dark brown, dense and compact rock which might easily be mistaken for a border facies of the diabase. Farther away the rock grades through various shades of gray or purple shale to the normal red shale. The shales are affected on both the top and bottom sides of the sill. The width of the metamorphosed belts depends upon the dip of the beds and the amount of metamorphism at the particular locality. As most of the shales have not been greatly changed, the sill probably was not intruded at a very high temperature.

Three zones of metamorphosed shale are crossed by U. S. Highway 15-29 south of Remington. Good exposures occur around Stony Ford, where a belt of black, tough metamorphosed rock crops out along the north side of Marsh Run; at Kellys Ford where similar rock forms rapids in Rappahannock River; and along the road just south of Brandy where this rock has been quarried. Where exposed on State Highway 17 just southeast of Bealeton, the rock dips northwest 10°, and is dark purple or chocolate in color. The shale of the small area about a mile north of Liberty Church is very thoroughly altered to a dense, black rock.

PETROLOGY

The shale is baked, fused, or recrystallized. In the outer edges of the metamorphosed belts there has been but little noticeable change except in color. Near the intrusive body a pseudo-igneous rock has been produced which rather closely resembles a chilled border phase of the diabase sill. The darkest and densest varieties are the most altered, but they are all so fine grained that very little change can be observed with a hand lens. Magnetite grains occur and in places irregular shaped patches of pyrrhotite possessing polarity may be observed. The rock is locally cellular and often sprinkled with small dark and white spots.

The former are sometimes composed largely of chlorite which may have been produced by the alteration of cordierite.

The constituents are so fine grained that they are difficult to recognize in thin sections. Dense, brownish varieties, consisting mainly of small laths of plagioclase in a groundmass of opaque material which locally is glassy, are recrystallized. In some thin sections secondary plagioclase crystals comprise the largest portion of the rock. Many thin sections show small angular quartz grains from the original rock and epidote grains are not uncommon. Small black specks—probably magnetite—are shown in nearly all thin sections.

FANGLOMERATE

OCCURRENCE

Fanglomerate occurs on the downthrown side of the Catoctin Mountain Border fault north of Brandy between Fleetwood Hill and Culpeper. Cedar Mountain southwest of Culpeper is composed of this rock. The fanglomerate, which overlies the Bull Run shale, is the youngest sedimentary rock of the area. It is composed, for the most part, of greenstone fragments that were washed down the escarpment from the west at the close of the period of Triassic faulting. The strata are inclined in directions that range between southeast and southwest. The thickness of the deposit is unknown. Examinations of samples from the deep well at Culpeper show that it is at least 676 feet thick at that locality.

The origin of this rock and its relation to faulting in Maryland and Pennsylvania have been discussed by Stose.[55]

The absence of this rock along the Border fault elsewhere in the quadrangle may be due to the fact that the escarpment at other places was not very prominently developed at the close of Triassic time. Hazel and Rappahannock rivers, which presumably occupied essentially their present positions in Triassic time, would have rapidly piled up fan deposits northwest of Remington if the displacement along the Border fault had resulted in an escarpment of any considerable height. In the past the deposits probably extended farther to the northeast than at present; they may have covered Fleetwood Hill prior to the faulting which resulted in the uplift of that block of greenstone.

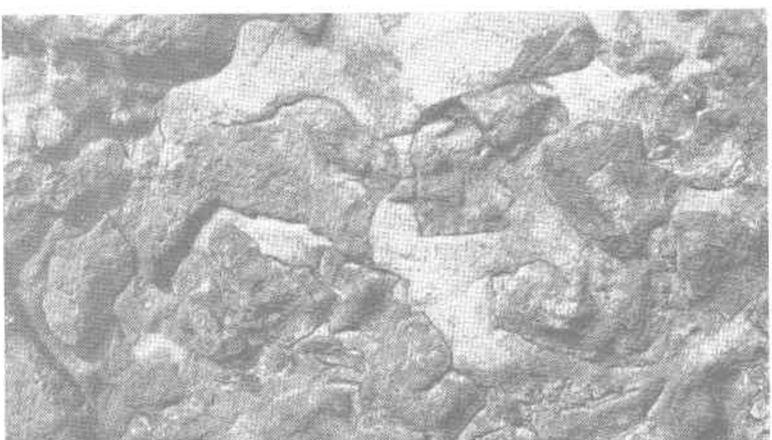
Good exposures of the fanglomerate may be found anywhere within the triangular area that crops out north of a line from Inlet School to Brandy. A good outcrop occurs on the Miller property a short distance northeast of the high school at Brandy. Here the rock shows a tendency to weather into large boulders which stand up in the fields

[55] Stose, G. W., Possible post-Cretaceous faulting in the Appalachians: Geol. Soc. America Bull., vol. 38, no. 3, pp. 493-503, 1927.

A. Unsheared greenstone fragment in schist. On James Madison Highway about 4 miles south of Warrenton.

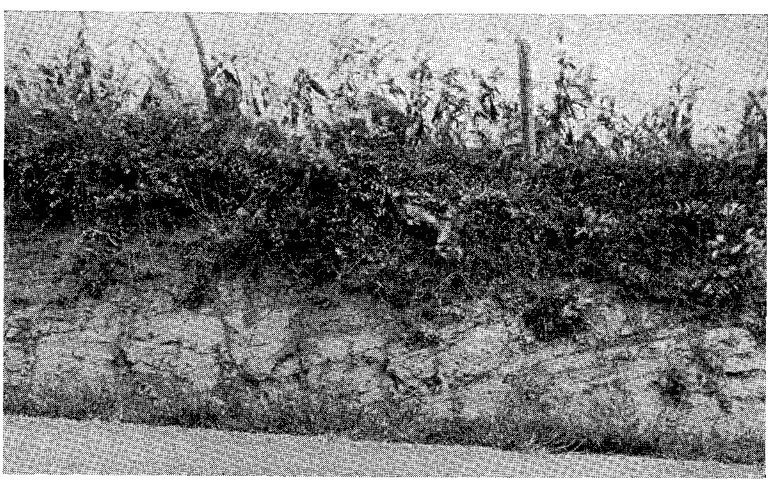
B. Catoctin flow (dark) intruded by biotite granite. In road quarry near Turnbull, Fauquier County.

A. Unsheared greenstone fragment in schist. On James Madison Highway about 4 miles south of Warrenton.

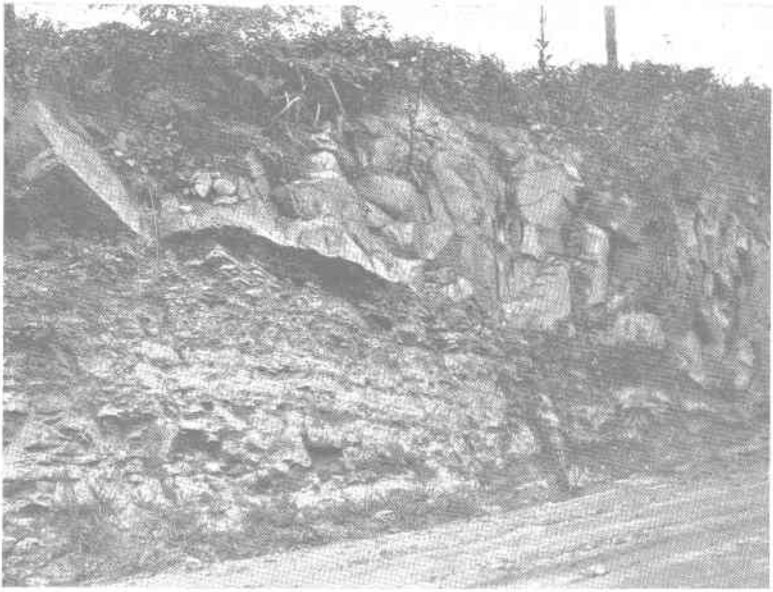


B. Catoctin flow (dark) intruded by biotite granite. In road quarry near Turnbull, Fauquier County.

A. Thick- and thin-bedded Loudoun arkose on State Highway 29, about a mile south of Jeffersonton, Culpeper County.



B. Detail of Triassic shale below Triassic diabase just west of Oak Shade Church, near Bealeton, Fauquier County.



A. Thick- and thin-bedded Loudoun arkose on State Highway 29, about a mile south of Jeffersonton, Culpeper County.

B. Detail of Triassic shale below Triassic diabase just west of Oak Shade Church, near Bealeton, Fauquier County.

(Pl. 13A). Pebbles and cobbles of Catoctin metabasalt or greenstone occur in a red sandy matrix (Pl. 13B). The largest fragments in the boulders here will measure about 8 inches in greatest diameter. One rounded fragment of granite was found and pebbles of white vein quartz are not uncommon. Numerous pebbles of a rather fine-grained Triassic brownstone indicate removal of Triassic sediments during this time, probably from a locality west of the Border fault.

Good exposures may be found around the southern outskirts of Culpeper, especially along State Highway 3 and U. S. Highways 15 and 29 where the rock has weathered into large boulders. Here boulders up to 10 inches in diameter are common and larger blocks up to three feet in diameter occur. In the boulders are found fragments of vesicular, amygdaloidal, Catoctin schist that are angular or somewhat rounded and are bound by a hard matrix of ferric oxide and finer rock particles (Pl. 13B). Locally fragments of Loudoun quartzite ranging in size up to a few feet are found. Some of the fragments contain epidote, and brownstone pebbles occur as they do at Brandy. Fragments of hornblende metagabbro are also found.

TEXTURE AND COMPOSITION

The fanglomerate is composed almost entirely of blocks of Catoctin greenstone that are subrounded or angular with little or no stratification. Definite bedding occurs in the outer edge of the deposit which locally is composed of sand and small rounded fragments from about the size of a pea to that of a walnut. An occurrence of this type may be observed about three quarters of a mile north of Inlet School.

Throughout most of the deposit, pebbles and cobbles about the size of a hen's egg are very common; the matrix consists of smaller fragments cemented by ferric oxide. Larger blocks which tend to be angular may be several feet in dimensions.

The rock derives its color from the red oxide of iron and the greenstone fragments; the latter may show the yellow-green color of epidote or the dark-green of chlorite. The writer has seen examples of this rock at Culpeper near the new town well in which iron oxide appears to be scarce or absent locally. Here the rock closely resembles Catoctin metabasalt or greenstone. Although the greenstone cobbles and pebbles are tough and difficult to break, in fresh specimens of the fanglomerate rock they are so firmly cemented that the rock will fracture across them.

STRUCTURE AND METAMORPHISM

FOLDS

The pre-Cambrian crystalline rocks of this area had been folded, metamorphosed into schists and gneisses, and eroded by late pre-Cambrian time. The amount or degree of metamorphism depended upon the general resistance of the original rocks to stresses and whether the rocks were within a zone where shearing stresses were operative. Schists and gneisses are not common in the Warrenton quadrangle, although Catoctin volcanic rocks and pre-Cambrian granite are distinctly less massive in this area than in the Blue Ridge. Close folding produced some movement and recrystallization of rock materials, realignment of minerals at right angles to pressure, and the crystallization of plastic constituents.

At the close of the Paleozoic era the Loudoun sediments were folded and somewhat metamorphosed. The Paleozoic sediments of the Appalachian Valley province were arched into open folds at this time, whereas, in the older crystalline Appalachians, folds were tightly compressed and overturned to the northwest. The regional strike is northeast and the dip is southeast. During the Permian folding a certain amount of recrystallization took place in the Loudoun formation. The finer, nonresistant sediments were altered to slates and phyllites, but the arkose or massive beds were but little metamorphosed. Kaolin and iron oxide were converted to muscovite and magnetite. Cubes of pyrite are common in the Loudoun formation and also in the Fauquier formation, in places measuring as much as two inches in diameter. When found, they are generally partly or entirely altered to limonite. In places differential stress encouraged further recrystallization and granulation of constituents; everywhere pressure has forced the mineral particles closer together.

During the Permian period of metamorphism and folding, a secondary cleavage was developed in the sedimentary pre-Cambrian and Lower Cambrian rocks. It is perfectly developed in the slates, although poorly shown in the massive arkose. These cleavage planes should be nearly vertical or should dip steeply southeast, yet in places, and especially in the vicinity of the Fauquier slate belts, dips are gentle, nearly horizontal and even northwestward. These anomalous dips may have been produced in part by Triassic faulting, which caused blocks of rock to become more or less rotated against the dip along an axis parallel to the strike. This, however, is regarded as improbable, for, generally, dips in the Fauquier formation are more gentle than in the other sedimentary rocks.

Triassic sediments were not folded but were tilted northwest during the late Triassic movement along the Catoctin Mountain Border fault.

NORMAL FAULTS

Faults of Triassic age are common in this area. They are gravity faults formed after this region was arched upward and, perhaps, after the contraction and settling of underlying intrusions of lava at or near the close of the Newark epoch (Late Triassic). Two sets of faults are recognized.

The Catoctin Mountain Border fault follows the east side of Bull Run Mountain, entering the quadrangle near Meetze. It is frequently broken and offset by later cross faults. It is not possible to determine the throw of this fault, which may have been active throughout the period of Triassic deposition. A Border conglomerate deposited locally, at least, at the close of the Triassic period on the downthrown (east) side of the fault, indicates a renewal of movement along the fault at this time.

Cross faults range in strike from nearly north to southwest. They are later than the Border fault because they offset it. They also offset the intrusive diabase sill as indicated by sudden terminations of its outcropping edges along the line of strike. In the crystalline rocks it is difficult to locate faults which do not happen to offset the Border fault or do not extend into the Triassic basin. The cross faults show a tendency to intersect the Border fault at angles of 30° to 50°, forming a pattern of converging and diverging triangular blocks. Fleetwood Hill is an interesting example, for at that place a triangular slice of Catoctin greenstone has been left standing in the Triassic basin by two cross faults which intersect the Border fault.

An example of fault breccia occurs in the triangular area between Rappahannock and Hazel rivers. Here fine-grained diabase outcrops as brecciated boulders in the fields along the Catoctin Mountain Border fault.

OVERTHRUST FAULTS

No overthrust faults have been recognized in the Warrenton quadrangle. If Paleozoic fossils are later found in the blue marble on the Horner property east of Marshall, the present structural interpretation must be changed. Such a discovery would leave no doubt but that Bull Run and Rappahannock mountains, north of this area, are overthrust westward.

EARTHQUAKES

Several minor earthquakes are recorded every year in the Piedmont and Blue Ridge regions of Virginia. The shocks are light, ranging between I and IV on the Rossi-Forel scale. Movable objects may be disturbed, windows, doors, and dishes may rattle, and plaster may fall from the ceiling.

Most earthquakes are caused by a renewal of movement along an active fault line. Minor adjustments along inactive Triassic faults where the rocks are subjected to unequal stress, due to Tertiary or recent uplift, may account for the earthquakes in this area. However, some of the earthquakes may originate in the region of the continental shelf.

GEOLOGIC HISTORY

GENERAL STATEMENT

The continent of North America consists of a basement foundation of pre-Cambrian crystalline rocks upon which other rocks have been deposited as sediments during the later eras of geologic time. The early Lower Cambrian sediments were derived from those portions of the pre-Cambrian foundation rocks which stood above sea level and which were subjected to erosion. In eastern North America these pre-Cambrian rocks are today generally deeply buried by later sediments, except in the great Canadian Shield and perhaps in the eastern part of the Piedmont region. The present continental surface has been developed through a long series of changes which have involved widespread deposition of sediments as well as by many periods of folding, metamorphism, uplift, and erosion. The outline of the continent as we recognize it today is of modern origin.

Historical geology is the history of the development of the earth and of the evolution of life. It is pieced together in an orderly sequence from the fossil records of life and from physical evidences such as ripple marks, mud cracks, rain prints, cross-bedding, and other features that are found in the rocks. This record is best preserved from Cambrian time to the present. In many places the rocks have been folded, faulted, and disturbed, but, unless considerably metamorphosed, they may be recognized as belonging to a definite geologic period or age by their fossil content or, when unfossiliferous, by their lithology and by tracing them into rocks of known age. In any locality there may be gaps in the record where erosion has removed great thicknesses of rocks. Such gaps are called "unconformities" and the rock layers may be likened to the chapters of a history book from which here and there the pages have been removed. Erosion in one locality implies deposition in another, thus over large regions the geologic record is normally pretty complete.

Pre-Cambrian rocks contain few or no fossils because the rocks are very old, and few living forms existed at the time these rocks were formed. Such forms as existed may have been too simple or did not have a hard skeleton and hence were unable to withstand the alteration or metamorphism the rocks have undergone since they were formed. The original minerals in these rocks have been folded, recrystallized, and converted into graphite, calcite, or lime-silicate minerals and any fossils they may have contained have been destroyed. Since many of the original rocks have been changed into schists and gneisses, it is in places difficult to determine whether they were originally of sedimentary or igneous origin. They have been folded, faulted, and overthrust, and because of the absence of fossils, it may be difficult to determine always their proper order or sequence. Where certain minerals are present, it is possible to determine the age of the rocks by the rate of atomic disintegration of the original mineral matter which the rocks contained. By such methods it has been determined that the oldest of the pre-Cambrian rocks of the Canadian Shield are nearly two billion years old.

PRE-CAMBRIAN ERAS

The oldest rocks of the Warrenton quadrangle are thought by the writer to be the marbles, slates, schists and gneisses which compose the Fauquier formation. These rocks are of sedimentary origin. No fossils have been found in them, and they are here classified as pre-Cambrian because of their relations to the other rocks of the area. The limestones and black slates indicate the presence of life at the time the rocks were deposited. The limestones have the appearance of marine deposits, whereas the older black slates and laminated metasilts suggest that they were deposited in a land-locked sea or lake. These rocks still show thin laminations and minor cross-bedding characteristic of lake silts. The limestone may not represent the top of the formation for the rocks of the Fauquier formation were eroded before the outpouring of the Catoctin volcanic series.

After erosion and folding of the Fauquier formation, the Catoctin lavas were poured out. The first event in this epoch of igneous activity was the extrusion of the Warrenton agglomerate member. This was followed by widespread outpouring of basaltic lavas accompanied by some pyroclastic materials. During this epoch dikes of basaltic material and gabbro were intruded into the Fauquier formation. The extrusive rocks were later altered to metabasalt and greenstone schist.

Little is known of the later pre-Cambrian history of this area except that at least the younger facies of the granite complex[56] was forced upward beneath the volcanic rocks. This took place at great depth since the granite mass under the Catoctin flows is coarse grained. Long erosion in late pre-Cambrian time removed much of the flows and granite. By the close of pre-Cambrian time the area was worn down to a common level, and all the rocks, including the coarse-grained intrusive bodies, were exposed at the surface.

PALEOZOIC ERA

At the close of the pre-Cambrian or early in the Paleozoic era, a great trough or geosyncline was formed in eastern North America, extending from Nova Scotia to Alabama. It was a wide, downwarped

[56] Furcron, A. S., Igneous rocks of the Shenandoah National Park area, Virginia: Jour. Geology, vol. 42, pp. 408-410, 1934.

trough extending along the western side of a great land mass known as Appalachia which then extended far to the east of the present eastern border of the continent. Sea water entered this shallow trough from the northeast and southwest; streams from land areas brought in sediments which formed the first Paleozoic rocks. The width of this geosyncline cannot now be definitely determined since in later geologic times during uplift and folding of the rocks of the area, the Blue Ridge and Piedmont regions were so uplifted to the west that much of the Paleozoic sediments which covered these regions was later removed by erosion.

The earliest period of the Paleozoic era is the Cambrian period. The Lower Cambrian sediments, Loudoun formation, of the Warrenton area are of local origin and generally rest upon the rocks from which they were derived. They are coarse, clastic sediments representing rapid mechanical weathering and transportation and their deposition probably took place within a short period of time. They contain no fossils; thus may be nonmarine. They are so irregular in thickness and variable in physical character in this area that no regular sequence of events has been recognized.

Thick deposits of arkose and finer sediments overlie granite and granodiorite, mostly west of the area of Catoctin volcanic series. They were derived in large part from the pre-Cambrian intrusive rocks of the Blue Ridge province.

A striking feature of the Lower Cambrian sediments is the preservation of their constituent material in fresh, unweathered condition. The absence of oxidation indicates rapid mechanical weathering immediately followed by transportation and deposition. In spite of this explanation, oxidizing conditions must have been largely absent and it seems necessary to assume that these deposits accumulated in an arid climate where very little chemical decomposition took place.

Little is known of the later Paleozoic history of this area. Later Paleozoic sediments may have been deposited and removed by erosion during the course of that era.

The Paleozoic era came to a close with the folding and uplift of the sediments of the geosyncline at the close of the Permian period. The old crystalline rocks of the Piedmont and Blue Ridge provinces were again metamorphosed and were overthrust westward over the folded sediments. Rapid and widespread erosion accompanied and followed this period of diastrophism. The old eroded land mass of Appalachia to the east became depressed and sediments from the mountains which have occupied, since Permian time, the position of the Appalachian geosyncline, were carried eastward by rivers and spread out over the submerged continental platform to assist in the upbuilding of our present Coastal Plain deposits.

MESOZOIC ERA

In the Triassic period, or early part of the Mesozoic era, areas in the Appalachian region were down-dropped by long northeast-southwest normal faults, forming long troughlike basins in the middle and eastern portions of the Piedmont region of Virginia. They quickly became filled with marshes and formed long, land-locked lakes into which streams brought sediments from the surrounding highlands. In some basins plants grew in profusion. They were later buried by a new influx of sediments and certain of them were converted into beds of coal.

The large Triassic basin of the Potomac area extends into the Warrenton area east of the Catoctin Mountain Border fault, where shales and sandstones accumulated during the Triassic period. During the deposition of these sediments a thick diabase sill and small dikes were intruded. Movement along the Border fault at the close of the period of sedimentation produced an escarpment down which in many places large pebbles and cobbles were carried by streams from the west to build up on the eastern side thick deposits of fanglomerate on top of the shales. This movement along the border of the Triassic basin produced a westward dip in the shales and diabase sill. Later cross faults offset the Border fault and the rocks of the basin.

The thickness of the fanglomerate is not known. At Culpeper it is at least 676 feet thick. It is composed mostly of fragments of Catoctin schist. The streams that entered the basin were mainly short, rapid torrents although some were at least 10 miles long, since fragments of granite, which were transported this distance and farther by the streams, occur in the deposits at Brandy.

Some geologists assume that the climate of the Triassic period in the eastern part of the United States was arid since the beds are red colored and contain much iron oxide. Roberts[57] from his study of the Triassic sediments of Virginia has come to the conclusion that the climate was moist and not unlike the climate of the Appalachian region today.

Throughout the remainder of the Mesozoic era the entire Piedmont region was eroded and by the close of Cretaceous time it may have been worn down to a low rolling plain—a peneplain—which sloped gradually eastward to the Atlantic Ocean. This is inferred because Cretaceous sediments cover the old erosion surface along the Fall Zone.

[57] Roberts, J. K., The geology of the Virginia Triassic: Virginia Geol. Survey Bull. 29, pp. 164-167, 1928.

CENOZOIC ERA

The present topography of the Warrenton quadrangle was developed mainly during the Tertiary and Pleistocene epochs.

During early Tertiary time, the first period of the Cenozoic era, the peneplain formed during Cretaceous time was uplifted and eroded. By late Tertiary time a second widespread peneplain had been formed in this area. Remnants of the peneplain of supposed Cretaceous age still remain locally along the top of the Blue Ridge, but not in this area. The late Tertiary peneplain—sometimes called the Piedmont peneplain—has been uplifted and dissected since its formation. This surface now stands around 300 feet above sea level in the Triassic lowlands of the Piedmont region and at altitudes of 500 to 550 feet along the eastern portion of the Blue Ridge province. Stose[58] has suggested that the difference in level between the two surfaces is due to a renewal of movement along the Catoctin Mountain Border fault since the formation of the peneplain.

Monadnocks rise above the surface of the peneplain in the Blue Ridge province where the rocks are hard and of unequal resistance, but in general the Triassic area was almost completely reduced to grade. The summits of monadnocks such as Bull Run Mountain, Rappahannock Mountain and others, do not attain a common level. They should be below the level of the supposed Cretaceous peneplain.

The courses of the present streams were established during the formation of the Tertiary peneplain. At present the streams are very nearly at grade, but in the Blue Ridge province they appear to be slightly intrenched in broad meanders.

PLEISTOCENE MAMMALS

During Pleistocene time marshes were formed along some of the streams in the Piedmont and Blue Ridge regions. Bones of mammals that lived in those areas are occasionally found. As remains of land animals are best preserved in caves and as caves are lacking in this part of the State, remains of mammals that lived at that time have seldom been preserved. Such forms as Megalonyx, horses, mastodons, tapirs, peccaries, deer, bison, and others were probably present in this area since they are found in other parts of the State.[59]

[58] Stose, G. W., Possible post-Cretaceous faulting in the Appalachians: Geol. Soc. America Bull., vol. 38, no. 3, pp. 493-503, 1927.

[59] Hay, Oliver P., The Pleistocene of North America and its vertebrated animals from the states east of the Mississippi River and from the Canadian provinces east of longitude 95°: Carnegie Inst. Washington, Pub. no. 322, p. 178, Feb., 1923.

In 1831, Richard Harlan[60] stated that a "Dr. 'W.' " of Warrenton had presented him with a fossil molar tooth of an elephant found in that vicinity. Part of a tusk of a mastodon was reported about 1910 from the Greendale farm near Rectortown in Fauquier County by R. W. P. Kincheloe.

[60] Harlan, Richard, Tour to the caves in Virginia: Monthly Am. Jour. Geol., vol. 1, pp. 58-67, 1831.

MINERAL RESOURCES

GENERAL STATEMENT

Although there are no mining activities in the Warrenton quadrangle, this area contains a variety of nonmetallic mineral resources of economic value, especially building stones, road materials, and brick clays. Building stones and road materials were not extensively utilized in the past but have become important resources in the present development of this area.

Due partly to the drought of 1930-1932 and partly to the need for additional supplies of water for new residences and stables, increased interest has been evidenced during the past several years in ground-water conditions and supplies throughout the area. Ground-water conditions are discussed in the last part of this section.

BUILDING STONE

GENERAL STATEMENT

The Warrenton quadrangle contains a large variety of stone adapted to building purposes. There is a wide range in colors, textures, and physical properties among the different types, and stone suited to almost any kind of construction may be obtained. The types include granite, greenstone, diabase, slate, gneiss, and schist.

GRANITE

Local occurrences of granite of a pleasing gray color offer supplies of a satisfactory and durable stone for building purposes Granite has not been extensively used in the Warrenton area, although it has been used for houses and foundations at Marshall, Upperville, Middleburg, and other places Granite has been quarried west of Warrenton for use in road building. Good building stone may be obtained near the surface along the Lee Highway (U. S. 211), at Amissville and elsewhere in the quadrangle.

GREENSTONE

Massive Catoctin greenstone is a beautiful building stone. It may be quarried in many places west of Warrenton and in other localities (Pl. 14A). Grace Episcopal Church (Pl. 14B) at The Plains is constructed of it. The surface of the stone becomes greener with age. The rock is adapted to many kinds of construction and has been used also for decorative stone fences. South and north of Warrenton sheared, slaty varieties have been successfully used for fences. Greenstone and granite make attractive service stations or stables and coach houses (Pl. 15A).

DIABASE

Diabase has been quarried in many places east of the Catoctin Mountain Border fault mainly for local highway construction. It has been used in foundations and bridge abutments, and should be an excellent stone for large buildings. Coarser varieties are dark gray and retain their color and fresh appearance for a long time. The stone is very durable, having a crushing strength of more than 23,000 pounds per square inch.[61]

SANDSTONE

The sandstones of this area make good building stone. Thick sandstone beds are rare in the Triassic rocks, but Lower Cambrian sandstone (quartzite) is widespread and has been quarried for local use since early times. These rocks are coarse grained with a pleasing gray color. They absorb considerable water which renders them easy to dress when quarried. After drying out they become much harder and are very durable.

Small bodies of sandstone are folded into the Catoctin volcanic series. Much of this rock is usually a medium-fine, even-grained grit which has been quarried for building stone in many places west of Warrenton and Turnbull. Ledges of this rock form slight ridges with steep southeast dips which facilitate quarrying operations. The stone cleaves into massive blocks of excellent light gray building stone.

Beds of gray Triassic sandstone occur between Rappahannock River and James Madison Highway (U. S. 15). The best outcrops are found near Tinpot Run, where the beds are thick enough to be quarried.

FLAGSTONE

Thin, flat slabs of rock suitable for flagging may be obtained in many different places and from several sources in the Warrenton quadrangle. South of Warrenton certain types of the greenstone are quite serviceable for this purpose. The tendency of sheared greenstone to break into regular slabs may be observed along the road between Warrenton and Fauquier White Sulphur Springs, where greenstone slabs are used as cap rocks on stone fences. Rocks of this type are adapted to stone veneering. Fine silty beds of the Fauquier formation are suitable for flagging and curbing (Pl. 16A).

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[61] Watson, T. L., Mineral resources of Virginia, p. 39, Lynchburg, Va., Virginia-Jamestown Exposition Commission, 1907.

FIELD STONE

Generally there is an abundant supply of loose stone blocks in the fields and woodlands of the Warrenton quadrangle, particularly in the areas of the Catoctin volcanic rocks, of the arkose Loudoun formation, and of granite. Stone fences and houses built of these field stones are common in these areas. Fences several miles in length have been built along granite and arkose outcrops in northern Fauquier and Loudoun counties. Near Turnbull, the writer discovered a house which was constructed, shortly after the War between the States, of Loudoun arkosic quartzite in the local "dry wall" manner, without the use of mortar. It remains today a waterproof house.

SLATE

Two belts of black slate occur in the quadrangle: one north and the other south of Fauquier White Sulphur Springs; both near the base of the Fauquier formation. (See Pl. 1.) Slate from near the Springs has been successfully used for roofing, but at other places in the area the slate is probably not of economic value.

Quarries were opened in the slate deposits at an early date, and roofing slate was quarried in this area before 1839.[62] Many old houses around Fauquier White Sulphur Springs and Turnbull (Pl. 15B) have roofs of slate from the local quarries which are 100 years old and are still serviceable. In the belt north of the Springs, quarries are found on the property of Colonel Alfred Pierce on the west side of Rappahannock River about half a mile east of the Lee Highway; on the property of Marvin Malvin 1 mile west of Turnbull Church; on the property of Mason Cunningham half a mile east of Turnbull; and, on the property of Robert C. Winmill about half a mile south of the Cunningham place.

In the quarry on Colonel Pierce's estate the slate dips to the northeast and is flanked by beds of arkose on the southwest. In the section here the slate is coarse grained, knotty and contains quartz and graphite. On the Malvin property an old quarry of considerable size is now concealed in a young pine forest. The slate strikes N. 47° E. Slaty cleavage is poorly developed and some of the beds are sandy and contain bands of iron oxide. Although slate has been quarried on the Cunningham property the quarries are so nearly filled that the quality of the slate could not be determined. According to local reports, slate was first quarried on the Winmill estate about 80 years ago and again in 1929, for building roads.

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[62] Rogers, W. B., A reprint of annual reports and other papers on the geology of the Virginias, p. 460, New York, D. Appleton and Co., 1884.

In the belt south of Fauquier White Sulphur Springs slate has been quarried in the triangular area between Great Run and the road about three-fourths of a mile southeast of the Springs, and on the property of J. W. Timberlake, on the west side of Great Run. In the former locality about 40 feet of dull bluish-black slate with a knotty surface is exposed in a quarry along the east bank of Great Run. The slate dips southeast about 10° to 18°. On the Timberlake property the slate is well exposed. It dips southwest about 18° to 25°, and has two sets of joints. It contains cubes of pyrite, muscovite, and occasional layers of mica schist. Slate is reported to have been quarried also farther west on the banks of Rappahannock River.

SCHIST

Green, slaty schist has been quarried recently in several places near Great Run. On the property of Mr. Robert Winmill on the south side of Great Run and about a quarter of a mile east of the highway, rock has been quarried for the construction of the near-by mansion. The rock appears to be adapted to various purposes.

At North Wales the mansion and coach-house are built of a similar rock that is quarried on the estate. Two quarries have been opened. The rock has been used for dimension stone, flagstone, as a decorative stone for the construction of gate posts, and crushed for other uses. It could be used in stone veneering.

There is a large quarry in a green slaty volcanic rock on the south bank of Rappahannock River just west of the race track on Colonel Pierce's estate near Fauquier White Sulphur Springs. Much stone from this quarry has been used for various purposes on the estate. At the quarry, where the rock dips about 25° S. 50° E., it is a green or gray-green schist or slate but cleaves into thicker blocks than is characteristic of slate.

Near a tributary of Great Run, about a mile northeast of Fauquier White Sulphur Springs, is a quarry in a slaty quartzite or quartz schist, which is operated by Mr. W. E. Robinson, Jr. The cleavage is nearly horizontal with a gentle westward dip (Pl. 16A). Slabs range in thickness up to 6 inches; the thicker slabs are sandy or saccharoidal quartzite. The rock is sold in Warrenton and locally. The thin slabs are used for walks around dwellings, and the thicker ones for flagging in garages. Two joint directions nearly at right angles, with one developed better than the other in places, cause the slabs to break off in board-shaped pieces; some of these are used for stone benches and tables.

ROAD MATERIALS

GENERAL STATEMENT

Since good roads have become an essential feature of a well organized community, road materials of various types, especially for the construction of hard-surfaced roads, have become an important natural resource. The roads of the Warrenton area have been built of local stone of which an unusually large variety is available. Greenstone, granite, Triassic diabase, metamorphosed shale, and Triassic fanglomerate have all been used successfully. These rocks have varying physical and chemical properties which affect their use and value as road materials.

Several types of hard-surfaced roads are now constructed. A stone suitable for one type may prove unsuitable for another. Water-bound macadam roads require a rock that will resist the wear of traffic as much as possible, as the rock materials break down slowly to form sufficient fine dust with cementing qualities to hold the large fragments together. For bituminous roads a rock with relatively high absorption is said to be better than one with low absorptive qualities, because the bituminous material tends to impregnate the former type of stone, binding it more solidly together. The cementing or binding qualities of the stone are not important in this type of road. The rock should be tough, however, to resist the shock of impact. Some of the hard-surfaced roads around Warrenton[63] have been constructed with an eight-inch compacted base and with a surface treatment rather than the penetration method. In the construction of concrete roads the stone used should be as hard at least as the cement, the hardness being not less than 16.[64]

GREENSTONE

Materials from the metabasalt flows and Warrenton agglomerate have essentially the same qualities for road construction, but generally the more massive metabasalt is preferred. It is harder and should contain less chlorite. South of Warrenton these rocks are generally too much sheared and chloritized for use as road materials.

Metabasalt may be considered as altered trap rock. Its physical properties vary greatly from place to place due to differences in the degree of alteration. It has been used extensively in the Warrenton area. Three quarries in massive Catoctin metabasalt were opened about a mile northeast of Rappahannock River during the construction of the

[63] Sanders, W. W., Jr., Fauquier County Engineer, Virginia Department of Highways, personal communication, 1931.

[64] Hubbard, Prevost, and Jackson, F. H., Jr., U. S. Dept. Agr., Office of Public Roads Bull. 370, 1916.

Lee Highway (U. S. 211). Greenstone was quarried west of Turnbull for the Warrenton-Fauquier White Sulphur Springs road, and was also used in the old macadam road between Warrenton and Middleburg.

GRANITE

Granite is hard but not very tough. The rock when used for surfacing, loses more by abrasion than does trap rock and usually more than metabasalt. Cementing values were not determined for the granite specimens, but when the rock is fresh they are probably low.

When the Lee Highway (U. S. 211) was built in 1930, much granite was used. The largest quarries were just west of Amissville. Here the rock is massive, coarse, dark gray granodiorite and granite of uniform appearance. Much good stone was also quarried just south of the highway along the local road to Jeffersonton. Here the rock is light gray and contains locally younger blue quartz facies. Another large quarry was made in light gray (Old Rag) granite near the Lee Highway just west of Sperryville.

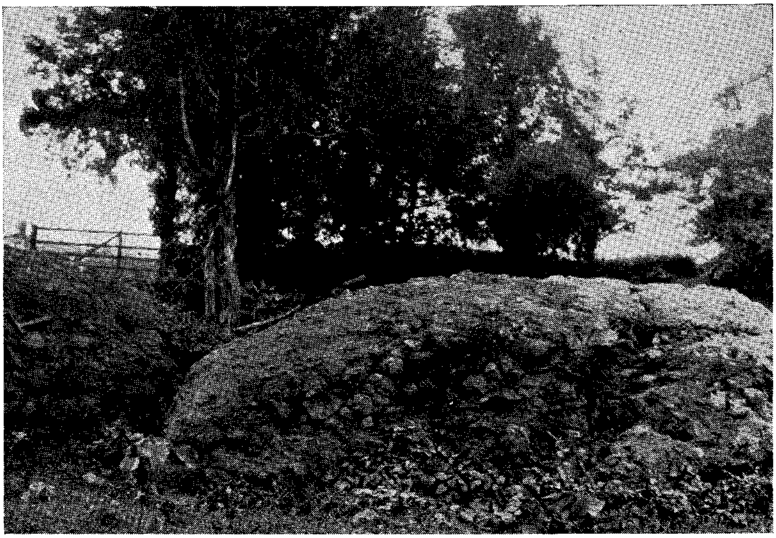
DIABASE

Intrusive sills of Triassic diabase or trap rock east of the Catoctin Mountain Border fault have been extensively used for road construction. The stone admirably meets the requirements for hard-surfaced roads. Small dikes, mostly west of the fault, in the Warrenton quadrangle, are very tough and the rock being difficult to crush is not used.

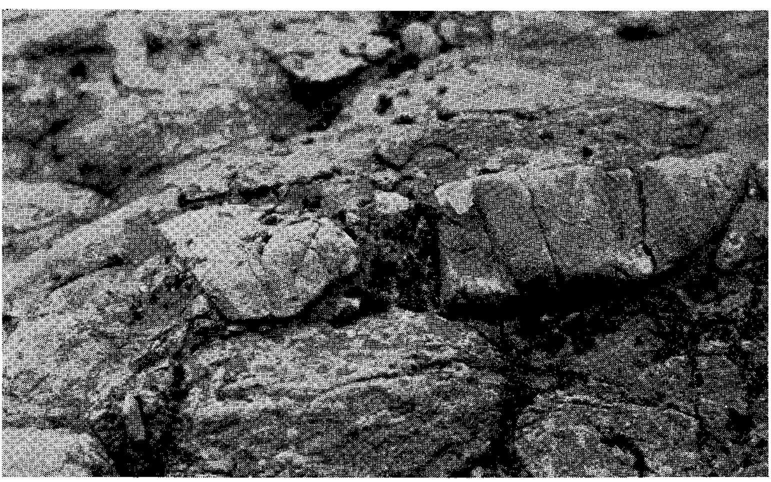
Diabase is characterized by low absorption and unusual toughness. It also has about the same hardness as granite. Its toughness is due to the presence of augite, to its fineness of grain, and to its ophitic texture. Physical properties are remarkably constant. It is an excellent stone for surfacing because of its wearing qualities. Greenstone and granite make a substantial base, but cannot equal diabase for wearing qualities.

Diabase rock was used in building the James Madison Highway (U. S. 15) south of Warrenton. A large quarry was opened about 3½ miles north of Remington on the property of A. L. Dodd, from which much excellent stone was removed. The rock is very fine grained, being near the border of the sill. It breaks easily with a conchoidal fracture.

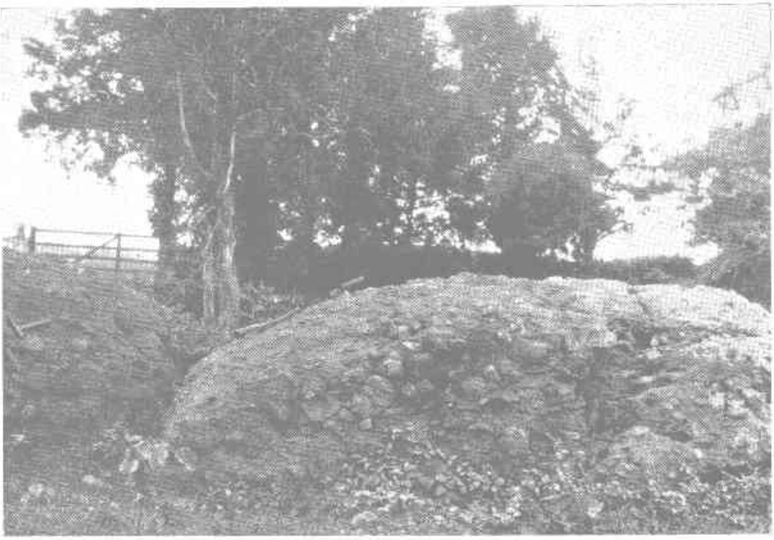
Much diabase rock has been quarried between Calverton and Catlett in Fauquier County. Near Catlett on the north bank of Cedar Run, medium-to coarse-grained diabase of excellent quality is obtained (Pl. 16B). A large crushing plant was installed there in the summer of 1931.



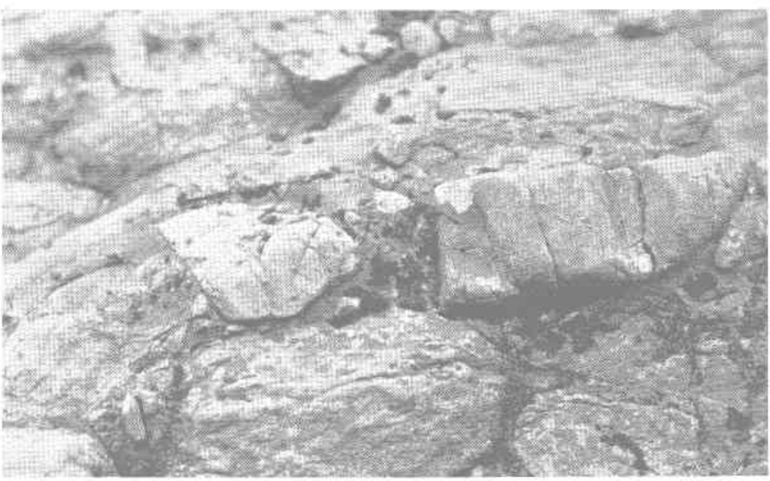
A. Triassic fanglomerate about three-fourths of a mile northwest of Brandy, Culpeper County.



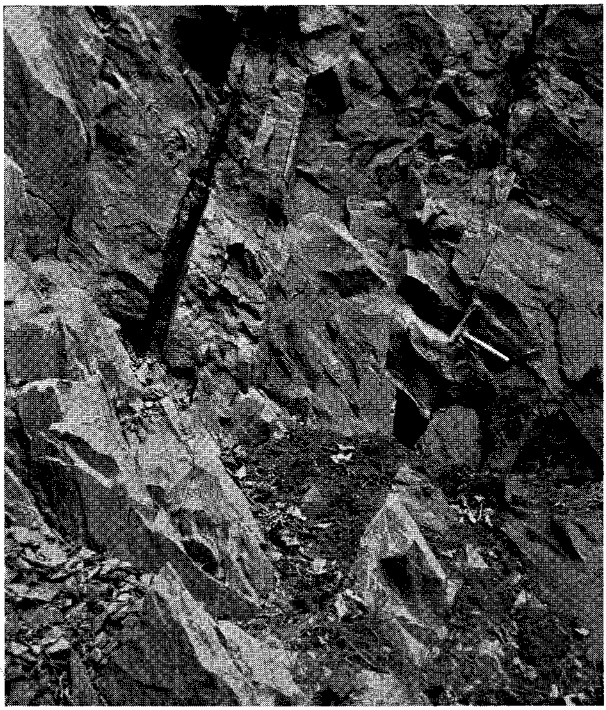
B. Detail of boulder of Triassic fanglomerate about three-fourths of a mile northwest of Brandy, Culpeper County.



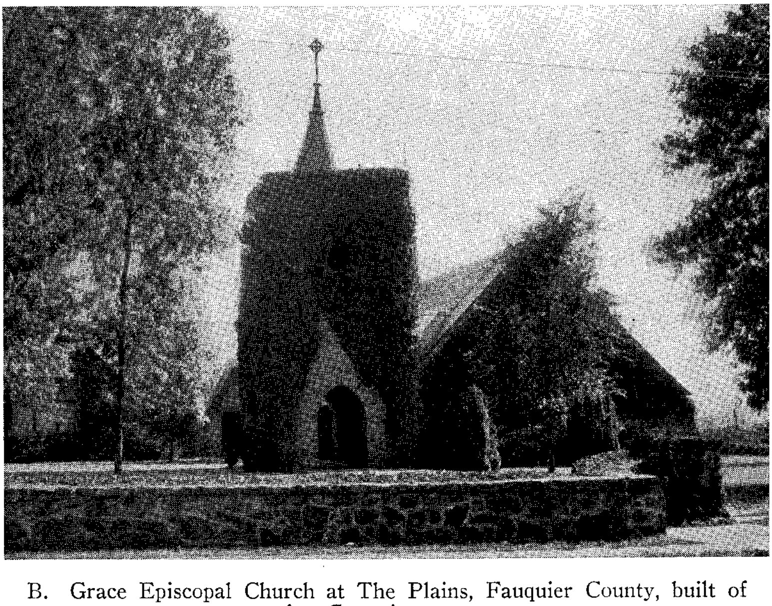
A. Triassic fanglomerate about three-fourths of a mile northwest of Brandy, Culpeper County.



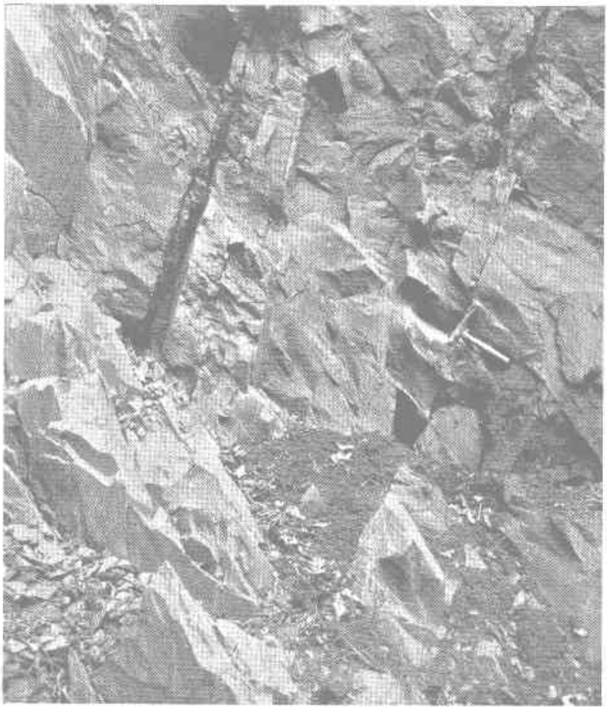
B. Detail of boulder of Triassic fanglomerate about three-fourths of a mile northwest of Brandy, Culpeper County.



A. Quarry in massive Catoctin greenstone on the Lee Highway west of Warrenton. Note the scarcity of joints, which have been opened by blasting. One joint direction is shown.



B. Grace Episcopal Church at The Plains, Fauquier County, built of massive Catoctin greenstone.



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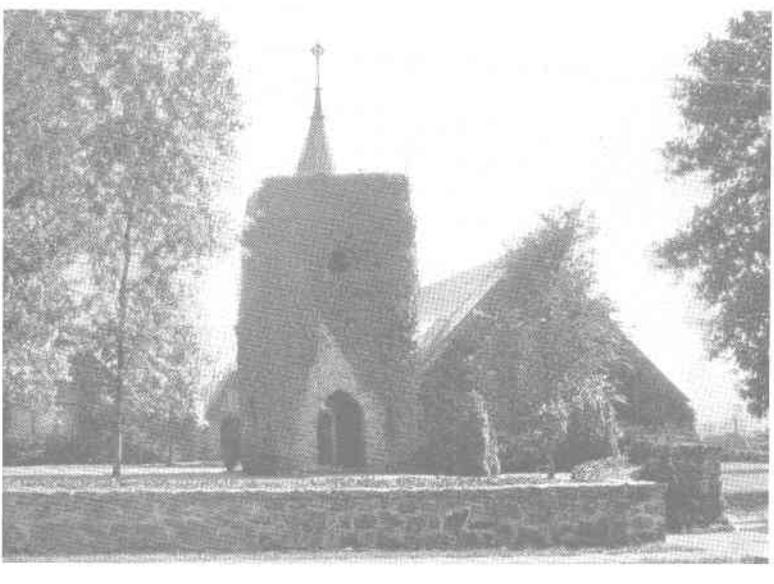
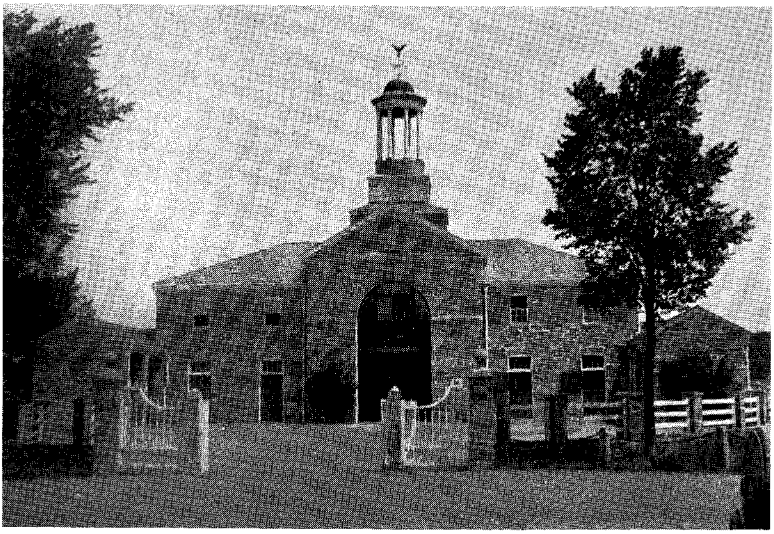
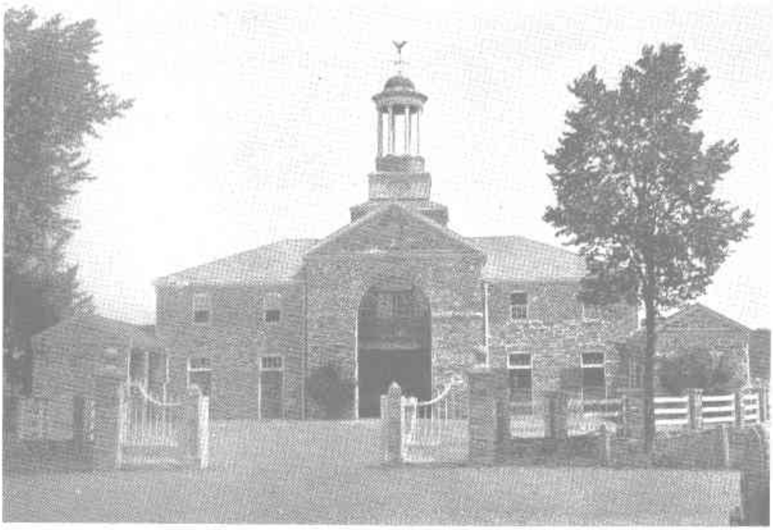


B. Grace Episcopal Church at The Plains, Fauquier County, built of massive Catoctin greenstone.



A. Coach House on estate near Warrenton, built of sheared Catoctin greenstone.

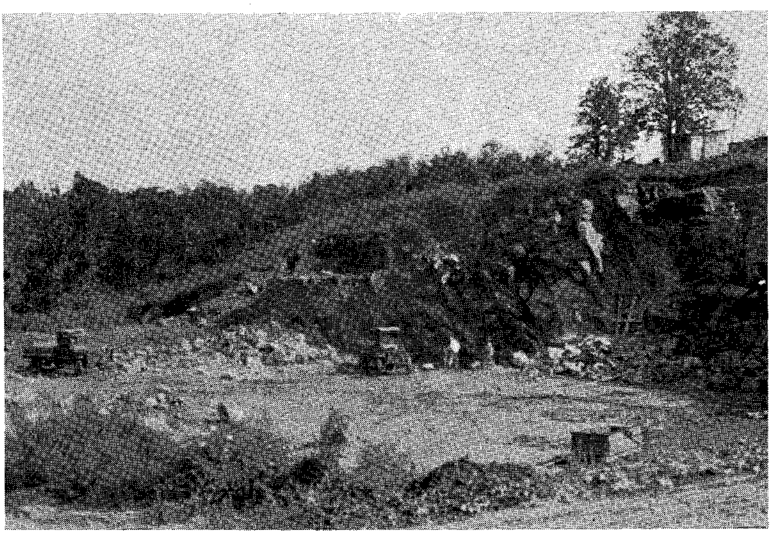
B. Loudoun slate on an old building near Turnbull, Fauquier County. The roof has not been repaired since the close of the War between the States.



A. Coach House on estate near Warrenton, built of sheared Catoctin greenstone.

B. Loudoun slate on an old building near Turnbull, Fauquier County. The roof has not been repaired since the close of the War between the States.

A. Flagstone quarry in the Fauquier formation near Fauquier White Sulphur Springs, Fauquier County.



B. Quarry in Triassic trap (diabase) near Catlett, Fauquier County.

A. Flagstone quarry in the Fauquier formation near Fauquier White Sulphur Springs, Fauquier County.

B. Quarry in Triassic trap (diabase) near Catlett, Fauquier County.

METAMORPHOSED SHALE

Metamorphosed Triassic shale is used locally. It has been quarried intermittently about half a mile south of Brandy Station on the property of P. T. Fitzhugh. Here the rock is thoroughly baked. The beds are nearly horizontal, and large quantities of stone are available.

OTHER MATERIALS

In recent years Triassic fanglomerate has been used successfully for road building. It has been extensively quarried around Culpeper. Loudoun quartzite is locally too weathered to be of much value for hard-surfaced roads. Quartzite and other rocks may be used to advantage in foundations.

In areas north of Warrenton where Loudoun arkosic quartzite and granite crop out, sand-clay roads are frequently constructed.

BRICK CLAYS

GENERAL STATEMENT

Deposits of residual clays which will yield bricks of good quality are numerous and widely distributed in the Piedmont province of Virginia. The strongest and densest bricks, however, are said to be made from the transported clays found in stream valleys. Such deposits, although locally rather extensive, are in many cases used only where they are immediately adjacent to towns and railroads. Although residual clays, derived from the weathering of all the formations shown on the geologic map (Pl. 1), occur in the Warrenton quadrangle, those from the Triassic shales and Catoctin volcanic series are probably the best. An exception exists where the shales have been baked by intrusive sills; also, where the shale, locally, is too sandy for making brick. Much of the Loudoun formation is too sandy to yield good clay; this is also true in large part of the granites. Before locating a brickyard the amount of clay available should be determined and samples of the clay should be tested to discover its exact brick-making qualities and the process best adapted to that particular clay.

The clays of the Piedmont province have been examined and their brick-making qualities tested by Ries and Somers.[65] In the following brief discussion of clays, the writer has drawn freely upon information in their publication.

[65] Ries, H., and Somers, R. E., The Clays of the Piedmont province, Virginia: Virginia Geol. Survey Bull. 13, 86 pp., 1917.

WARRENTON DISTRICT

Clays derived from the weathering of greenstone occur in the Warrenton district. Good clays should not be expected to occur in areas mapped as arkose and schist northeast and southwest of Warrenton (Pl. 1), as these rocks are generally too high in quartz and muscovite to make bricks.

A sample collected by Ries and Somers, 2 miles northeast of Warrenton on the road between Auburn and New Baltimore required 37 per cent water for mixing, had high plasticity, 6.4 per cent air shrinkage, and a tensile strength of 71.0 pounds per square inch. It burned to a good red color and was steel hard with a good ring at Cone 03, although even at Cone 05 it would probably be hard enough for common brick. The material did not dry press successfully. It is classed as a red-burning brick clay and is representative of the better type of clay found in the vicinity.

Another sample taken from a small cut south of Warrenton may be from weathered mashed greenstone. Its plasticity is fair, air shrinkage is 5.6 per cent, absorption 30 per cent, with a fair brick at Cone 010. Exposures of red clay that would probably burn to good bricks occur along the Lee Highway (U. S. 211), west of Warrenton in the area shown on the geologic map as underlain by the Warrenton agglomerate member.

CULPEPER DISTRICT

Residual clays from the Catoctin series occur west of the Catoctin Mountain Border fault at Culpeper, but few large bodies are reported. Ries and Somers examined a yellowish-brown, gritty clay, about a mile southwest of town which should make good brick. With 22 per cent of water it gave a mass having 4.5 per cent air shrinkage and burned to a good brick at Cone 05. A low-grade brick clay is reported 1½ miles southwest of Culpeper.

About half a mile southwest of Culpeper is a red, slightly gritty clay apparently derived from the weathering of Triassic fanglomerate. It burns red but does not produce a very hard brick.

Southeast of Culpeper on the road to Stevensburg (State 3), are numerous occurrences of Triassic clay, the best being near Culpeper. Tests show that this clay will make good bricks.

A deposit of stream-bed clay has been worked at Clarke's brickyard on the northeastern edge of Culpeper near Mountain Run. The clay is variable in character as would be expected in a floodplain deposit. According to Ries and Somers, nearest to the works the surface is underlain by a tough blue clay, about 5 feet thick, whereas on the farther side of the pit towards the highway, occurs yellow, less sticky clay. Next to the run the clay becomes very sandy. The blue clay is too tough and has too much shrinkage to work alone, consequently it is mixed with the yellow clay which has much less shrinkage. Both clays are plastic. By mixing the two it appears that the high shrinkage of the first and the porous burning character of the latter are avoided.

BRANDY-ELKWOOD DISTRICT

Near the Southern Railway, a short distance northeast of the place where the old State highway crossed the railway between Culpeper and Elkwood, excellent brick clay occurs. It is covered by 1 to 2 feet of sandy loam which could be mixed with the clay. The clay is plastic and, with 25 per cent of water, has an air shrinkage of 8.3 per cent. The average tensile strength is 95.0 pounds per square inch. It burns red with a good brick at Cone 010, but yields an excellent brick at Cone 05. It was nearly steel hard at Cone 010 and completely so at Cone 03. According to reported tests, this material will make good brick by the soft-mud process.

Material that gives promise of making a good brick for general use occurs about half a mile northeast of the above locality. It burns to an excellent brick with a good ring at Cone 010.

Exposures of Triassic clay are reported around Brandy. The Catoctin volcanic series in Fleetwood Hill is deeply weathered and well exposed in cuts where crossed by U. S. Highway 29 northeast of town. This clay is well located for working, being not more than half a mile from the Southern Railway. It is very plastic, but has an air shrinkage of 11.4 per cent. It burns to a good red color, has a good ring and is steel hard, even at Cone 010. It would be desirable to mix it with some clay having a lower air shrinkage.

Around Bealeton near the Southern Railway and along U. S. Highway 29, occur exposures of weathered shale which should make good bricks, although no tests have been run on samples from them.

BARITE

Small deposits of barite ($BaSO_4$) have been reported from the Warrenton area, but none is now mined.[66] According to Watson,[67] the barite, in the Triassic area near Catlett in Fauquier County and in Prince William County, is associated with red shale and impure lime-

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[66] Watson, T. L., Biennial report on the mineral production of Virginia during the calendar years 1909 and 1910: Virginia Geol. Survey Bull. 6, pp. 102-103, 1911.
Roberts, J. K., The geology of the Virginia Triassic: Virginia Geol. Survey Bull. 29, pp. 132-133, 1928.
Edmundson, R. S., Barite deposits of Virginia: Virginia Geol. Survey Bull. 53, pp. 51-55, 1938.
[67] Watson, T. L., op. cit., pp. 102-103.

stone. It is of secondary origin filling fractures of variable size and extent in shale and occurs in tabular, cleavable masses in limestone.

The Cedar Run mine, 4 miles southeast of Catlett, was last operated about 30 years ago. Barite is reported to have been mined here as early as 1845.[68] The St. Stephens mine, about 2 miles northwest of Catlett, was operated shortly after the War between the States, when 2,200 tons of barite was produced.[69] The barite occurred in decomposed Triassic diabase. The Gear mine, about 3 miles southeast of Bealeton, is reported to have been opened about the same time as the Cedar Run mine but was not an important producer.[70] Among other local properties from which production has been reported are the Kemper mine, about one-fourth of a mile south of the Gear mine, and the Botts prospect, about 2 miles northeast of Elk Run Village.[71] Barite has also been reported from near Marshall.

PETROLEUM AND NATURAL GAS POSSIBILITIES[72]

The folding and metamorphism of the sedimentary rocks west of the Bull Run escarpment have driven out all volatile hydrocarbons that may have been present and no commercial quantities of petroleum or natural gas will be found in the crystalline rocks of the Warrenton quadrangle. Slight, unimportant accumulations of marsh gas may occur in local bogs, and thin, iridescent films of iron oxide which accumulate on stagnant water may be easily mistaken for petroleum. If some of this material is skimmed off the surface, collected in a bottle and shaken, it will settle to the bottom. The black slate of this area may have been at one time a shale from which a small amount of petroleum might have been distilled, but of the original hydrocarbons only graphite has remained after metamorphism. In a locality west of Rixeyville black shaly material was prospected for coal about 1925. The rocks of this area were deposited before coal deposits were formed, and if coal had ever existed here it would long since have been changed into graphite. About 1909 considerable money was spent in drilling for petroleum in the Loudoun formation and the granite near The Plains in Fauquier County. Naturally no oil was found.

The Triassic shales east of the Border fault have never given any indications of containing petroleum or natural gas. They are much faulted and contain no source rocks from which petroleum may have been derived. Tests for oil were drilled at Brandy Station in 1915 without success. The town is underlain by a thick diabase sill.

[68] Edmundson, R. S., op. cit., p. 54.
[69] Idem.
[70] Edmundson, R. S., op. cit., p. 55.
[71] Edmundson, R. S., op. cit., pp. 54-55.
[72] See also McGill, W. M., Prospecting for natural gas and petroleum in Virginia: Virginia Geol. Survey Bull. 46-B, pp. 11-22, 1936.

SOILS

General statement.—The nature and quality of soils in the Warrenton area depend largely upon the type of the underlying rock, steepness of the slopes, and depth of rock decay. There are three distinct soil types in this area, based upon rock composition: (1) Soil formed from the decomposition of slates and schists of the Fauquier formation, granites, and Lower Cambrian arkosic quartzite and schists; (2) soil derived from the Catoctin volcanic series; and (3) soil derived from the Triassic shales and sandstones. Each of these types, and especially the first two, are much modified from place to place by topographic position.

Granite soils.—The granites and the Lower Cambrian sediments derived from them contain potash feldspar and quartz. Thorough decomposition produces a sandy loam. Where the slopes are steep, the soil is thin and poor. In the Warrenton quadrangle the soils on the Lower Cambrian arkosic quartzite are generally somewhat thinner than those overlying the granite.

Arkosic quartzite soils.—Soils of the Loudoun (Lower Cambrian) formation are very different from greenstone soils. They are pervious and in ordinary seasons produce good crops with little effort. They contain enough undecomposed rock particles to be loose and easily cultivated. So characteristic is the soil of this rock and its effects upon crops, that the itinerant tenant farmer who knows it, almost invariably chooses a farm underlain by Loudoun arkosic quartzite. Loudoun arkosic quartzite yields unexcelled meadow pasture land.

The dominating color of soils from the granites and Loudoun arkosic quartzite is light gray since there are few iron minerals in the parent rocks. Since there is little calcium in these porous soils, fields are greatly improved by adding lime. Loudoun arkosic quartzite soils generally produce scrub timber thus are hard to keep cleared.

Greenstone soils.—Greenstone soils are regarded as the best for general farming purposes in the Piedmont upland section. They contain abundant lime and phosphoric acid. Drainage and penetration are good, but rapid run-off frequently forms gullies; hence mountainous sections underlain by greenstone have locally remained uncultivated since the War between the States. The greenstone soil holds humus well, thus is resistant to drought, especially where a mulch is maintained on cultivated fields. No soil maps have been prepared for the Warrenton quadrangle, but soils in Orange County[73] similar to local greenstone soils are classified as Davidson clay loam.

[73] Hendrickson, B. H., Soil survey of Orange County, Virginia: U. S. Dept. Agr. Bur. Chem. Soils, ser. 1927, no. 6, 33 pp. 1930.

Chemical weathering is largely responsible for the bulk of the greenstone soils. The principal base is kaolin derived from original feldspar in the basalt. The iron-bearing minerals, epidote and chlorite, although more resistant than ferrous silicates in the zone of weathering, break down with the production of much hydrated ferric oxide, which imparts the characteristic red color to these soils. Quartz resists weathering and locally greenstone soil contains many fragments of vein quartz. In areas underlain by the volcanic agglomerate facies of the metabasalt (greenstone) (Pl. 1), pebbles and cobbles of greenstone are common in the soil. Soils of the agglomerate facies of the metabasalt south of Fauquier White Sulphur Springs are in places thin, gray, and covered with scrub timber.

Soils from Triassic rocks.—Triassic rocks, mainly diabase and shale, occur in the southeastern part of the quadrangle, underlying a low plain. Normally no sharp difference in soil types is apparent. Areas underlain by wide and somewhat elevated belts of diabase are covered with a heavy red clay soil which is locally quite stony. Low ridges formed by outcropping diabase sills are often rocky, poor, and covered with scrub timber.

GROUND WATER[74]

Amount and movement.—The amount of ground water held in rocks below the surface varies greatly from place to place. Granting a nearly equal rate of evaporation throughout the quadrangle with uniform or nearly uniform annual precipitation, the important controlling factors are rock porosity, surface slope, and local relief. The influence of these factors upon the ground-water content of the various kinds of rock is discussed later.

When rain falls upon a land surface some water runs off directly, some evaporates, and the remainder seeps into the surface mantle. Below the surface, water seeps downward by gravity until it reaches a zone in which all porous rocks are saturated. This zone is termed the zone of saturation and its top surface is called the water table. The water table fluctuates in wet and dry seasons. The zone of saturation varies from place to place in depth below the surface. Its lower limits depend upon the character of the rock, since pores and openings become closed in depth by the increased pressure of overlying rock. Thus a depth is reached at which the rock, although saturated, may carry little or no water. Rocks of high crushing strength, such as granite and quartzite, may contain water locally to a depth of 500 feet or more,

[74] See also Cady, R. C., Preliminary report on ground-water resources of northern Virginia: Virginia Geol. Survey Bull. 41, 48 pp., 1933; Ground water resources of northern Virginia: Virginia Geol. Survey Bull. 50, 200 pp., 1938.

whereas in weak rocks, such as shale, all fissures are closed at shallow depths.

Valleys, when cut to the water table, lower that level due to the fact that the water in the adjacent saturated zone above the level of the bottom of the valley moves toward the valley. Thus the water table stands high under hills. A well will produce the same effect but on a smaller scale. If there were no rain for a long time, all of the ground water above the level of the valley bottoms would run into the valleys as surface water, the water table would become essentially horizontal and thus would stand at a relatively low level.

Water moves in two directions beneath the surface. Above the saturated zone it moves downward, but when it reaches the water table it moves laterally toward the valleys. If valleys are deep, water will move rapidly towards them. If the supply of water above the saturated zone fails, as it does during a drought, or during seasonal differences in rainfall, the water table will drop much more rapidly in areas of strong relief than in flat areas. For this reason west of the Catoctin Mountain Border fault in the Warrenton quadrangle, wells should be sunk deep into the saturated zone. Where the water table is intersected by valleys, springs may occur. In the Warrenton quadrangle springs are fewer in the greenstone than in the Loudoun formation, partly because fissures are less abundant in the former.

Valleys cut below the water table contain permanent streams fed by seepage and by springs. Thus in passing down a valley towards its mouth, one finds first a shallow gulley which contains water only when it rains. Farther down the valley, within the belt of fluctuation of the water table, springs and seepages occur in wet seasons. Below this level, or nearer the mouth of the valley, springs are generally permanent. In this report, the first permanent springs toward the heads of valleys are called "branch head springs." They issue from the upper part of the saturated zone and consequently are the first to go dry during a drought. Springs farther down in the bottom of the valley are here termed "branch bottom springs." "Branch side springs" issue from the valley sides above the local valley stream.

Wells are frequently dug or drilled on hills or uplands to intersect the water table. Water enters the well from openings in the rock. It is best to dig or drill wells in the dry season since the water table then is lowest beneath the surface. Such wells, if carried below the lowest level of the water table, will contain water throughout the year. A modern dug well is illustrated in Plate 17A. Artesian wells[74b] may be obtained in the crystalline rocks or the Triassic Border conglomerate. For large supplies of water deep wells are not recommended.

[74b] An artesian well is one in which the water is under sufficient hydrostatic pressure to rise above the saturated zone. A flowing well is one in which the water rises above the land surface.

Drillers may determine the character of the rock to be encountered in drilling in any locality from the geologic map (Pl. 1). Due mainly to variations in hardness and character of the different rocks, wells will be more expensive in some rocks than in others. The appearance of a rock at the surface does not reveal the true character of the deeper unweathered rock, although a fair idea of drilling conditions may be formed from an examination of exposures of the rocks in road cuts. Normally, the deepest wells will be in areas of greenstone, the hardest rock, and the shallowest wells in areas of Triassic shale, generally the softest rock.

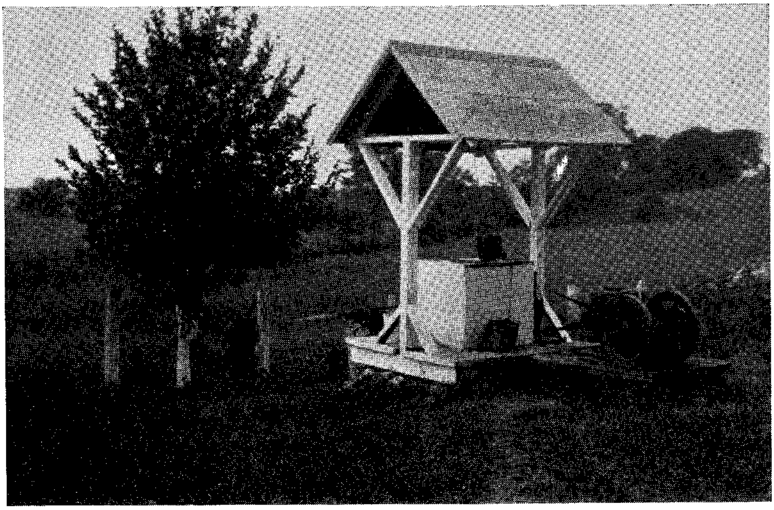
Where several wells must be drilled to obtain an adequate supply of water, they may have to be distributed over so large an area as not to be economical. In such localities, the use of surface streams with a filter plant may be desirable. The initial cost is much greater than that of a deep well, but since towns which grow may have to abandon the deep-well system, a surface water supply may be found to be the most suitable and economical development. Deep wells are adequate for local water supplies, although only wealthy people can afford them. A well 500 feet deep in this area will cost $2,000 or more. If it is placed upon a hill or high spur, it may be a failure. Wells in low places may prove unsanitary. Points below the "valley head springs" in valleys generally prove satisfactory and give, in the case of deep wells, between 30 and 80 gallons a minute. Wells drilled in such valleys will prove on the average to be less satisfactory for areas underlain by greenstone than for areas of other rocks.

Careful examination of the cuttings from wells may save a hundred feet or more of drilling. It is the rule in the crystalline rocks to drill through the weathered rock and into fresh unaltered rock. The upper horizons, sources of water in ordinary dug wells, are cased off.

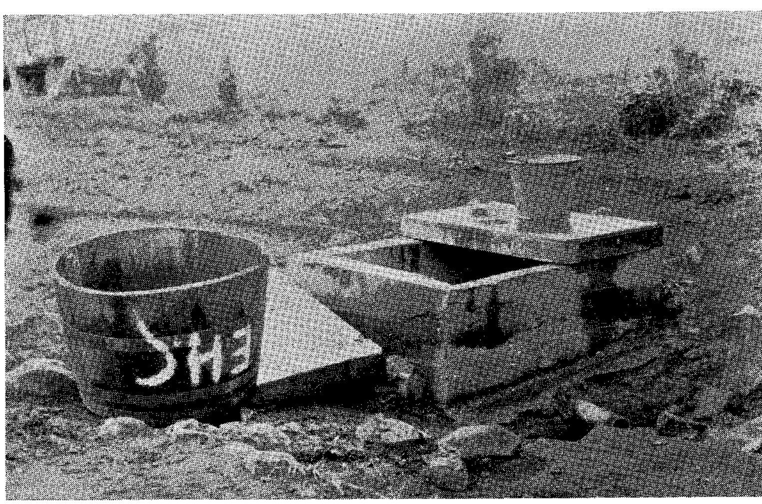
The summer of 1931, when the field work for this report was done, was an opportune time to study ground-water conditions, since drought conditions then prevailed in this area and the zone of saturation was very low. A summary of ground-water conditions and suggested methods by which satisfactory water supplies may be obtained from the various types of rocks in the area are given below.

Conditions in greenstone and agglomerate.—Ground-water conditions in areas of greenstone and agglomerate are similar. These two types of rock generally contain less ground water than other rocks of the area. The agglomerate probably contains more than the greenstone.

In massive greenstone, cracks and crevices (joints) are spaced far apart. They tend to become closed a short distance below the surface. The rock also has low porosity; hence it is not favorable to circulation of water. Unfilled cavities are common, but as they are not

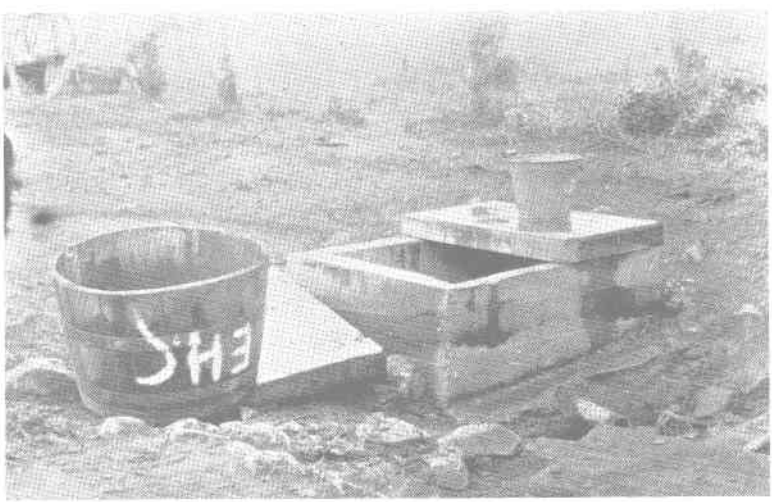


A. A modern dug well.



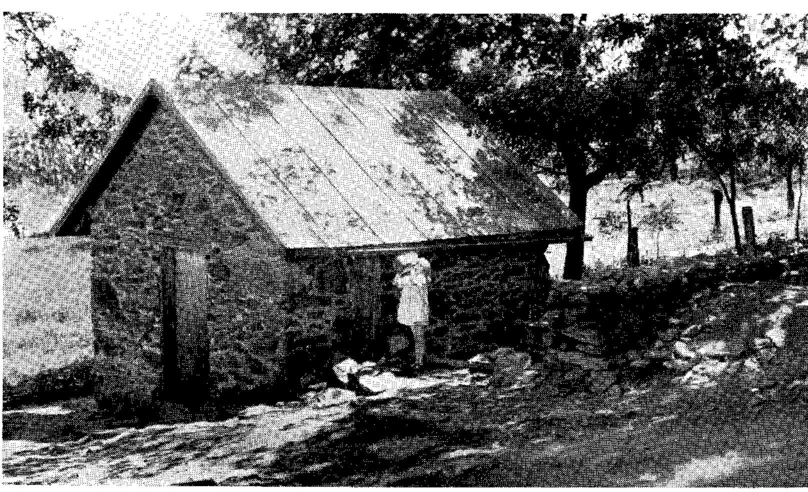
B. An unsanitary spring. Surface drainage enters the spring through openings beneath the improperly set concrete spring box.

A. A modern dug well.



B. An unsanitary spring. Surface drainage enters the spring through openings beneath the improperly set concrete spring box.

A. An unsanitary spring, but excellent water, in granite.



B. A good spring house in the Loudoun arkose country.

A. An unsanitary spring, but excellent water, in granite.

B. A good spring house in the Loudoun arkose country.

continuous they do not contain much water. The greenstone crops out in the sections of highest altitude; thus the run-off is rapid. The zone of saturation also lies deeper, consequently wells must be drilled deeper to reach the saturated zone. Since the water in the zone of saturation is confined to a few poorly connected joints, a well may be drilled and not find water unless favorable joints are encountered.

Well water from the greenstone and the agglomerate is in places hard, which places a premium on good springs. Spring water is locally piped considerable distances to houses. Many residents of the area rely on the upper "branch head" springs, which were dry in 1930 and 1931. The use of springs nearer the mouth of the valley would insure a more continuous supply of water during the dry seasons.

Greenstone is the hardest rock in the area to drill. Schistose facies are less resistant than the massive rock, but there is very little greenstone in this area that is not massive. Sheared, chloritic greenstone east and south of Warrenton should be less difficult to drill. In drilling agglomerate rapid changes in hardness may occur, depending upon whether the drill is cutting boulders or the softer matrix of the conglomerate.

Conditions in granite.—Granite is an excellent water-bearing rock since normally it contains numerous closely spaced joints which are open near the surface. The rock is also more or less mashed and locally is schistose. Several sources of water are locally found in granite in comparatively shallow wells. The water is soft and excellent for all purposes. Areas in the western and northwestern part of the Warrenton quadrangle underlaid by granite have subdued topography and low relief. Wells, although on hills, do not start far above the water table. Many shallow dug wells in granite areas went dry during the drought of 1930 and were dry again in the summer of 1931; but wells 60 feet or more in depth afforded a satisfactory supply of water even under the unusual demands of the drought period. Wells in granite are common in this area, and there are also many good springs (Pl. 18A). Most of the drilled wells around Amissville are about 60 feet deep, and nearly all of them were satisfactory during the drought period. Several dug wells 18 to 25 feet deep also contained sufficient water throughout the dry season of 1930-1931.

West of Amissville the hills are higher, and in the higher areas wells must be drilled deeper to reach the saturated zone. In such localities the problems of drilling become similar to those in areas of greenstone, except that the granite contains more joints, and the likelihood of striking water-bearing zones is greater.

Marshall derives much of its water supply from a well in granite, near the residence of the late Mr. T. H. Maddox, which was drilled about 1920. The well is said to be about 380 feet deep. Several small supplies of water were found below 200 feet and at 370 feet the bit encountered a cavity and dropped 10 feet. The well then filled with water to within 10 to 20 feet of the surface.

Conditions in the Loudoun and Fauquier formations.—Ground-water conditions are more favorable in the Loudoun and Fauquier formations than in any other rocks west of the Triassic belt. Both formations contain many bedding planes and joints in which water may collect, and both are so porous as to act as natural filters. Springs are more abundant in these rocks than in any others in the quadrangle.

Soluble mineral matter is scarce in these rocks; thus the water is soft and does not have a mineral taste. Most wells in these rocks are on divides or hills. If dug or bored below the level of the nearest "branch head springs" they are not apt to fail, as they will be below the water table at that place. Shallow wells rarely penetrate much bedrock. The arkosic beds of the Loudoun formation near or below the water table are soft and easily excavated. Wells on high hills should be drilled.

In this area the economic condition of a family is reflected in its water supply. In general, wells or sanitary springs characterize the more progressive families, but only the prosperous residents have drilled wells. Most wells are dug and the bucket and chain type of well prevails (Pl. 17A).

Springs constitute the most common source of water for household purposes. The topographic map of the Warrenton quadrangle shows that most dwellings are situated upon the divides; consequently the water supply is generally obtained from the nearest "branch head spring." These springs are the first to fail in dry weather. In the summer of 1930 the writer found most of the upper "branch head springs" of this area to be dry. Many families were using the water of lower springs, some carrying water from the spring of a neighbor as much as a mile away. In many cases this was due to the fact that lower springs on their own properties had not been cleaned out (Pl. 17B). By selecting a good spring, and by using a ram or windmill, it appears that an abundance of good water may be obtained almost anywhere in the areas underlain by the Loudoun and Fauquier formations, even in unusually dry seasons.

Of nine springs examined at random, eight were found to be subject to contamination. One had been dug out and walled with concrete at slight expense, thus rendering it free from contamination. A dry wall and an embankment above the mouth of a spring to turn away surface drainage are much better than no protection and a more frequent use of cement in the walls of springs would insure more sanitary conditions. A good spring house is shown in Plate 18B.

Conditions in Triassic rocks.—Ground-water conditions in the area of Triassic rocks east of the Border fault are very different from those in the areas of crystalline rocks to the west. The topography of this area is flat; thus the zone of saturation is near the surface and run-off is reduced to a minimum. Springs are rare. As wells may be had at very shallow depths most of them are dug. In the areas of dissected crystalline rocks, "branch bottom springs" are abundant. Even in dry seasons it is uncommon to find large fields without running water. In the area underlain by Triassic rocks, however, cattle are often watered from wells. Owing to the slow run-off, special care should be taken to insure sanitary conditions around the well. (See Pl. 17B.) A dug well is more difficult to keep tightly sealed at the surface than is a drilled well. Most of the wells examined were tightly walled with cement or tiling and their mouths protected with a concrete slab. More care has been taken generally in this area to insure a sanitary water supply than in other parts of the quadrangle. This is probably due in part to the fact that this is an important dairying section.

In areas of Triassic shale, shallow, dug wells are the prevailing sources of water for household purposes. Run-off is slow, and water accumulates in the wells by seepage. If the wells are very shallow the water is soft, but if the wells are in shale the water may be hard. In the town of Remington a number of wells examined at random yielded hard water. Several shallow wells 15 to 20 feet deep went dry in 1930, but few wells 40 to 60 feet deep failed. A well that functions in a dry season may easily be obtained in the Triassic shale areas.

Soft shales are the least resistant rocks in the quadrangle. Where the shale has been baked by sills, it may be as difficult to drill as the Triassic diabase which is a very hard rock. Since the sills are intercalated with shale, and have low dips, deep wells drilled near the east or southeastern margins of shale areas may reach baked shale or diabase. The location of sill outcrops is shown on the geologic map (Pl. 1).

Outcrops of Border conglomerate are not very extensive in the Warrenton quadrangle. Drilled wells are common in such areas because the water table is deeper than in other parts of the Triassic area. The water is locally soft and of excellent quality.

In the area underlain by the Triassic diabase sill, wells are common and springs are rare, due to the low relief. The diabase contains many joints, which are open in contrast to joints in soft shale. Since the water table is near the surface, good wells are easy to obtain at shallow depths and are generally dug. Many are only 15 to 18 feet deep, but even at this shallow depth most have proved satisfactory during droughts. Permanent wells may be had locally at depths of 40 to 60 feet. Water from the diabase is generally soft in contrast to that from the shale.

MUNICIPAL WATER SUPPLIES

Warrenton and Culpeper derive their municipal water supplies from streams. The Warrenton Water Works is located at a dam on a tributary of Cedar Run about a mile northeast of town. Culpeper, formerly obtained its water supply from Mountain Run but has recently obtained a large flow of water in a deep well drilled in the Triassic fanglomerate. It was planned to drill a second well and to develop a new municipal water supply from the wells. The well is located on the east side of Mountain Run. The hole is 8 inches in diameter. Bedrock was struck at a depth of 5 feet. About 75 gallons a minute of water was obtained at a depth of 590 feet. Additional water was found at a depth of about 650 feet, and a test showed a total amount of about 120 gallons a minute. The well was completed at a depth of 676 feet with no important increase in the quantity of water.[75] A microscopic examination of samples from the lower part of the hole shows that the well is wholly in Triassic fanglomerate.

MINERAL SPRINGS

Fauquier White Sulphur Springs.—Fauquier White Sulphur Springs are situated on the east side of Rappahannock River, near State Highway 28, about 6 miles southwest of Warrenton. The estate, although not maintained as a resort during recent years, is kept in good condition. In the early decades of the last century it was a famous watering place. A native of Boston published a book on the Springs in 1839,[76] and the English traveler Buckingham[77] described in detail his trip to the resort in the fall of 1839. The property consisted of 2,934 acres divided into two parts by Rappahannock River. Nearly a quarter of the property is low alluvial ground. The spring, from which the resort derived its prominence, issues from thin sandy beds alternating with gray phyllite in the Fauquier formation, near Barrs Run. The sandy beds weather red and contain considerable green mica, probably bleached biotite. They dip southeast 10° to 15°. The water has a strong odor of hydrogen sulphide, and is not unpleasant to taste after one is accustomed to it. It is said to operate "purgatively and diuretically." According to Peale,[78] the spring has a temperature of 56° F. and a flow of 175 gallons an hour; the water is alkaline and carbonated. The following analysis was made by Thomas Antisell in 1878.[79]

[75] Information regarding the well drilled in the summer of 1931 was obtained through the courtesy of Mr. V. Von Gemmingen, Town Manager of Culpeper, Virginia.

[76] Six weeks in Fauquier, by a Visitor, 67 pp., New York, S. Colman, 1839.

[77] Buckingham, J. S., The slave states of America, vol. 2, pp. 555-563, London, Fisher, Son and Co., 1842.

[78] Peale, A. C., Lists and analyses of the mineral springs of the United States: U. S. Geol. Survey Bull. 32, p. 60, 1886.

[79] Idem.

TABLE 1.—*Analysis of Fauquier White Sulphur Springs water*

(Thomas Antisell, Analyst[a])

Constituents	Grains per gallon
Calcium bicarbonate	7.88
Magnesium bicarbonate	2.47
Calcium sulphate	3.39
Potassium sulphate	[b] 1.63
Iron sulphate	[c] 2.14
Sodium chloride	3.75
Calcium and magnesium phosphate	0.64
Gaseous matter	0.10
Total	22.00

Gases	Cubic inche
Carbonic acid	11.00
Sulphuretted hydrogen	Little

[a] Peale, A. C., op. cit., p. 60.
[b] With sodium sulphate; [c] With iron phosphate.

Berry Hill Mineral Spring.—Berry Hill Mineral Spring, which prior to 1880 was known as "Thom Spring," is in Culpeper County about 2½ miles from Elkwood, and about 9 miles from Culpeper, just beyond the limits of the Warrenton quadrangle. It is situated on a nearly flat plain, and issues from Triassic shale. It has been known for nearly 100 years. Previous to 1898 water from the spring was free to the public, and people frequently came from considerable distances to drink it. In 1902 a stock company was organized to bottle and sell the water. This company is said to have been highly successful for several years, but later, due to legal difficulties, the property was sold. It is now owned by Mr. R. A. Bickers of Culpeper. The average flow of the spring is said to be 1,000 gallons per day. The water is pleasant to taste and has no odor. An analysis is given below:

TABLE 2.—*Analysis of Berry Hill Mineral Spring Water*

(Froehling and Robertson, Analysts)

Constituents	Parts per million	Grains per U. S. gallon
Ammonium chloride	0.124	0.007
Lithium chloride	Trace	Trace
Potassium chloride	7.4	0.431
Sodium chloride	36.48	2.128
Potassium bromide	Trace	Trace
Potassium iodide	.042	.002
Sodium sulphate	457.3	26.677
Magnesium sulphate	294.8	17.197
Calcium sulphate	1614.7	94.194
Calcium phosphate	Trace	Trace
Sodium borate	Strong trace	Strong trace
Sodium nitrate	None	None
Sodium nitrite	.012	.001
Calcium bicarbonate	187.5	10.938
Magnesium bicarbonate	None	None
Ferrous bicarbonate	5.4	.315
Manganese bicarbonate	Trace	Trace
Silica	28.0	1.633
Alumina	Trace	
	2631.758	153.523

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APPENDIX: SUGGESTIONS TO TEACHERS

It is hoped that teachers in the schools in the Warrenton and nearby areas will find this report useful in courses in physical geography, agriculture, and nature study. Good roads make it possible to visit readily all parts of the quadrangle by automobile, and various trips offer much of interest to supplement class-room studies. Planned field trips or supervised visits to features and places of geologic interest will not only give the students a clearer understanding of such features and their geologic origin or relationship but will also serve to relate textbook statements to the actual features.

Many localities in this area illustrate principles of geology and physical geography. (See Pl. 1.) An outline of the stages in the formation of the rocks and the development of the present surface features is given under "Geologic History." The location of good exposures of different kinds of rocks, which may be studied in the field, is given in the description of the different rock formations. The mineral resources of the area and their uses are discussed under "Mineral Resources." Classes in agriculture will find information of interest under "Soils."

Each of the three main groups of rocks—igneous, sedimentary, and metamorphic—is represented in the Warrenton quadrangle. Some of these rocks are very old (Cambrian and pre-Cambrian), whereas some (Triassic) are relatively recent.[80] Their relative age and position are shown in the legend on the geologic map (Pl. 1) which accompanies this report, and in Table 3. The geologic map shows the distribution of the different kinds of rocks, classified according to group and geologic age.

Sedimentary rocks are deposited chiefly in the ocean, in lakes, and along rivers. East of the Catoctin Mountain Border fault, in the southeastern part of the quadrangle, Triassic sedimentary rocks, consisting of shales and sandstones, crop out where they were laid down as muds and sands in long inland basins.

Along the east side of the Catoctin Mountain Border fault the shales have been dropped down along a great fracture, relative to rocks on the west. At one time a high cliff, or escarpment, was formed along the line of the fault. Rock fragments of various sizes from the higher land west of the escarpment were transported eastward by streams, forming thick deposits of fragmentary materials. These deposits are termed conglomerates, as they are composed of rock particles of varied composition and size bound together by a siliceous matrix. Because the sediments were spread out in a fan-shaped de-

[80] See geologic time scale, Table 3.

TABLE 3.—*Geologic Time Scale*

ERA	Period	Characteristic Life
Cenozoic	*Quaternary Tertiary	Man. Mammals.
Mesozoic	Cretaceous Jurassic *Triassic	Higher plants, early insects, reptiles (dinosaurs), and birds.
Paleozoic	Permian Pennsylvanian Mississippian Devonian Silurian Ordovician *Cambrian	Ferns and allied plants, many invertebrates, and lower vertebrates (fishes and amphibians).
*Proterozoic[a]	....	Low forms of plants and invertebrates.
Archeozoic[a]	....	Primitive forms of plants and invertebrates.

[a] The Archeozoic and Proterozoic eras are commonly grouped together as pre-Cambrian.
*Rocks of this age occur in the Warrenton quadrangle.

posit they are termed fanglomerate. The town of Culpeper is built upon a deposit of this rock, exposures of which may be seen in quarries south of the town, where the rock is quarried for use on local roads. This rock also crops out west of the high school at Brandy.

Fossils are scarce in the rocks of the Warrenton area, but locally impressions of plants are found. Near Leesburg, in Loudoun County, footprints of dinosaurs have been found in Triassic red shaly sandstone. These large reptiles made the three-toed tracks, which for a long time were thought to be tracks of an ancient bird, in similar rocks of the Connecticut Valley. Good exposures of Triassic shale and thin sandstone occur along the main highways and near Liberty Church north of Bealeton.

At several localities in the western part of the quadrangle, mainly along roads, are occurrences of sand which have been derived by weathering from a coarse-grained and very old sandstone (Loudoun formation of Early Cambrian age). The sandstone was probably deposited as sand, in a sea which covered this area.

Limestone is uncommon in this part of Virginia. It is found on the Vickers and Horner properties east of Marshall in Fauquier County. These beds show little alteration and resemble limestones of Shenandoah Valley. As the limestone dips under the Catoctin series, it is believed to be very old (pre-Cambrian). Some of the limestone is called marble, as it will take a good polish and may be used for decorative stone.

Many types of igneous rocks occur in the area. Through the central part of the quadrangle extends a belt of greenstone, which was poured out on the surface as lava flows or was blown out of surface vents. The original minerals of the parent rock have been so changed that the rock is now green instead of black. Gases escaped rapidly from the hot flows and left holes in the cooling and solidifying mass. Some of these cavities were later filled with minerals deposited by ground water. In many places in this area the gas pockets of the greenstone have been filled with white quartz and green epidote, producing a very striking effect. The greenstone is a very old rock (pre-Cambrian).

The most peculiar rock of the area is an ancient agglomerate, composed mainly of rounded fragments of greenstone, probably thrown out of old volcanoes. This rock belongs to the same series as the greenstone and has been named the Warrenton agglomerate member. Exposures of the agglomerate occur along U. S. Highway 15, between Warrenton and Marshall, about a mile east of Dudie, at The Plains, and in the fields east of the intersection of U. S. Highways 15 and 55.

Southeast of the Catoctin Mountain Border fault, in the southeastern part of the quadrangle, occurs another type of igneous rock in the form of sills. Molten rock was forced upward into layers of shale and then it was forced laterally along the bedding planes in such a manner as to appear at first glance as if the molten material had been laid down with the shale. The hot lava baked the shale above and below it. As the surface has been worn down and the overlying beds of shale have been eroded away, parts of the sill have been exposed locally. The rock is so resistant to erosion that it forms ridges. Exposures of both the sill and the metamorphosed shale may be seen at the bridge over Rappahannock River at Remington, along U. S. Highway 15-29, south of Remington, and at other places. Where the molten rock was forced upward and solidified in crevices or fissures, dikes were formed. The dikes have also been exposed by the erosion of former overlying rocks. One dike is exposed just north of Bealeton. Several occur west of the Catoctin Mountain Border fault, where the dike rock weathers into peculiar rounded masses.

Much molten rock did not reach the surface, but hardened and crystallized slowly at great depths into granitic rock. The rock of such bodies is generally coarse grained, because of slow cooling of the molten mass. Later erosion has in places removed the overlying rocks and exposed the formerly buried mass of igneous rock. Belts or bodies of granite, now well exposed in the northwestern part of the Warrenton quadrangle were originally deep-seated intrusive masses. This granite is commonly composed of crystals of gray, cleavable feldspar and blue or purple quartz.

In certain localities north of Culpeper and south of Fauquier White Sulphur Springs, is found another type of coarse-grained igneous intrusive rock. This rock is generally dark green, fine to coarse grained and contains heavy black minerals. It is described in this report as hornblende metagabbro.

Along the road to Thorofare Gap are many good examples of stream erosion. Broad Run, in the deep valley it has cut through Bull Run Mountain, is filled with large boulders which have been transported to their present position when the stream was at flood stage.

As one approaches Thorofare Gap from the east, across the flat surface of the Triassic shale plain, Bull Run Mountain rises abruptly along the line of the Catoctin Mountain Border fault, which locally has been called also the Bull Run fault. After leaving the Triassic shale the Thorofare Gap road crosses a belt of hard white sandstone, which contains flakes of mica along its bedding surfaces, and then ascends the mountain on greenstone. The sandstone which dips to the southeast was laid down upon the surface of lava flows (greenstone). It caps the highest knob (High Point) of Bull Run Mountain, just north of Thorofare Gap. This knob can be climbed from the western side. The sandstone breaks into blocks of different sizes and has been quarried for flagstone. From High Point may be had an excellent view of the country (Piedmont upland surface) between Bull Run Mountain and the Blue Ridge.

The best exposures of greenstone in this part of the State occur in the rugged area east of The Plains; other good exposures may be seen west of Thorofare Gap, along State Highway 55, from New Baltimore to The Plains; and along U. S. Highway 15, between Aldie and Leesburg. The great fault which extends along the east side of Bull Run Mountain—the Catoctin Mountain Border or Bull Run fault—passes under the Episcopal church at the eastern edge of Aldie. Triassic trap rock crops out from Aldie to Oatlands, where it is well exposed in a quarry on the southeast side of U. S. Highway 15, and east of the bridge over Little River. Other exposures of this rock may be seen in the fields at Oatlands, where about fifty yards to the west occurs a belt of the white Cambrian sandstone on the western side of the fault. Triassic fanglomerate is well exposed in road cuts along U. S. Highway 15, a short distance northeast of Leesburg, where it is a coarse limestone conglomerate called "Potomac marble."[81]

[81] Roberts, J. K., The geology of the Virginia Triassic: Virginia Geol. Survey Bull. 29, pp. 10-13, 1928.

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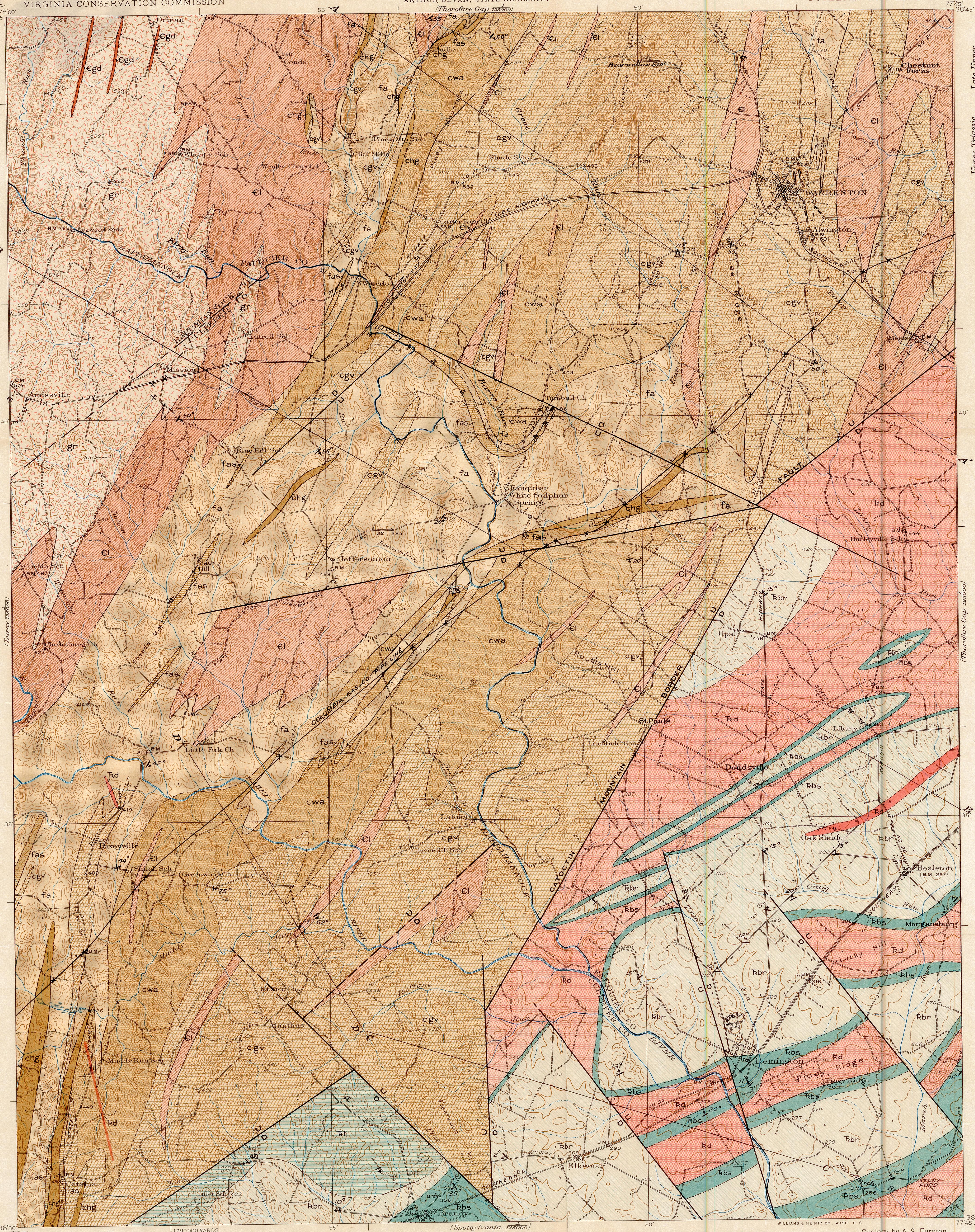


EXPLANATION

TRIASSIC

Late Upper Triassic

Ŧd — Diabase
(sills and narrow dikes)

Upper Triassic (Newark group)

Ŧf, Ŧbr, Ŧbs — Bull Run shale
(Ŧbr, red and olive shale and some interbedded reddish-gray sandstone; Ŧbs, zone of baked shale adjacent to diabase sill; Ŧf, fanglomerate, composed mostly of cobbles and angular blocks of Catoctin greenstone, adjacent to Catoctin Mountain fault northwest of Brandy.)

UNCONFORMITY

CAMBRIAN (?)

Ꞓgd — Greenstone dikes
(narrow dikes cutting the granite complex near Orlean.)

CAMBRIAN

Lower Cambrian

Ꞓl — Loudoun formation
(gray arkosic quartzite and ferruginous quartzite with thin slate layers; locally conglomerate at base; pebbles largely granite and blue and white quartz.)

UNCONFORMITY

PRE-CAMBRIAN

gr — Granite complex
(Old Rag granite, granodiorite and granite not separated on map.)

UNCONFORMITY

chg, cgv, cwa — Catoctin series
(cgv basaltic lava flows and dikes, altered to epidote-chlorite greenstone; schistose east and southeast of Warrenton; cwa, Warrenton agglomerate member at or near base of greenstone; composed of large and small blocks of vesicular basalt in a greenstone matrix with quartz grains; chg, hornblende metagabbro, metapyroxenite or amphibolite; includes some Catoctin greenstone.)

UNCONFORMITY

fas, fa — Fauquier formation
(fa, biotite garnet gneiss and mica schist; fas, graphitic black slate, locally mapped.)

U/D — Normal fault
U, *upthrow;* D, *downthrow*

15° — Dip and strike of rocks

⚒ — Abandoned quarries

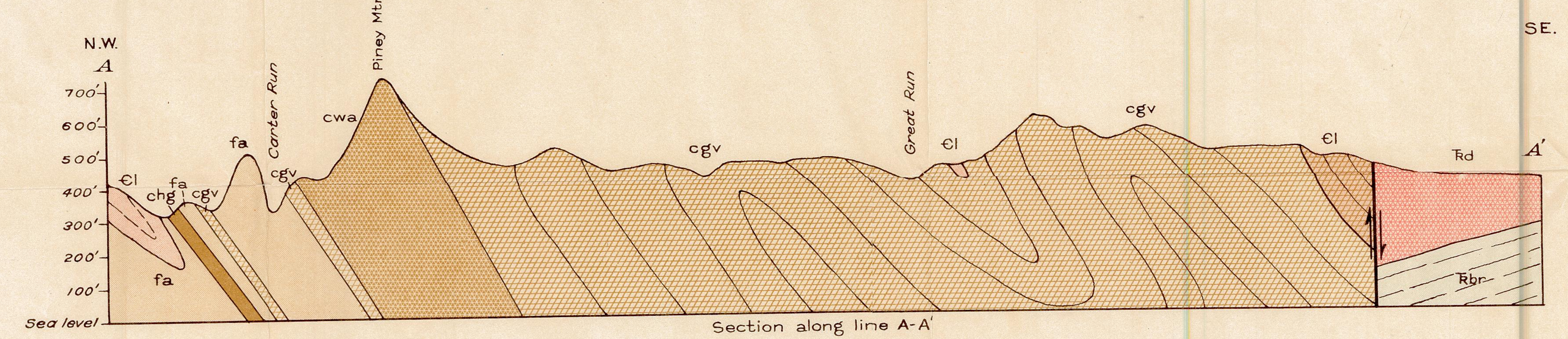
Base from United States Geological Survey map of Warrenton Quadrangle. Surveyed in 1927.

GEOLOGIC MAP OF THE WARRENTON QUADRANGLE, VIRGINIA

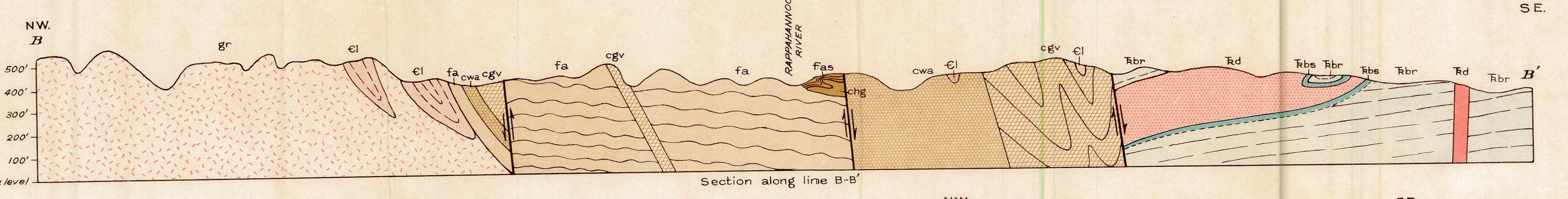
Geology by A. S. Furcron
Surveyed in 1931, 1933

Scale $\frac{1}{62500}$

Contour interval 20 feet
Datum is mean sea level



Section along line A-A'



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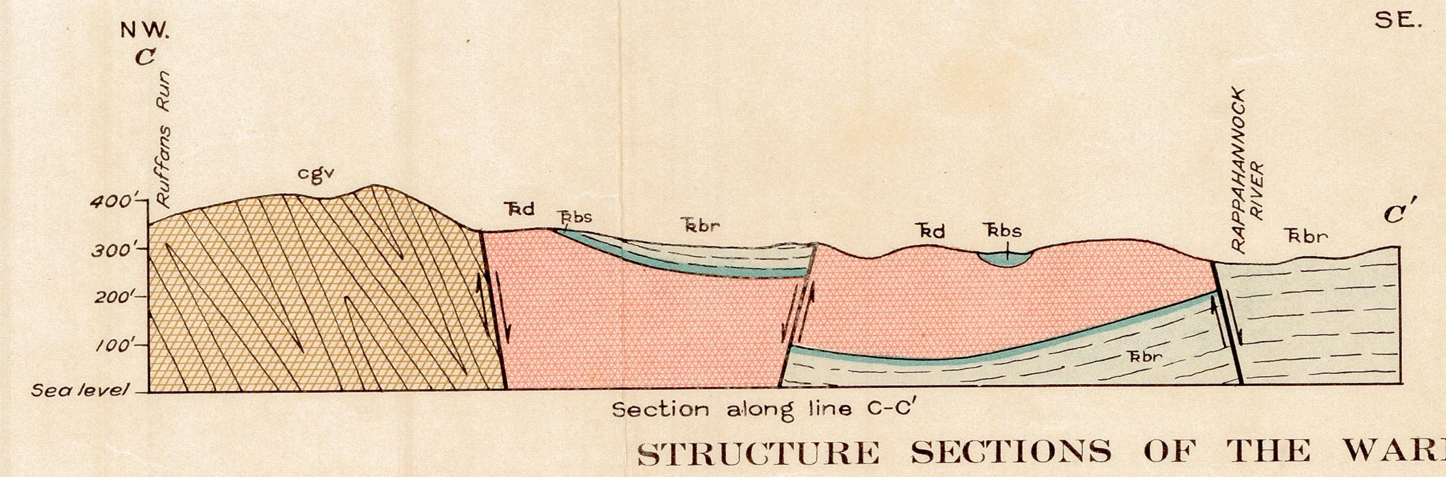

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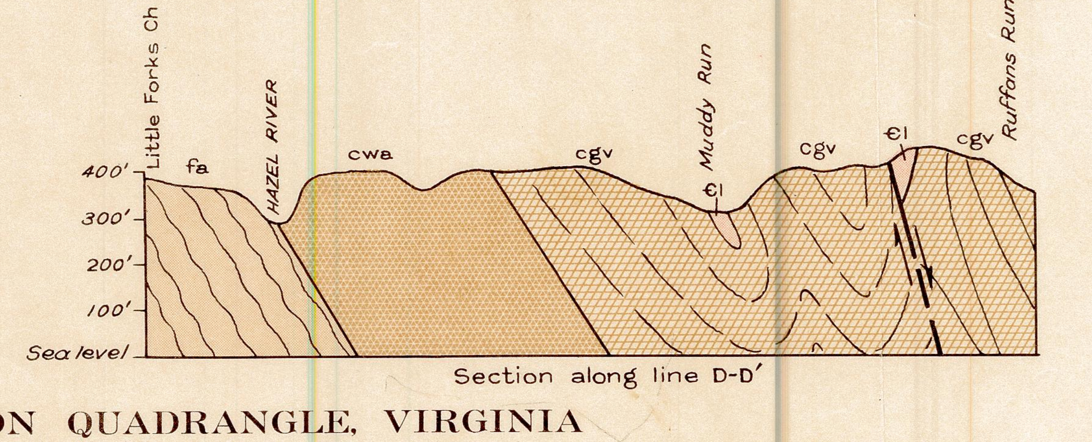

Section along line D-D'

STRUCTURE SECTIONS OF THE WARRENTON QUADRANGLE, VIRGINIA