COMMONWEALTH OF VIRGINIA

STATE COMMISSION ON CONSERVATION AND DEVELOPMENT

VIRGINIA GEOLOGICAL SURVEY

ARTHUR BEVAN, *State Geologist*

Bulletin 39

James River Iron and Marble Belt, Virginia

BY

A. S. FURCRON

UNIVERSITY, VIRGINIA

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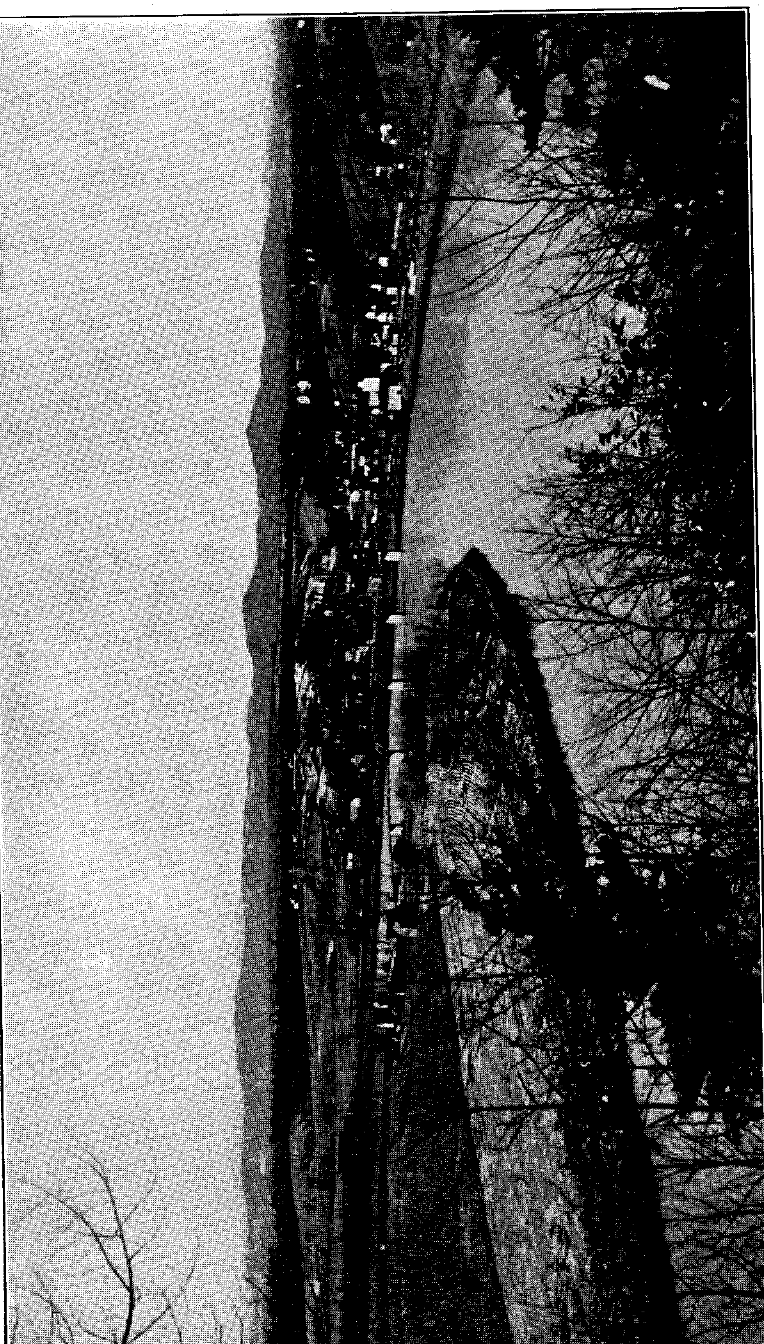
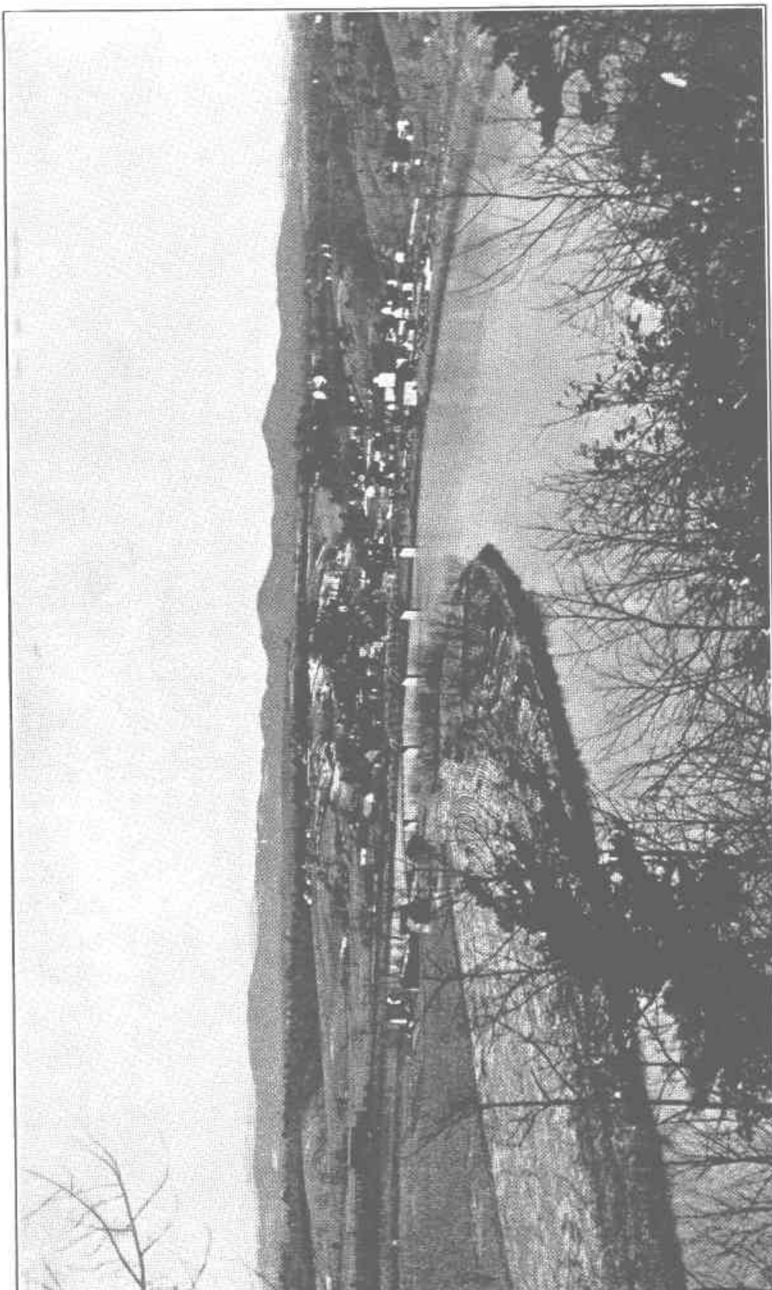


Horseshoe Bend on James River at Scottsville, Albemarle County. View looking west. High dissected terrace in foreground and the Blue Ridge in the distance. (Enlargement of a photograph by W. E. Burgess, taken before construction of present bridge.)



Horseshoe Bend on James River at Scottsville, Albemarle County. View looking west. High dissected terrace in foreground and the Blue Ridge in the distance. (Enlargement of a photograph by W. E. Burgess, taken before construction of present bridge.)

STATE COMMISSION ON CONSERVATION AND DEVELOPMENT

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LETTER OF TRANSMITTAL

COMMONWEALTH OF VIRGINIA

VIRGINIA GEOLOGICAL SURVEY

UNIVERSITY OF VIRGINIA

CHARLOTTESVILLE, VA., April 20, 1932.

To the State Commission on Conservation and Development:

GENTLEMEN:

I have the honor to transmit and to recommend for publication as Bulletin 39 of the Virginia Geological Survey series of reports the manuscript and illustrations of a report on the *James River Iron and Marble Belt, Virginia,* by Dr. A. S. Furcron, of the Department of Geology, Western Reserve University.

This investigation was undertaken by Dr. Furcron as a thesis problem for the degree of Doctor of Philosophy at the State University of Iowa, upon completion of the course in the School of Geology, University of Virginia, leading to the degree of Master of Arts. Thus the extensive field work has been done at slight cost to the State.

This report treats of an area on both sides of James River between Lynchburg and Howardsville, including parts of Albemarle, Amherst, Appomattox, Buckingham, Campbell, and Nelson counties. It describes the distribution and character of the rocks in the district and discusses the mineral resources. Large deposits of limestone, marble, and iron are most important.

As very little information has been published on the resources of this part of the State, this report should be of interest and value to the residents and to those who wish to aid in the development of this region.

Respectfully submitted,

ARTHUR BEVAN,
State Geologist.

Approved for publication:
State Commission on Conservation and Development,
Richmond, Virginia, December 15, 1932.
RICHARD A. GILLIAM, *Executive Secretary and Treasurer.*

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ABSTRACT

This report discusses the geology and mineral resources of more than 800 square miles of territory located in Campbell, Appomattox, Buckingham, Amherst, Nelson and Albemarle counties in central Virginia. The rocks are of igneous, sedimentary and metamorphic origin and are pre-Cambrian except the Lower Cambrian Loudoun formation of the Blue Ridge province and the Triassic sediments and dikes.

The oldest pre-Cambrian rocks of the iron and marble belt are basaltic lava flows of unknown thickness which are altered to greenstone containing epidote, chlorite and hornblende. Over these flows occur about 200 feet of schist and quartzite called the Mount Athos formation. The principal quartzite member, usually less than 100 feet thick, occurs generally near the middle of the formation and is enclosed by micaceous and talcose schists. Cockeysville marble rests upon this formation and is overlain by Wissahickon schist and phyllonite. The marble crops out in narrow synclinal belts which are frequently interrupted by normal faults. The formation averages 600 feet in thickness and consists of interlayered blue, blue-gray, white and pink marbles, and talcose and micaceous schists. The blue marbles crop out frequently and may be burned to make good lime. Marble composes a large part of the formation in some localities and in other places it is greatly subordinate to schist.

East of the marble belt in Appomattox and Buckingham counties, Wissahickon schist occurs. The schist contains interlayered greenstone flows and sills and is intruded by hornblende gabbro.

The western side of the marble belt is bounded by the Catoctin Mountain Border fault. On the western upthrow side of this fault occurs a biotite gneiss and schist known as the Lynchburg gneiss. It is intruded by hornblende gneiss, hornblende gabbro, and by more basic rocks which in many places are altered to soapstone. The Catoctin schist, which resembles in general character the greenstone flows of the iron and marble belt, is interfolded with these rocks. Lynchburg gneiss is also intruded by the Lovingston gneiss and by pegmatites. The Lower Cambrian Loudoun formation, which consists of arkose and slate, unconformably overlies these rocks where it has been preserved from erosion in synclines.

Red shales and sandstones of Triassic age occur east of the Catoctin Mountain Border fault in basins with a northeast trend. These basins are dropped down on the northwest side by normal faults. The most recent intrusive rocks are small dikes of Triassic diabase.

The iron ores of the district consist of magnetite and hematite which occur as lenses and replacements in the Mount Athos formation.

There are also deposits of limonite and manganese. Small deposits of copper sulphides occur in the greenstones.

The most important nonmetallic resources of the district are marble, soapstone, building stone and road materials.

James River Iron and Marble Belt, Virginia

By A. S. Furcron

INTRODUCTION

PURPOSE AND SCOPE OF REPORT

It is the purpose of this report to discuss the geology and mineral resources of the James River basin in central Virginia. This region contains many geologic materials of economic importance. The location, mode of occurrence and origin of limestone and marble, building stone and road material, and iron and copper are discussed in considerable detail. Soapstone is discussed briefly, as a separate investigation has been made of it. The structure and petrology of the deposits and of the enclosing rocks are discussed in some detail, as the successful exploitation of the economic materials requires an understanding of these features.

FIELD WORK AND ACKNOWLEDGMENTS

The field work was done in June, 1925, in a part of the months of August and September, 1926 to 1929, and for 10 days in June, 1929.

The writer is greatly indebted to Dr. Anna I. Jonas for assistance and suggestions in the field and for timely advice and criticism during the investigation; to Professor Wilbur A. Nelson, former State Geologist, and to Professor J. J. Runner of the State University of Iowa, for suggestions about the geology of the region. The writer wishes also to express his thanks to Dr. Albert W. Giles, who as Acting State Geologist, assigned the problem, and to Dr. Arthur Bevan, State Geologist, for the privilege of completing the report and preparing it for publication by the Virginia Geological Survey. Finally, the writer wishes to express his appreciation to the many people of the region who, through their kindness and hospitality, have made the work a pleasant task, and by their interest and cooperation have been of assistance in the collection of data in the field.

PREVIOUS GEOLOGICAL WORK

In 1809, William MacClure[1] who has been called the father of American geology, recognized Primitive, Transitional, Secondary, and Alluvial rocks. The rocks of the Blue Ridge and Piedmont provinces were mapped as Primitive.

The first geological work in this region, known to the writer, was done by William Barton Rogers. In 1839, he examined exposures of

[1] Maclure, William, Observations on the geology of the United States, explanatory of a geological map: Am. Philos. Soc. Trans., vol. 6, pp. 411-428, map, 1809.

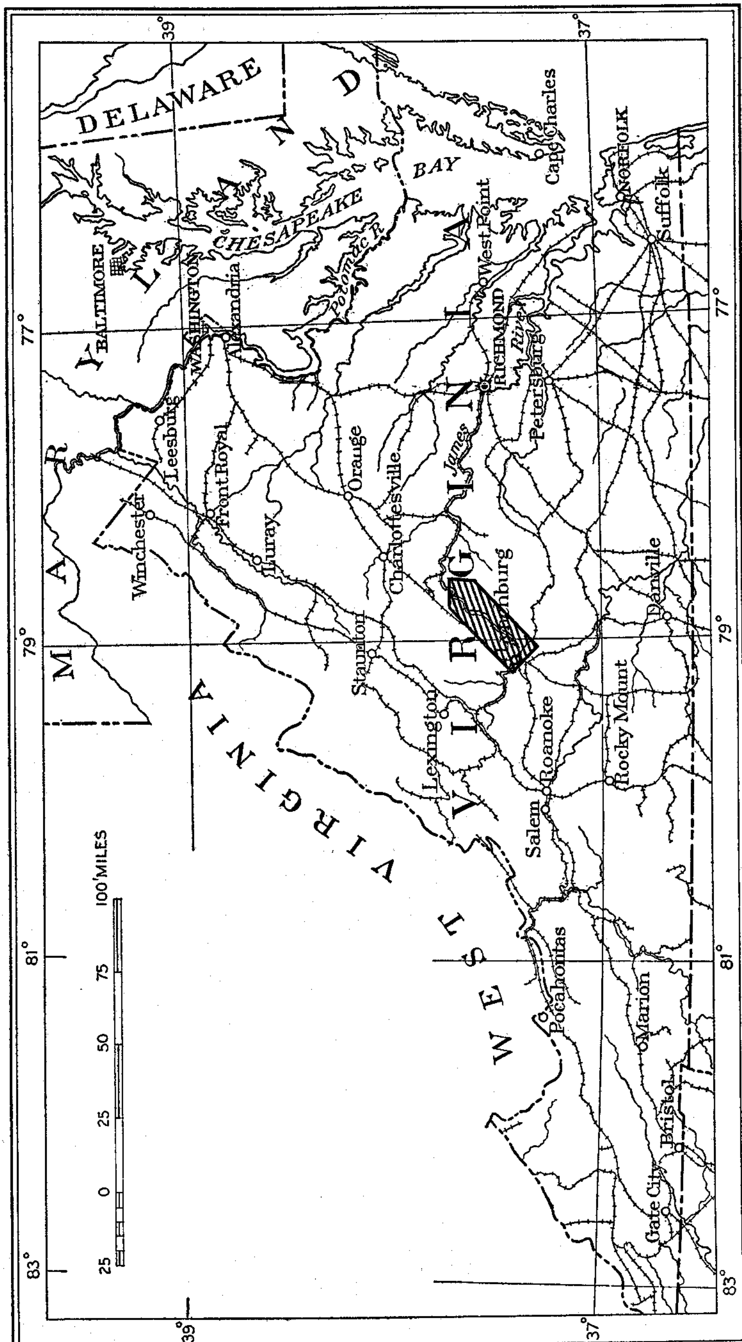

Figure 1.—Index map showing the location of the James River iron and marble belt, Virginia.

limestone and marble along the James River canal and the results of those observations were published in his report of that year to the Board of Public Works.[2]

During the iron boom in 1880-1882, articles on the iron mines and iron industry were written by Campbell, McDonald, Frazer, Kimball, Hotchkiss and others. (See Bibliography.) The Tenth Census Report summarizes the information at that time and also contains an article upon the district.[3].

In 1880, Hotchkiss published in his monthly mining magazine, *The Virginias,* a geological map of Virginia by W. B. Rogers. On it all the rocks of the Blue Ridge and Piedmont provinces, except the Triassic, are shown as Archean.

Numerous references to economic resources of this district may be found in Watson's "Mineral resources of Virginia," published in 1907, and in reports of the Virginia Geological Survey by Watson, Taber, Laney, Lonsdale, and others. Geologic maps of Virginia published in 1911, 1916 and 1928 by the Virginia Geological Survey, show the rocks of this district.

The crystalline rocks of Virginia have recently been reclassified and correlated with the rocks of Maryland and Pennsylvania, by Anna I. Jonas. The results of this work are shown on the "Geologic map of Virginia," published in 1928.

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[2] Rogers, W. B., A reprint of annual reports and other papers on the geology of the Virginias, pp. 281-330, New York, D. Appleton and Co., 1884.

[3] Benton, E. R., Notes on the samples of iron ore collected . . . in Virginia: United States, 10th Census, vol. 15, pp. 261-288, 1880.

GEOGRAPHY

LOCATION OF AREA

This report deals with the geology and mineral resources of parts of the Piedmont and Blue Ridge provinces in central Virginia. (See Fig. 1.) The area comprises more than 800 square miles, including portions of Campbell, Appomattox, Prince Edward, Buckingham, Amherst, Nelson, and Albemarle counties. It extends along James River Valley from Lynchburg to Howardsville and includes that part of the James River basin between the Southern Railway in Amherst and Nelson counties and the southeastern boundary of Buckingham County projected into Prince Edward County. (See Pl. 1.)

TOPOGRAPHY AND DRAINAGE

The topography of this district shows considerable variation from place to place.[4] The western part lies upon the east flank of the Blue Ridge and is mountainous. East of James River, the country is a flat or rolling plateau which is considerably dissected near main streams. A few low peaks rise somewhat abruptly from this surface.

James River flows northeast through the district, somewhat west of its central part. The valley is about 2 miles wide and has a broad floodplain. (See Pl. 2.) James River and its main tributaries are responsible for most of the dissection of the upland surface. This is especially true of the larger tributaries, Tye and Rockfish rivers, which enter the James from the west, because they have steep gradients down the eastern slope of the Blue Ridge.

Tye River rises at the crest of the Blue Ridge at Tye River Gap near the intersection of the Nelson, Rockbridge, and Augusta County lines and enters James River at Norwood. It has formed a natural thoroughfare through the Blue Ridge. It receives Piney and Buffalo rivers which rise in the Blue Ridge to the south. Rockfish River rises in the Blue Ridge of Augusta County and enters James River at Howardsville. These rivers flow across the structural trend of the rocks of the region, but their tributaries pursue northeast-southwest courses, parallel to the ridges.

James River has no large tributaries from the southeast in this region. Appomattox and Slate rivers rise near it but flow southeast and northeast away from it. These streams have dendritic patterns because the underlying rocks are almost equally resistant to erosion.

[4] See topographic maps of the Lynchburg, Appomattox, Buckingham, and Lexington (Buena Vista) quadrangles. These maps may be obtained from the Virginia Geological Survey, University, Va.

CLIMATE

The climate is equable and suitable for agriculture. The mean annual temperature at Lynchburg is 56.4°F. The coldest month is January with an average temperature of 35.8°F., and the warmest month is July with an average temperature of 77.3°F. Nights are generally cool and pleasant during the warmest season of the year. Precipitation is generally abundant and well distributed. The average annual precipitation at Lynchburg from 1871 to 1906 was 43.42 inches. The driest months are October and November; heavy precipitation is frequent in the months of July and August and in the late winter and early spring. The average length of the growing season in this part of the James River basin is 190 days. The first killing frost comes about October 25 and the last killing frost is about April 15.

SOILS AND AGRICULTURE

Farming is the chief occupation and the important crop is tobacco. Much corn and tobacco are raised on the floodplains of James River and its tributaries. Between the river and the Southern Railway where the country is wooded, lumbering is more important than agriculture. Many ties, mostly of oak, are hauled from this district to the towns along the railroads. Much poplar and pine are cut for pulpwood. Chestnut is used at the tannery in Lynchburg.

The quality of farm land is uniformly better east of James River than west of it. Large tributaries enter the James from the west, and that part of the region is characterized by more rugged topography and steeper slopes. Areas underlain by soapstone and Cambrian arkose are for the most part unfarmed. The best farm land is on the floodplains of James River and its larger tributaries. Soils formed by the decay of marble and associated schist are also excellent farm land. Much corn and tobacco are raised upon these soils. This section is in the so-called "Dark Tobacco Belt."

Practically every summer, crops on the James River floodplains are injured more or less by floods. In August, 1928, the river covered almost all of the floodplains and most of the crops in this district were a total loss. The large floodplain is divided into two levels by a low alluvial terrace. The walls of the dividing terrace are locally called the "False Banks," because in flood time they fail to restrain the river. (See Pl. 2.) The most successful farmers cultivate both high and low ground each year, but much of the tobacco is raised on the low ground. The channel of the river is wide and deep enough to care for considerable increase in volume. Low dikes in places would protect valuable bottom lands from floods. At Norwood, in August, 1928, when the writer saw Tye and James rivers flooded at the same time, James River rose above the level of Tye River, forcing the latter to back up over its floodplain and the county road, and causing considerable damage to crops and dwellings.

East of James River, the upland soils are deep and have resulted from long and thorough chemical weathering of a peneplaned surface. The soil reports[5] for this region show that the same soil type is found upon rocks of very different physical character and mineral composition. This is probably due to long and thorough chemical weathering with the consequent leaching and removal of soluble products, causing soils originally different to approach a common composition. The Cecil loam may be cited as an example. It is found covering rocks as diverse in composition as marble, quartzite, Wissahickon mica schist, and greenstone volcanics. From 1 to 3 feet beneath the surface, the soil changes quickly into a stiff red clay subsoil which resembles the Cecil clay. The Cecil clay, as mapped, covers slopes adjoining streams where the Cecil loam has been removed. Thus, due to the prolonged leaching of the soil products, the flat surface of the upland commonly contains light-colored sandy or gravelly loams and red clay subsoils. Hillsides, where erosion has removed the soil since the uplift of the region, are chocolate-red—the Piedmont "red lands."

In this part of the Piedmont province, the local "soil roads" are popular, because travel on unimproved roads quickly cuts through the natural soil into the red clay subsoil, causing them to become impassable when muddy. The light-colored, siliceous top soil is stripped from the surface of the fields and spread several feet thick over the stiff red clay of the old road-bed. After this becomes packed by travel, it is so hard and firm that even in winter it remains in excellent condition and does not become muddy.

After the War between the States, when the slaves were freed, owners of the plantations in Appomattox and Buckingham counties found themselves "land poor." The large farms were broken up and much land that was under cultivation before the war is now covered with a second-growth scrub forest. Much of the soil throughout the region has been impoverished by constant cultivation but could be generally improved by the addition of ground limestone or lime.

Between James River and the Southern Railway, there are many small farms. Much of this region is forested, including Buffalo Ridge, and Hawkins and Findlay mountains. Soapstone rocks occupy a relatively large valley between Hawkins and Findlay mountains on the west and Buffalo Ridge and Green Mountain on the east. This valley is locally known as "The Glades." These rocks characteristically under-

[5] Winston, R. A., Soil survey of Campbell County, Virginia: U. S. Dept. Agr. Bur. Soils, Eleventh Rept., pp. 309-343, 1909.
Caine, T. A., and Bennett, H. H., Soil survey of Appomattox County, Virginia: U. S. Dept. Agr. Bur. Soils, Sixth Rept., pp. 151-168, 1904.

lie low flats covered with scrub timber. The soil is rocky and poor and is dark gray in contrast to the common red soils of the adjacent areas. "Getting out ties" is locally one of the profitable activities. Between the Southern Railway and the mountains, there are many fine farms on the brick-red clay soils formed by the decay of the Lovingston gneiss.

CULTURAL FEATURES

The region is characterized by considerable diversity in occupations and living conditions, due to the fact that soils and topography, which depend directly upon the kind and structure of underlying rock, change abruptly. In many places prosperous and well-ordered farms are found and in other near-by localities, an inhospitable soil may discourage agriculture. All types of city, village, and rural life, characteristic of the Piedmont plateau, are found in this portion of the James River basin.

The people are of English stock—industrious, courteous, and hospitable. Many of them are the descendants of original settlers. They show a keen interest in all factors that may lead to the development of the region. The region is not thickly populated, but the city of Lynchburg and Appomattox, with well-populated farming country about them, counterbalance the more thinly settled districts. The mountain sections are forested and sparsely settled. Wooded sections east of James River in Appomattox and Buckingham counties are also sparsely settled; many families live along James River.

Mining and quarrying have been important in the past, but little mining is being carried on at present (1931).

Several good roads traverse part of this district. A hard-surfaced highway (U. S. 460) between Lynchburg and Farmville follows the general course of the Norfolk and Western Railway. State highways 15 and 24 connect Buckingham with Dillwyn and Appomattox. East and south of Appomattox there are many good soil roads. There are good roads from Amherst to Appomattox via Gladstone and Bent Creek and from Shipman to Buckingham via Wingina. In general, the local roads west of the James are not as good as those on the east side. The constant improvement of roads is making it possible to use automobiles at all seasons of the year.

HISTORY

SETTLEMENT

James River has played an important rôle in the settlement of the region and in the location of towns, railroads, roads, and political boundaries. The early settlers in this region traveled mainly along the course of the river and located on its floodplains where they found excellent soil for corn and tobacco. Later a canal along the course of the river connected the sea coast with the interior and today the Chesapeake and Ohio Railway follows the river throughout this region. (See Pl. 1.) The river has long been a barrier to north and south travel and still divides this part of the State into two districts. Its course also determines political boundaries, for between the Blue Ridge and Chesapeake Bay, no county line crosses James River.

Until very recently, settlement of the eastern United States was controlled by the large rivers that rise in the Blue Ridge or Piedmont Plateau and flow eastward into the Atlantic. In New England, the pioneers were held close to the sea by mountains, but in the South early settlements were made inland along the rivers. In the Coastal Plain of Virginia, the rivers are wide, deep, quiet estuaries, favorable to navigation. Early settlements were made along the rivers and it was up their courses that pioneers first advanced westward into the wilderness. As a result, large plantations along the rivers quickly came into existence.

The English and French Huguenot settlers of eastern Virginia found cleared sections along the broad rivers occupied by peaceful Indians who were farmers and fishermen. To the west in the Piedmont plateau were scattered, roving, warlike tribes known as the Tuscaroras. They lived by hunting and frequently found it necessary to defend themselves against the powerful and aggressive Iroquois, who made sallies upon them through the gaps in the Blue Ridge.[6] When the French Huguenots reached Virginia in 1699, they found the lower course of James River occupied by English settlers. Sailing past Jamestown, they settled upon the abandoned site of an Indian village, Monacan Town (Manakan Town[7]). Near here the first coal mined in America was found and worked with profit.

The first permanent English settlement in America was made in 1607 at Jamestown, about 25 miles above the mouth of James River. By 1621, the most adventurous pioneers had advanced westward to the

[6] From linguistic evidence it has been suggested that the tribes of the Piedmont plateau were descended from the Dakotas. This fact emphasizes west to east migration of aboriginal tribes who came through gaps in the Blue Ridge. Thus the original settlement of this region was determined by the large eastward flowing streams that crossed the mountains. See Mooney, James, The Siouan tribes of the East; U. S. Bureau of Ethnology Bull. 22, pp. 40-42, 1894.

[7] Document of 1701 in Virginia Historical Collections, new ser., vol. 5, p. 42, 1886.

Fall Zone where the city of Richmond now stands. The Fall Zone cities prospered because they have been natural trading centers. For a long time the Fall Zone at the head of tide and navigation served as a barrier to westward migration, but as the Coastal Plain became more generally settled, a new advance westward began up the rivers and into the Piedmont Plateau.

In 1729, early settlers had moved up the James Valley as far as the present city of Lynchburg, and Buffalo Ridge and Elk Creek had been named.[8] Records of buffalo seen and killed by pioneers in Virginia and West Virginia have been published.[9] The pioneers also moved westward along the old trail between Monacan Town and Sapon but did not settle in that district in early days. By 1760, English settlers had passed through the James River gap in the Blue Ridge into the Valley of Virginia.

The section now occupied by Buckingham and Cumberland counties and a part of Appomattox County, lying between James and Roanoke rivers, was practically unsettled at this time. Between 1760 and 1775 this district became sparsely settled. According to a map in the census report of 1790, there were no towns at that time on James River west of Bremo. All of the main tributary streams on the west side of the river, such as Hardware, Tye, and Buffalo rivers and Rucker's Run, were named and correctly mapped. The region on the east side of the river in this district appears to have been practically unsettled and unknown.

In 1795, Lynchburg is said to have contained only five houses. By 1840, it had a population of somewhat less than 5,000 and was the fifth largest city in Virginia. The town was founded by John Lynch, an Irish Quaker, who ran a ferry there before the Revolution. The town grew rapidly. It became an important junction point on the turnpike to Knoxville, Tenn., and before 1845 it was the terminus of the James River canal. Lynchburg had a population of 40,661 in 1930. It is the largest city in the Piedmont Plateau between Pennsylvania and North Carolina. It is one of the important tobacco markets of the South, a railroad center, and consequently an important center of distribution.

An important factor in the industrial development of the region was the construction of the James River canal.[10] James River was the first river in the United States to be regularly navigated. In the early days navigation by large vessels ended at the Fall Zone at Richmond.

[8] The Valley of Virginia along the northwest foot of the Blue Ridge was a hunting ground visited by Indians from the east and the west. There they hunted buffalo, elk and other game. In early days, buffalo came through gaps in the Blue Ridge and occupied the Piedmont plateau.

[9] McWhorter, L. V., The border settlers of northwestern Virginia, pp. 377-387, Hamilton, Ohio, Republican Publishing Co., 1915.

[10] James River's importance again stressed: Richmond Times-Dispatch, pp. 1-2, Sept. 16, 1926.

Because of the numerous rapids in its course between the Fall Zone and Lynchburg, that part of the river was not navigable until the construction of the canal. In 1765, a company was formed for improving the section west of Richmond. It was succeeded by the James and Kanawha River Canal Company which began to construct the James River and Kanawha Canal in 1836. In 1872, the canal was completed from Richmond to Buchanan, Virginia, a distance of 195 miles. The canal rights were later bought by the Chesapeake and Ohio Railway Company and the old tow path now forms portions of the road-bed of the Railway.

There are 16 small river towns between Lynchburg and Howardsville. All except Gladstone and Norwood consist of a general store and a few dwellings. Gladstone is an important railway terminal along the Chesapeake and Ohio Railway between Richmond and Clifton Forge. Norwood, formerly known as New Market, is an old settlement where tobacco was sold.

With no important exception, these towns are located on the west side of the river. This is because bluffs more generally bound the eastern side and the floodplains, which comprise excellent farming land, are mainly on the west side of the river. (See Pl. 2.) Moreover, the land in Buckingham and Appomattox counties immediately east of the river is not favorable to agriculture and much of it is forested. Strips of fertile floodplain on the east side of the valley were quickly occupied by early settlers who were dependent upon the towns on the west side for supplies, and in many places were forced to take their produce across the river on flatboats to the railroad. Hardwicksville and Bent Creek are the only towns on the east side of the river in this region. They have grown up near old wagon bridges across the river into Appomattox and Buckingham counties. Hardwicksville is unfavorably situated near the base of bluffs and contains but three dwellings. Bent Creek is a village of about a dozen houses.

Important towns in this area east of James River are Appomattox, Concord, Pamplin, and Prospect. They are along the Norfolk and Western Railway and are the centers of farming districts. Appomattox, formerly known as Nebraska, is the most important town. The original town of Appomattox Court House was about 1½ miles northeast of this place. It was at "Old Appomattox" that General Lee surrendered on April 9, 1865. Because James River was a barrier to the advance of the Federal troops, Lee retreated from Richmond westward along the south side of the river until his forces were surrounded at Appomattox. The old bridges over the river at Wingina and Bent

Creek were destroyed by the Confederate soldiers to retard the Federal advance. The present bridge at Bent Creek, rebuilt several years ago, is said to stand upon the original stone foundations.

MINING

The mineral resources of central Virginia were discovered at an early date. Cleaveland[11] records the occurrence of magnetic and micaceous oxide of iron from Virginia, most probably from this section. Jefferson,[12] at an early date, described marble near the mouth of Rockfish River. Copper was mined previous to 1825 near James River in Amherst County.[13] Copper is said to have been mined and smelted before the Revolution, on Wreck Island Creek.

The first iron mined in the United States was mined in 1619 on Falling Creek in Chesterfield County, Virginia. Iron was needed for pots, ovens and wagon tires and, as the Piedmont Plateau became settled, charcoal furnaces were built to supply the local need for such products. Local limonite ores were used. Local limestone deposits were used for flux in this district and limestone was also burned for lime to be used in mortar. In 1880, there was a boom in the mining of iron and manganese in the James Valley and much ore was shipped.

The history of the extraction and use of iron ore, limestone, and other economic resources is discussed under "Economic Geology."

[11] Cleaveland, Parker, An elementary treatise on mineralogy and geology, Boston, Cummings and Hilliard, pp. 484, 488, 1816.

[12] Jefferson, Thomas, Notes on the State of Virginia, p. 26, Boston, Wells and Lilly, 1829.

[13] Robinson, Samuel, A catalogue of American minerals with their localities: 316 pp., Boston, Cummings, Hilliard and Co., 1825.

PHYSIOGRAPHY

PHYSIOGRAPHIC PROVINCES

The district covered by this report lies in the west-central part of the Piedmont province and a part of the eastern foothills of the Blue Ridge province. (See Fig. 1.) The Piedmont Plateau is coextensive with a great area of crystalline rocks, which extends southwest from New Jersey to central Alabama. It is bounded on the west by the Blue Ridge province and on the east by the Fall Zone along the inner margin of the Atlantic Coastal Plain. It is about 175 miles wide in southern Virginia, but tapers to a width of about 25 miles in northern Virginia.

PIEDMONT PENEPLAIN

GENERAL CHARACTER AND AGE

The rolling surface of the Piedmont Plateau bevels the upturned edges of gneisses and schists or truncates broad areas of igneous rocks, such as granite; hence it is an old erosion surface, or peneplain, which has since been uplifted and dissected to its present form. This peneplain extends from the Blue Ridge on the west to the Fall Zone on the east, where it is covered by Tertiary sediments. This surface has been correlated with the Valley-floor peneplain in the Valley of Virginia west of the Blue Ridge, and is generally considered to be of Tertiary age.[14]

The terms, Piedmont province and Blue Ridge province, are physiographic rather than stratigraphic and structural. The normal fault on the east side of Bull Run Mountain in northern Virginia and Buffalo Ridge in this region forms a convenient boundary between these two provinces. The Piedmont peneplain, however, extends to the west of this fault line. The Catoctin Mountain Border fault forms a convenient eastern boundary of the Blue Ridge province to a point south of Bull Run Mountain in this region. The Piedmont peneplain extends farther westward.

The peneplain slopes gently eastward from a general altitude of 900 to 1,000 feet in the Blue Ridge foothills, to an altitude of between 600 and 800 feet in Prince Edward, Appomattox, and Buckingham counties. It has an average gradient in this section of about 20 feet to

[14] Stose, G. W., Manganese deposits of western Virginia: Virginia Geol. Survey Bull. 23, pp. 16-24, 1922.
Renner, G. T., The Fall Line of the eastern United States: Science, new ser., vol. 66, no. 1711, pp. 356-357, 1927.
Wright, F. J., The older Appalachians of the South: Denison Univ. Bull., Jour. Sci. Labs., vol. 26, pp. 143-250, Dec., 1931; The newer Appalachians of the South: Idem, vol. 29, no. 13, pp. 1-105, Apr., 1934.

a mile. Farther east, its slope is even gentler. At the Fall Zone the peneplain has an altitude of 200 to 300 feet.

The Piedmont peneplain has been considerably dissected since its uplift, especially near large streams, such as James River and its tributaries. (See Pl. 2.) This is because sufficient time has elapsed since uplift to permit the main eastward flowing rivers to trench back to their headwaters in the Blue Ridge. When entrenchment along the larger streams passed the mouths of tributaries, the latter began cutting their channels headward and deeper while the main stream began to build a floodplain. Terraces along the larger rivers and their tributaries show that there has been more than one uplift since the development of the peneplain.

Character East of James River

East of James River, the peneplain surface between stream courses is generally monotonously flat, and is generally traversed by roads which extend for many miles with no exposure of bedrock. Outcrops are scarce except in valleys where the products of weathering have been partly removed since uplift of the peneplain and rejuvenation of the streams. The flat interstream divides are wide and extensive, and are about 500 feet above sea-level.

Character West of James River

The surface of the peneplain rises gradually towards the Blue Ridge and in many places extends well into the Blue Ridge province. It is not as well developed in the Blue Ridge province west of James River. (See Pl. 2.) It is from 700 to 800 feet above sea-level and is more dissected. Monadnocks become more abundant and higher west of the Catoctin Mountain Border fault. Near James River, these monadnocks are ridges, but farther west, in the massive and more uniform rocks of the Blue Ridge province, there is, at best, northeasterly alignment of ragged peaks.

Monadnocks

The surface of the peneplain is in places broken in this section by low peaks and short ridges, some of which rise rather abruptly from the plain. These elevations, however, are not well-defined ridges that can be traced for considerable distances. It is believed that they were left behind as monadnocks upon the old peneplain surface because they represent local areas of more resistant rock that were not entirely reduced during the formation of the peneplain. These monadnocks have sharp or gently rounded summits which rise to various heights. Sharp peaks are rare and occur only where the difference in resistance between the rocks of the monadnocks and those of the plain is uncommonly great.

Willis Mountain about 15 miles north of Farmville, is composed of a resistant kyanite-quartz schist and rises abruptly about 500 feet above the general level of the surrounding peneplain.[14a]

Spear Mountain, in Buckingham County, is higher than Willis Mountain but does not rise so abruptly from the peneplain surface. The Spear Mountain district consists of two short ridges along the prevailing strike of the rocks. The main ridge is composed of three distinct peaks rising about 800 feet above the surrounding country and is called Spear Mountain. It is underlain by a tough, crumpled, garnetiferous mica schist that may be more resistant to erosion than the rocks of the surrounding district.

Piney and Bald mountains, in Appomattox County, and Pilot Mountain, in Appomattox and Campbell counties, are underlain by garnetiferous and staurolite-mica schist. Long Mountain, southwest of Concord, which rises about 500 feet above the peneplain, is at the southwestern end of this belt.

The first long continuous ridge east of James River is Buffalo Ridge which extends continuously in a northeast direction from northeastern Amherst County to Mount Alto in southern Albemarle County. The ridge is composed of Wissahickon chlorite-muscovite schist, which is more resistant to erosion than the underlying limestone and greenstone schist on the east and the Catoctin greenstone and soapstone on the west. The ridge ends suddenly west of Walker Ford, where the mica schist is cut off by a prominent cross-fault.

Hawkins and Findlay mountains, southwest extensions of Ragged Mountain in Albemarle County, form a ridge in the center of a syncline of resistant Lower Cambrian quartzite which ends rather abruptly at Tye River.

West of Hawkins and Findlay mountains, the ragged foothills of the Blue Ridge rise as isolated peaks above the surface of the peneplain. A few miles farther west they coalesce and become connected with the Blue Ridge. They consist of the same type of crystalline schists and igneous rocks as those which underlie the peneplain surface.

RELATION TO THE BLUE RIDGE PROVINCE

The peneplain surface is terminated on the west by the Blue Ridge, into whose coves it appears to extend. The sudden break between the general level of the Piedmont peneplain at 900 to 1,000 feet and the steep, ragged peaks of the Blue Ridge 2,000 to 3,000 feet above that

[14a] Jonas, A. I., Geology of the kyanite belt in Virginia: Virginia Geol. Survey Bull. 38, pp. 1-38, 1932.

level, presents a beautiful and impressive contrast. (See Pl. 2.) (The Blue Ridge province appears to have been a high unreduced area, a remnant of an older peneplain at the time of the formation of the Piedmont peneplain.)

VALLEY DEVELOPMENT

DISTRIBUTION OF MAJOR VALLEYS

The master stream of this region is James River. Important tributaries from the Blue Ridge province to the northwest are Tye and Rockfish rivers. They have valleys very similar to that of James River and are likewise entrenched in the Piedmont peneplain.

There are no important tributaries to James River from the east in this region. Small streams, such as Stonewall, Wreck Island, and Bent creeks, flow across the strike of the rocks into the river. Large streams to the east, such as Appomattox, Slate, and Falling rivers, flow east. The valleys of the larger streams have the same general characters as those of the larger tributaries from the northwest.

JAMES VALLEY

James River rises far west of the Blue Ridge. It flows directly across the strike of the rocks to Lynchburg, where it turns northeast along the prevailing strike of the rocks, and maintains this course as far as Scottsville, a distance of 50 miles. Here it swings eastward in a large horseshoe bend and again flows directly across the prevailing strike to the Fall Zone at Richmond. (See Pls. 1 and 2.)

Between Lynchburg and Scottsville, James River is adjusted to the structure of the rocks, but it does not flow exactly parallel to the strike, because beds of rock commonly cross the stream at oblique angles. In this area the river is largely on limestone and greenstone schists which are less resistant to erosion than the other rocks of the region. This series trends northeasterly in a belt, between resistant Cambrian quartzite and Lynchburg gneiss of the Blue Ridge province and the tougher Wissahickon schists of Appomattox and Buckingham counties. At Mount Athos, the river parallels the Mount Athos quartzite, which forms a distinct ridge, east of the river as far as Gladstone, a distance of 16 miles. Loops of the river in places cross the strike of the schists on its west side, because these rocks are of nearly uniform resistance. Northeast of Gladstone there is no formation of sufficient resistance to affect the course of the river for any considerable distance.

Small tributary streams are well adjusted to the structure. Because of abrupt local variations in rock resistance, they generally turn northeast or southwest a short distance above their mouths and follow belts of less resistant rock. Hence the more resistant rocks of the Glenarm series, especially the quartzite, form ridges. The least resistant rock is marble, which commonly crops out in valleys and stream beds. It controls the course of many small streams, such as Owens Creek and a part of Stonewall Creek.

TERRACES

There are several distinct terrace levels in the James Valley. They are cut in crystalline rocks and appear as more or less discontinuous benches above the floodplain. They may occur on only one side of the valley at a given point, because the opposite valley wall at that place may be an undercut bluff so that lower terraces on that side have been entirely removed by stream erosion. On the terraced side, the valley slopes are generally more gentle and are farmed. Between Greenway and Caskie, the floodplain is narrow and bluffs rise abruptly from both sides of the river. Here the river has cut through a higher unreduced area on the old peneplain, forming a water gap.

The valley of James River appears to have been uplifted at least four times since the Piedmont peneplain was produced. The oldest stream level is about 150 feet above the river and is much dissected; the intermediate level is about 75 to 100 feet above the floodplain; and a lower level, frequently absent, is about 25 to 50 feet above the floodplain. (See Pl. 2.) The geological age of these erosion levels is not known. Wentworth[15] believes that they are pre-Pleistocene because they do not carry striated cobbles, such as are found in terraces along the lower James which he ascribes to ice-rafting during Pleistocene time.[16]

The terrace flats are covered with a thin mantle of pebbles, cobbles and boulders. All are well rounded and most of them are hard gray quartzite. These materials represent only the coarser stream deposits, as the finer materials have been washed into the river during the long intervals of entrenchment following the uplifts. Terrace deposits are locally thicker and better preserved, as for example near the mouth of Little Beaver Creek, southeast of Lynchburg, where brown sandstone pebbles derived from the Triassic (Newark) rocks may be found at a point about 100 feet above the river. Such pebbles are abundant on a similar level north of Buffalo Springs station. Both of these occurrences are west of any known outcrops of Newark sediments. Gravel deposits also occur on Tye River near the mouth of Rucker Run, west of Norwood.

Two of the terrace levels on James River can be seen from the bridge at Wingina. The upper is 100 feet or more above the flood-

[15] Wentworth, C. K., Personal communication, 1929.

[16] Wentworth, C. K., Sand and gravel resources of the Coastal Plain of Virginia: Virginia Geol. Survey Bull. 32, pp. 46-47, 111, 1930.

plain and corresponds to the intermediate level. On the east side of the floodplain, it is a narrow bench but on the Wingina side, it is well developed and its surface is mantled by round cobbles and pebbles. The terrace is considerably dissected. About 50 feet below this level, there is a second terrace on the west side of the river. It is narrow, being in no place more than 100 feet wide, and is generally discontinuous. It slopes towards the river, the lower edge being about 25 feet above the floodplain.

Most of the floodplain is on the west side of the river and it is about one-third of a mile wide. The river is about 200 feet wide and flows between low banks that are generally 6 to 10 feet high. The floodplain is divided into two levels by abrupt banks about 10 feet high which are 40 to 100 feet back of the stream banks; thus the main floodplain has the appearance of an alluvial terrace. Because the walls of this terrace may prove insufficient to hold the river during flood stages they are locally called "False Banks." The floodplain below the "False Banks" is farmed but is very often flooded. (See Pl. 2.)

Three terrace levels can be seen from the James River bridge between Bent Creek and Caskie. The highest level is perhaps 150 feet above the river and is best developed on the west side, where it is mantled by cobbles. The lowest level is found on this side. It is narrow and is about 20 feet above the floodplain. The sloping intermediate level is 20 to 50 feet above the lower level.

Main Street, in Lynchburg, is along the lower edge of a sloping flat, about 50 feet above the river, which may correspond to the intermediate level. Church Street, to the south, follows the southern side of this surface. Court Street, the next street to the south, is about 100 feet above Church Street and appears to be on the highest level. Looking north from Court Street across James River, one may see this level obscurely shown and considerably dissected above the river bluffs in Madison Heights.

GEOLOGY AND PETROLOGY

INTRODUCTORY STATEMENT

This district is separated into an eastern and western part by the Catoctin Mountain Border fault. (See Pl. 1 and Fig. 1.) The rocks of both areas are mostly pre-Cambrian igneous and metamorphic rocks, but they are distinctly different in character on opposite sides of this fault.

The area west of the Border fault contains the Lynchburg gneiss and several types of igneous rock, namely, hornblende gneiss, soapstone and associated rocks, hornblende gabbro, Lovingston granite gneiss, pegmatite, and Catoctin schist, all presumably of pre-Cambrian age.

The pre-Cambrian metamorphic rocks on the east side of the Border fault belong in the lower part of the Glenarm series, which here consists of the Mount Athos formation, Cockeysville marble, and Wissahickon formation. The principal pre-Cambrian igneous rocks in this part of the district are various gneisses and granites, quartz veins, hornblende gabbro, and some greenstone volcanics.

Lower Cambrian and Triassic sedimentary rocks are found unconformably upon the pre-Cambrian rocks. The Cambrian rocks are west of and the Triassic rocks are east of the Border fault. There are also intrusive dikes of Triassic age. (See Pl. 1.)

PRE-CAMBRIAN METAMORPHIC ROCKS OF SEDIMENTARY ORIGIN

LYNCHBURG GNEISS

Definition and distribution.—This term was first applied by Jonas[17] to a belt of biotite gneiss and schist west of the Catoctin Mountain border fault, which extends from near Schuyler in Nelson County, southwest through Lynchburg into North Carolina, where it appears to be at least in part equivalent to the Carolina gneiss of Keith. It is bounded on the east by the Catoctin Mountain Border fault and is intruded by rocks that form the core of the western Piedmont and Blue Ridge provinces. Just north of Lynchburg it occupies a belt 5 to 6 miles wide which widens to at least 20 miles in southern Virginia. (See Pl. 1.)

Occurrence.—The Lynchburg gneiss is typically exposed in an anticline on the north side of James River at Lynchburg. North of Lynchburg it becomes generally covered by Lower Cambrian sediments.

[17] Jonas, Anna I., Geologic reconnaissance in the Piedmont of Virginia: Geol. Soc. Am. Bull., vol. 38, p. 845, 1927.

Narrow bands crop out on both sides of Hawkins Mountain. The easternmost one is intruded with basic rocks and is a part of the "Soapstone belt." (See Pl. 1.)

Megascopic character.—The Lynchburg gneiss consists of biotite gneiss and schist extensively intruded by igneous rocks which have in many places produced contact metamorphism. Where not affected by intrusive rocks, it is a fine-grained biotite gneiss or schist. The massive gneissoid beds contain more feldspar. The gneiss is light to dark blue-gray, and becomes more lustrous and schistose where micaceous. White granular quartz, feldspar, biotite and muscovite may be identified with a hand lens. (See Pl. 3A.)

The quartz monzonite and pegmatites found near the western border have produced characteristic contact metamorphic effects, which are discussed under "Lovingston granite gneiss" and "Pegmatites." Zones of similar metamorphism, in which the gneiss is pseudoporphyritic due to the development of garnet and biotite, occur where no intrusive rocks can be found. This metamorphism was probably produced by underlying intrusive rocks. The gneiss in places contains hornblende. There is evidence to show that the hornblende was not introduced by the intercalated hornblende gneiss but was derived from granitic rocks intruded into Lynchburg gneiss containing interlayered hornblende gneiss.

Microscopic character.—The most important constituents of the Lynchburg gneiss are feldspar, quartz and mica. Feldspar is present in all thin sections but is much less abundant in the schistose facies. Several determinations indicate that it is near albite in composition. Several varieties of biotite occur, the most common being yellow-brown. At the quarries on the north side of James River at Lynchburg, where the gneiss is distinctly micaceous, the rock contains a very pleochroic biotite which is brown to almost black. Greenish to brown biotite was found in thin sections of the gneiss from Variety Mills. Muscovite is locally an important constituent, especially in the schists, where it appears to have been formed from the feldspar during regional metamorphism. It is as abundant as biotite in the gneiss on the eastern flank of the Lynchburg anticline. In places, it is not oriented with the schistosity but cuts across biotite flakes, and has been formed later than the period of regional metamorphism. Small garnets are common in all thin sections. Secondary minerals are uncommon and unimportant.

Minerals of igneous metamorphism.—Certain zones in the Lynchburg gneiss are characterized by the development of biotite, garnet, and in places microcline. These minerals were more probably produced by granitic intrusions than by regional metamorphism. Such a zone extends along the east flank of Hawkins Mountain and is found in the county road at Variety Mills, at the footbridge over Piney River near Phoenix, and farther to the southwest. (See Pl. 3A.) The microcline occurs in a crumpled schist at Variety Mills and on the Amherst-Gladstone road west of Buffalo Ridge, as small, white, capsule-shaped bodies. The gneiss also contains numerous euhedral garnets and many biotite flakes. The garnet and biotite are crowded with inclusions of quartz and older minerals. Biotite occurs in large, ragged, yellow-brown plates that are poikilitic and contain many pleochroic halos around zircon inclusions. Some zones contain considerable hornblende where the gneiss is associated with bands of hornblende gneiss. Large grains of twinned calcite are common in thin sections.

Contact metamorphic effects directly associated with intrusive quartz monzonite and pegmatite are discussed in the sections on those rocks.

Relations and age.—The Lynchburg gneiss and its intrusive masses are unconformable beneath the Lower Cambrian slates and arkoses west of the Catoctin Mountain Border fault.

GLENARM SERIES

GENERAL FEATURES

In the Piedmont province east of the Catoctin Mountain Border fault there is a thick series of metamorphosed pre-Cambrian sediments and greenstone flows that has been ascribed by Jonas[18] to the Martic thrust block. In this area the basal sediments of the Glenarm series overlie greenstone lava flows and comprise, from the base upward, the Mount Athos formation, the Cockeysville marble, and the Wissahickon formation. The latter is much thicker than the others and covers broad areas in the Piedmont province. (See Pl. 1.)

MOUNT ATHOS FORMATION

General features.—The formation overlies greenstone flows and underlies the Cockeysville marble. It consists of quartzite, muscovite schists, and talcose or sericitic schists. The schists are in places tuffaceous and are locally graphitic. Beds and stringers of hematite and non-titaniferous magnetite are especially common in the quartzite facies. There is more schist than quartzite in the formation.

The formation is about 200 feet thick but shows some variation in thickness from place to place. Its most characteristic feature is a zone of quartzite, or quartzite and quartz schist, which is nowhere more than 100 feet thick. At Mount Athos, in Campbell County, this quartzite zone lies near the middle of the formation. (See Pl. 4A

[18] Jonas, A. I., op. cit., pp. 837-846.

and Fig. 2.) At Stapleton, quartzite lies upon greenstone and is separated from overlying Cockeysville schist by slaty talcose or sericitic schist. In the northern part of this region, quartzite appears to make up a larger part of the formation but schist bands are more numerous. It contains graphitic bands west of Greenway and Allen Creek.

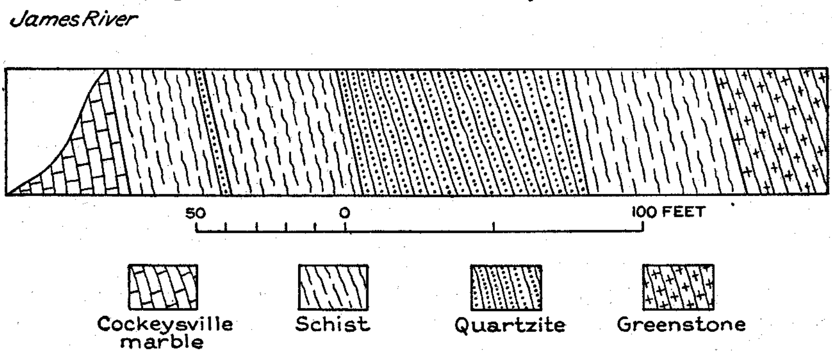


Figure 2.—Cross section of Mount Athos formation at Mount Athos, Campbell County.

Near James River in Appomattox County, east of Stapleton and Galts Mill, the schist resembles greenstone and is tuffaceous. Near Evington, in Campbell County, basal schist bands alternate with thin bands of greenstone schist, indicating that deposition of the parent sediments began here before the cessation of volcanic activity. Variations in composition in general occur more rapidly from west to east than along the northeasterly strike. Good exposures are not found northeast of Greenway. Northeast of Norwood, the formation is concealed by overlying formations.

At Mount Athos, this formation is well exposed and may be conveniently studied. The overlying marble and underlying greenstone are also well exposed. (See Pl. 4A and Fig. 2.) The Mount Athos formation occupies the same position in regard to the Cockeysville marble as does the Setters quartzite in Maryland. The Setters formation, however, lies unconformably upon Baltimore gneiss, whereas the Mount Athos formation overlies greenstone lava flows, which may or may not be at the base of the Glenarm series.

Megascopic character.—Quartz-mica schist, slaty talcose schist, and quartzite compose the Mt. Athos formation. Certain beds of the schist contain numerous large and small biotite crystals and garnets.

The quartzite is conglomeratic and between Galts Mill and Greenway contains pebbles as much as three-quarters of an inch in diameter. (See Pl. 5A.)

The quartz grains and pebbles are well rounded. Where unmashed, they are generally deep blue or violet, but mashing leaves the fragments milky to white. The pebbles are much flattened, and many are mashed into flat discs or are completely granulated. In other places, the quartzites are mashed to a fine white quartz rock which weathers to a white or gray gritty dust. This is the peculiar "quartz rock" of Rogers.[19] Where unweathered, the iron miners called it the "corundum quartzite."

In the eastern exposures of the formation between Beckham and Bent Creek, the most characteristic rock is a crumpled white quartz-muscovite schist some of which contains small flakes of biotite. Muscovite schist in places alternates with beds of schist containing abundant biotite.

Microscopic character.—Several varieties of micaceous and talcose schists are recognized in thin sections. Quartz-muscovite schists are dominant in Appomattox County. (See Pl. 3B.) Quartz-muscovite or sericite schists with biotite porphyryoblasts are more characteristic of the formation as a whole.

East of Stapleton and Galts Mill, the quartz-muscovite or muscovite schist appears to grade along the strike into water-laid tuffs. Slaty talcose schists are associated with beds of iron.

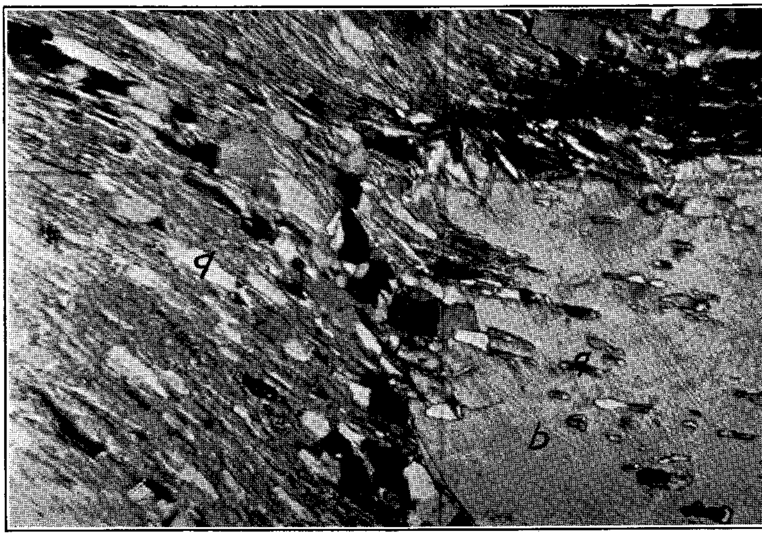
At Mount Athos, the schist is coarser grained and the biotite crystals are larger. In thin sections, the biotite appears in large ragged crystals that include the other minerals. Quartz and muscovite compose most of the rock. Small, rounded tourmaline prisms are present.

A short distance northeast of Mount Athos the schist becomes distinctly tuffaceous. A thin section of this tough, green schist from the upper part of the formation near Stapleton consists mostly of twinned and untwinned feldspar and many ragged flakes of brown biotite. Yellow epidote and colorless zoisite are very abundant. Blue-green amphibole occurs sparingly. Glass or fragmental volcanic materials are not recognized. The rock approaches the composition of the underlying greenstone. The mineral association is one that would be expected from the metamorphism of a basic tuff mixed with some argillaceous sediment.

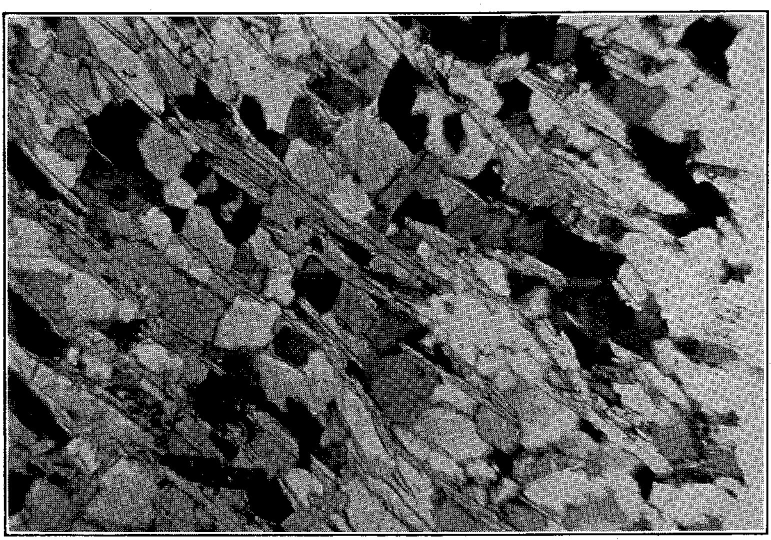
Thin sections of the quartzites show them to be composed mostly of quartz with more or less muscovite. Feldspar, generally plagioclase, is common. Accessory minerals are magnetite, hematite, and pyrite. Some calcite may occur. The quartz grains and pebbles show all stages of mashing, from those having wavy extinction to those completely granulated. The rock is generally somewhat schistose, due to the presence of mica.

Mount Athos area.—At Mount Athos, 6 miles east of Lynchburg, at the crossing of the Chesapeake and Ohio and the Norfolk and Western railways, are excellent exposures of this formation. Good exposures are found east of Mount Athos along the highway and along

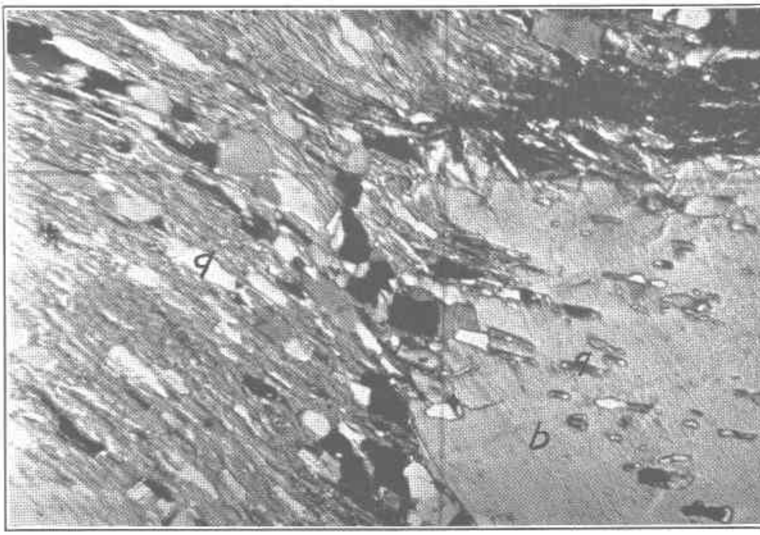
[19] Rogers, W. B., A reprint of annual reports and other papers on the geology of the Virginias: p. 302, New York, D. Appleton and Co., 1884.



A. Lynchburg gneiss on Tye River near Phoenix, Nelson County. The larger grains of the groundmass are quartz (q) and most of the remainder is muscovite. The large biotite porphyroblast (b) includes these minerals. Crossed nicols; X 50.



B. Quartz-muscovite schist north of Mount Airy Church, Appomattox County. It is probably from the Mount Athos formation. Crossed nicols; X 42.



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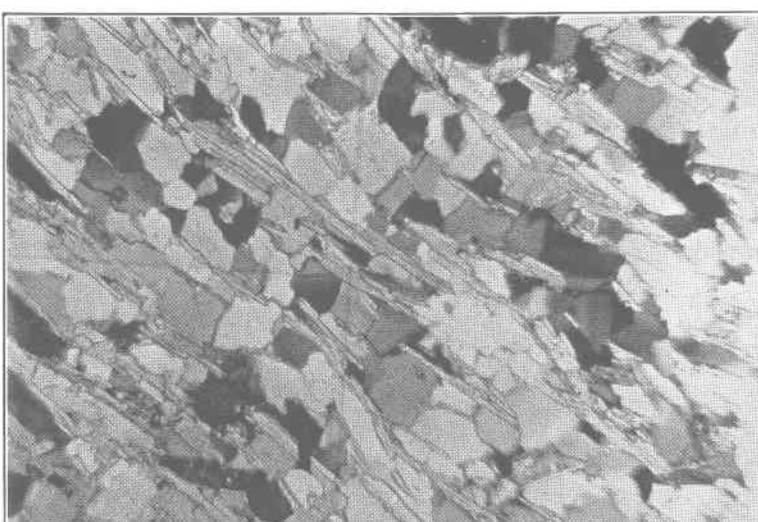
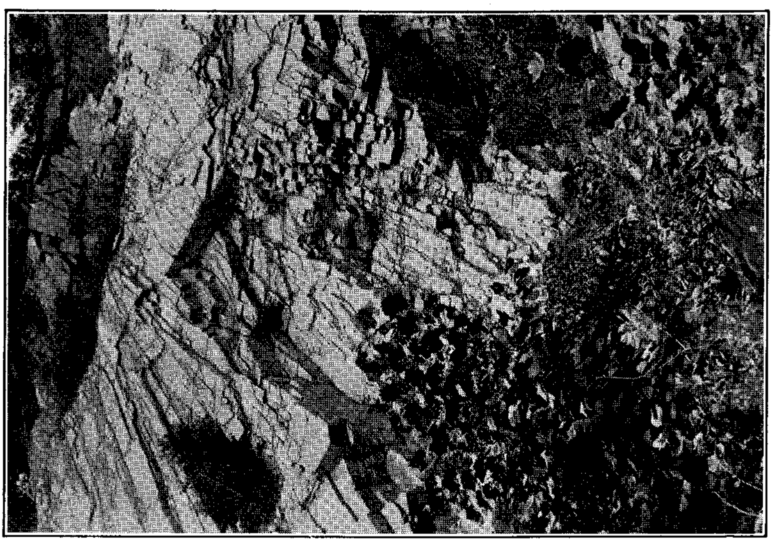
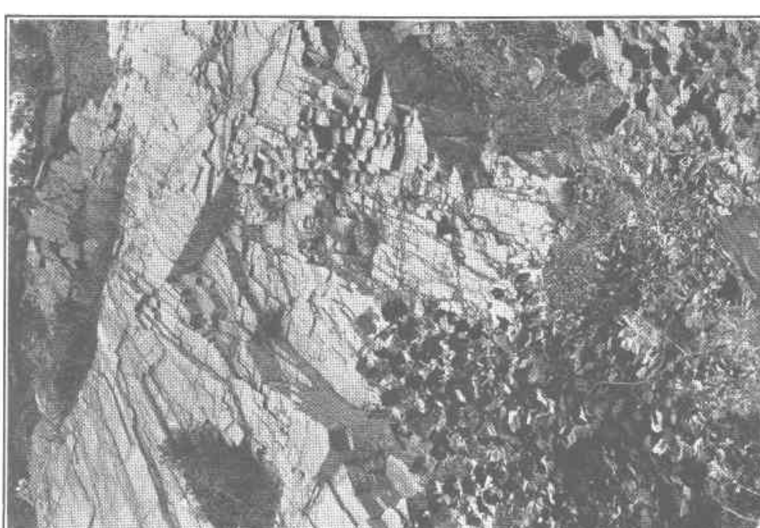


B. Quartz-muscovite schist north of Mount Airy Church, Appomattox County. It is probably from the Mount Athos formation. Crossed nicols; X 42.



A. Principal quartzite member of the Mount Athos formation, Mount Athos, Campbell County. (Photo taken in a quarry with camera tilted upward.)

B. Mount Athos quartzite on the south side of James River below Norwood.



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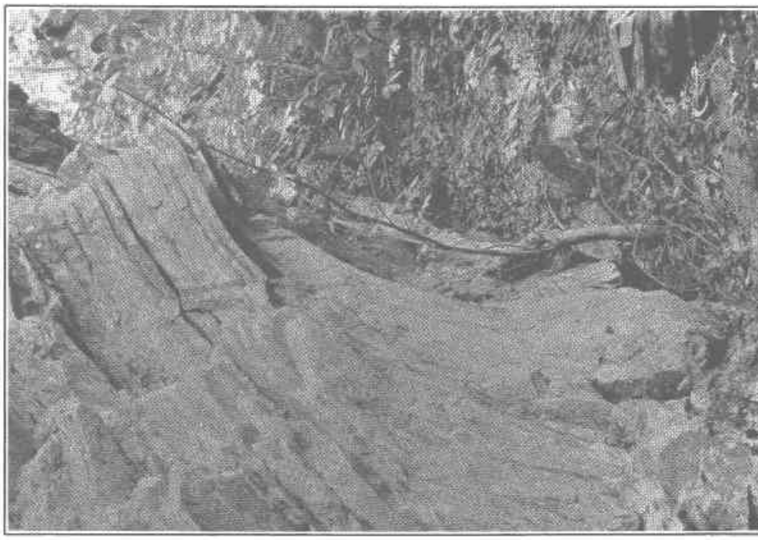


B. Mount Athos quartzite on the south side of James River below Norwood.

the Norfolk and Western Railway between Lynchburg and Appomattox. The total thickness of the formation at Mount Athos is estimated to be between 175 and 200 feet. It consists of beds of quartzite flanked on both sides by mica schist. The quartzite is best exposed in the quarry just north of the station, where it has an estimated thickness of about 80 feet. (See Pl. 4A and Fig. 2.)

Mica schist, speckled with flat tabular prisms of biotite, constitutes the upper part of the formation and lies against quartzite on the west wall of the quarry. This schist is probably about 80 feet thick. It contains a bed of quartzite about 3 feet thick which lies about 50 feet above the main beds of quartzite. The lower 50 feet of the formation is not well exposed. In the east wall of the quarry it is a fine slaty schist speckled with numerous small biotite crystals. Thin, slaty quartzite in the middle of the formation is completely exposed. It is broken into rectangular blocks by closely spaced joints that intersect nearly at right angles.

In hand specimens the quartzite is grayish-white and shows fine grains of sugary white quartz and in some places large grains of blue quartz and pink feldspar. Some sericite and small specks of magnetite and pyrite are present, as are also some plagioclase and small patches of calcite. In thin section, ungranulated grains are optically distorted or partly granulated. Pyrite in small grains and cubes and magnetite are common.

A thin section from the schist in the upper part of the formation near the river is a quartz-mica schist with large ragged biotite prisms. (See Pl. 3B.) The biotite is poikilitic and includes quartz and other minerals of the schist arranged parallel to the schistosity of the rock.

Quartzite and schist infolded with greenstone are well exposed along the State highway north of Beaver Creek. The formation has the same general character as at Mount Athos, but some beds of the lower mica schist have small garnets and biotite porphyroblasts altered to chlorite.

Stapleton area.—Excellent exposures of the Mount Athos formation occur along Porridge Run northwest of Stapleton station in Amherst County, where the formation is repeated several times by folding. (See Fig. 3.) Except at the Maud mines, the quartzite is much mashed and granulated and its conglomeratic character is obscured. The basal beds are mashed quartzite, less than 100 feet thick, lying upon greenstone. This contact is shown a short distance east of the Maud mines where Porridge Run crosses the beds. The quartzite is white to grayish-white and breaks into platy blocks which have been affected by shearing. The grains vary in coarseness, due to different degrees of mashing. The upper part of the formation is a finely crystalline slaty schist with biotite porphyroblasts.

At the Maud mines, a short distance to the west, the quartzite is conglomeratic and has been thickened by folding. (See Fig. 3.) Thin beds in the schist are completely granulated or converted into quartz-mica schist. Infolded with conglomerate, quartzite and schist are bands and numerous thin stringers of iron-bearing rock. (See Fig. 11.)

Riverville area.—Good exposures of the Mount Athos formation occur in the Riverville syncline, for example, along the county road[19a] west of Riverville, where the formation is infolded with Cockeysville limestone. Between Riverville and Saint James, this limestone crops out in three narrow synclines. (See Fig. 6.)

The formation, which consists of schist, conglomerate, and quartzite, has been much thickened by folding. The schist is greenish, slaty, and talcose. Some contains, in places, large and small biotite crystals which are not always visible in hand specimens. The schist contains several beds of quartzite, 3 to 10 feet thick. About 500 feet west of Saint James, occurs 50 feet of greenish-white talc schist, which is locally almost a pure talc. It is not gritty and weathers to a white powder. Some of the thick quartzite beds are conglomeratic and others are mashed to fine-grained white or blue-gray quartzite.

Topography and soils.—The

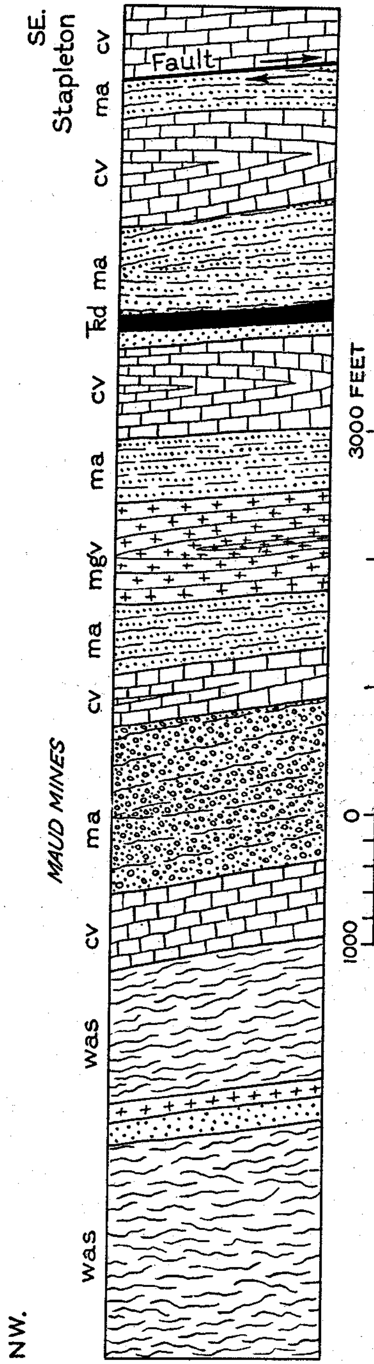


Figure 3.—Cross section of the Glenarm series along Porridge Run west of Stapleton, Amherst County. mgv, greenstone; ma, Mount Athos formation; cv, Cockeysville marble; was, Wissahickon formation; Rd, Triassic diabase dike.

[19a] County as used in this report applies to former county roads now maintained by the State Department of Highways.

greater resistance of the quartzite to erosion causes it to crop out as low, narrow, distinct ridges. Higher and wider ridges, such as Round Top near Galts Mill and Mine Ridge west of Greenway, are found where the formation is thickened by folding. Soils derived from the quartzite are poor and not well suited to agriculture.

COCKEYSVILLE MARBLE

General features.—This formation consists of blue marble (generally called limestone), white and pink marble, and schist. It crops out in a long narrow belt that extends from southern Albemarle County, southwestward into Pittsylvania County.[20] This belt in the central part of the State has an average width of about 7 miles. The formation is thickest, and marble and limestone crop out most abundantly, in Campbell, Appomattox, Amherst, Nelson, and Buckingham counties. (See Pl. 1.)

Definition and correlation.—The Cockeysville marble[21] was named from a typical occurrence at Cockeysville, Baltimore County, Maryland.

The pre-Cambrian age of the formation in eastern Maryland and Pennsylvania has been established by Knopf and Jonas,[22] who have shown that it grades through a calcareous mica schist into overlying Wissahickon schist, which in Carroll and Frederick counties, Maryland, is overlain unconformably by Lower Cambrian rocks.

In 1926, Jonas[23] described white crystalline marble between Potomac River and Aldie, Loudoun County, Virginia, which is like the Cockeysville marble of Maryland and which underlies pre-Cambrian metabasalt flows. The belt of crystalline limestone and marble extending from Albemarle County southwestward in Virginia was also considered by Jonas to be of Cockeysville age.

The so-called limestone is true marble, being crystalline and containing mica, a product of regional metamorphism. As blue or blue-gray marble is generally called limestone in this district, it has been found convenient to retain the term.

Occurrence.—The Cockeysville marble occurs in central Virginia east of Buffalo Ridge in a belt about 4 miles wide, which is followed by James River. This belt consists of interfolded marble, quartzite, mica schist and greenstone. The marble overlies the Mount Athos quartzite and underlies Wissahickon biotite schist. The formation crops

[20] See Geologic map of Virginia, Virginia Geol. Survey, 1928.

[21] Mathews, E. B., and Miller, W. J., Cockeysville marble: Geol. Soc. America Bull., vol. 16, pp. 347-366, 1905.

Knopf, E. B., and Jonas, A. I., The geology of the crystalline rocks of Baltimore County: Maryland Geol. Survey Report on Baltimore County, pp. 162-166, 1929.

[22] Knopf, E. B., and Jonas, A. I., Stratigraphy of the crystalline schists of Pennsylvania and Maryland: Am. Jour. Sci., 5th ser., vol. 5, pp. 43-44, 1923.

[23] Jonas, A. I., Geologic reconnaissance in the Piedmont of Virginia: Geol. Soc. America Bull., vol. 38, pp. 844-845, 1927.

out chiefly in narrow synclinal belts which are offset by many faults. Near the borders of the belt, as west of Norwood and at Wingina, the marble is exposed in anticlines and is surrounded by Wissahickon schist. (See Pl. 1.)

The blue limestone and white marble invariably crop out in valleys. Where the formation crosses highlands, the soluble constituents have been removed near the surface and schist rather than marble is commonly found. Exposures of limestone range from a few to several hundred feet in width and can be traced along the strike for distances ranging from several feet to several miles. (See Pl. 14.) Blue, finely crystalline marble is more common than the white variety and is, as a rule, more continuous along the strike.

Thickness.—The thickness of the Cockeysville marble can not be certainly determined. Where impure, it is a schist that is difficult to separate from the overlying Wissahickon formation. In some localities, as in the westernmost belt near Buffalo Ridge, it is composed mostly of schist. In other places, as east of Beckham, Appomattox County, the formation is white marble at least 600 feet thick. At Gladstone (Fig. 8), Greenway, and on Stonewall Creek in Appomattox County (Fig. 4), blue, crystalline limestone, which makes up a large part of the formation, is 250 to 350 feet thick. In most places, it is impossible to determine the amount of thickening by folding. It is estimated that the formation ranges from 250 to less than 1,000 feet thick and has an average thickness of about 600 feet.

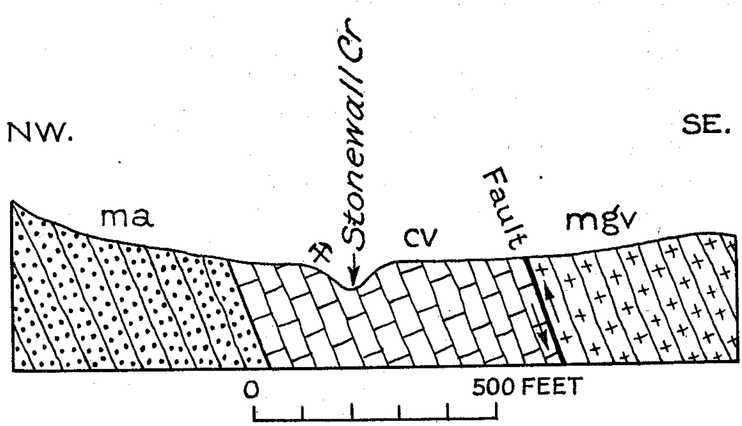


Figure 4.—Cross section on Stonewall Creek east of Stapleton, Appomattox County. mgv, greenstone; ma, Mount Athos formation; cv, Cockeysville marble.

Relation to enclosing formations.—The Cockeysville marble generally grades through an impure zone into Wissahickon schist, but in places the change is abrupt. Along the county road between Greenway and Buffalo Springs and on the west side of Owens Creek, talcose Cockeysville schist grades into phyllitic, green, chlorite Wissahickon schist. Near the contact zone, the Cockeysville schist contains small lenses of white dolomitic marble. The contact between the two formations is exposed near the base of bluffs on Hackett's Creek at Hardwicksville. The upper layers of the Cockeysville are gray-white dolomitic marble containing abundant sand grains.

At Mount Athos and at Gladstone, the Cockeysville marble is separated from quartzite in the underlying Mount Athos formation by a zone of mica schist. (See Figs. 2 and 8.) At Greenway, Norwood, and east of Beckham, marble containing abundant quartz grains lies upon quartzite.

Limestone.—The limestone ranges from dark-blue and light-blue to gray crystalline, slaty to massive rock. Blue slaty limestone is common. (See Pl. 14.) The gray limestone is compact to finely granular. Bedding planes are frequently obliterated in the slaty limestone which has a satin-like luster on the cleavage due to the development of mica. Brown mica occurs in the blue limestones and in places, as southeast of Mount Athos, it is sufficiently abundant to make the rock schistose. (See Pl. 6A.) Cubes of pyrite occur sparingly. Some rutile was found in the limestone just east of Stapleton. Veins and small lenses of white to pink calcite and milky quartz occur in all exposures.

Schistose beds are common in the limestone and thin, sandy beds occur in places. Near Mount Comfort church on a tributary to Wreck Island Creek, blue limestone containing biotite grades laterally into biotite-quartz schist. Thin sections show all gradations from nearly pure, granular, blue limestone and white dolomitic marble to quartz-mica schist and talc-quartz schist. These rocks are coarse to fine grained and show complete recrystallization of the calcareous and argillaceous constituents and granulation of the quartz grains. The purer limestone consists of calcite with some dolomite and quartz grains, and small amounts of mica. Quartz grains, mica and calcite occur in bands in some of the limestone and thus indicate the original bedding. Many of the cleavage planes and twinning lamellae in the carbonates are twisted, especially in the blue, slaty limestone. Mica occurs as wisps and large plates which include other constituents. It is a faintly colored variety resembling phlogopite, having yellowish pleochroism that is especially strong in halos around inclusions of zircon.

Marble.—The marbles are generally white to cream-colored, but some are pink and yellow. They vary from fine-grained and compact to coarsely granular masses. The masses of fine, compact, white to cream-colored marble are dolomitic. Some have been brecciated and recemented with dolomite, as at Norwood, or with coarsely crystalline white to pink calcite, as on the Cunningham property below Norwood. (See Pl. 6B.) On the Cunningham property and at Howardsville, the blending of several varieties produces a beautiful variegated marble.

Quartz is a common impurity in the marble. Grains of blue quartz are so abundant in certain beds that upon weathering the rock resembles a quartzite. Sandy layers are found in the marble at Norwood, Gladstone, and Hardwicksville but are not conspicuous or thick. Some beds of quartzite or quartz-muscovite schist also occur, as at Norwood. In places, as at Ninemile bridge below Lynchburg, the rock is white, talcose schist containing more sericite than dolomite. Pyrite occurs sparingly.

Under the microscope, the magnesian marble resembles the blue crystalline limestone. It has less mica, although talc and muscovite are rather common. It is also massive.

The beds of white marble have no definite stratigraphic position in the formation. They are interbedded with schist or with limestone and schist, as along the county road between Caskie and Gladstone. White marble occurs also in lenslike masses, a few feet wide, in schists and blue limestones along the Chesapeake and Ohio Railway near Buffalo Springs station. One marble lens 12 feet thick extends from the railway cuts at James River, southwestward for about an eighth of a mile, where it is exposed in a small tributary to Owens Creek.

Talcose schist.—Heavy, silvery-green, talcose schists are generally associated with the marble and limestone. Upon weathering they become light-colored. Excellent exposures are found between Norwood and Buffalo Springs station, where the schists alternate with bands of limestone and marble. Several thin sections show this rock to be composed chiefly of alternating bands of talc or sericite and quartz. Secondary calcite occurs as rhombs and irregular grains which are crowded with inclusions and which have crystallized between the foliae of the schists. These schists were derived from impure dolomitic limestone.

Chemical composition.—The rocks of the Cockeysville formation range from nearly pure limestone and dolomite to impure schist. They have been successfully burned for lime throughout the region. The dense, white marble contains a high but variable content of magnesium carbonate. The coarsely crystalline, white and pink marbles (Pls. 6B and 14B) contain a high percentage of calcium carbonate, but such deposits are secondary, in general filling fractures. Detailed analyses of the limestones and marbles are given in Tables 1 and 2.

Igneous metamorphism.—Dikes of Triassic diabase cut the marble but have produced no contact effects. Veins of quartz intrude white marble east of Beckham, and small segregations of hematite occur in the marble. Bornite, chalcopyrite and hematite are associated with the quartz stringers. A gray marble at Gladstone contains some thin bands of sphalerite. Between Gladstone and Caskie, blue limestone has been locally converted to a hornblende schist. No intrusive rocks were found near these outcrops.

Topography and soils.—The Cockeysville marble produces narrow lowlands between quartzite ridges. The limestone and marble invariably crop out in valleys. The limestone and associated schist weather to a stiff blue clay which may be the only evidence of the formation in some valleys. The limestone soils afford excellent farm lands. Public roads rarely follow limestone valleys.

WISSAHICKON FORMATION

Definition and correlation.—The schists and gneisses of sedimentary origin east of James River in this district are considered equivalent to the Wissahickon formation of Maryland and Pennsylvania. This formation in Virginia was first described by Jonas[24] who traced it from Maryland.

General character and relations.—The Wissahickon formation is a part of the Glenarm series in Maryland and Pennsylvania, where it is divided by Jonas and Knopf[25] into an oligoclase-biotite schist facies and an albite-chlorite schist facies. Both of these facies extend into Virginia. The area described in this report lies for the most part in the western belt which contains the facies of low-grade metamorphism.

BIOTITE-MUSCOVITE-CHLORITE SCHIST

Distribution and character.—The biotite-muscovite schists are in places feldspathic and chloritic and contain much garnet, staurolite, and magnetite. Biotite and garnet are extensively altered to chlorite, and the staurolite to sericite. The schists crop out in a long belt east of James River from the vicinity of Spear Mountain in Buckingham County southwestward beyond Long Mountain in Appomattox County. (See Pl. 1.) This belt is mapped as garnetiferous Wissahickon schist. Two other belts of similar rock which contain more staurolite and garnet, join in Piney Mountain in Appomattox County. The eastern belt extends southwest to a point several miles beyond Appomattox and the western one extends through Spout Spring and Pilot Mountain.

The schist in the belt from Spear Mountain southward to Long Mountain has dark-red garnets scattered rather sparingly through it. Staurolite is generally absent, but at Rustburg garnet and staurolite are common. In Spear Mountain, the rock is a tough, green, crumpled schist or gneiss containing considerable garnet and magnetite and some

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

[25] Knopf, E. B., and Jonas, A. I., Geology of the McCalls Ferry-Quarryville district, Pennsylvania: U. S. Geol. Survey Bull. 799, pp. 14, 25-35, 1929.

plagioclase. On David Creek, southwest of the mountain, the schist is green, slaty, and speckled with magnetite porphyroblasts. In some places, as in Piney and Pilot mountains, staurolite and garnet are very abundant. In the railroad cut on the northwestern edge of Appomattox, large crystals of garnet and staurolite can be picked from the weathered rock. Other typical exposures occur at Spout Spring, where the staurolite is generally altered to sericite.

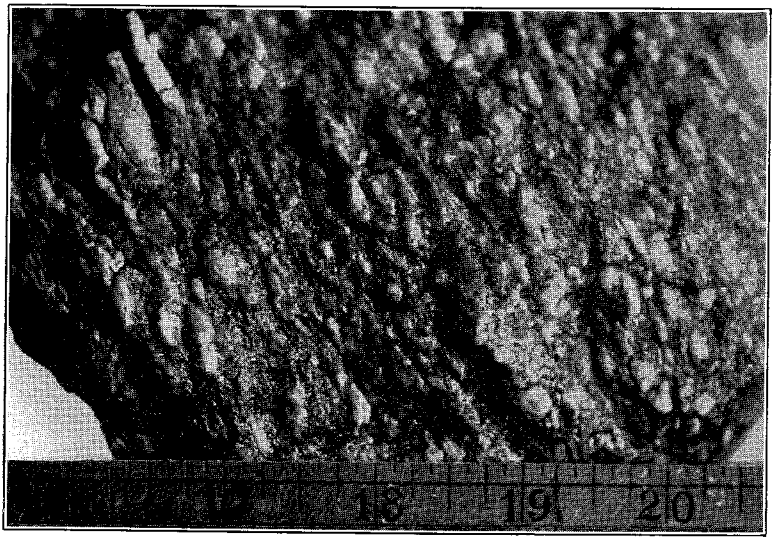
The largest staurolite crystals average about half an inch in length, but most of them are much smaller. They are dark-brown to black, and many are covered with an alteration product. (See Pl. 7A.) Staurolite schist is rare east of Appomattox.

Megascopic character.—The fresh rock is a tough, crumpled, dense, fine-grained, greenish to blue-gray schist. It oxidizes to a golden-brown and becomes red when thoroughly decayed. It contains biotite, muscovite, and chlorite. In places red garnet, brown to black staurolite, and magnetite are abundant. The garnet is more widely distributed than the staurolite and is rarely absent. It is generally scattered through the rock in rounded subhedral grains from microscopic size to half an inch in diameter. Much of the garnet is oxidized to turgite and limonite. Staurolite is very abundant in some layers of the schist and is commonly altered to a fine-grained, white, micaceous mineral resembling sericite. This alteration begins along cross-fractures and continues until the entire grain is replaced. When this change is complete, only white patches with the original crystal outline remain.

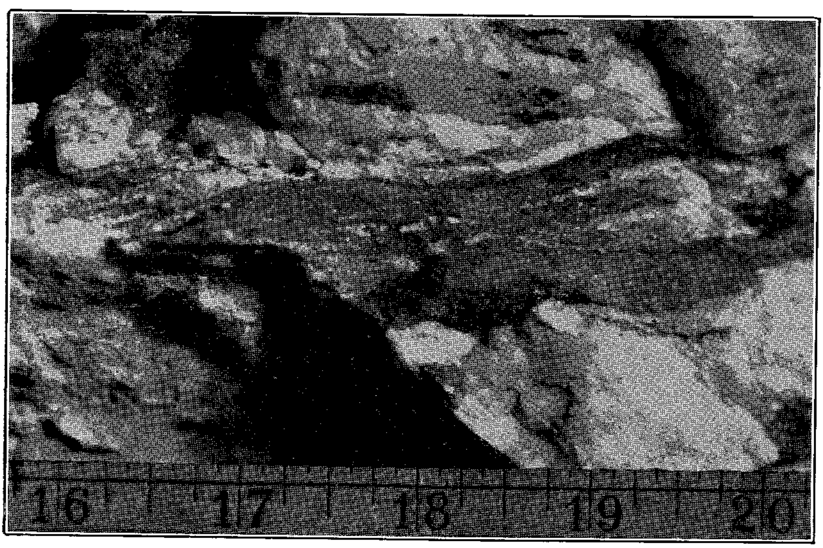
Microscopic character.—More than 40 thin sections of the rock from all parts of the region show it to be mica schist with muscovite, quartz, and chlorite dominant. Biotite is usually altered to chlorite. (See Pl. 8A.) Magnetite is present in all sections and is frequently an important component. Large crystals of garnet and staurolite are locally abundant. The bands and zones of blue-gray micaceous material are mostly chlorite with some quartz and magnetite. Cataclastic structures, as fault-slip cleavage, slicing, twisting, and mortar structure are common.

Muscovite is generally the dominant mica. It occurs typically as long shreds woven among the other minerals. It is iron-stained, brown to green, and is faintly to distinctly pleochroic. Much of it may be leached biotite. Some of the muscovite or sericite occurs as plates and as elongated flakes which are not oriented with the schistosity and are thus of more recent origin. Aggregates of fine sericite entirely replace some of the staurolite. Brown pleochroic biotite is common but not generally abundant. It is partly altered to chlorite as is some of the garnet. (See Pl. 8A.)

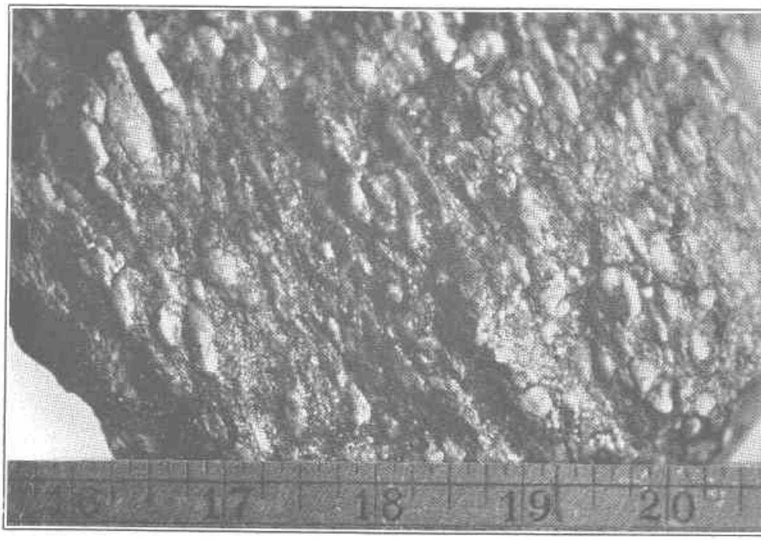
Chlorite is abundant and is a common alteration product of biotite.



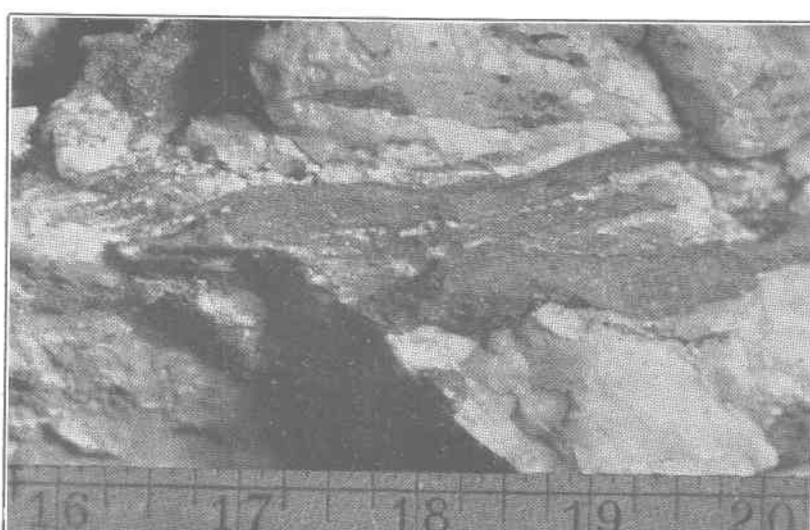
A. Conglomerate facies of the Mount Athos quartzite in Mine Ridge west of Greenway, Nelson County. The quartz pebbles have been mashed into thin discs.



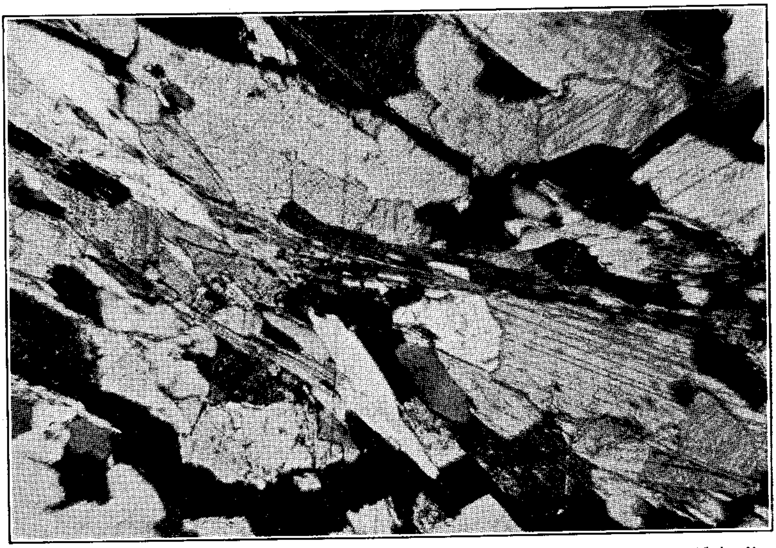
B. Milky vein quartz including chlorite schist, near Riverville, in Amherst and Appomattox counties. The scale is in inches.



A. Conglomerate facies of the Mount Athos quartzite in Mine Ridge west of Greenway, Nelson County. The quartz pebbles have been mashed into thin discs.

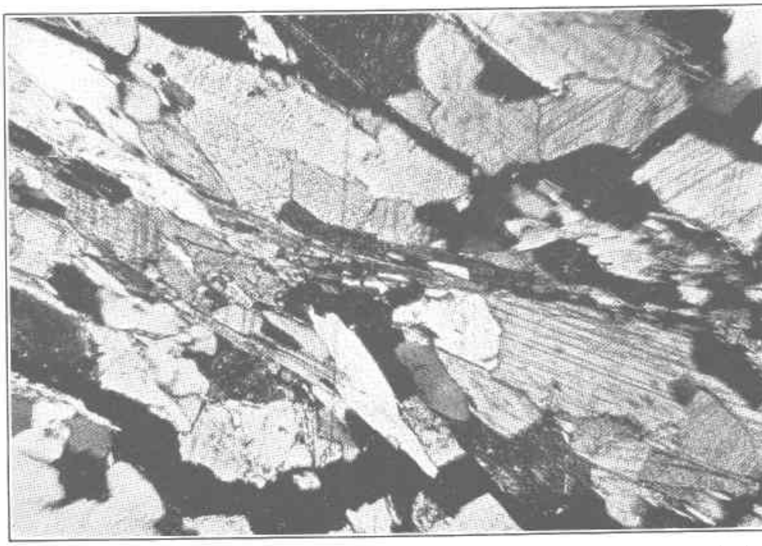


B. Milky vein quartz including chlorite schist, near Riverville, in Amherst and Appomattox counties. The scale is in inches.



A. Gray schistose marble along the Norfolk and Western Railway, 1¼ miles east of Mount Athos, Campbell County. Most of the calcite is twinned; brown mica occurs in long shreds and some of the small, light-colored grains are quartz. Crossed nicols; X 42.

B. Coarsely crystalline, pink marble along Nigger Creek in Buckingham County, below Norwood. Crossed nicols; X 58.



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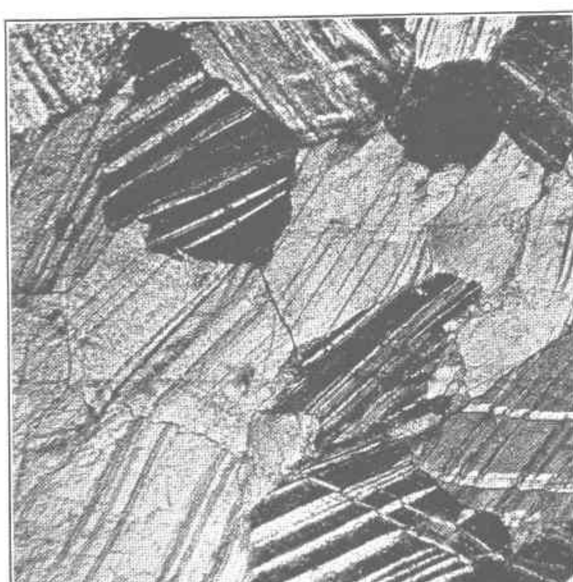

B. Coarsely crystalline, pink marble along Nigger Creek in Buckingham County, below Norwood. Crossed nicols; X 58.

Some garnet is partly altered to chlorite. Some large flakes of chlorite occur as alteration products of staurolite.

Magnetite is abundant and occurs as irregular grains and as abundant small rods and needles which conform to the schistosity, and in places alternate with wisps of muscovite. These rods and needles are probably residual products of altered biotite. Some large grains of magnetite are derived directly by alteration of garnet. Some magnetite occurs also as porphyroblasts. The schist contains some ilmenite which alters to leucoxene.

Quartz is abundant throughout the schists. It shows optical distortion unless it has been completely granulated.

Yellow pleochroic staurolite is locally abundant and is generally altered to sericite. It contains inclusions of quartz, magnetite, and other minerals. Staurolite shows a greater tendency to alteration than the garnet.

Garnet is an ubiquitous mineral and is locally very abundant. It is colorless to pale red. Some grains have good crystal outlines, but they are generally irregular. Common alteration products are chlorite and magnetite.

Feldspars are common, being generally obscurely twinned plagioclase, whose extinction angles indicate a soda variety.

A soda amphibole, pleochroic in shades of blue and yellow-blue and resembling riebeckite, occurs locally. It occurs sparingly in the schist east of Bent Creek, east of Spear Mountain, and from Piney Mountain.

Some small, mauve-colored prisms of tourmaline are locally present.

BIOTITE GNEISS FACIES

General features.—Biotite gneiss, intercalated with biotite schist, has been found in three places, but it is probably more abundant and has not been found because of lack of exposures. The gneiss is massive and some contains straight bands in contrast to the crumpled schist that encloses it. It is more resistant than the schist because of the higher content of quartz and feldspar. It resembles the Lynchburg gneiss very closely but contains more feldspar and locally some blue quartz. It is the mesozone oligoclase-biotite schist and gneiss facies of the Wissahickon that has not undergone retrogressive metamorphism, whereas in the schists previously described, biotite and garnet are altered to chlorite and staurolite to sericite.

Distribution and character.—Biotite gneiss crops out on the west side of Slate River about half a mile west of Buckingham, where it is intruded by amphibolite. The rock is gray or pepper- and salt-colored and weathers to a golden-brown. It is derived from a coarse feldspathic rock, perhaps an arkose. Large granulated quartz grains and considerable biotite are seen in hand specimens. In thin sections, plagioclase, quartz and biotite are the principal minerals.

Outcrops of biotite gneiss occur where county roads cross Wreck Island Creek between Oakville and Stonewall. Bands of biotite gneiss alternate with bands of quartz-muscovite schist. About 1 mile southwest of Mount Comfort church, where the county road crosses a tributary of the creek, the biotite gneiss contains thin bands of hornblende gneiss into which it grades. As shown in thin sections the gneiss consists of green hornblende and considerable biotite, and resembles that of the Sherwell area described below but is more cataclastic. It is composed mostly of feldspars, quartz, and biotite. Plagioclase, frequently untwinned, is the common feldspar. The biotite is reddish-brown, very pleochroic, and contains pleochroic halos. Small garnets are common and some larger broken garnets include the other minerals.

There is a large body of biotite gneiss in Appomattox and Campbell counties, around Sherwell, which extends southwest. It is intruded by pegmatite and muscovite granite and contains bands of hornblende schist. It resembles Lynchburg gneiss. The rock is fine to medium grained and pepper- and salt-colored. Biotite is an abundant constituent and feldspar and quartz are present.

Good exposures of this rock are found on the property of Dr. Evans, southwest of Pilot Mountain, where there are several abandoned quarries. It occurs in massive, nearly vertical bands. Considerable weathering causes the rock to become golden-brown and more schistose.

In the valley of Reedy Creek, northeast of Sherwell, the gneiss is arkosic. It is intruded by muscovite granite and pegmatite and interbanded with hornblende gneiss. Just west of the Evans property, the rock is arkosic and some bands are graphitic, resembling the Loudoun formation. Thin sections show the rock to consist mostly of feldspars, quartz and biotite. The feldspar is mostly plagioclase, but some microcline occurs. The biotite is reddish-brown, very pleochroic, and contains pleochroic halos around large inclusions of zircon. Muscovite occurs sparingly as large plates which are not well oriented and are filled with inclusions. Small garnets are common. Chlorite and magnetite are rare.

MUSCOVITE-CHLORITE SCHIST

Distribution and character.—Much of the area east of James River is underlain by the chlorite-muscovite schist and muscovite-quartz schist facies of the Wissahickon formation. Small porphyroblasts of garnet or euhedral magnetite may be present.

The rocks between Buckingham and Spring Mill and east of Tower Hill and Rosebower are typical muscovite-chlorite schists. Strain-slip cleavage, granulation, and mashing of quartz grains are generally shown in thin sections. Around Wingina, the schists grade imperceptibly westward into crushed chlorite phyllonite, to be described later. The change from the coarser-grained biotite muscovite schist with garnet and staurolite to this chlorized phyllitic schist is very marked. The rocks are more variable around Oakville and Stonewall. At the mill on Wreck Island Creek about 3 miles west of Oakville, tough, green, chlorite-muscovite schist contains garnet and biotite porphyroblasts. Numerous quartz stringers are intercalated in the schist. Just west of here, near Stonewall and elsewhere, are muscovite-quartz schists which generally contain scant chlorite. Muscovite-quartz schist is found also near Concord in Campbell County.

Microscopic character.—The microscope shows most of these rocks to be fine-grained muscovite-chlorite schists with muscovite as the dominant mineral. Much of the muscovite is probably leached chlorite. Biotite showing alteration to chlorite also occurs. Secondary magnetite, generally oriented with the schistosity, is common and in places abundant. Small garnets are common. Muscovite-chlorite schists grade in places into muscovite schists, some of which also contain much magnetite.

CHLORITE-MUSCOVITE PHYLLONITE

Distribution and character.—Chlorite-muscovite phyllonite is exposed north of Norwood and Wingina, in Nelson County, and south and east of Hardwicksville, in Buckingham County. East of Hardwicksville it grades into muscovite-chlorite schist. West of Wingina it can be traced into Buffalo Ridge.

Near Wingina there are good exposures of a slaty phyllitic rock, which is generally dark-blue, bluish-black, or green, and is soft and platy. The slaty cleavage has been mashed so that the slaty beds dip at various angles; some are nearly horizontal. The beds are sliced by many small thrust faults and much of the rock has the appearance of having been broken across older schistosity into many separate flattened blocks that have slipped upon each other. Slickensides are common.

Small quartz lenses and stringers are abundant and most of them are parallel to the platy structure. The rock around some of the lenses is more massive. Green talcose inclusions occur in some of the quartz. The quartz lenses are commonly platy, mashed, and include considerable schist. Some are broken by the thrust faults. A few small quartz veins cut the slaty cleavage or follow joints.

The schists of Buffalo Ridge are green, chloritic, in places slaty, and are rather uniform in mineral composition. They weather brown and purple near the surface.

A heavy, green chlorite schist with scattered, black, rectangular crystals (porphyroblasts) of a soda amphibole, occurs west of Galts Mill, about 4 miles west of Walker Ford, on Tye River, near Norwood, and west of Wingina.

QUARTZITE

Distribution and character.—Thin bands of mashed and granulated quartzite are abundant in the Wissahickon schist. They are common northeast of Norwood, in the Wreck Island Creek area north of Stonewall, around Appomattox, and between Appomattox and Buckingham.

Conglomeratic quartz-sericite schist, containing large, blue quartz grains in a matrix of sericite and granulated quartz, is found about 6 miles southeast of Rosebower and west of Appomattox River. Beds of mashed, schistose, arkosic quartzite occur on the east bank of Austin Creek, west of Buckingham. About half way between Buckingham and Hardwicksville, almost horizontal massive beds of quartzite containing blue quartz grains and fine schistose quartzite are well exposed in Mathews Creek. Beds of mashed quartzite and white quartz-muscovite schist are common north of Stonewall and Oakville, in Appomattox County. White, thinly banded, fine-grained quartz-mica schist, spangled quartz-muscovite schist, and mashed quartzite occur northeast of Stonewall between Wreck Island and Bent Creek. Southwest of Tower Hill, thick beds of mashed quartzite which dip 35° SE., crop out in Bent Creek and along the county road to Oakville. Some beds are pinkish, which is not an uncommon color in the fine-grained mashed quartzites of this district.

Mashed, gray, white, and pink quartzite or quartz schist overlies the large greenstone body in Appomattox county. Outcrops are abundant around Appomattox, and excellent exposures occur between Appomattox and Oakville. The rock weathers to a white dustlike powder. About 1 mile west of Appomattox, fine-grained white quartzite lies above greenstone and is interbedded with a heavy, coarse-grained biotite schist. In other places, quartzite with some schist is interbanded with greenstone. A fine-grained, mashed, pink quartzite occurs with greenstone at Tower Hill. Bands of quartzite are common in the schist northeast of Norwood, and west of Wingina and Midway Mills.

Microscopic character.—In thin sections, these quartzites show complete granulation and consist mostly of small angular interlocking quartz grains. Muscovite, generally in small amounts, is present and makes the rock schistose. Along the State highway west of Wingina, the quartzite beds weather to fine white dust. In places the less weathered rock is a conglomerate composed of fine granules. Some of these weathered quartzite zones are conveniently located for use in sanding roads.

GEOLOGIC AGE OF THE GLENARM SERIES

The Wissahickon gneiss of Pennsylvania was named and considered to be pre-Cambrian by Bascom,[26] and Knopf and Jonas[27] have confirmed this by showing that the Glenarm series is overlain unconformably by Lower Cambrian conglomerate and quartzite. The Wissahickon formation of Maryland continues southwestward across Virginia. The marble of the James River basin has been tentatively correlated with the Cockeysville marble of Maryland and Pennsylvania because of its position below the Wissahickon formation. The Mount Athos quartzite, which underlies the marble, may be the equivalent of the Setters quartzite of Maryland.

TOPOGRAPHY AND SOILS

Hills and ridges (monadnocks) on the Piedmont peneplain are composed of tougher, more resistant parts of the garnet-staurolite schist or of kyanite schist. The soils are thick and have been produced by thorough chemical weathering. Soils from the mica schist and granite in the eastern section are lighter, more sandy, and produce a light tobacco. Roads generally follow flat divides. East of James River, ridge roads are generally on garnetiferous schists. There are many good soil roads in the region.

SEDIMENTARY ROCKS

LOWER CAMBRIAN ROCKS

LOUDOUN FORMATION

Distribution.—The Loudoun formation was named by Keith,[28] from exposures in Loudoun County, Virginia. In central Virginia, the formation occurs in synclines in the eastern part of the Blue Ridge province and extends south as far as Buffalo River. It is unconformable upon Lynchburg gneiss and pre-Cambrian rocks intruded into the gneiss. In a narrow, tightly folded syncline just west of Buffalo Ridge, the Loudoun formation lies unconformably upon Catoctin schist with which it is here infolded. (See Pl. 1.)

Megascopic character.—The Loudoun formation consists of arkosic conglomerate and quartzite interbedded with dark to black slate and slaty muscovite schist. The arkose is generally coarse grained, but conglomerates are not common in this district. There is no definite

[26] Bascom, Florence, U. S. Geol. Survey Geol. Atlas, Philadelphia folio (No. 162), pp. 3-4, 1909.

[27] Knopf, E. B., and Jonas, A. I., Stratigraphy of the crystalline schists of Pennsylvania and Maryland: Amer. Jour. Sci., 5th ser., vol. 5, pp. 40-62, 1923.

[28] Keith, Arthur, Geology of the Catoctin belt: U. S. Geol. Survey Fourteenth Ann. Rept., pt. 2, pp. 324-329, 1894.

sequence of beds. The basal beds are generally slaty. On Tye River near Norwood, arkose overlies Catoctin schist; in Hawkins and Findlay mountains, the basal beds are massive arkose that overlies Lynchburg gneiss with little or no intervening slate. South of Piney River, the basal beds are dark- and light-colored slate about 100 feet thick, which grades upward into coarse arkose interbedded with dark-colored slate and slaty muscovite schist. East of Arrington and Shipman, the lower beds are slaty. (See Pl. 9A.) Thick zones of dark-colored slate are interbedded with arkose west of Hawkins Mountain. At Rockfish in Nelson County, basal conglomeratic beds rest on Lovingston granite gneiss and Lynchburg gneiss.

The coarse arkosic facies where fresh is blue-gray, due to large grains of blue quartz and grains of gray feldspar. This rock is generally massive but is schistose where muscovite or biotite is present.

The conglomerate at Rockfish is a gray rock in which rounded to angular pebbles, mostly of granite, are contained in a finer mass of sand grains and small fragments. The groundmass contains considerable biotite.

Microscopic character.—The arkose consists mainly of quartz and feldspars. Most of the feldspar is microcline, with some orthoclase and plagioclase. Biotite and sericite are common. Thin sections of a coarse arkose at Variety Mills show considerable calcite and scant pyrrhotite near small quartz stringers.

The dark slates are fine grained and consist largely of quartz and mica with abundant small specks of graphite. Most of the mica is sericite with some biotite. In the gap of Findlay Mountain east of Shipman, some thin graphitic layers alternate with quartzose layers which contain much feldspar, considerable biotite, some sericite, and scant graphite. The graphitic layers contain very fine-grained quartz, sericite and graphite. (See Pl. 7B.)

Topography and soils.—Sandstone beds in the Loudoun formation make ridges which are very favorable to the growth of chestnut oak and chestnut. In general the Loudoun makes poor soil.

TRIASSIC ROCKS

NEWARK GROUP

Occurrence.—Triassic rocks are preserved in narrow basins that trend northeast. The northern end of the Danville area extends into this region and is exposed at Spring Mills. The southern end of the Scottsville area is exposed at Midway Mills. (See Pl. 1.) These basins have been discussed recently by Roberts.[29]

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

Structure.—The Triassic sediments are preserved in long, rather narrow troughs in the crystalline rocks of the Piedmont province. The basins have been dropped down on the west by normal faults which strike northeast. The basins may end at cross-faults. In view of the great amount of erosion that has taken place since Triassic times, it is evident that these basins were formerly much larger and that the preserved areas are only downfaulted remnants.

Distribution and character.—The Triassic rocks of the Danville basin disappear about 1 mile north of Spring Mills. They dip northwest and are bounded on the west by a normal fault. On the upthrow (west) side of this fault is exposed, next to the Triassic sediments, chlorite-muscovite Wissahickon schist.

The sediments are chocolate-red to brick-red and consist of rudely bedded materials in which argillaceous beds alternate with conglomeratic beds. Some of the conglomeratic beds contain well-rounded pebbles of slaty mica schist and garnet-mica schist, about the size of a pea. Some are about 3 inches in diameter. They are much weathered and were probably deposited in a weathered condition. The materials are of local origin.

A small area of Triassic rocks near Midway Mills, of less than two square miles in extent, is separated from the Scottsville basin. It is bounded on the west by a normal fault, but on the east the sediments unconformably overlie mica schist. The Triassic rocks are poorly exposed on the county road north of Wingina. West of Midway Mills, the contact between the downthrown Triassic block and the slaty schist of the upthrown block is well exposed. At the fault contact, the schist is red, much broken, and dips in all directions for about 20 feet from the contact. The prevailing dip of the schist west of this brecciated zone is abnormal and to the northwest.

The Triassic sediments comprise conglomerate, sandstone and shale. Near the Border fault, there is a conglomerate consisting mainly of fragments of schist derived from a local source. A thin section shows brown sandstone from this area to be composed of well-sorted angular to slightly rounded grains of quartz and feldspars. The feldspars are mostly plagioclase with some microcline, some of which are partly altered to kaolin and sericite. (See Pl. 9B.) Scant muscovite and several rounded grains of mica schist make up the remainder of the rock. The grains are too firmly cemented by ferric oxide for a mechanical analysis.

The Scottsville basin is bounded on the south, near Warminster, by a cross-fault and on the west by a normal fault which throws the Triassic rocks against greenstone. The Triassic border conglomerate consists of large, angular fragments of greenstone which were deposited as a fanglomerate east of the Border fault.

IGNEOUS ROCKS

PRE-CAMBRIAN ROCKS OF THE BLUE RIDGE PROVINCE

GENERAL FEATURES

Intrusive and extrusive igneous rocks are abundant in this region. (See Pl. 1.) All except the diabase dikes are believed to be of pre-Cambrian age. The intrusive rocks consist of (1) older basic rocks, such as hornblende gneiss and hornblende gabbro in places altered to soapstone, and (2) younger rocks, such as quartz monzonite and pegmatite. All of them intrude the Lynchburg gneiss. Ancient lava flows have been altered to greenstone. Watson and Taber[30] have described in Amherst and Nelson counties a series of closely related intrusive rocks (syenite, gabbro, and nelsonite) that are believed to represent successive differentiates from a biotite-quartz monzonite which is now metamorphosed to a gneiss.

BASIC INTRUSIVE ROCKS

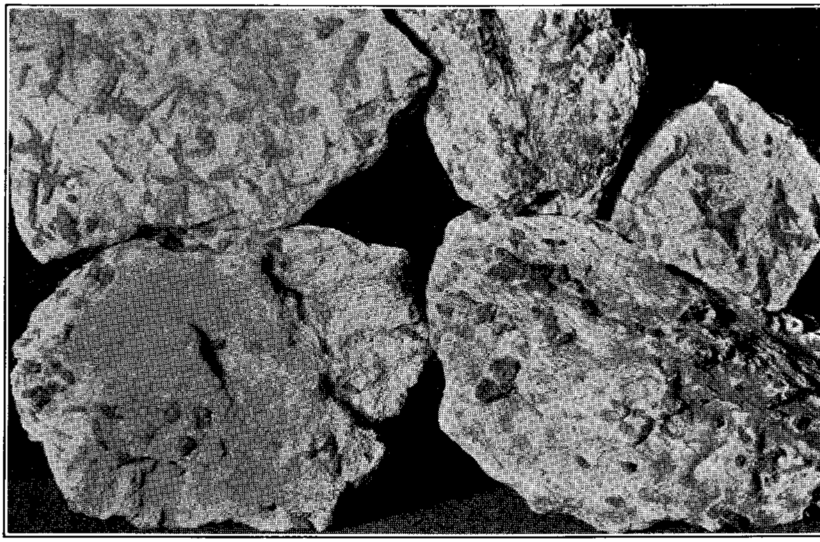
HORNBLENDE GNEISS

Megascopic character.—Hornblende gneiss is a greenish-black, schistose rock consisting mostly of hornblende. Thin bands of it are commonly intercalated with Lynchburg gneiss, and also occur in the Lovingston granite gneiss. Contact metamorphism is evident near pegmatitic intrusions. The hornblende gneiss is a very old rock that is in places associated with soapstone. One of the best exposures is at Brightwells Mill, or Evergreen Mill, in Amherst County.

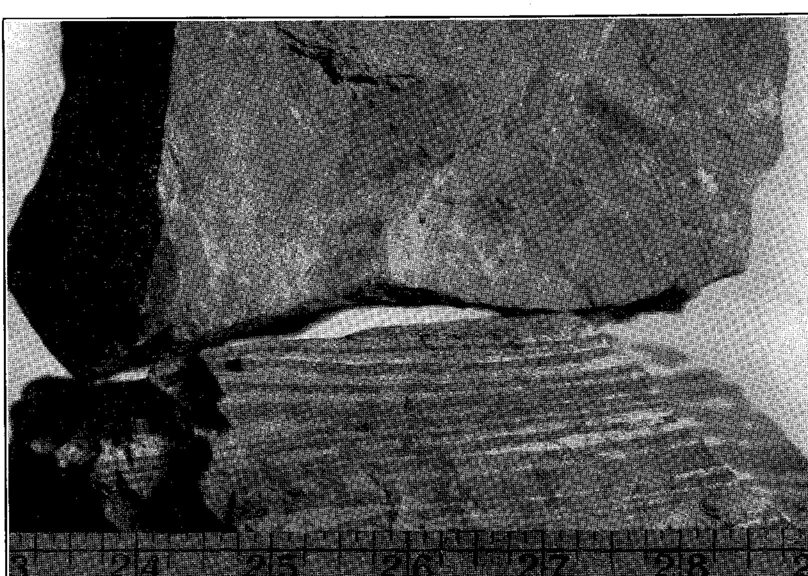
Microscopic character.—One-half or more of the rock consists of greenish-brown hornblende, and the remainder is mainly feldspar, largely plagioclase, and quartz. It contains also some magnetite and titanite, and some epidote which is derived from hornblende.

Origin.—This rock resembles very closely the hornblende gneiss intruded into Wissahickon schist to the east and may belong to the same period of intrusion as the hornblende gabbro which is described later. It is interlayered with the Lynchburg gneiss in bands of variable thickness and the two rocks have been deformed together. It may be the oldest igneous rock in the district. It is not closely associated with the other basic intrusive rock. Contact metamorphic effects have not been found in it. It is possible that this gneiss represents metamorphosed flows or sills in the Lynchburg gneiss.

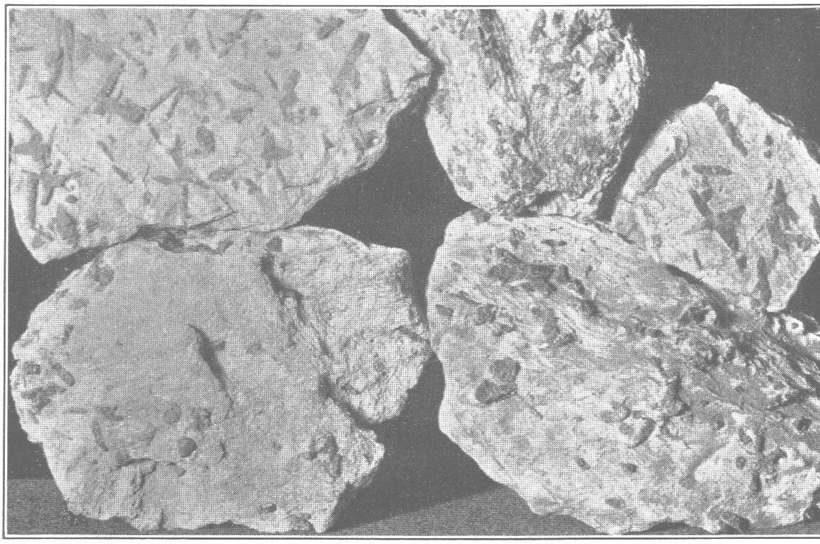
[30] Watson, T. L., and Taber, Stephen, Geology of the titanium and apatite deposits of Virginia: Virginia Geol. Survey Bull. 3A, pp. 151-154, 1913.



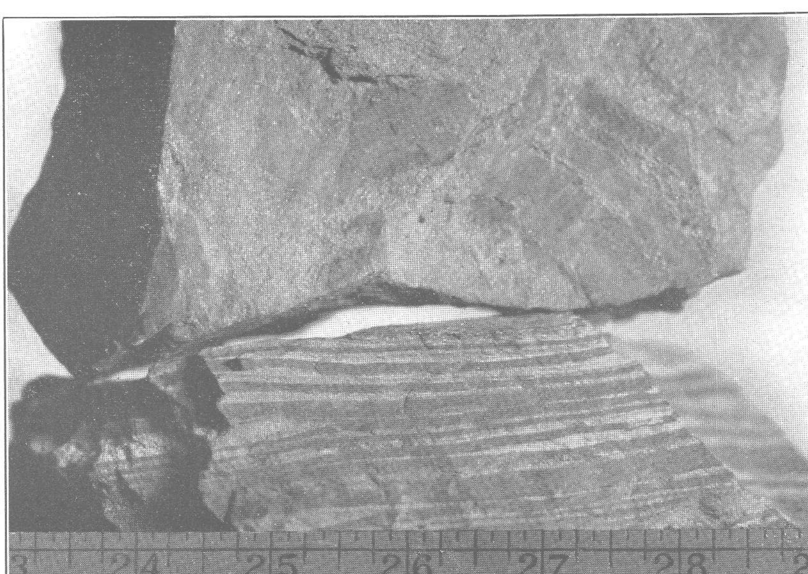
A. Staurolite-mica schist in the Wissahickon formation at Piney Mountain, Appomattox County.



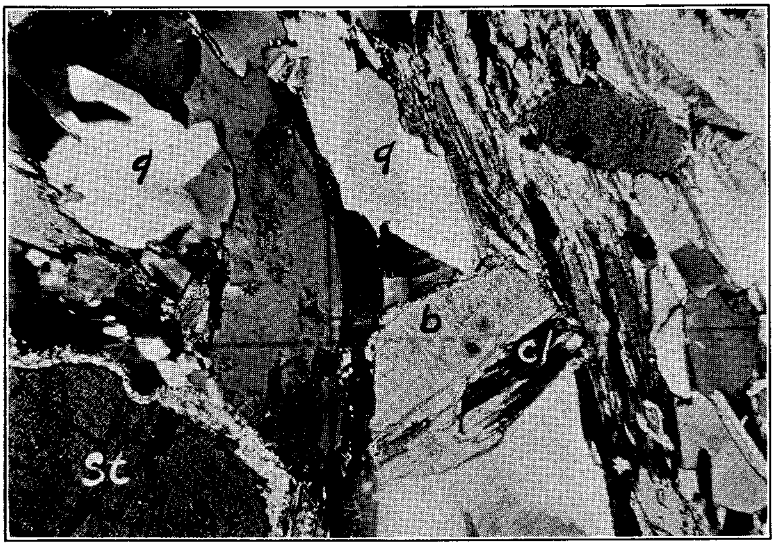
B. Graphitic layers in the Loudoun formation from Findlay Mountain, Nelson County. In the upper specimen the original bedding lies nearly in the plane of the paper.



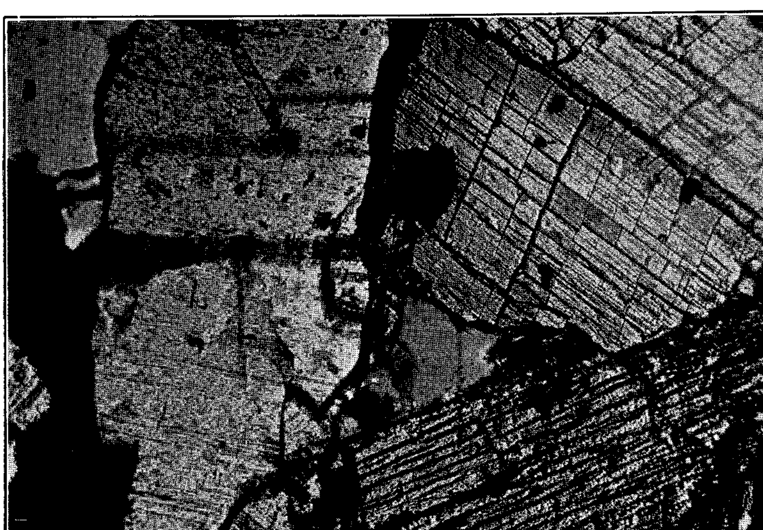
A. Staurolite-mica schist in the Wissahickon formation at Piney Mountain, Appomattox County.



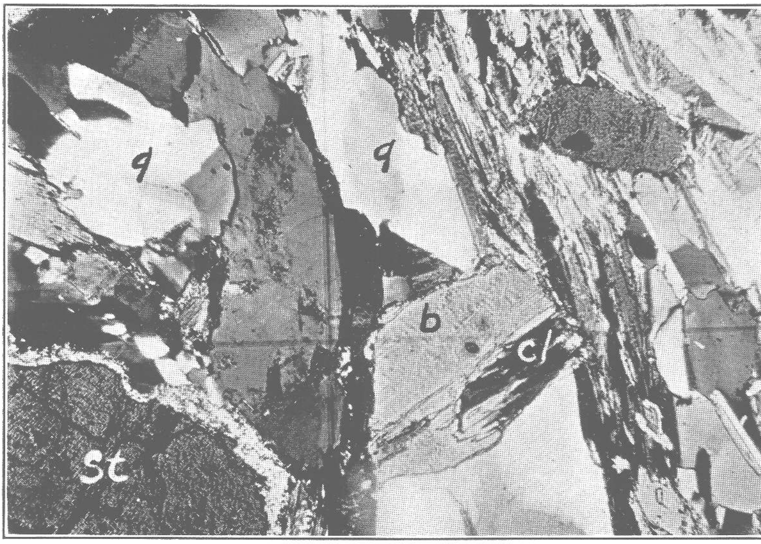
B. Graphitic layers in the Loudoun formation from Findlay Mountain, Nelson County. In the upper specimen the original bedding lies nearly in the plane of the paper.



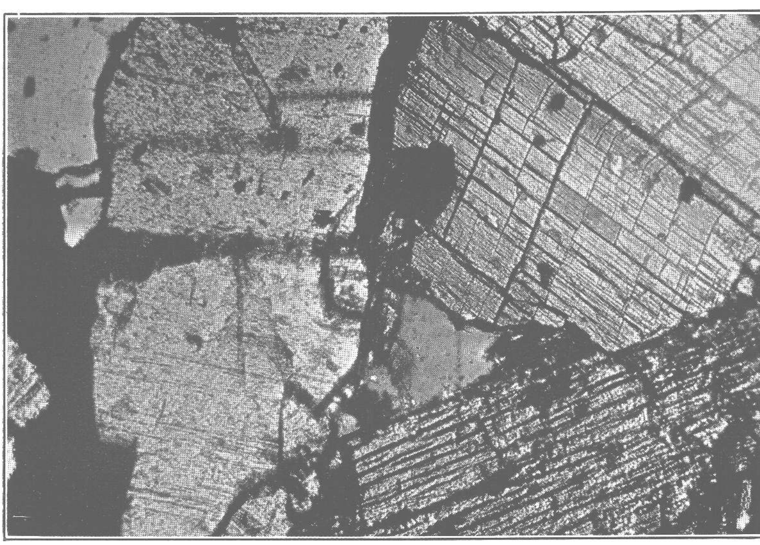
A. Wissahickon schist near Rustburg, Campbell County. The principal minerals are staurolite (st), biotite (b), and quartz (q). The biotite shows some retrogression to chlorite (cl). Crossed nicols; X 45.



B. Kyanite schist from Willis Mountain, Buckingham County. Crossed nicols; X 64.



A. Wissahickon schist near Rustburg, Campbell County. The principal minerals are staurolite (st), biotite (b), and quartz (q). The biotite shows some retrogression to chlorite (cl). Crossed nicols; X 45.



B. Kyanite schist from Willis Mountain, Buckingham County. Crossed nicols; X 64.

SOAPSTONE AND ASSOCIATED INTRUSIVE ROCKS

Introductory statement.—Soapstone or steatite is not uncommon in the Blue Ridge and Piedmont regions. Soapstone is an impure form of talc which, with other secondary minerals, has been produced by the alteration of magnesium-bearing silicates such as olivine, pyroxene and amphibole.

Occurrence.—The Albemarle soapstone belt extends into this district west of Buffalo Ridge and east of Hawkins and Findlay mountains. The belt averages less than 1 mile in width. (See Pl. 1.) It is interrupted near Lynchburg by the Galts Mill cross-fault. The soapstone-bearing rocks are closely associated with Lynchburg gneiss, Catoctin schist and the Loudoun formation. They are intruded into the Lynchburg gneiss and are intercalated wtih the Catoctin schist. They are more or less schistose and generally dip steeply to the southeast. The belt is dikelike in outcrop pattern and follows the strike of the enclosing rocks.

Megascopic character.—Soapstone is a grayish-green massive to schistose rock. In thin sections the important minerals are talc and serpentine which may completely replace the original silicates. Considerable carbonate is present in some sections and all contain small grains of magnetite.

Several types of basic rocks occur in close association near the Standard Soapstone Company's quarry in the vicinity of Norwood. The gray soapstone contains in places small veins of brown siderite and scant pyrrhotite. Serpentine asbestos is not uncommon, some fibers being 6 inches long.

Several thin sections from fragments of drill cores show a fine-grained, dense, dark-gray peridotite to be the characteristic type of rock here. The rock is slightly talcose and contains olivine. The original minerals are almost wholly altered to talc which is extensively replaced by serpentine showing the typical lattice structure of antigorite. Small black grains of magnetite occur sparingly. Another type of rock is a dense, greenish-black, vesicular basalt. The vesicles are open or filled with calcite. Thin sections show much hornblende that is pleochroic in shades of green and brown. Considerable quartz, or untwinned feldspar, which shows optical distortion, a few large calcite grains, and some magnetite make up the remainder of the rock.

A greenish-gray soapstone is found two-thirds of a mile east of Variety Mills. Some resinous serpentine may be seen with a hand lens, but the original minerals are completely altered. A thin section shows talc and serpentine. Gray-green soapstone from the American Soapstone Company's quarry west of Norwood is composed almost entirely of apple-green talc containing grains of a dark-colored, cleavable carbonate.

(See Pl. 15A.) In thin section, there are many large, irregular, ragged grains of carbonate which enclose talc and small specks of magnetite along cleavage planes and fractures. Some faintly pleochroic serpentine is also noted. A thin section of soapstone from near the Phoenix quarries shows colorless amphibole (tremolite) extensively altered to talc.

Origin.—The several rock types are closely related and are probably differentiates from an original magma having the composition of a gabbro. The soapstone is considered to have been derived from amphibolite, peridotite, and pyroxenite which are the more basic facies of metagabbro of metapyroxenite.[31]

HORNBLENDE GABBRO

Occurrence.—Hornblende gabbro commonly intrudes Lynchburg gneiss and is associated with soapstone. Typical occurrences are found near Lynchburg on the north side of James River in Amherst County. Just above the State highway bridge is a dike of massive to schistose, moderately coarse hornblende gabbro about 50 feet wide. Farther west at the mill is another dike, about 100 feet wide, which is coarse to fine grained. Hornblende crystals average a quarter of an inch in diameter in the coarse part. A large, coarse-grained dike is found near the west base of Hawkins Mountain, and it is well exposed on Tye River and on the county road west of the north end of the mountain. Hornblende gabbro, associated with soapstone, occurs south of Buffalo River about 3 miles south of the Amherst-Nelson county line. A narrow dike occurs in Lynchburg gneiss south of the junction of Rucker Run and Meadow Creek in Nelson County.

Megascopic character.—Hornblende gabbro is dark-colored and fine to coarse grained. Coarse, greenish-black hornblende makes up most of the rock. Some white feldspar containing hornblende occurs in spaces between the large crystals.

Microscopic character.—Hornblende is the most abundant mineral, generally composing more than half of the rock. Some is altered to titanite. Plagioclase showing more or less optical distortion may be abundant and is rarely absent, and some quartz is commonly present.

A hornblende gabbro associated with soapstone at the Standard Soapstone Company's quarry contains dark-colored amphibole and patches of white feldspar. A thin section made from a fragment of drill core shows hornblende, having moderate absorption in shades of green and brown, to make up more than half of the rock. The groundmass consists

[31] Jonas, A. I., Geologic reconnaissance in the Piedmont of Virginia: Geol. Soc. America Bull., vol. 38, p. 844, 1927.

Burfoot, J. D., Jr., The origin of talc and soapstone deposits in Virginia: Econ. Geology, vol. 25, no. 8, pp. 805-826, 1930. Hess, H. H., Hydrothermal metamorphism of an ultrabasic intrusive at Schuyler, Virginia: Am. Jour. Sci., 5th ser., vol. 26, pp. 377-408, 1933; The problem of serpentization and the origin of certain chrysotile asbestos, talc and soapstone deposits: Econ. Geology, vol. 28, no. 7, pp. 634-657, 1933.

of indistinctly twinned plagioclase. Considerable titanite, closely associated with the hornblende, is found in elongated patches that are composed of tiny rounded particles. Some of the patches contain small amounts of serpentine and biotite.

ACID INTRUSIVE ROCKS

LOVINGSTON GNEISS

Definition.—This rock was named[32] from exposures in the vicinity of Lovingston, Nelson County. It is widely exposed in Virginia along the east slope of the Blue Ridge and intrudes the Lynchburg gneiss. (See Pl. 1.)

Megascopic character.—The principal minerals are feldspar, quartz, and biotite. Where the rock was porphyritic, the original feldspar phenocrysts were mashed out and enclosed by biotite during metamorphism to form a porphyroclastic rock resembling an augen gneiss. Quartz grains are commonly fine, granular, and milky, but larger ungranulated grains are blue to purple. The rock varies in appearance from place to place due to variations in texture, degree of metamorphism, and amount and distribution of biotite.

Microscopic character.—The following microscopic description is by Watson and Taber:[33]

"In thin sections the rock is a biotite-quartz monzonite-gneiss of granitic texture, varying from fine- to medium-coarse, even-granular to porphyritic, sometimes exhibiting a banded or foliated structure. The minerals are potash feldspar (orthoclase and microcline), soda-lime feldspar (albite-oligoclase and oligoclase), quartz, and biotite, together with accessory ilmenite, apatite, rutile, zircon, and occasional titanite and pyrite, and secondary chlorite, colorless mica (muscovite), epidote, kaolin, zoisite, calcite and leucoxene." (See Pl. 10A.)

Relations.—Lovingston gneiss intrudes Lynchburg gneiss at several places. This relationship may be seen at Coolwell, in the cuts along the county road near the church. On the north side of James River at Lynchburg, between the highway bridge and the dam, stringers of fine-grained, gray Lovingston gneiss intrude Lynchburg gneiss. Biotite and red garnet occur near the intrusion. (See Pl. 10A.)

PEGMATITE

General features.—Lenses and stringers of white pegmatite intrude Lynchburg gneiss, intercalated hornblende gneiss, and intrusive Lovingston gneiss in a road quarry just east of the Southern Railway at Winesap.

[32] Geologic map of Virginia, Virginia Geol. Survey, 1928.
[33] Watson, T. L., and Taber, Stephen, Geology of the titanium and apatite deposits of Virginia: Virginia Geol. Survey Bull. 3A, p. 61, 1913.

Contact metamorphism.—Contact metamorphism is pronounced even near stringers scarcely thicker than sheets of paper. Lynchburg gneiss near pegmatites is dark-colored and contains much more biotite and hornblende than elsewhere. It is pseudoporphyritic due to the development of biotite and white feldspar. A zone containing coarse biotite has been developed near some pegmatites.

The hornblende gneiss has been much altered by pegmatitic intrusions, the most pronounced effect being the development of a zone of coarse biotite near the intrusion. Some small lenses and "eyes" of plagioclase in this gneiss are completely surrounded by biotite. In other localities, stringers of pink granite pegmatite sometimes intrude the Lynchburg gneiss.

QUARTZ VEINS

Occurrence.—Quartz veins cut the other rocks of this district. (See Pl. 5B.) At Wrights Shop about 3 miles northeast of Lynchburg, three carloads of quartz were mined and shipped from a vein in the Lynchburg gneiss. Irregular stringers of coarse muscovite rendered much of the quartz unfit for market.

AGE

The basic and acid intrusive rocks discussed above are very old. The rocks of both series, except perhaps the later pegmatite, have been mashed and metamorphosed. Quartz monzonite (Lovingston gneiss) and pegmatite intrude the Lynchburg gneiss and the basic rocks, with the exception of soapstone. The quartz monzonite is very gneissic. None of the igneous rocks intrude the Lower Cambrian Loudoun formation. The intrusion and the metamorphism of these rocks were followed by a long period of erosion which preceded Cambrian deposition, because pebbles of biotite gneiss, granite, and blue quartz derived from the Lovingston gneiss are found in the Lower Cambrian sediments.

EXTRUSIVE ROCKS

CATOCTIN SCHIST

Definition.—This formation, named by Keith,[34] from Catoctin Mountain, Maryland, extends along the Blue Ridge as far as the central part of Virginia. It is described[35] as consisting of "metabasalt lava flows and volcanics altered to amygdaloidal and schistose epidote-chlorite amphibolite; in the Blue Ridge, it is copper-bearing in places."

Megascopic character.—In this district, the Catoctin schist is found in a narrow belt. (See Pl. 1.) It does not contain biotite porphyroblasts,

[34] Keith, Arthur, Geology of the Catoctin belt: U. S. Geol. Survey, Fourteenth Ann. Rept., pt. 2, pp. 293-294, 1894.

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

and is schistose to rather massive. Little or none of the character of the original basalt flow is preserved. It contains in places amygdules filled with quartz and epidote.

The important minerals are epidote, chlorite and quartz, which are secondary, mainly after plagioclase and pyroxene. Considerable magnetite, which also appears to be largely secondary, is present.

Age.—The pre-Cambrian age of the Catoctin schist was established by Keith.[36] In the western belt along the Blue Ridge front, the schist is intruded by granite and granodiorite. As the quartz monzonite and the Catoctin schist do not occur together in this district, their relationship is not known. The Catoctin schist is cut by quartz veins and is probably intruded by granite, which may have been responsible for the local occurrence of copper. It underlies Lower Cambrian sedimentary rocks.

INTRUSIVE ROCKS IN THE PIEDMONT PROVINCE

GRANITE

At Red House in Charlotte County and at Morris Church in Campbell County, a mashed, coarse-grained, pink, porphyritic granite containing chloritized biotite occurs. Similar granite was mapped as the Shelton granite gneiss on the geologic map of Virginia (1928). A dike-like body of fine-grained, slightly gneissic granite, containing microcline, chloritized biotite and a little muscovite, intrudes Wissahickon schist on the west side of Reedy Creek, about 2 miles north of Spring Mills. (See Pl. 10B.) A dike of rather fine-grained granite of pegmatitic character is intruded into Wissahickon schist on the west side of Reedy Creek about 2 miles by road east of Sherwell. A similar body occurs upon the farm of Dr. Evans north of Sherwell. A thin section of this granite shows the minerals to be orthoclase, microcline, plagioclase, quartz, biotite, sericite and apatite. Rods of orthoclase are micrographically intergrown with plagioclase along twinning planes, forming an antiperthite.

GRANITE PEGMATITE

General features.—Granite pegmatites are not rare east of the Triassic Border fault in the eastern part of Appomattox and Buckingham counties, where they intrude all the other pre-Cambrian rocks. They appear to be in general parallel to the direction of schistosity. In some localities, the schists are saturated with pegmatitic intrusions. Contact effects are especially noticeable in the hornblende gneiss.

Occurrence and character.—Pegmatite occurs at several places in the district: (1) West of the Maud mines near Stapleton and northeast

[36] Keith, Arthur, op. cit., p. 328.

of Porridge Run in Amherst County, where lenses of pegmatite less than 1 foot in diameter and of variable composition occur in Wissahickon schist and quartzite and where the enclosing green chlorite schist contains tourmaline; (2) on the county road, about half a mile west of Allen Creek in Nelson County, where two pegmatite lenses, probably late intrusives closely related to quartz veins, are found in the schist; (3) about 6 miles southeast of Rosebower, a short distance north of Appomattox River in Appomattox County, where short pegmatite veins occur in Wissahickon schist; (4) around Prospect in Prince Edward County, where pegmatite is abundant as intrusions in hornblende gneiss; (5) about 5 miles south of Elam and north of the Five Forks road in the same county, where hornblende gneiss is intruded by pegmatite, producing an injection gneiss in which contact effects are pronounced and where veins of amphibole asbestos 5 to 8 inches thick occur associated with chalcedony veins and masses of white talc; (6) along U. S. highway 460, on the western and eastern limits of Pamplin in Appomattox County, where the pegmatite consists mainly of quartz and muscovite with considerable black tourmaline being present in places; and (7) east of Sherwell in Campbell County, where granite pegmatite is common.

Microscopic character.—Thin sections show this rock to consist of microcline, orthoclase, muscovite, and quartz with locally some tourmaline.

QUARTZ-TOURMALINE VEINS

West of Riverville, the schists and quartzites are intruded by quartz-tourmaline veins, showing gradations from nearly pure black tourmaline segregations to quartz lenses and veins that contain little or no tourmaline.

QUARTZ VEINS

Quartz veins are common in the pre-Cambrian rocks of this region. They appear to belong to several periods of intrusion as some are shattered by faults, whereas later ones are along the courses of normal faults. None seem to have been formed by secondary deposition from the surface. (See Pl. 5B.)

HORNBLENDE GABBRO

Occurrence.—Near Buckingham, a large mass of hornblende gabbro having the form of a stock, intrudes Wissahickon biotite schist and gneiss. Good exposures are found where State highway 283 crosses Slate River. North of Buckingham, the hornblende gabbro is superficially altered to soapstone. A smaller body occurs between Falling

River and Cane Branch, north of Morris Church in Campbell County, and a small outcrop is found near Rosebower in Appomattox County.

Character.—The rock resembles similar occurrences in the Blue Ridge province. The hornblende is more or less altered to epidote.

TALC-ACTINOLITE SCHIST

Distribution and character.—Two areas of talc and talc-actinolite schist which are discussed here, although they may represent much metamorphosed bodies of dolomitic Cockeysville marble, are present west and north of Appomattox. The rocks appear to lie within mica schist and above greenstone. The northern area is exposed on the county road between Vera and Oakville, on the eastern slope of Piney Mountain about half a mile west of Bent Creek. It is enclosed by layers of garnetiferous and staurolitic mica schist into which it appears to grade. The rock is either an apple-green, foliated talc or a massive talc-actinolite schist. A thin section of the schist shows a mat of fine talc and some actinolite crystals. A second area lies near the county road about 2½ miles north of Appomattox, where it can be traced southward as a distinct ridge for at least three-fourths of a mile. It is surrounded by greenstone which apparently lies just below it. This is a large area which contains much white talc of good grade.

Talc layers in the Wissahickon schist are shown in railroad cuts near the county road bridge over the Norfolk and Western Railway just southwest of Concord in Campbell County. As at other localities, the talcose beds lie close to greenstone.

EXTRUSIVE ROCKS IN THE GLENARM SERIES

GENERAL FEATURES

The terms greenstone, greenstone schists, and greenstone volcanics have been applied to basic lava flows in the Glenarm series, which have been extensively altered to epidote, chlorite, and hornblende. The greenstones in central Virginia were derived mostly from lava flows. They are common below the Mount Athos formation, where they are thick and probably widespread, but local flows are found at other horizons in the series and especially in the Wissahickon schist.

LOWER GREENSTONE FLOWS

Megascopic character.—The most common color of the greenstone is gray-green, but it is also dark-green, blue-green, and yellow-green, according to the proportions of hornblende, chlorite, epidote and feldspar it contains. Epidote occurs in large and small patches, or "eyes," through the rock, and as amygdaloidal fillings. (See Pl. 11A.) Some hornblende and biotite porphyroblasts are large enough to be easily identified. Veins of fibrous amphibole, resembling actinolite, occur with epidote and zeolites.

Three facies of the greenstone have been recognized: (1) A gray-green porphyritic rock containing small feldspar phenocrysts, which is not uncommon; (2) an amygdaloidal type which is less common and in which the cavity fillings, epidote, quartz and zeolites, are generally mashed into ovals or into linear streaks (Pl. 11A); and (3) a fine-grained, bluish-green rock that is common, which generally contains biotite porphyroblasts, or more rarely long needles of green hornblende.

Microscopic character.—The minerals of the greenstone series are plagioclase, hornblende, chlorite, epidote, biotite, magnetite, hematite, quartz, calcite, zeolites and pyrite. The first seven minerals are the most important and are listed in the order of their abundance in the greenstone throughout the district.

Plagioclase is the most abundant mineral and is everywhere present as phenocrysts in porphyritic facies and as small lath-shaped crystals in the groundmass. (See Pl. 11A.) Some of the phenocrysts are completely granulated. Considering the amount of alteration that the rock has undergone, the feldspar appears to be remarkably well preserved.

Hornblende occurs as a secondary mineral, probably derived from pyroxene, which in places may make up at least half of the rock. It occurs as small, irregular, elongated fragments and less commonly in long needles along the planes of schistosity. It is altered to epidote and chlorite.

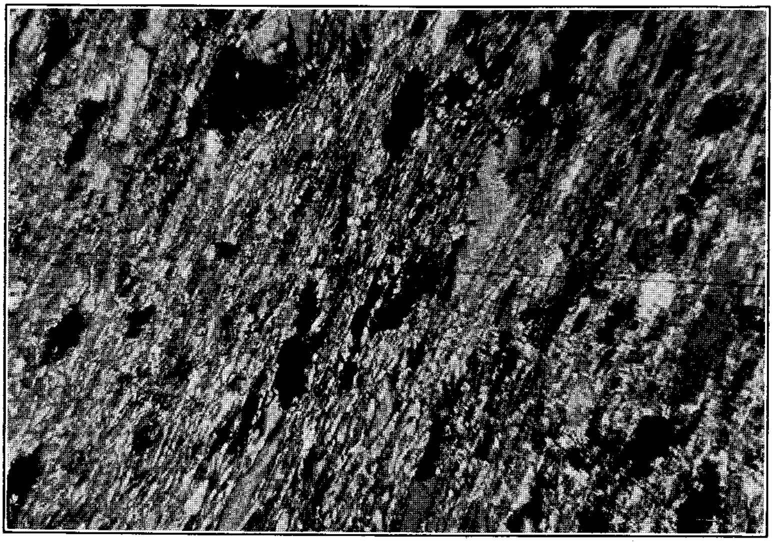
Biotite is locally an important mineral, occurring as porphyroblasts in the blue-green variety of greenstone. Biotite crystals have been formed from other ferromagnesian constituents, during regional metamorphism.

Chlorite is an abundant dark-green mineral derived from hornblende and biotite. Some of it shows abnormal blue interference colors.

Epidote is present to a more or less extent in all of the rock, occurring in patches, as disseminated grains, as yellow-green striated prisms in quartz, and as amygdaloidal fillings. (See Pl. 11A.) It is associated with quartz, chlorite, zeolite and black "ores."

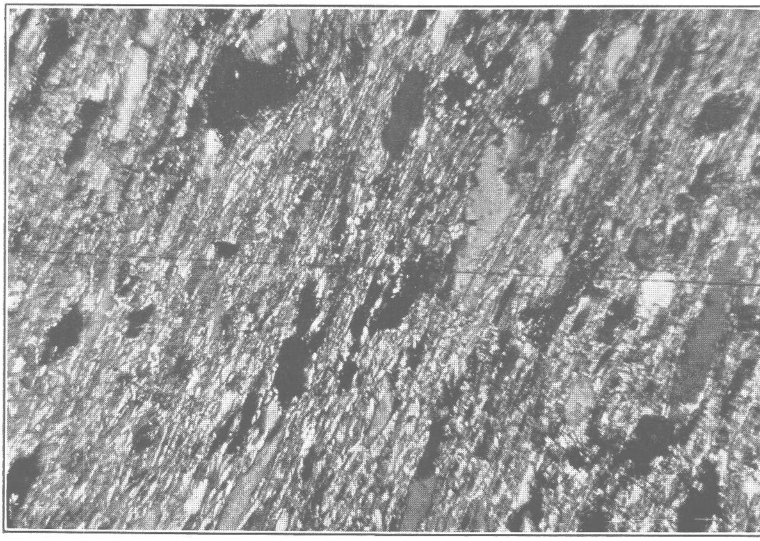
Magnetite and hematite are present in all of the rocks of the greenstone series and are very common in the yellow-green epidotic varieties. Quartz is also common in the yellow-green varieties. Calcite is not common. Some zeolites occur with epidote in amygdaloidal fillings. Pyrite is rare.

Occurrence.—Greenstone volcanics below the Mount Athos formation are exposed along James River, where they are infolded with quartzite and marble. They crop out in narrow belts, whose strike is



A. Dark Loudoun slate showing dimensional parallelism by mashing with little recrystallization. It occurs near Shipman, Nelson County. The larger elongated fragments are mostly quartz and the thin shreds are muscovite. Crossed nicols; X 100.

B. Triassic (Newark) brownstone at Midway Mills, Nelson County. Microcline (mi), orthoclase (or), quartz (q), and plagioclase (pl) are shown. Crossed nicols; X 36.



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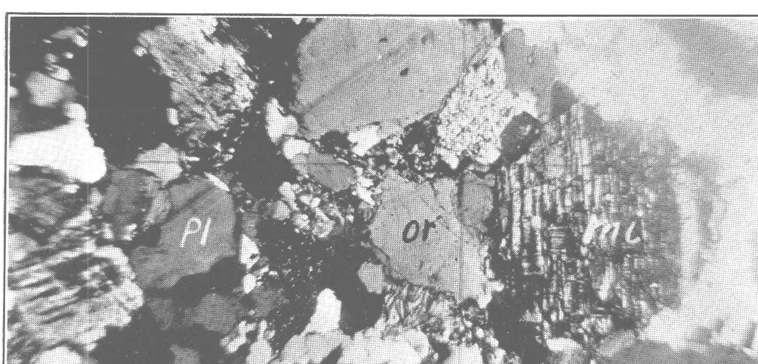

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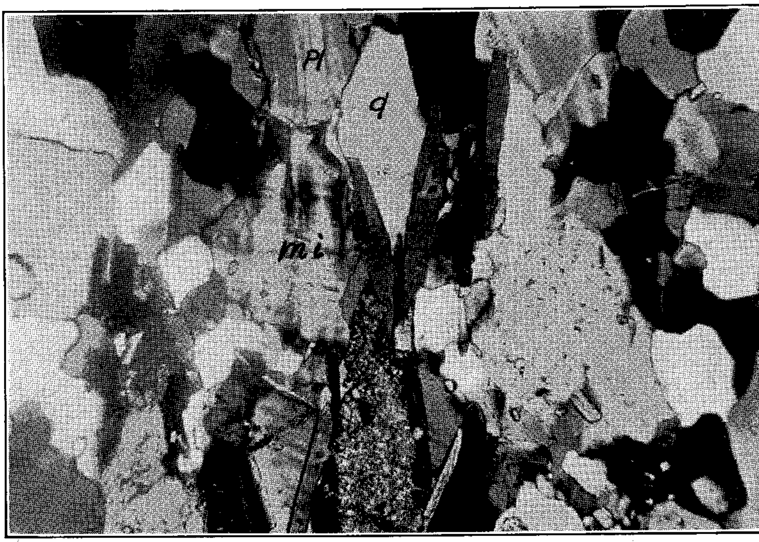
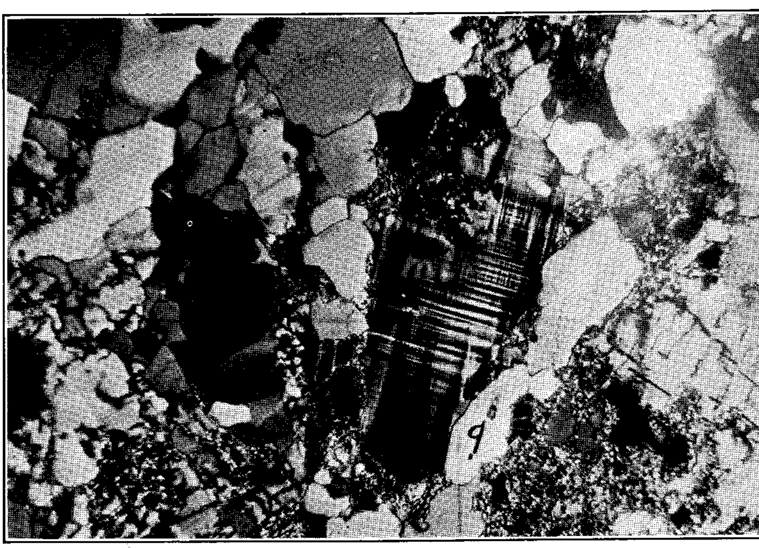
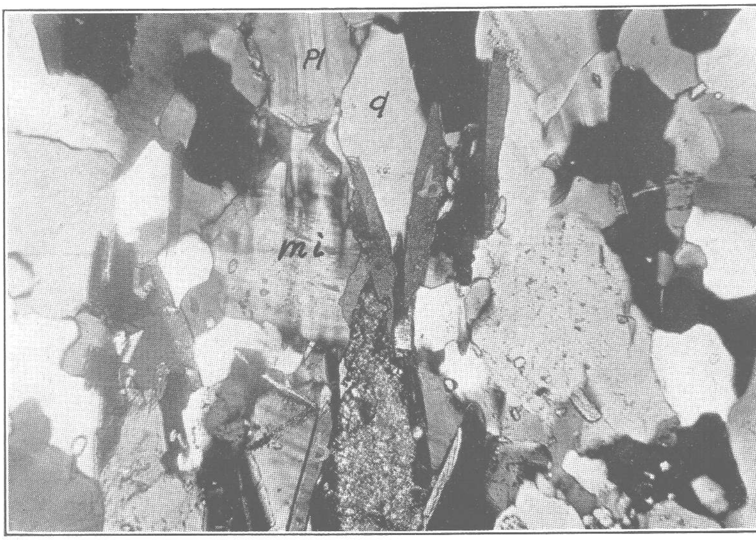


A. Lovingston gneiss from Amherst County, near Lynchburg. Plagioclase (pl), microcline (mi), quartz (q), and biotite (b) are the principal minerals in this thin section. Crossed nicols; X 42.



B. Biotite granite on Reedy Creek, Appomattox County. The minerals are considerably granulated. Most of the grains are quartz (q) and potash feldspar. A large unbroken grain of microcline (mi) is shown. Crosssed nicols; X 64.



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about N. 40°E., along the crests of eroded anticlines or along the upthrown side of faults. (See Pl. 1.) As the base of the greenstone volcanics is not exposed, they may lie within the Glenarm series.

The greenstones in general vary only slightly from place to place in texture and mineral composition. A fine-grained, dark bluish-green rock with abundant biotite porphyroblasts and bands of almost pure biotite is common in the eastern part of this district. Excellent exposures are found east of Mount Athos, along the highway (Pl. 12A), and along the Norfolk and Western Railway. Exposures along the county road, just east of Stonewall Creek, show an amygdaloidal facies in which the amygdules have been squeezed into flat discs or blebs, giving the rock a streaked appearance. Blue-gray greenstone crops out boldly to the northeast along the east wall of Wreck Island Creek. It contains small porphyroblasts of biotite, small lath-shaped crystals of dark-gray plagioclase, and numerous patches of yellow-green epidote. Good outcrops are found along the bluffs of James River on the Cunningham property 2 miles east of Norwood. Greenstones west of James River generally are porphyritic or amygdaloidal. Where the Nelson-Amherst county line crosses Allen Creek, a very fine-grained, blue-gray schist which contains long slender crystals of greenish-black hornblende is found. A dark-gray gneissic rock not altered to greenstone, which may be a dike, occurs about two-thirds of a mile northeast of "the Arch" in Campbell County.

GREENSTONE IN THE WISSAHICKON FORMATION

Occurrence and character.—Greenstone volcanic rocks are common only in the Wissahickon formation of the Glenarm series. These rocks are very similar in general appearance and mineral composition to those just described. No flows have been found in the Mount Athos quartzite. A tuffaceous facies of the quartzite has been previously described. A small flow is associated with marble at Buffalo Springs station.

Similar flows near the base of the Wissahickon schist are in places overlain by thin beds of quartzite, as west of Stapleton. Thin flows associated with quartzite are common north of Norwood.

The largest area of greenstone in this district is in the vicinity of Appomattox and Spout Spring. It may represent a sill. The rock is uniform in composition and appearance and is not porphyritic or vesicular. A mashed amygdaloidal rock west of Vera may not be connected with this body. The area is crossed by many bands of schist which are too narrow to show on the geologic map. Dips are gentle and the rock, although of wide extent, is not very thick. It is generally enclosed by biotite schist that contains staurolite and garnet, but in places it is overlain by a mashed quartz schist. This greenstone is well exposed along the county road between Appomattox and Oakville, where it has been folded into very gentle anticlines and synclines. About 1 mile west of Appomattox, a fine-grained, white quartzite, or quartz schist, is interbedded with a coarse-grained, heavy bronze-colored biotite schist. Here both types of rock overlie the greenstone, but at other places along the road they are intercalated with it.

The greenstone south of Concord may be connected with the one described above. It is interbedded with staurolite-biotite schist along U. S. highway 460 just east of Concord.

Other small and unimportant bodies of greenstone occur in this region. Those northwest of Hurtsville are less than 50 feet thick. West of Rustburg, in three cuts along U. S. highway 501, greenstone alternates with staurolite-biotite schist.

Mineral composition.—The greenstones resemble those of other areas. East of Appomattox the large body has not been extensively altered and closely resembles a fine-grained hornblende gneiss. The small bodies are commonly schistose and contain much epidote. A thin section of the greenstone at Rosebower shows much plagioclase, considerable epidote and magnetite, and a few shreds of green hornblende.

Physiography and soils.—Greenstone is more resistant to erosion than marble and less so than quartzite. It tends to produce low flats or valleys where it crops out between beds of quartzite. Where faulted against marble, a pronounced escarpment may be developed by erosion along the fault line, for example, west of Stonewall, where the eastern wall of Stonewall Creek valley for several miles is greenstone.

Greenstone finally weathers to a stiff, red clay soil that is especially good for growing dark tobacco. Unimproved roads in such sections become slippery after a shower and muddy or impassable after hard rains.

TRIASSIC IGNEOUS ROCKS

DIABASE DIKES

General features.—Diabase dikes similar to Triassic diabase elsewhere in eastern North America are somewhat common, though not equally distributed in this district. They cut vertically across all other rocks and are thus younger. (See Pl. 1.) They are not genetically related to the other igneous rocks of the region. Diabase dikes are common between Wingina and Gladstone but are rare between Gladstone and Lynchburg.

The principal diabase dikes in this region are listed below. (1) Three small dikes 1½ to 2 miles east and northeast of Norwood, which strike slightly west of north and may be parts of one dike which have been offset by faulting; (2) a dike which strikes N. 30° W. through

Cambrian and pre-Cambrian rocks 2 miles northeast of Variety Mills and passes through the gap of Findlay Mountain, and which may be a continuation of (1) above; (3) a fine-grained, augite diabase dike, about 200 feet wide, which strikes N. 5° E., in Joe Creek at Norwood and along the Chesapeake and Ohio Railway half a mile south of town, apparently offset by a fault at Bent Creek; (4) a dike of medium-coarse augite diabase about 1 mile northwest of Norwood, on the road to Variety Mills, which strikes N. 8° E.; (5) apparently an olivine diabase dike, which strikes N. 30° W. along the county road from half a mile west of Greenway nearly to "White Rock"; (6) a dike which strikes nearly due north, exposed half a mile west of Bent Creek along the road to Oakville; (7) a dark-gray, coarse-grained dike several hundred feet thick cropping out at the eastern edge of Gladstone and crossing the Amherst road north of town and striking N. 4° E., which was referred to by Rogers as "dark sienite," and is said to have been quarried for stone for locks and culverts; (8) a fine-grained dike, striking about N. 35° W., in the saddle of Spear Mountain and which can be traced southeast along the county road for 3 miles; and (9) another dike, which strikes N. 2° W., extending from near Stapleton and Porridge Run south for 4 miles.

These dikes almost invariably cut the strike of enclosing rocks at large angles. The prevailing strike is from slightly west of north to east of north. Many dikes have been offset by faults of northeast trend. They vary in width from a few feet to several hundred feet. Their mode of outcrop is extremely characteristic. The rock weathers into rounded masses that are surrounded by concentric shells of decayed rock. (See Pl. 12B.) The rounded masses are produced by weathering along joints and their size is determined by the joint spacings. The largest of these masses known to the writer are at Gladstone, where a church has been built upon one of them. Where the dikes show little or no topographic relief, they can be traced by the residual "boulders."

Megascopic character.—The fresh diabase ranges from almost black in fine-grained types to a dark-gray pepper- and salt-color in coarse-grained types. Dark-colored augite and grayish-white plagioclase are easily recognizable if the rock is not too fine grained. Hand specimens of the dike west of Greenway contain olivine, but no olivine was found in thin sections made from other diabases in this region.

Microscopic character.—Thin sections of the diabase show little variation except in texture. The rock consists of lath-shaped labradorite, considerable augite, and small amounts of magnetite, quartz and apatite. (See Pl. 11B.) Chlorite and biotite are present as alteration products of augite, but the diabase shows slight alteration in comparison with the other igneous rocks.

STRUCTURE

FOLDS

All the rocks, except the Triassic, of the Piedmont and Blue Ridge provinces, show close folding, and the cleavage in the schists and gneisses dips at high angles. This cleavage is generally developed at an angle with bedding planes which in part of the area have been obliterated by metamorphism. As a rule, the folds are overturned to the west so that the rocks dip steeply southeast. The axes of folding trend northeast in the same general direction as the folds in the Blue Ridge and in the Appalachian Valley to the west. (See Pl. 1.)

FAULTS

Thrust faults.—The oldest faults in the region are great overthrusts. The Blue Ridge overthrust has been mapped and discussed by Stose[37] and others. The Martic overthrust has been traced by Jonas[38] from Pennsylvania and Maryland across Virginia. It is believed to have been faulted down on the east side of the Catoctin Mountain Border fault in this district.

Small thrust faults are common in the Wissahickon schist at Hardwicksville and at Wingina, in Buckingham and Nelson counties. Their positions are marked by zones of broken quartz, schist, and ferruginous earth.

Normal faults.—The rocks of this district are broken into more or less rectangular blocks by normal (gravity) faults of Triassic age. A prominent set of faults which trends northeast is intersected by a set of cross-faults.

The most prominent normal fault in this district is the Catoctin Mountain Border fault. It delimits structurally the Blue Ridge anticlinorium on the east. Its presence is indicated by a great discordance in crystalline rock types. In this district and especially farther north, Triassic fanglomerate and other sediments occur along the eastern downthrow side of the fault. It is not possible to determine its throw in this district, but it must be great. Stose[39] has estimated the displacement at South Mountain, Pennsylvania, to be at least 6,000 feet.

Normal faults parallel to the Border fault are numerous in the lower part of the Glenarm series along James River. On the east

[37] Stose, G. W., and others, Manganese deposits of the west foot of the Blue Ridge, Virginia: Virginia Geol. Survey Bull. 17, pp. 27-34 and pl. 3, 1919.

[38] Jonas, A. I., Structure of the metamorphic belt of the central Appalachians: Geol. Soc. America Bull., vol. 40, pp. 503-514, 1929.

——— ———, Geology of the kyanite belt in Virginia: Virginia Geol. Survey Bull. 38, pp. 1-38, 1932.

[39] Stose, G. W., Possible post-Cretaceous faulting in the Appalachians: Geol. Soc. America Bull., vol. 38, p. 495, Fig. 1, 1927.

this belt of rocks is also separated from the overlying Wissahickon schist by normal faults. Normal faults should be more abundant in this anticlinal belt near the Border fault, but as they are difficult to locate in the Wissahickon schist some may have been overlooked. They are found especially on the western side of Triassic basins.

The northeast-southwest faults are cut by faults that trend northwest. Three prominent faults of this type are the Galts Mill fault, the Stapleton fault, and the Warminster fault, all of which offset the Border fault and extend into the Blue Ridge province.

The Galts Mill fault is the most conspicuous. From Galts Mill westward along the upper Lynchburg road continuous exposures of Wissahickon schist are shown, whereas similar exposures of the lower Glenarm rocks are shown along the lower road along Stovalls Creek. At Evergreen Mill, on Stovalls Creek, one can stand in the county road just south of the mill and see hornblende gneiss and soapstone rocks outcropping along the strike at the mill on the north side of the valley.

AGE OF STRUCTURES

Folds.—The folds in this district involve Cambrian and Ordovician rocks and it is probable that the latest major folding occurred when the Appalachian geosyncline was deformed, near the close of the Paleozoic era. The pre-Cambrian rocks were folded and metamorphosed in pre-Paleozoic times because Cambrian rocks contain pebbles derived from metamorphosed rocks, as, for example, pebbles of Lynchburg gneiss.

The pre-Cambrian rocks were in part metamorphosed a second time during late Paleozoic orogeny when the Wissahickon schist and other rocks of the Glenarm series were closely folded and cataclastically deformed and their mesozone minerals, biotite, garnet and staurolite were altered to epizone minerals, chlorite and muscovite.

Faults.—The Martic overthrust in Pennsylvania cuts Ordovician limestone and was developed during the late Appalachian deformation. The rocks of the Martic overthrust block override those of the Catoctin Blue Ridge anticlinorium, lying west of it. The overthrust parallels and is probably of the same age as the Blue Ridge overthrust on the western side of the Blue Ridge.[40]

Normal faults cut the Triassic sediments and commonly offset diabase dikes. Stose[41] has discussed the probability of post-Cretaceous faulting along the Catoctin Mountain Border fault. He suggests that movement along these faults may account for the minor earthquakes in the Piedmont and Blue Ridge provinces.

[40] Jonas, A. I., Personal communication; also Geology of the kyanite belt in Virginia: Virginia Geol. Survey Bull. 38, pp. 1-38, 1932.

[41] Stose, G. W., Possible post-Cretaceous faulting in the Appalachians: Geol. Soc. America Bull., vol. 38, pp. 493-503, 1927.

METAMORPHISM

Introductory statement.—Many students of Piedmont geology have stressed the importance of regional metamorphism[42] and the deformation of rocks by directed pressure. At shallow depths and under low temperature, cataclastic changes such as faulting and fracturing, are to be expected, and new minerals such as sericite, talc, epidote, chlorite, and glaucophane, which are adjusted to the particular physical conditions of that environment, are formed. At greater depths and high temperatures, complete recrystallization of the rocks with the production of minerals characteristic of a deeper zone may take place under stress.

The assemblage of minerals and the structure of the rock, therefore, show the nature of and the degree of metamorphism. Large crystals (idioblasts) developed in a fine-grained crystalline groundmass are called porphyroblasts. Crystallization under stress produces dimensional parallelism and if hornblende or mica is present, the rock assumes the texture of a schist or gneiss.

If crystalloblastic rocks with minerals formed in a deep zone are brought into a higher zone by thrusting, retrogressive metamorphism may take place under certain conditions. Thus biotite and garnet porphyroblasts, formed in the mesozone, may be altered to chlorite, an epizone mineral.

General features.—All of the pre-Cambrian sediments of this district, as well as the older intrusive rocks, have been more or less recrystallized. Massive zones of feldspar and quartz occur in the Lynchburg gneiss and Glenarm series. Conglomerate beds in the Mount Athos formation are partly granulated, whereas the enclosing finer sediments have become schists. Both low- and high-rank metamorphic types are recognized in this district.

Low-rank metamorphism.—The green slaty schists characterized by muscovite, chlorite, epidote, and amphibole represent low-rank metamorphism. The Wissahickon schist of Buffalo Ridge and Wingina, the Mount Athos and Cockeysville formations, and the underlying greenstone belong to this class. Cataclastic structures are common. A peculiar feature of these rocks is the production of biotite porphyroblasts. They are common in the schist of the Mount Athos formation and in some belts of the greenstone beneath it.

High-rank metamorphism.—Staurolite, garnet and biotite, which are deep-zone idioblasts, are developed in the Wissahickon schist of the central part of the district from Spear Mountain southwest, and in other areas, for example, east of Appomattox. Metamorphism of

[42] For further discussion of the terminology of metamorphism, see Tyrrell, G. W., The principles of petrology, 349 pp., New York, E. P. Dutton, 1926.

high intensity also characterizes the kyanite schists east of this district.

Retrogressive metamorphism.—The zones of staurolite-garnet schist from Spear Mountain southwest to Spout Spring, Concord, and Rustburg have undergone retrogressive metamorphism; that is, the staurolite, garnet, and biotite which are deep-zone minerals have been extensively altered to chlorite, a mineral characteristic of the epizone. This feature has been discussed by Jonas[43] who concludes:

"The schist is therefore a diaphthorite, such as would be produced by mylonitization and crystallization of the biotite schist in a zone of thrusting. The repetition of diaphthoritic zones may indicate the imbricate nature of the movement."

A sharp contrast in degree of metamorphism occurs along the Martic overthrust east of Lynchburg, where the Lynchburg gneiss is in contact with Wissahickon chlorite-muscovite schist. The gneiss has been recrystallized at great depth and has been brought to the surface by vertical uplift and erosion without being involved in later metamorphism. The Wissahickon schist which is thrust over it shows epizone metamorphism superimposed on an earlier high-rank metamorphism. Its apparent low-rank metamorphism is a product of retrogression and differential movement during a second period of metamorphism and not the result of progressive metamorphism of a phyllite.

Contact metamorphism.—Contact metamorphism is not important, and its effects have been previously mentioned. East of this district, garnet and amphibole have been locally produced where pegmatite intrudes hornblende gneiss.

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[43] Jonas, A. I., Structure of the metamorphic belt of the central Appalachians: Geol. Soc. America Bull., vol. 40, p. 509, 1929.

GEOLOGIC HISTORY

PRE-CAMBRIAN TIME

Lynchburg epoch.—The oldest known rock of the Blue Ridge anticlinorium is the Lynchburg gneiss.[44] It has been highly metamorphosed under conditions of deep burial and intruded by pre-Cambrian igneous rocks—the Lovingston gneiss and gabbro and associated ultra-basic rocks—which have also been subjected to great metamorphism.

Epoch of lava flows.—In Virginia east of the Blue Ridge anticlinorium in the area of the Martic overthrust, the oldest known rocks are lava flows of unknown thickness which underlie the Mount Athos formation. These extrusions were accompanied or soon followed by submergence and the deposition of a thick series of sedimentary rocks, beginning with the sands of the Mount Athos quartzite. Volcanic activity continued intermittently during the deposition of the Glenarm sediments, as is shown by the local occurrence of tuffaceous beds and lava flows.

Mount Athos epoch.—The Mount Athos formation, which is about 200 feet thick, is the oldest known pre-Cambrian sediment in this district. It contains locally some tuffaceous material, but most of the sediment appears to have been derived from the decay of granitic rocks. Variations in thickness are probably due to irregularities in the underlying greenstone floor. No lava flows have been found in the quartzite, but the local occurrence of water-laid tuffs indicates explosive volcanic action during this time.

East of James River in Appomattox County, the formation appears to be more micaceous and less sandy; hence it seems probable that the nearest shore was to the west. The pebbles of blue quartz may have been derived from rocks of the Blue Ridge anticlinorium. It is possible that the Mount Athos sediments were derived from rocks which now underlie them or were exposed farther east, these source rocks having been concealed later by the overthrust block which carries the sediments.

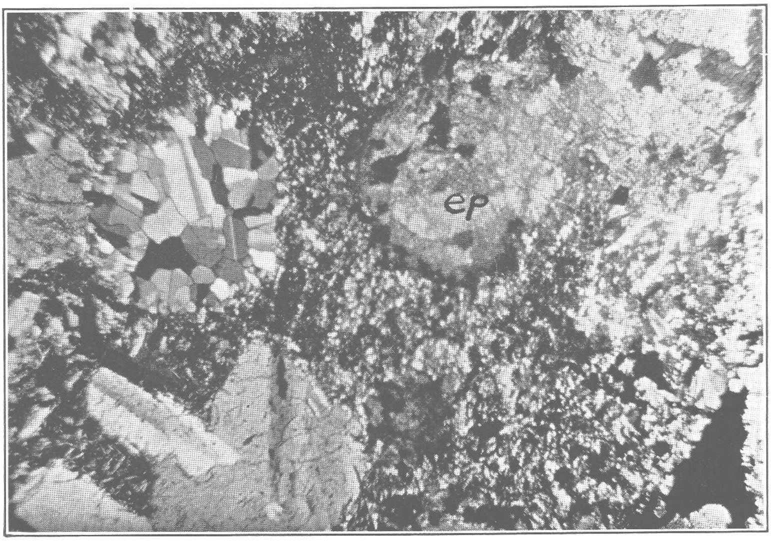
Cockeysville epoch.—At the close of Mount Athos time, the seas cleared and calcareous sediments, now the Cockeysville marble, were deposited. There is no apparent break between the Mount Athos and Cockeysville formations, and northeast of Stapleton the upper beds of the Mount Athose quartzite are calcareous.

The Cockeysville formation in this district is at least 200 feet thick and consisted originally of alternating layers of nearly pure

[44] The Lynchburg gneiss has not been correlated with rocks in other districts.

A. Basal greenstone flows showing large laths of primary plagioclase. They occur east of James River near Galts Mill, Amherst County. Two amygdules, one filled with secondary plagioclase and one with epidote (ep), are shown. Crossed nicols; X 22.

B. Coarse-grained diabase near Tye River, about 1 mile west of Norwood, Nelson County. The minerals are labradorite and augite. Crossed nicols; X 90.



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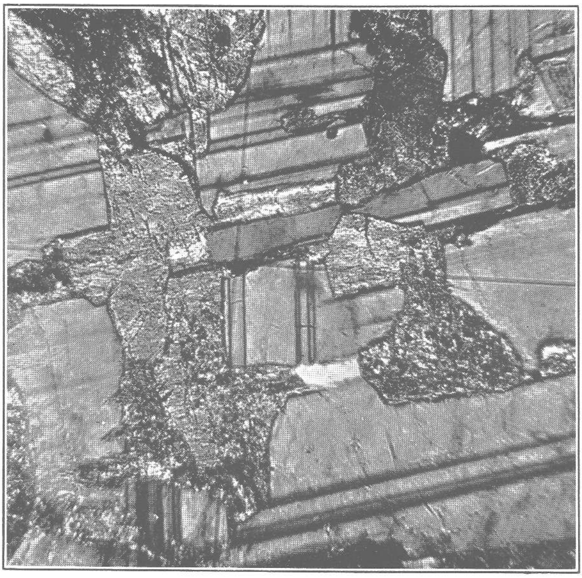

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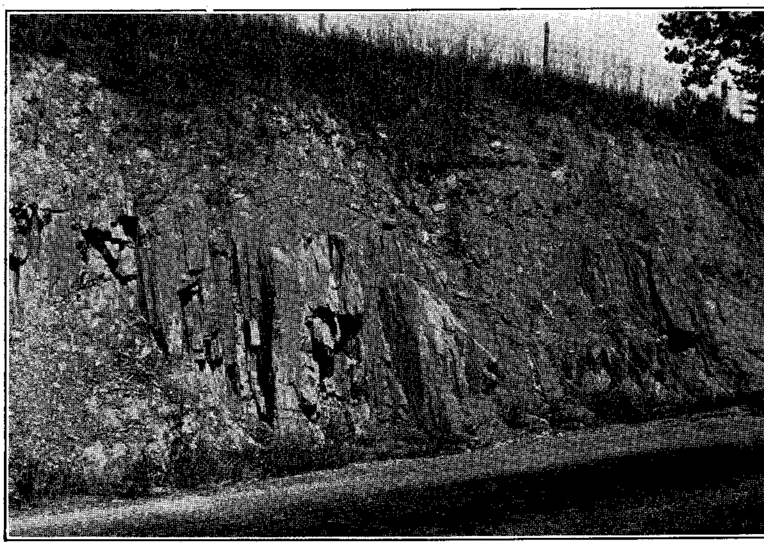
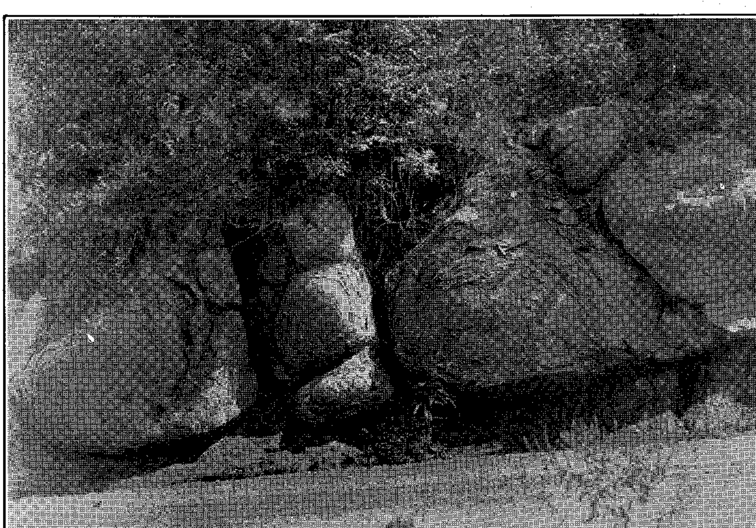
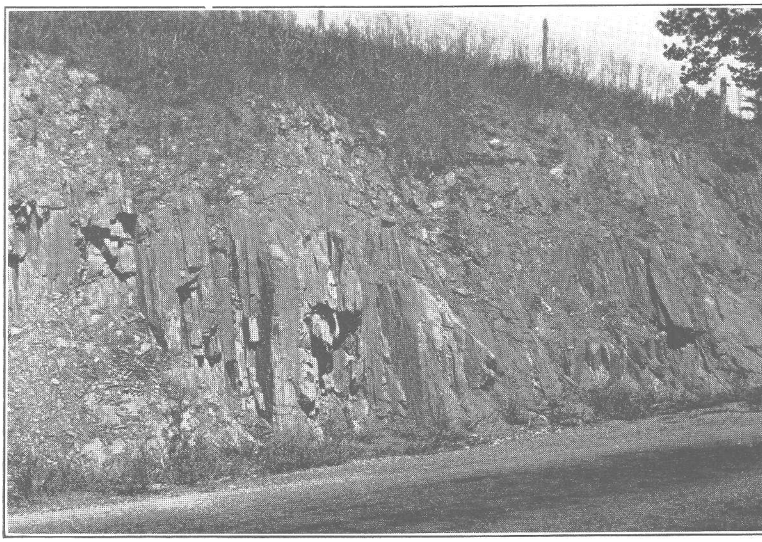


A. Typical exposure of basal greenstone volcanics along the highway east of Mount Athos, Campbell County.



B. Characteristic mode of weathering of a Triassic diabase dike. This dike is near Bent Creek, Appomattox County.



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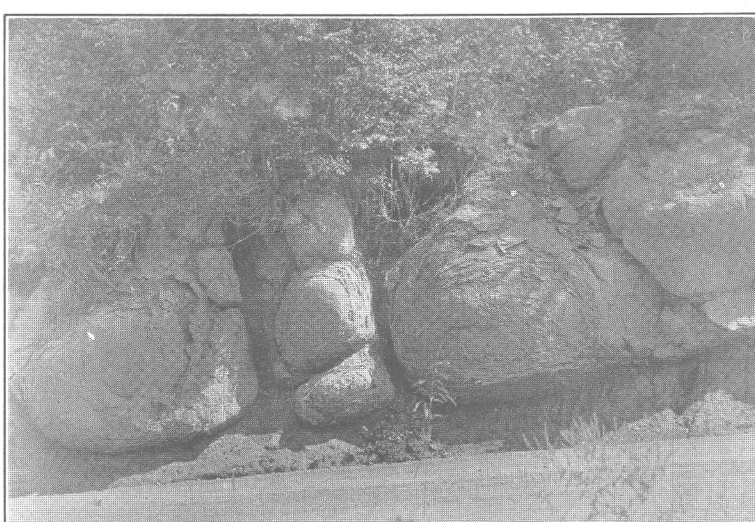


B. Characteristic mode of weathering of a Triassic diabase dike. This dike is near Bent Creek, Appomattox County.

calcareous and dolomitic sediments and calcareous muds. If these sediments once contained organic remains, they have been destroyed by intense metamorphism and recrystallization of the limestone into marble.

Wissahickon epoch.—The Cockeysville beds grade upward into Wissahickon biotite schist and gneiss, of great but undetermined thickness and wide distribution. Beds of quartz-mica schist and quartzite are insignificant in proportion to the thick beds of mica schist which are believed to have been derived by the metamorphism of argillaceous sediments. The extent of the formation indicates an extensive basin in which muds and fine sands were deposited. Lava flows were poured out several times upon the floor of the basin during Wissahickon time. The tendency of beds of quartzite to overlie the lava flows suggest that each outpouring of lava may have been accompanied by a slight relative elevation of adjacent lands so that erosion and clastic sedimentation were renewed.

Other events.—Prior to Cambrian time there were intrusions of molten materials now represented by the Lovingston gneiss and gabbro and similar rocks. These intrusions were followed by the thick lava flows of the Catoctin greenstone. Then there was deep erosion before Cambrian time.

PALEOZOIC ERA

The Appalachian geosyncline.—The pre-Cambrian rocks were folded into mountains and altered to crystalline rocks before the deposition of the first Paleozoic sediments. At the close of pre-Cambrian time, this region of ancient crystalline rocks was again uplifted and the region to the west was warped down to form a long structural trough known as the Appalachian geosyncline. The ancient eastern land mass (Appalachia) was uplifted along and beyond the present continental margin and early Paleozoic sediments covered the region now occupied by the Piedmont, Blue Ridge, and Appalachian Valley provinces. In early Paleozoic time, the Appalachian geosyncline probably extended eastward beyond the present edge of the Piedmont province as indicated by Ordovician rocks (Quantico slate) now found along the Fall Zone.[45]

Cambrian period.—It is not known whether the Lower Cambrian sediments in this district are marine or non-marine. To the northeast in Maryland, they are overlain along the strike by fossiliferous Lower Cambrian rocks. On the west side of the Blue Ridge, the

[45] See Geologic map of Virginia: Virginia Geol. Survey, 1928.
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. 33-43, 1911.

oldest beds grade upward into beds containing Lower Cambrian fossils.[46]

The Lower Cambrian sediments in this district do not in any way resemble marine rocks. They were not chemically weathered before deposition and probably represent materials derived from near-by sources by short and rapid transportation. The occurrence of fine graphitic layers alternating with coarser layers points to periodic differences in the rate of rainfall. In their distribution, rapid variations in thickness, and composition they resemble piedmont fans.

Post-Cambrian time.—There is no Paleozoic record in this district later than that in the Lower Cambrian beds. Ordovician sediments were deposited farther west and east in the Piedmont region. If Silurian or later sediments were deposited, they have all been removed by erosion. As there must have been a considerable load of rocks under which the late Paleozoic thrust faulting took place, it appears reasonable to infer that great thicknesses of Paleozoic sediments once covered this district.

MESOZOIC ERA

After the great period of folding and uplift which took place near the close of the Paleozoic era, the Appalachian region was subjected to erosion which has lasted to the present time. This region was a high land area in Mesozoic time and erosion was rapid. The sediments were carried into the Atlantic by eastward flowing rivers and spread out on the wide continental shelf. Frequent periods of uplift undoubtedly rejuvenated streams during this time and accelerated the rate of erosion.

At the beginning of the Triassic period, this district was arched up and block-faulted. The most pronounced faulting extended northeast-southwest in the general direction of Appalachian structure. This produced many long, inland basins into which streams and wash from the near-by highlands carried the weathered products of crystalline rocks. They were deposited as gravel, sand, and mud to form conglomerates, sandstones, and shales. In places, marshes existed in these basins and coal-forming deposits were laid down, although no coal occurs in this district. The rocks have a characteristic red color, because the cementing material is ferric oxide. Some believe that the abundance of red iron oxide indicates that the climate at this time was arid, but Roberts[47] marshals

[46] Stose, G. W., and others, Manganese deposits of the west foot of the Blue Ridge, Virginia: Virginia Geol. Survey Bull. 17, p. 14, 1919.

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

much evidence to show that such deposits accumulated in moist climates rather than under desert conditions. Lava flows were poured out and mingled with the sediments, which during the same time were intruded by dikes and sills. There are no sills in this district, but diabase dikes are intruded into the crystalline rocks at many localities. At the close of the period of Triassic sedimentation, movement along the Catoctin Mountain Border fault gave the newly deposited sediments a westward dip and produced an escarpment down which large blocks of crystalline rocks were carried to form piedmont fans. In this district, the Border conglomerate thus formed consists mainly of fragments of Catoctin schist.

CENOZOIC ERA

By the close of the Mesozoic era or in early Cenozoic time, this region was worn down to a low, gently rolling plain of great extent which is called the Piedmont peneplain. Its character and extent have been previously discussed under Physiography. The surface of the Piedmont peneplain is thought by some to be of Cretaceous age, because it is covered by Cretaceous sediments along the Fall Zone. Others correlate the Piedmont peneplain with the Valley-floor (Harrisburg) peneplain and thus ascribe a Tertiary age to it.[48] Subsequent uplifts in Tertiary and Pleistocene times have rejuvenated the streams, with the result that the peneplain is in places considerably dissected. The terraces along James River indicate several times of uplift or halts in downcutting by the river since the formation of the peneplain.

[48] Wright, F. J., The older Appalachians of the South: Denison Univ. Bull., Jour. Sci. Labs., vol. 26, pp 143-250, Dec, 1931; The newer Appalachians of the South: Idem, vol 29, no. 13, pp. 1-105, Apr., 1934.

ECONOMIC GEOLOGY

GENERAL FEATURES

The James River iron and marble belt is an old mining district which contains a variety of mineral resources. Mining has been carried on in this district since the early settlement of the State. Much iron ore, mostly limonite, was mined and smelted in this region in the past, and after the War between the States, both hematite and magnetite ores were mined and shipped. When the Lake Superior iron district was opened, the local iron industry declined and no iron has been mined recently. Some manganese and small amounts of copper have been mined locally in this district.

The most important nonmetallic resources are limestone and soapstone. The local limestones have been burned for lime since early times, and deposits are so scattered that practically every farmer in the marble belt could burn his own lime if he desired to do so. Soapstone was worked by the Indians and has been quarried in many localities in this section in recent times. Much good stone remains, but none is quarried at present.

The accompanying map (Pl. 13), shows the location of old and recent mines, prospects, furnaces, quarries and lime kilns of the district, which are discussed below.

LIMESTONE AND MARBLE

INTRODUCTORY STATEMENT

The Cockeysville marble has been described. The distribution of the limestone and marble is shown on the geologic map (Pl. 1), and the location of quarries is shown on Plate 13. The economic features of all known occurrences are fully discussed below and chemical analyses, collected from various sources, are given. The limestones and marbles, although undeveloped, constitute an important economic resource of the James Valley.

DISTRIBUTION AND CHARACTER

Mount Athos area.—An important belt of limestone is found about 1 mile east of Mount Athos, Campbell County. (See Pl. 1, and Fig. 2.) The limestone is well exposed at "the Arch" where the Norfolk and Western Railway passes over the old stagecoach road between Richmond and Lynchburg. The belt can be traced with interruptions from James River below Norwood southwest across the Norfolk and Western

Railway and along Beaver Creek. It is the most continuous belt of limestone and marble in the region. East of Mount Athos, the limestone is thrown against greenstone by a normal fault. The limestone beds are enclosed in mica schist and are about 100 feet thick at "the Arch," where they dip 63° SE.

The limestone is mashed and slaty. It includes some schist bands that are graphitic. It is dark to light blue, in many places coarsely crystalline, with streaks and small lenses of white calcite and rarely milky quartz, and contain numerous bands of brown mica parallel to the schistosity. A thin section shows interlocking grains of twinned calcite, some quartz grains, and a few sheaf-like wisps of phlogopite. (See Pl. 6A.)

This was the easternmost belt of limestone known to Rogers, who describes the outcrops at "the Arch" as blue, micaceous, somewhat slaty, and containing calcspar. The following analyses of limestones near "the Arch," about 1 mile east of Mount Athos, are quoted from Britton:[49]

About 1½ miles southeast of "the Arch," blue limestone crops out for a short distance in a creek along a prominent normal fault near the Norfolk and Western Railway.

Analyses of limestone from Beaver Creek, Nelson County, made by Rogers,[50] are given in Table 2.

A thick belt of limestone and calcareous schist, interbedded with non-calcareous schist, crosses James River west of Mount Athos and east of the sharp bend in the river just below Lynchburg. It is well exposed along the Norfolk and Western Railway in Amherst County and at places along Opossum Creek in Campbell County. This belt is about 1½ miles wide, probably due to the duplication of beds by folding.

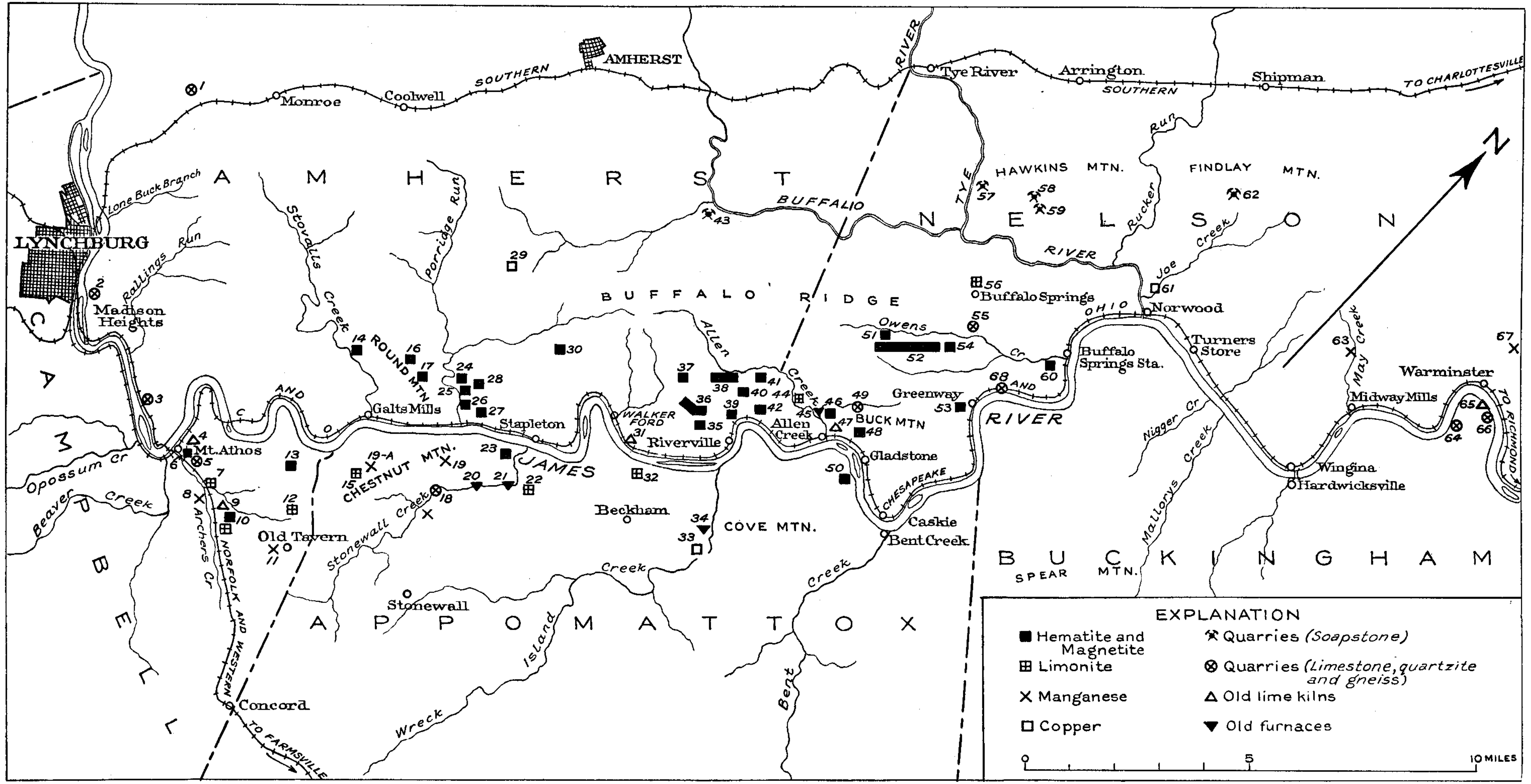
A short distance down the river, east of the Norfolk and Western Railway bridge at Mount Athos, is an outcrop of blue slaty limestone of good quality, about 48 feet thick. This rock is said to have been burned about 50 years ago and to have made excellent lime. The remains of an old kiln are present.

According to Campbell,[51] fluxing material for the Lynchburg furnace was obtained prior to 1882 from the limestone near the base of Mount Athos and near the Richmond and Alleghany Railroad. It is a compact stone about 300 feet thick, from which several thousand tons were mined for use as a flux. An analysis of this stone showed 92 per cent calcium carbonate.

[49] Britton, J. B., Analyses of Campbell and Appomattox counties, Virginia, iron and manganese ores and limestones: The Virginias, vol. 2, no. 11, p. 171, 1881.

[50] Rogers, W. B., A reprint of annual reports and other papers on the geology of the Virginias, p. 390, New York, D. Appleton and Co., 1884.

[51] Campbell, J. L., Geology and mineral resources of the James River Valley, Virginia, U. S. A., p. 84, New York, G. P. Putnam & Sons, 1882.



Map of mines, prospects, quarries, kilns and furnaces along James River northeast of Lynchburg, Virginia.

EXPLANATION OF PLATE 13

1. Lynchburg gneiss road quarry.
2. Lynchburg gneiss quarry.
3. Limestone quarry.
4. Mount Athos lime kiln.
5. Mount Athos quartzite (ballast).
6. Iron mines.
7. "Railroad" property.
8. Leet, or Whitman, mine.
9. Archers Creek lime kiln.
10. Cross cuts, Archers Creek property.
11. Old Tavern property.
12. "Red Belt" (turgite and limonite) properties.
13. Prospect.
14. Lone Pine mine.
15. Blankenship mines.
16. Round Top prospect.
17. Round Top shaft.
18. Limestone quarry.
19. Chestnut Mountain mine.
19-A. Chestnut Mountain prospects.
20. New Ross furnace.
21. Stonewall furnace.
22. Furnace vein.
23. Ferguson and Isbell properties.
24. Maud mines.
25. Matthews tunnel.
26. Beulah tunnel.
27. Prospect.
28. Ice Cliff tunnel.
29. Buffalo Ridge prospects.
30. Old shaft.
31. Mundy property.
32. Folley mine.
33. Moore property.
34. Old Revolutionary copper furnace.
35. Prospects.
36. Hart tunnel.
37. Old shafts.
38. Ames tunnel.
39. Canal tunnel.
40. Lathrop tunnel.
41. Gardenfield tunnel.
42. Tunnels, open cuts, and shafts.
43. Piedmont soapstone quarries.
44. Brown hematite mine.
45. Old Elk Creek furnace.
46. Tunnel.
47. Lime kiln.
48. Megisson property.
49. Limestone quarry.
50. Kirby Smith prospect.
51. Kimball tunnel.
52. Greenway mines and Church tunnel.
53. Quartzite prospects.
54. Lewis tunnel and Price shaft.
55. Limestone quarry.
56. Buffalo Springs property.
57. Phoenix soapstone quarry.
58. American soapstone quarry.
59. Standard soapstone quarry.
60. Gay prospect.
61. Joe Creek shaft.
62. Plummer soapstone quarry.
63. Midway Mills mine.
64. Limestone quarry.
65. Old lime kiln.
66. Limestone quarry.
67. Old mines.
68. Mount Athos quartzite (ballast).

TABLE 1.—*Analyses of Cockeysville limestone about one mile east of Mount Athos, Campbell County, Virginia*

(J. B. Britton, Analyst)

	1	2	3	4	5
Lime carbonate	77.67	67.85	82.45	65.10	91.51
Magnesia carbonate	3.78	6.02	2.10	2.96	2.59
Silica	15.88	20.42	10.98	26.90	....
Alumina	.97	1.20	.70	.86	....
Water	.27	.41	.16	.21	.41
Iron protocarbonate	1.16	3.80	2.90	3.94	....
Iron peroxide	....				
Iron pyrites	....	.22	.19	....	....
Phosphoric acid	.003	.006	trace	.004	....
Manganese oxide	.07	trace	trace	trace	....
Iron and manganese oxides and alumina	....	....	....	....	2.77
Insoluble siliceous matter	....	....	....	....	2.56
Undetermined and loss	.197	.074	.52	.026	.16
	100.00	100.00	100.00	100.00	100.00

1. Blue limestone from a nearly vertical stratum about 3 feet wide, on the north side of the Norfolk and Western Railway.
2. Light-blue limestone from seam about 25 feet wide, about 300 feet north of "the Arch."
3. Same as above, but of a dark-blue color.
4. Blue limestone from a stratum about 50 feet wide, exposed in a branch a little south of the railroad.
5. From a stone crystalline in structure, and locally known as white limestone; taken from a stratum, about 40 feet of which is exposed in the bed of a branch.

From this locality westward along the Norfolk and Western Railway, the following occurrences are worthy of mention: (1) About 200 yards west, about 10 feet of blue limestone containing white calcite veins, which is enclosed by blue, slaty phyllite; (2) from 1,100 and 1,600 yards west, exposures of alternating layers of blue limestone, calcareous schist, or schistose limestone, and fine-grained slaty, mica schist; and (3) a bed of limestone about 6 feet thick, slightly more than 1 mile from the west end of the railroad bridge. The limestone in the second belt ranges from narrow bands to beds several hundred feet thick. The beds have been quarried by the railroad company. At a point about 1,460 yards to the west, the following section is exposed.

Geologic section of Cockeysville formation at abandoned quarry on north side of Norfolk and Western Railway, west of Mount Athos, Virginia

	Thickness Feet
At east end of section, blue limestone with white calcite veins; dips 80° SW.	18
Fine-grained, blue, slaty limestone	78
Fine-grained mica schist	50
Weathered, gray marble	4
Blue, laminated limestone; dips 40° SE.	6
Green, slaty, phyllite; dips 80° NW.	168
Blue and green, slaty vertical limestone containing quartz stringers; large quarry in this bed	120

Rogers found that a white, slaty limestone with a talcose surface, on the James River Canal between Fishing and Opossum creeks, contained 25 per cent of calcium carbonate.

The northeastern part of this belt, between this locality and Galts Mill, is either largely non-calcareous or else the limestone is not exposed. There is an opening in blue limestone about 300 yards northeast of the brick plant near James River about 1½ miles northeast of the railroad bridge.

According to Rogers,[52] a gray limestone with small rhombs of calcite found on James River below Archers Creek contains 79.5 per cent calcium carbonate. Near Ninemile bridge, the second crossing of the James by the Chesapeake and Ohio Railway from Lynchburg, is found a blue calcareous schist which physically resembles limestone. At Ninemile bridge and again near Galts Mill along the county road west of the railroad are outcrops of gray to white, impure magnesian marble.

Stapleton area.—Slaty limestone crops out in the bluffs of James River in Appomattox County almost opposite Stapleton station. The stone is light blue, very finely crystalline, and has a silky luster produced by very small flakes of mica. A thin section shows small grains of twinned calcite and quartz, with some muscovite. The limestone appears to be of good quality and is said to have been burned to good lime. The thickness of the limestone can not be determined, as the western side of the body is concealed by the river.

Limestone crops out also close to James River opposite Old Stapleton, where it is exposed in a branch which has cut through the floodplain of the river. The stone can be traced for a quarter of a mile along the creek bed across the strike. It is much mashed, but crumpled

[52] Op. cit., p. 391.

bedding can be seen. Schist bands are common, but much of the stone is of good quality.

Stonewall Creek area.—A thick deposit of blue marble crops out along Stonewall Creek on the road between Galts Mill and Stonewall. It has been quarried and used as crushed stone and as burned lime for agricultural purposes from time to time for nearly 40 years. Messrs. T. A. Drinkard and J. R. Horsley are the present owners of the quarry. (See Fig. 4.) It is reported that a sample analyzed at Virginia Polytechnic Institute, Blacksburg, contained 90 to 95 per cent of calcium carbonate.

The marble is dark blue and contains "eyes" and stringers of coarse white calcite, some milky quartz, and a few specks of pyrite. Crumpled bedding planes show on the weathered surfaces. The true thickness is difficult to determine, but about 200 feet is exposed at the quarry near the county road. The marble can be traced along the strike for 1 mile up Stonewall Creek. According to Watson,[53] a belt of limestone at least 300 yards wide occurs between schists and the limestone contains schist layers about 6 inches thick, and "eyes" and lenses of calcite and quartz. The dip is recorded as 80°-85° NW.

This limestone was described by Rogers:[54]

"On Stonewall creek, a short distance below Ross's furnace, and about 2 miles in a direct line from the river, a belt of limestone is exposed, measuring at this place upwards of three hundred feet in thickness. It is blue, sometimes sparry and white, sometimes granular, and inclined to be crystalline. This belt possesses great importance, not only on account of its extent, but its contiguity to the extensive beds of rich iron ore which are used at the furnace, the limestone lying a little east of the most eastern band of ore." Rogers analyzed this marble and reported a content of 88.4 per cent calcium carbonate. It was used as a flux in the old furnace.

Campbell[55] stated in 1882, "On Stonewall Creek, about two miles from its mouth, several large kilns were in operation two years ago making lime for the general market."

Beckham area.—A large body of white marble is exposed on the property of Alonzo Moore, 1½ miles southeast of Beckham, Appomattox County, near the west bank of Wreck Island Creek. (See Fig. 5.) The marble is bounded on the northwest by beds of slabby quartzite which dip 30° SE. The contact of the marble and overlying Wissahickon schist is exposed on the southeast side of the creek valley. The marble is mineralized and contains in places copper sulphides and hematite associated with quartz stringers. Small nodules of micaceous

[53] Marginal note upon a topographic map.

[54] Rogers, W. B., A reprint of annual reports and other papers on the geology of the Virginias, p. 304, New York, D. Appleton and Co., 1884.

[55] Op. cit., p. 83.

hematite weather in relief upon the surface. A short tunnel has been driven through the schist into the west bank of the creek to intersect the marble.

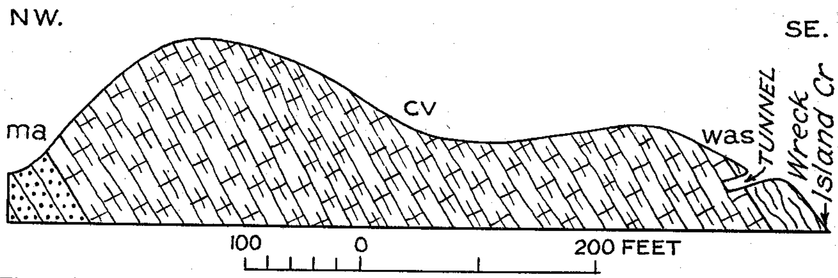


Figure 5.—Section through marble on the Moore property 1 mile southeast of Beckham, Appomattox County. ma, Mount Athos formation; cv, Cockeysville marble; was, Wissahickon schist.

A large body of blue, slaty marble is exposed nearby in a tributary to Wreck Island Creek, on the property of Jim Burge and Howard Harding, a short distance northwest of Mount Comfort Methodist Episcopal Church, where it lies at the northern base of a steep ridge in Wissahickon mica schist. The stone appears to be of variable value, but much of it would probably be suitable for agricultural purposes. It contains some cellular nodules of milky quartz and is greatly crumpled. It strikes nearly north and appears to be in line with the body of white marble. A thin section shows interlocking grains of twinned calcite, some quartz and considerable pale-brown, pleochroic mica. The western side of this marble is well exposed and grades into a quartz-biotite schist.

Limestone is said to be found on the property of Tom Moore, one-fourth to half a mile southeast of the main Beckham-Bent Creek road. Another body of limestone, said to be of good quality for agricultural lime, is reported to be exposed for a quarter of a mile in a branch west of the house of J. A. Burns.

Walker Ford area.—Nearly a mile northeast of Walker Ford on the north side of the Chesapeake and Ohio Railway, blue limestone of good quality crops out on the property of Dillard Mundy. It represents an extension of the beds that crop out near the railroad at Allen Creek and near Riverville. According to Campbell[56] and Mr. Mundy, considerable lime was burned here in former years. The thickness could not be determined.

Riverville area.—Three bodies of blue limestone are exposed in the centers of small synclines along the county road between Riverville and Saint James. The mode of occurrence of these three marble bodies suggests a folded syncline in which the marble has become dis-

[56] Op. cit., p. 83.

connected by erosion. (See Fig. 6.) West of Riverville, the first exposure of blue marble is about 120 feet thick. In a second belt, marble enclosed in schist is about 100 feet thick. The dip here is abnormal, being 60° NW. The third and thickest bed of limestone extends eastward for about three-eighths of a mile from Saint James. At the road crossing at Saint James, schist weathered to blue clay is exposed and 48 feet of blue marble occurs at the eastern limit of this schist. West of Saint James is about 250 to 300 feet of poorly exposed, dark, crumpled schist, probably associated with the marble.

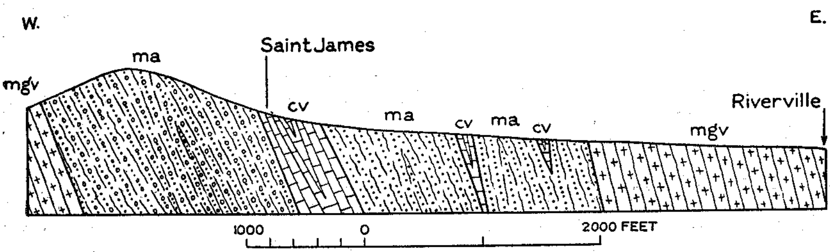


Figure 6.—Cross section west of Riverville, Amherst County. mgv, greenstone; ma, Mount Athos formation; cv, Cockeysville marble.

Limestone which crops out about 1 mile northeast of Riverville close to the west side of the Chesapeake and Ohio Railway is an extension of beds exposed near the railroad at Allen Creek. About 80 feet is exposed. The dip ranges from 18° to 30° SE. The limestone is separated from greenstone to the west by a normal fault. The greenstone on the west wall dips 60° SE. The limestone is of variable quality and contains schist bands. A limestone from near Jordans Lane on Dr. Mundy's property is reported by Frazer[57] to contain 45.08 per cent of calcium oxide (73.88 per cent calcium carbonate).

Allen Creek area.—A compact, fine-grained, blue marble crops out in the bed of Allen Creek west of Riverville, on the property of Messrs. Boettler and I. L. Drumheller. It extends for an unknown distance in the direction of strike and is found on both sides of the Saint James-Galilee Church (colored) road. On the Boettler property, it is said to have been burned for lime before the War between the States. According to Mr. Drumheller, it extends for 1 mile or more southwest of the Boettler place and the same distance northeast of the county road. Figure 7 shows the relations of this marble to the enclosing rocks. The marble dips 60° SE., and, where exposed in the creek, is about 200 feet thick. The beds have been intricately folded and crumpled with the development of some mica.

[57] Frazer, Persifor, Jr., The iron ores of the middle James River: Am. Inst. Min. Eng. Trans., vol. 11, p. 214, 1883.

Marble also appears lower on Allen Creek, about 1 mile northwest of the Old Riverville mines, near the base of a quartzite ridge. A thin band of blue-green schist lies against it to the east. The marble dips 41° SE. and is 150 feet thick.

At Allen Creek station.—Limestone of good quality is found on the property of Dr. W. L. Watts on both sides of Buck Mountain at Allen Creek station. On the west side of the mountain, the limestone is more than 300 feet thick. In a small quarry opened by Dr. Watts in the eastern edge of the limestone belt, the dip is 54° SE. Limestone is also exposed along a small creek west of the quarry.

The limestone is much mashed and contains abundant lenses and stringers of coarse, white calcite, some pink calcite, and a few small lenses of milky quartz. The stone is of excellent quality and has been burned by the present owner who reports that it makes a good grade of lime for fertilizer and whitewash. This stone was used as a flux in the old Elk Creek Furnace. An analysis supplied by Dr. Watts shows 78.70 per cent calcium carbonate and 1.40 per cent magnesium carbonate, with some iron and silica.

A bluish-gray, micaceous, crystalline limestone of compact texture from Elk Creek, which was used as a furnace flux, was analyzed by Rogers[58] with the result given in Table 2.

TABLE 2.—*Analyses of Cockeysville limestone and marble from James River belt, Virginia*
(W. B. Rogers, Analyst)

	1	2	3	4	5	6
Calcium carbonate	16.89	13.94	20.87	16.03	12.95	11.17
Magnesium carbonate	6.32	10.18	.72	7.58	10.80	8.50
Alumina and iron oxide	1.00	.39	.38	.49	.28	1.04
Silica	.67	.38	2.88	.78	.88	4.12
Water	.12	.11	.15	.12	.09	.17
	25.00	25.00	25.00	25.00	25.00	25.00

1. Light-gray limestone from Mr. Wright's property east of Beaver Creek, Campbell County.
2. White limestone from Captain Perrow's property along Beaver Creek, Campbell County.
3. Bluish-gray limestone from Elk Creek, Nelson County.
4. White, dolomitic marble from James River canal between Elk Creek and Greenway, Nelson County.
5. Pink, magnesian marble from Pounding Mill Creek near Norwood, Nelson County.
6. Pink limestone, mottled with gray, from south side of James River opposite Warminster, Buckingham County.

Limestone is exposed along the county road at the east end of Allen Creek village near the railroad. On the west, the limestone is thrown against greenstone by faulting. The stone is blue, somewhat micaceous, and contains lenses of white calcite. A width of about 240 feet is exposed. The dip is 58° SE.

[58] Op. cit., p. 390.

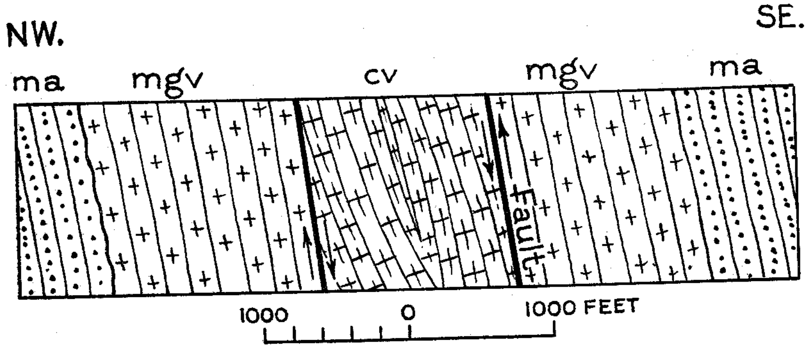


Figure 7.—Cross section on Allen Creek west of Riverville, Amherst County. mgv, greenstone; ma, Mount Athos formation; cv, Cockeysville marble.

This limestone is reported to be of good quality. It is said that lime made from it was used in constructing locks on the canal and that the old brick factory at Bent Creek was built with mortar made of this lime. A blue, slaty, slightly micaceous limestone, said to have been quarried for locks at Allen Creek, is reported by Rogers[59] to contain 65.5 per cent calcium carbonate.

Gladstone area.—Limestone and marble are exposed almost continuously in bluffs along the county road between Caskie and Gladstone and along the railroad from Gladstone to Allen Creek. (See Fig. 8.) The thickest continuous exposure of marble in the region is found between Gladstone and Caskie. The rock ranges from blue limestone to gray marble, is thickened by folding, and about half way between the two points is separated by about 300 feet of Wissahickon schist. Between the schist here and the Wissahickon schist at Caskie, is an anticline containing 600-800 feet of blue-gray to gray marble with some schist bands. West of the infolded band of Wissahickon schist, is a band of gray-white crumpled marble that is platy or schistose, contains numerous thick schist bands, and is apparently of poor quality.

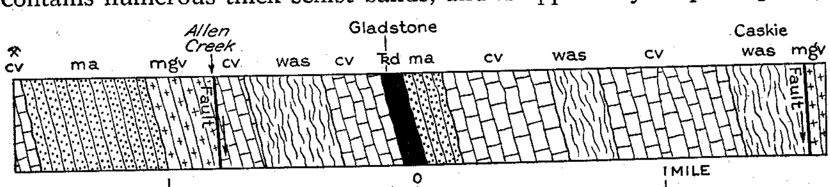


Figure 8.—Cross section of the Glenarm series near Gladstone, Nelson County. mgv, greenstone; ma, Mount Athos formation; cv, Cockeysville marble; was, Wissahickon formation; Ꞧ d, Triassic diabase dike.

A thick series of marble and schist crops out in the railroad yards west of Mundys store at Gladstone. Blue limestone, and white, pink,

[59] Op. cit., p. 392.

and gray marble are interbedded with schist. These rocks crop out for three-eighths of a mile, the unusual width being due to folding and gentler dips. The westernmost exposure of marble here is massive, white, gray-white, and pink, and about 40 to 50 feet thick. The upper beds are sandy and the weathered rock resembles quartzite. West of this marble is a blue limestone of good quality about 300 feet thick.

An analysis made by Rogers,[60] of a dolomitic marble from the James River canal between Elk Creek and Greenway in Nelson County which probably came from this outcrop is given in Table 2. The marble was described by him as white, compact, crystalline, conchoidal, and containing disseminated small crystals of quartz.

In Appomattox County.—The belt of limestone and marble crosses the river and extends southwest to a point east of Beckham in Appomattox County. It crops out along the bed of a small creek in Brooks Hollow, on the southwest side of the river just south of Smiths Island. The rock is blue limestone apparently of good quality and is possibly 150 feet thick. The dip is 56° SE.

Blue limestone apparently of good quality is exposed in this belt about 2½ miles northeast of Beckham along the road to Bent Creek. It crops out in a branch near the road and can be traced along the strike for 900 feet. About 20 feet is exposed, but it is probably much thicker. Blue limestone is exposed one-fourth of a mile northeast of this point, in the bed of Wreck Island Creek.

At Greenway station.—A thick body of blue limestone is exposed in ledges near the Chesapeake and Ohio Railway and on both sides of the county road for half a mile southwest of Greenway station. (See Pl. 14A.) The limestone lies in a syncline and its thickness has been increased by folding. An estimated thickness of 480 feet is exposed. The limestone is enclosed in mica schist. The contact between marble and schist and the upper blocky quartzite beds of the Mount Athos formation is shown along the railroad. The quartzite beds are calcareous and contain in places bands of gray-white marble which carry abundant grains of blue quartz.

The limestone is dark-blue, slaty, and greatly mashed. Crumpled bedding planes appear to lie nearly parallel to the cleavage. Lenses and "eyes" of coarse white calcite, or more rarely milky quartz, are parallel to the cleavage. Calcite stringers cut across the schistosity. No chemical analyses are available. The rock is of good quality and its great thickness and proximity to the railroad should make this one of the most important bodies of limestone in the region.

Owens Creek area.—About 1 mile east of Buffalo Springs, on the property of J. R. McNutt, between 80 and 100 feet of blue limestone is exposed on the west side of Owens Creek about one-quarter of a

[60] Op. cit., pp. 390-391.

mile east of the Buffalo Springs-Greenway road. Its thickness is probably more than 100 feet.

The original bedding is much contorted due to flowage but may be recognized by the development of mica upon the bedding planes. Stringers and "eyes" of coarse, white calcite are abundant and lie between the bands of blue limestone. Veins of white calcite also fill joints and small lenses and "eyes" of milky quartz also occur but are not of sufficient extent to mar the quality of the stone. Several blocks taken from an opening show thin ferruginous sandy bands along the bedding planes. The limestone lies between layers of green crumpled phyllite or fine mica schist and has the appearance of a large lens enclosed by schist. A small lens of blue limestone and another of white marble, each only a few feet thick and enclosed by schist, occur in the southwest bank of the road.

Two small quarries were opened in the main limestone body by Mr. McNutt, who intended to pulverize it for use on his farm. When the locality was visited in 1929, considerable rock had been blasted out. An analysis of this stone, not available to the writer, is said to show a high percentage of calcium carbonate. According to Campbell,[61] lime of good quality has been made from limestone near the northwest base of Mine Ridge, near the Greenway mines. This is the only known limestone body in that area.

About one and one-eighth miles southeast of the McNutt property, a body of white, massive, magnesian marble is exposed just west of Owens Creek, on the property of C. D. Mundy. The exposed area is about 25 feet in diameter, but the actual size of the body of limestone can not be determined. The enclosing rocks are phyllite and quartz-mica schist.

No limestone or marble has been found from this point to the southwest terminus of the belt west of Galts Mill. Willis West of Stapleton reports that a narrow belt of impure limestone crops out above his house west of the Maud mines.

At Buffalo Springs station.—Blue limestone at least 200 feet thick is exposed at Buffalo Springs station near the mouth of a tributary branch to Owens Creek and along the county road from Norwood. Schist bands are present, but much of the stone is of excellent quality. On the northwest side of this limestone body occurs a lens of massive, white dolomitic marble, 12 feet wide, enclosed by schist.

Along the Chesapeake and Ohio Railway from Buffalo Springs station northward for three-fourths of a mile, talcose schist is exposed, which contains zones of blue calcareous schist and limestone and small lenses of white marble. Small lenses of quartz also occur, the largest one measuring 3 by 6 feet. This section is in line with the blue and

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[61] Op. cit., p. 83.

white marbles described above and not more than one-fourth of a mile distant. Three zones of blue marble have the same strike and dip as the enclosing talcose schist into which they grade. The thickest zone measured 80 feet, the intermediate 30 feet, and the other only 9 feet. Some of it contains numerous stringers and lenses of white and pink marble. Lenses of white marble near Buffalo Springs station are rather small and easily overlooked, being enclosed in the calcareous and talcose schist. Two zones of these lenses were noted in which the largest lenses measured 2 by 3 feet and were mainly of coarse, white marble.

According to Rogers,[62] blue marble was quarried for locks on the canal half a mile above Norwood. An analysis showed 79.5 per cent of calcium carbonate.

Blue limestone, closely resembling that at Greenway station, crops out on the property of Mrs. B. K. Gay, near the Chesapeake and Ohio Railway three-eighths of a mile southeast of Buffalo Springs station, where 60 feet is exposed in the bed of a spring branch. It dips 80°-90° SE., and is enclosed by green phyllite. The following section is exposed:

Section of limestone southeast of Buffalo Springs station, Nelson County, Virginia

	Thickness Feet
Blue-gray, slaty limestone	30±
Finely crystalline, blue limestone, with bands and "eyes" of white calcite and quartz	24
Blue-gray, finely crystalline marble	6
	60

Norwood area.—A body of white marble is exposed at the west end of the wagon bridge over Tye River at Norwood. It underlies a hill just west of the county road and is exposed at the base of the hill near the floodplain of Tye River. (See Fig. 9.) This outcrop of marble was known to Rogers,[63] who states:

"The same bed is again exposed on the west side of Tye River near its mouth, forming several small ledges on the line of junction of the river bottom with the rising ground." The marble is white to gray, compact, fine grained, and where exposed, contains numerous small joints. The specific gravity indicates a highly magnesian marble, although no analysis is available. Small irregular segregations of smoky quartz weather in relief upon the surface.

[62] Op. cit., p. 391.
[63] Op. cit., p. 302.

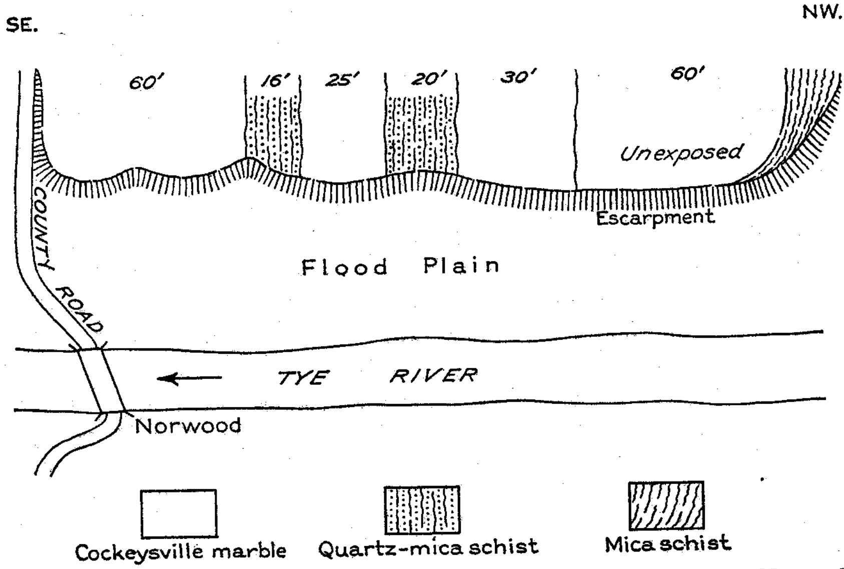

Figure. 9—Areal sketch map of Cockeysville marble in Nelson County, near Norwood

The body was estimated to be about 200 feet wide, but it contains two thick schist bands which range in composition from coarse micaceous quartzite to coarse quartz-mica schist. The easternmost band is about 16 feet thick. It contains much white muscovite and grains of blue, lavender, and pinkish quartz, the largest being about one-fourth of an inch in diameter. The westernmost band, about 20 feet thick, is more schistose and the quartz grains are smaller. A thin section of the micaceous quartzite shows that much of the rock is completely granulated. A thin section of the marble shows small interlocking grains of twinned carbonate with some larger irregular grains. West of the marble, green weathered phyllite bends around the end of the body.

About 1 mile west of Norwood, limestone crops out in a small tributary branch on the west side of Tye River. The rock is dark blue to blue-gray and contains veins of white calcite. It is enclosed in Wissahickon schist and is exposed along the axis of an anticline. The stone is apparently of good quality but was not found northeast of Tye River.

An undetermined thickness of slaty blue limestone crops out in a branch near the county road about three-quarters of a mile southwest of Norwood near the railroad. It is probably of good quality, but no analysis is available.

White, pink, and blue marble occurs along the south side of James River in Buckingham County, a short distance below Norwood. Fine-grained, white, gray, yellow, and pink marble is exposed in the river bluffs on the property of Mrs. Anna Wheelan, three-quarters of a mile below the mouth of Tye River. The exposed marble is about 125 feet thick and is said to extend 100 feet into the bluffs. A Triassic diabase dike, 9 feet wide, cuts the marble. The west wall of the marble is in contact with massive quartzite, 50 to 80 feet thick. This is succeeded westward by fine, white, hard quartzite impregnated with more or less fine-grained white marbles, 40 feet thick. Next is 190 feet of gray and white quartzite. The quartzite is evidently thickened by folding.

Marble exposed at the mouth of Nigger Creek consists of two lenses separated by quartzite which appears to underlie the marble. (See Fig. 10.) The western body, about 50 feet thick, consists of massive, generally coarsely crystalline, white or white and pink variegated marble. On the west, it is bounded by quartz-mica schist. The other body of marble is about 70 feet thick and is enclosed by quartzite. It is a coarsely crystalline, massive white marble, with small segregations of milky quartz. The enclosing quartzites and mica schists dip southeast at a high angle and strike N. 40° E.

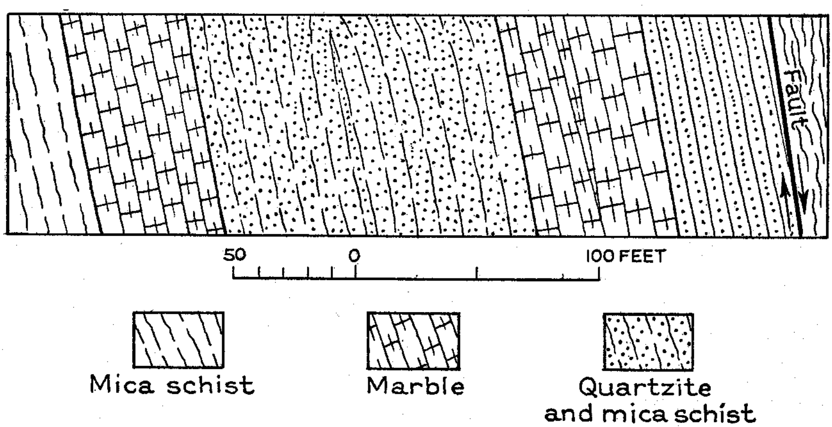

Figure 10.—Cross section through marble on the Cunningham property in Buckingham County, near Norwood.

Immediately southwest of the white and pink marble, blue slaty limestone, apparently of good quality, crops out upon the property of Sam Cunningham. (See Fig. 10.) It lies east of the quartzite, from which it is separated by schist that is not well exposed. The stone crops out in ledges on the west side of Nigger Creek in such a manner that it could be easily quarried. No analyses are available. The dip is 75° SE. A thickness of about 90 feet is exposed and the outcrop can be traced southwest for at least three-quarters of a mile.

White marble and limestone on the north side of the river below

Norwood are probably the extension of beds discussed above. Blue, slaty limestone containing white calcite stringers crops out in a branch north of the residence of James Dolan. This belt can be traced northeast through the Dolan and Finch properties, and is last found in a branch which crosses the Warminster road below the home of Tom Flood, where the rock is a white marble.

An analysis by Rogers,[64] of a pink, magnesian marble at Pounding Mill Creek below Norwood, believed to lie in this belt, is given in Table 2.

Campbell[65] reported that lime had been burned successfully on a small scale on a property, formerly belonging to Dr. Peters, between Warminster and Norwood.

Wingina area.—Excellent exposures of limestone and marble are found along Hacketts Creek near Wingina, on the property of J. E. Johnson. A thickness of 85 to 100 feet is exposed in the valley near James River, but since the bottom beds are covered, the thickness could not be determined. The formation here is nearly horizontal. It is overlain by Wissahickon mica schist.

The lowest beds are dominantly slaty, blue-gray limestone, containing cubes of pyrite (or limonite) along the cleavage planes and intercalated plates and "eyes" of white quartz and calcite. Bands of coarser, grayish-white marble are interbedded with the blue, slaty rock. The beds dip up stream at an angle of about 20°. These beds are overlain by a fine-grained green chloritic schist which crops out in the creek bed 60 feet to the southeast. It contains pyrite and mashed quartz lenses but is not calcareous. The schist band is not thick and is overlain by blue slaty limestone. Good exposures of gray marble are found along the east wall of the valley and at the base of the bluffs along the road at Hardwicksville. The gray marble bed is 60 to 80 feet thick and is overlain by Wissahickon schist. Some layers weather schistose, whereas others contain abundant grains of quartz and resemble sandstone.

About 5 feet of blue slaty limestone, dipping 10° to 15° SE., is exposed in a tributary branch on the property of W. H. Woody, about one-third of a mile west of Branch Store. A thin section of this stone shows coarse and fine calcite crystals and numerous quartz grains.

These limestone and marble outcrops are favorably situated and could be quarried without difficulty, although they have never been worked so far as the writer is aware. Some of the marble beds are high in magnesia and would, therefore, be unsuitable for lime.

Warminster area.—A large lens of white and pink marble is exposed on the property of A. C. Horsley in the bluffs of James River

[64] Rogers, W. B., A reprint of annual reports and other papers on the geology of the Virginias: p. 391, New York, D. Appleton and Co., 1884.

[65] Campbell, J. L., Geology and mineral resources of the James River Valley, Virginia, U. S. A., p. 83, New York, G. P. Putnam's Sons, 1882.

nearly opposite Warminster. It is enclosed by phyllite or slaty schist and blue limestone. A maximum width of about 180 feet is exposed. The enclosing phyllites contain zones of blue marble.

The marble is mainly white to gray, but some is pink. It contains in places small irregular masses of milky quartz. (See Pl. 14B.) The marble is in places massive and some is slaty or schistose. According to Mr. Horsley, three blocks of this white marble, 12 inches square, were shown at the St. Louis Exposition.

A short distance west of this outcrop, blue limestone is found between phyllite layers, and into which it appears to grade. The limestone is reported to be from 12 to 15 feet thick and of good quality. It is said that it was burned and used for agricultural purposes about 1840. A layer of blue slaty limestone 4 feet thick, containing calcite and quartz seams, occurs in the phyllite below the white marble. The Warminster marble is mentioned by Rogers,[66] who states in part:

"In Yancey's cliff, on the E. side of the James River, immediately opposite the village, a belt of limestone is exposed having a width of about 75 feet. It occurs in thick layers or strata which are highly inclined and rise up from the river to a height of more than 100 feet. Several varieties occur here, white, reddish and blue, and varying in texture from close granular to slaty and micaceous. It is quarried extensively for the locks and other works on the James River canal."

According to Rogers,[67] blue, slaty limestone from the vicinity of Warminster, which had been burned for lime, had a calcium carbonate content of 81.4 per cent, and a blue limestone containing white veins from the same locality, 88.4 per cent. An analysis made by him[68] is given in Table 2. The rock is a pink, hydraulic limestone, mottled with gray, and was described as being moderately fine grained, subcrystalline, with a rather compact texture and a conchoidal fracture.

The old Dean furnace at New Canton is said to have been supplied with limestone from quarries about 2 miles below Warminster, but this limestone was not found by the writer. Rogers[69] reports that a blue, slaty, micaceous limestone on the James River canal, 2 miles below Warminster, contains 72.7 per cent calcium carbonate.

A limestone is reported by Watson,[70] "from the Buford property, near Manteo station on the Chesapeake and Ohio Railway, in the vicinity of Warminster, Nelson County." The following analysis indicates it to be a magnesian marble:

[66] Rogers, W. B., op. cit., p. 314.
[67] Op. cit., p. 82.
[68] Rogers, W. B., op. cit., p. 391.
[69] Op. cit., p. 391.
[70] Watson, T. L., Mineral resources of Virginia, pp. 67-68, Virginia-Jamestown Exposition Commission, Lynchburg, Va., 1907.

Analysis of marble near Warminster, Nelson County, Virginia

(Henry Froehling, Analyst)

Calcium carbonate	54.833
Magnesium carbonate	33.524
Alumina and iron oxide	3.600
Silica	5.500
Water	1.240
Phosphoric oxide	.170
Organic matter	.827
	99.694

Lewis property.—About 1 mile northeast of Warminster, near Dog Island and near the Chesapeake and Ohio Railway, is exposed a white marble which appears identical with the Warminster marble. It is in contact with phyllite on the west, but the eastern side of the body is concealed by the floodplain. A thickness of about 100 feet is exposed on the property of H. G. Lewis. This may be either an extension of the Warminster marble lens or else a separate lens along the same strike. Jefferson[71] mentions marble near the mouth of Rockfish River, which probably refers to the cliff at Warminster. He describes it as follows:

"There is a very good marble, and in very great abundance, on Jame's River (?), at the mouth of Rockfish. The samples I have seen, were some of them of a white as pure as one might expect to find on the surface of the earth; but most of them were variegated with red, blue and purple. None of it has been ever worked. It forms a very large precipice which hangs over a navigable part of the river."

Rockfish River area.—A small narrow body of marble is exposed on Rockfish River about 1 mile above Howardsville on the property of Mrs. W. L. Johns. The marble is white and pink and fine grained. It dips southeast and grades into mica schist on the west and into quartzite on the east side.

USES

These limestones are generally of good quality and most analyses show a high percentage of calcium carbonate. They have been quarried in the past throughout the region and have been burned successfully for many years to make good lime for agricultural purposes and for use in construction work. According to local reports, this lime was used to build many old houses in the district.

[71] Jefferson, Thomas, Notes on the State of Virginia, p. 26, Boston, Wells and Lilly, 1829.

Thick exposures of limestone in which large quarries could be opened are common. Many are located near the Chesapeake and Ohio and the Norfolk and Western railways, James River, and county roads. In spite of the fact that most of the farm lands in this belt are situated near one of these outcrops little or no lime is used in this district for agricultural purposes although the farm lands need it badly.

Limestone was quarried and used with success as a flux in local blast furnaces, when iron was mined in the district.

The white magnesian marbles have not been used. The white marble or the white and pink variegated marble would make beautiful decorative stone, if blocks without joints and flaws can be extracted. It is possible that marble granules could be obtained for use in "artificial" or molded stone. White Cockeysville marble has been quarried on a large scale in Maryland.[72]

SOAPSTONE

Soapstone was quarried and used by the Indians for making pots and mortars and for carving into pipes.[73] It was highly prized by the Indians for such uses. The pots were generally large with two ear-shaped handles, and were made from surface fragments or from blocks quarried from soft weathered ledges. Soapstone implements have been found in Appomattox County 25 miles or more from the soapstone district. Soapstone pipes were found in a large Indian burial mound 2 miles north of Linville,[74] Rockingham County. The white settlers of this district used soapstone at an early date in hearths, jambs, and chimneys. Near the quarries, discarded slabs are much used for chimneys, stone walks, and foundations. At Ebenezer Church, 3 miles from Coolwell, the tombstones are of soapstone quarried from the Glades.

Certain basic parallel zones of the soapstone intrusive series of rocks are altered to talc. Quarries are opened along these zones or "veins" which, according to Watson,[75] range from 30 to 165 feet in thickness.

Much good soapstone has been quarried and shipped from this district, but no quarries are now in operation (1930). The crude soapstone was manufactured near the quarries into sinks, tubs, slabs, furnace blocks, and laboratory equipment. Much of the stone was produced at the American, Phoenix and Piedmont quarries in Nelson County. (See Pl. 15A.) The plant of the Standard Soapstone Com-

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[72] Mathews, E. B., and Watson, E. H., The mineral resources of Baltimore County, *in* Baltimore County Report, Maryland Geol. Survey, pp. 229-230, 233-236, 1929.

[73] Bushnell, D. I., Jr., The five Monacan towns in Virginia, 1607: Smithsonian Misc. Coll., vol. 87, no. 12, pp. 25-26, 35-38 and pls. 13-14, 1930.

[74] Fowke, Gerard, Aboriginal remains of the Piedmont and Valley region of Virginia: Am. Anthropologist, vol. 6, p. 419, 1893.

[75] Watson, T. L., Mineral resources of Virginia, p. 294, Virginia-Jamestown Exposition Commission, Lynchburg, Va., 1907.

pany near Norwood was dismantled in 1929. The quarries of the Asbestine Stone Company at Piedmont are said to have been abandoned for 10 years. Stone was manufactured into various products at the plant near the quarry and sold as "Asbestine Stone." The following products were manufactured:[76] Laundry tubs, kitchen sinks, laboratory sinks and table tops, shower stalls, urinals, acid tanks, stair treads, and electrical equipment.

TALC

Several small bodies of talc and talc-actinolite schist occur in the Wissahickon formation in Appomattox County and are discussed in previous pages. They have not been developed. The most promising occurrences are near Appomattox.

GLASS SAND

The Mount Athos quartzite, where pure and much mashed, weathers to a very fine-grained, white sand. It is locally so thoroughly weathered that large quantities of sand of probable glass sand quality are available.

An excavation has been made in this sand on the Lee property, about 1½ miles from Stapleton in Amherst County. According to A. W. Lee of A. S. Lee & Sons Company, of Norfolk, possibly 10 to 20 carloads were shipped several years ago to Baltimore and used in glass manufacture. At an earlier date, some of this sand was shipped to England and cut glass was manufactured from it.

The following data by Froehling and Robertson were submitted to the writer through the courtesy of A. W. Lee:

(1) "Beds of Silica." Solid, granulated, and with a bluish tint; disintegrates and becomes white by exposure to weather for considerable time but can be shipped as quarried, with but little waste in transportation; contains 80.56 per cent silica (SiO_2), dried at 212°F.

(2) "Sand; thin layers mostly broken up in mining and by short exposure to weather. It contains 90 per cent silica, dried at 212°F."

QUARTZ

Veins and lenses of quartz are of common occurrence in the quartzite and schist formations throughout the district. In places the quartz intrusions are impure, but locally relatively pure or high-grade bodies of quartz are found. Quartz has been mined and shipped from Wrights Shop, about 3 miles northeast of Lynchburg and probably also from other localties.

[76] Prospectus of Asbestine Stone Company, Boston, Mass., Southgate Press, Boston, 1907.

BUILDING STONE

The Lynchburg gneiss, the Wissahickon gneiss, and Triassic diabase in this district contain building stone.

LYNCHBURG GNEISS

Lynchburg gneiss has been extensively quarried for local use along the north side of James River in Amherst County, opposite Lynchburg. The rock is a dark blue-gray biotite gneiss that splits into slabs of any desired thickness. It has been used extensively in Lynchburg in general building and for paving and curbstones. According to Watson,[77] it is hard but easily dressed and very resistant to atmospheric agents. The quarries have not been worked recently. This stone has also been quarried in Campbell County near Lynchburg.

The following is a description by Watson,[78] of quarries south of Lynchburg:

"The quarries opened about 1 mile south of Lynchburg are located in beds forming the southeastern limb of the anticline. The gneissic bands are very regular and even as a rule, vary in thickness from 6 inches to several feet, and dip 45°S. They are cut by a well-developed system of joints striking N.5°-10°W. Pegmatite dikes, composed in essential part of pink feldspar with some quartz, are in places developed parallel to the banding. Along the planes of banding very thin, finely crinkled laminae of sericite mica, in part chloritic, occur locally."

According to Rogers,[79] a micaceous gneiss was quarried on the east side of Findlay Mountain near Variety Mills. The rock was called granite and was extensively employed for the construction of locks, aqueducts, and other structures along the James River canal.

WISSAHICKON GNEISS

On the property of Dr. Evans, southwest of Pilot Mountain and near Concord, biotite gneiss has been quarried. Three openings have been made here by the Norfolk and Western Railway Company but have not been recently worked. The rock is medium to fine grained, and is similar in appearance to that quarried at Lynchburg. The dip is vertical and the strike is N. 55° E. Slabs of desired thickness were split off in the quarries opened on a hillside.

DIABASE

Diabase dikes crop out at Norwood, Gladstone and at other places in the district. The Gladstone dike is thick and the stone is coarse

[77] Op. cit., p. 34.

[78] Watson, T. L., Granites of the southeastern Atlantic States: U. S. Geol. Survey Bull. 426, p. 81, 1910.

[79] Rogers, W. B., A reprint of annual reports and other papers on the geology of the Virginias, pp. 313-314, New York, D. Appleton and Co., 1884.

grained and has a pleasing color. According to Rogers,[80] this stone (called dark sienite) was quarried for locks and culverts near Gladstone. The diabase makes a beautiful building stone and takes a high polish.

OTHER MATERIALS

Other stone suitable for general building purposes occurs in this district. Marble and limestone are abundant and conveniently located. Limestone is abundant, especially along James River. This district is well dissected by streams, and quarries could be opened in many places along the Chesapeake and Ohio Railroad. The distribution and quality of limestone have been discussed. Lower Cambrian quartzite has been used extensively in Virginia in general building and for chimneys and foundations. It is soft and is easily quarried and cut; later it case-hardens and becomes quite durable. Massive greenstone is a beautiful building stone and has been used in other parts of the State. Triassic brownstone has been locally used. (See Pl. 15B.)

ROAD MATERIALS

GENERAL STATEMENT

Rapid advances in road construction in the last several years have stressed the importance and need of satisfactory road-building materials, which are thus becoming an increasingly valuable resource. Good road-building materials are conveniently located near railroads and highways at many places in this district. Where possible, utilization of local stone will be found to be much cheaper than broken stone hauled from any distance. Long haulage of rock may often be avoided by constructing the type of road for which available local materials are suitable. Local stone is sometimes discredited when its use is attempted for a purpose for which it is not adapted.

CRYSTALLINE ROCKS

In numerous localities, quarries may be opened in igneous and metamorphic rocks. In places, relatively deep quarries must be excavated to obtain the desired grade of stone for the road. Quarry sites should be carefully selected. Quarries in gneiss and schist should be so located that the dip of the schistosity is to the right or left of the working face.

Mount Athos quartzite has been quarried for railway ballast at Mount Athos and Greenway. Numerous closely spaced joints in the stone aid greatly in crushing it but tend to make it of slight value for other uses.

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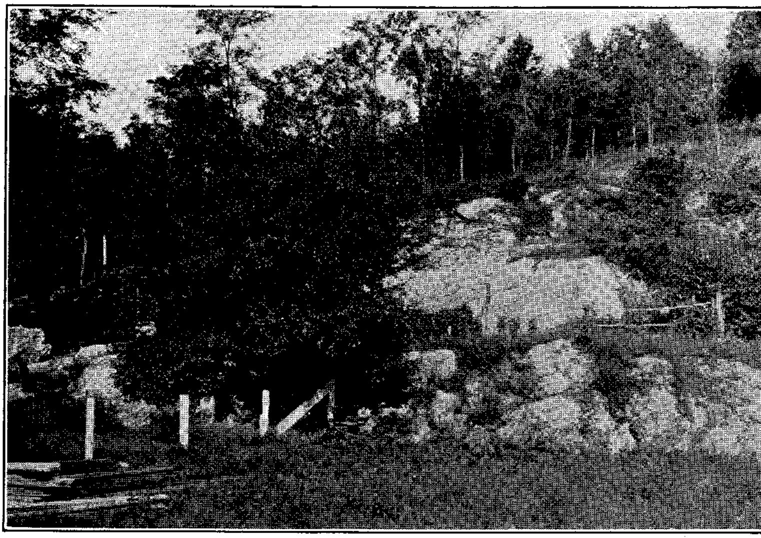
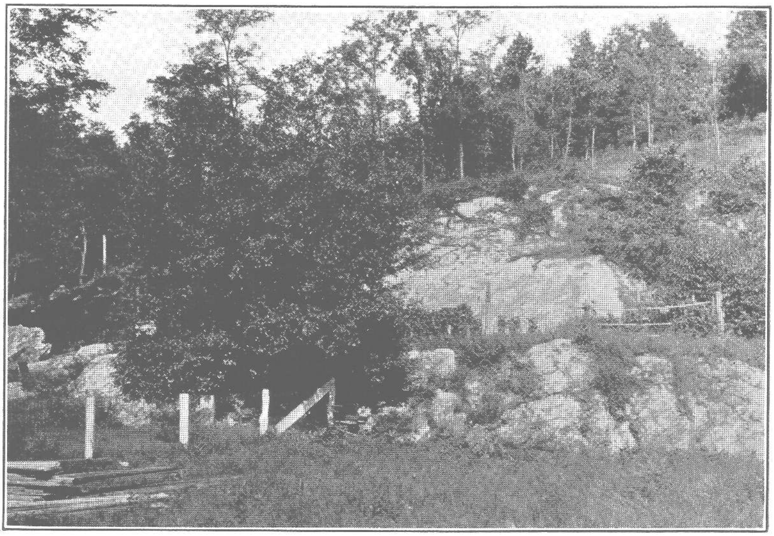
[80] Op. cit., p. 288.



A. Limestone ledges at Greenway, Nelson County.

B. Ledges of white and pink marble on James River at Warminster, Nelson County.



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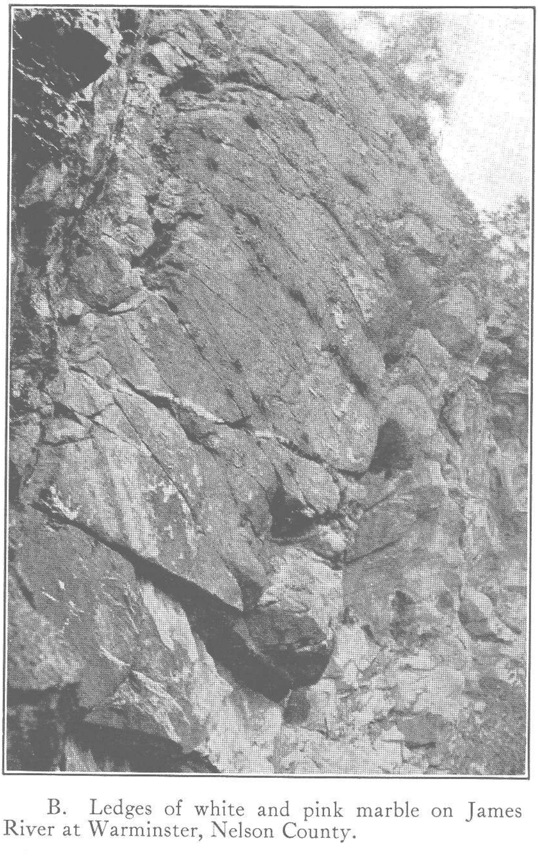
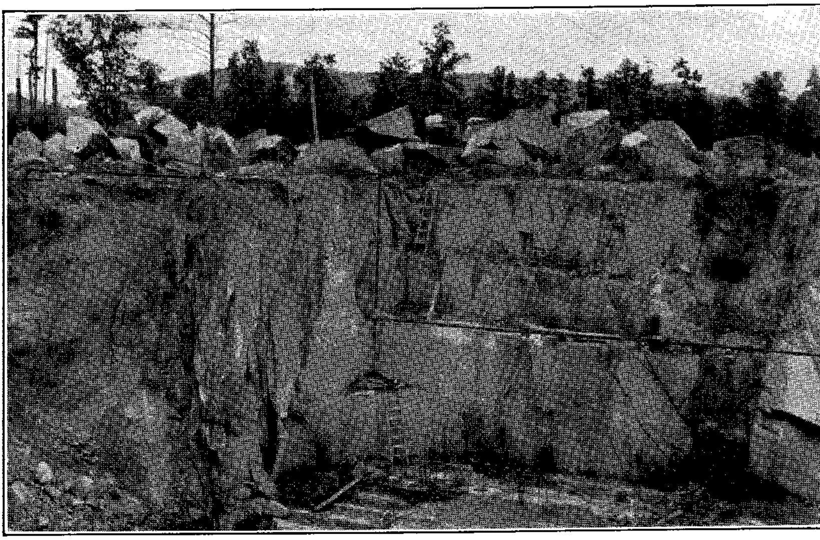
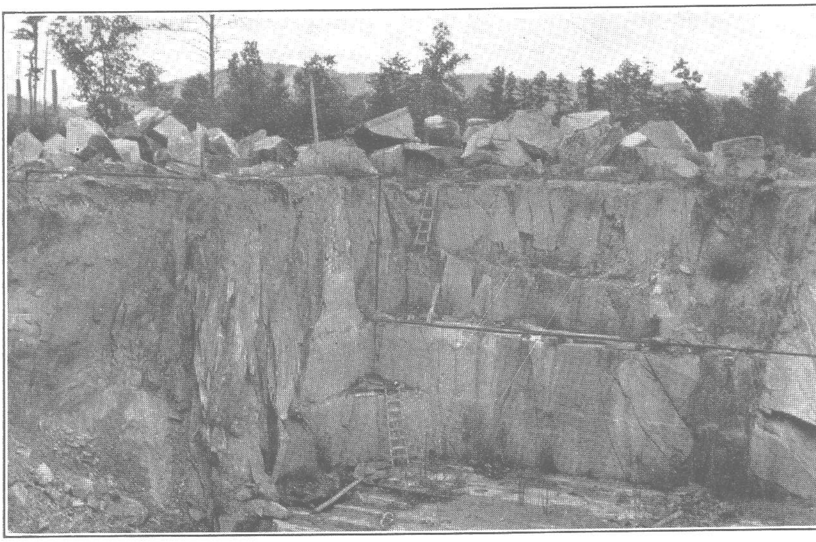


B. Ledges of white and pink marble on James River at Warminster, Nelson County.



A. The American Soapstone Company's quarry near Norwood, Nelson County.

B. Midway Mills, Nelson County, built of Triassic (Newark) brownstone.



A. The American Soapstone Company's quarry near Norwood, Nelson County.

B. Midway Mills, Nelson County, built of Triassic (Newark) brownstone.

Most of the other types of rocks have been deeply weathered near the surface. Lovingston gneiss, Lynchburg gneiss, and Catoctin greenstone are available in the western half of the district, and granites and gneisses in the eastern part. Diabase makes excellent stone for road construction but is difficult to crush.

SAND AND SOILS

Sand-clay and soil roads are popular east of James River. They are well suited to moderate traffic, comparatively cheap and easy to construct, and the cost of their maintenance is low. In some localities, as over certain granite areas east of James River, are natural soil roads.

The result sought in the construction of sand-clay roads is such a mixture of clay, sand and gravel that the plasticity of the clay when wet is reduced to the extent that it will withstand the wheel load of vehicles.[81] In addition to stiffening the clay, the sand and gravel also resist the wear of traffic. Since clay is impervious to surface water when properly compacted by road machines and vehicular traffic, it becomes suitable for constant use even in the wettest winter months. Over weathered granite and muscovite schist, a small amount of top soil is necessary to produce a hard-packed surface. More soil must be added to the clayey road beds in greenstone or Wissahickon biotite schist. Less commonly, the roadbed contains too much sand and clay must be added. A careful study of local materials is necessary to obtain a satisfactory road.

Near James River, sand and gravel from several sources are available for road construction. Sand and gravel may be taken from the bed of James River at convenient points and transported short distances by railroad. At many places, the deep weathering of quartzite has produced an almost unlimited supply of sand that could be used for road-building; for example, west of Wingina where State highway 56 crosses several ridges of deeply weathered Wissahickon quartzite. This sand could be taken from the hilltops and easily transported down grade in either direction. The position of the quartzite beds north of Norwood is shown on the geological map of the district. (See Pl. 1.)

IRON

HISTORY AND PRODUCTION

The first iron ores mined in the United States were the pot ores—brown hematites or limonites of eastern Virginia.[82]. Furnaces were built near the local deposits to supply local needs for pots and ovens.

[81] For information concerning the construction of soil roads in this section, the writer is indebted to C. W. Ryan of Lynchburg.

[82] Holden, R. J., Iron, *in* Watson, T. L., Mineral resources of Virginia, pp. 402-403, Lynchburg, Va., 1907.

The ore was smelted with charcoal and in this district local limestones were used as a flux. By the close of the eighteenth century, the iron industry was well established in James Valley west of the Blue Ridge.

There were several old charcoal furnaces in this district before 1839. The old Ross furnace near Lynchburg and the Elk Creek cold-blast furnace which stood about 800 yards north of the James River canal at Allen Creek in Nelson County, were among the oldest. The Elk Creek furnace was abandoned in 1850. The Stonewall furnace on Stonewall Creek in Appomattox County, about 2 miles from James River, was abandoned in 1845. The William Ross, or Lagrange, furnace, on Stonewall Creek, 1 mile above Stonewall furnace, was abandoned in 1843. The Amherst furnace was still in blast in 1882. Deans furnace in Buckingham County near New Canton began operations in 1835.

All of these furnaces used local brown hematite ores. Ore was also shipped from this district at an early date to the old Westham furnace (later called the Powhatan Iron Works) 10 miles above Richmond. These furnaces were out of blast at the time of the iron boom of the eighties in James Valley.

Beginning in 1879, there was a great boom in the iron industry of this part of James Valley because of the development of hematite and magnetite ores. Beginning in June, 1880, and for several years thereafter, iron mining was the most important industry along James River and there was a notable increase in the population of the district during this time. All probable ore-bearing ground was examined or prospected.

According to local reports, mineral lands sold for fabulous prices and large sums, ranging up to $60,000.00, were sometimes refused for farms in the mineral district. A notice in *The Virginias* for January, 1881, stated that the farm "Edgewood," owned by John J. Dillard at Riverville, was purchased by the Pennsylvania Mining Company for $40,000.00. An undivided half of the Sleepy Hollow tract below Norwood sold for $23,200.00 at a public sale in 1881.

Cessation of iron mining in this district was due to several causes: Declining interest due to unwarranted speculation, the increased cost of deeper mining, poor mining methods which caused the most profitable shaft mines in the widest ore beds to fill with water and become unworkable after reaching water-level, and, perhaps most important, the rapid development by this time of the extensive high-grade hematite ores of the Lake Superior region which made available great quantities of ore minable at much less expense. No iron is mined in this district at the present time and the old workings are all more or less inaccessible.

In the eighties, the ore was carted to the canal wharves. Spur tracks were built from the canal to the mines at Riverville and at Stapleton. The ore was shipped via the canal to railroad connections at Lynchburg or taken down the river to Richmond. Some of the ore was smelted in Lynchburg, but most of it went to northern markets, especially Pittsburgh.

Only high grade ore was shipped, with the result that much ore containing considerable iron was left as waste. First-class ore contained generally 50 per cent or more of metallic iron. Ore with an iron content of less than 30 per cent was generally considered as waste. Due to the prevailing high content of quartz, the quality of the ore could have been much improved by washing. Some ore was beneficiated in that way.

It has not been possible to determine the total amount of ore mined in this district. The total production of ore from Campbell, Amherst and Nelson counties in 1880 is said to have amounted to 57,124 tons. These figures were regarded by Hotchkiss as very low. According to Kimball, writing in March, 1880, the Stapleton, Riverville and Greenway tracts could be simultaneously developed within one year to yield 500 tons a day. At that time, the combined output of the three tracts was about 150 tons daily of high-grade ore used exclusively for Bessemer steel.

A writer in *The Virginias* of June, 1880, names 19 places along the river between Lynchburg and Greenway where iron mines were being worked. Not less than $600,000.00 had been expended in the purchase and development of these operations and at that time not less than 500 men, exclusive of those engaged in transportation, were employed in the mines.

HEMATITE AND MAGNETITE

Distribution

Piedmont hematite and magnetite ores occur in a narrow belt along James River from Norwood to Lynchburg. Farther southwest, valuable deposits of magnetite occur at Pittsville in Pittsylvania County and near Rocky Mount in Franklin County.

Along James River, magnetite and hematite are confined to the Mount Athos quartzite. In this section most of the mines were west of the river between Stapleton and Greenway, where the veins were thicker and more numerous. (See Pl. 13.)

Mode of Occurrence

The magnetite and hematite deposits occur in quartzite and talcose schist. At Stapleton, Riverville and Greenway, the iron is in quartz conglomerate and in talcose and micaceous schist. The deposits are in the form of beds, lenses, or disseminations in the quartzite and schist. Beds and lenses dip at high angles and follow the schistosity of the enclosing rocks. The disseminations are zones in schist and quartzite that are peppered with magnetite crystals partly altered to martite.

The iron deposits have been folded and metamorphosed with the enclosing rocks. The beds thicken and thin along both the dip and the strike, in places disappearing entirely. A new vein may replace, in the same stratigraphic position or slightly above or below it, one that has run out, so that in places the ends of the lenses overlap. Two veins, representing outcrops of the same bed on opposite limbs of a pitching fold, may run together. In such instances, the ore may be thick on one limb and thin or absent on the other limb. In places the veins divide and reunite. At the Ames mine of the Dover Company, near Riverville, the main vein was divided for a distance of 125 feet by about 8 feet of quartzite. Where the vein was divided, one part was magnetite and the other part was mainly hematite.

The veins are in slaty talcose schist, in quartzite, or between quartzite and schist. Veins in quartzite contain grains of blue quartz, in places more or less abundant. The vein may be separated from the wall rock by a soft black dirt, or "dig," containing little or no iron. The color of the black dirt is probably due to manganese oxide, but there are no analyses to verify it.

The ore-bearing zones vary from thin stringers to veins more than 10 feet thick. The veins worked by the principal mines averaged from 1 to 3 feet in thickness, including schist partings. The main vein in the Greenway mines was 10 feet thick, about 8 feet of which was ore.

COMPOSITION OF THE ORES

The ore minerals are specularite, martite, and non-titaniferous magnetite. Some manganese (pyrolusite) is present in places and there is one recorded occurrence of barite in the mines at Riverville. Magnetite, originally a very abundant constituent, is partly or completely altered to martite, so that hematite and martite are the leading ore minerals. Complete analyses generally show a rather low content of ferrous oxide and consequently but little magnetite. The massive granular, blue ore at the Maud mines near Stapleton was mostly martite after magnetite, with interlacing wisps of specularite and some muscovite and quartz. Limonite wads fill cavities or replace other oxides of iron. Specularite is locally called "specular ore" or "hard hematite." A massive variety of steel-gray color is called "steel ore." Magnetite and hematite may occur separately in the deposits, but where both are present they are generally intermixed.

The minerals associated with the iron minerals are quartz, chlorite, talc, muscovite and some biotite from the enclosing rocks. In the early days of mining in this district, it was impossible to separate these minerals from the ores, and this fact accounts for the high silica content of the analyses. Quartz was the main impurity. The ores are characterized by a low phosphorus content and the practical absence of titanium. Although many analyses of these ores are available, most of them are incomplete.

According to Frazer,[83] the average yield of an ore from a vein explored for 2 miles was iron (18 analyses), 55.36 per cent and phosphorus (16 analyses), 0.0375 per cent. Another vein 2 miles long, averaged 50.49 per cent iron and 0.18 per cent phosphorus.

Frazer also made analyses to determine how weathering would affect the ores. He found that fresh ore held 52.82 per cent iron and 0.08 per cent phosphorus, whereas ore which had been weathered on a face opened 1½ years before, contained 54.35 per cent iron and 0.11 per cent phosphorus. The following table of average analyses of James River ores is reported by Frazer:[84]

TABLE 3.—*Analyses of iron ores from the James River belt, Virginia*
(N. A. Stockton, Analyst)

No. of Determinations			Kind of Ore	Average		
Iron	Phosphorus	Silica		Iron	Phosphorus	Silica
31	31	8	No. 6½ ore	51.32	.0398	23.24
15	14	3	No. 11 ore	48.51	.118	24.1
8	6	1	Greenway ore	49.33	.071	18.2
18	17	7	Maud ore	48.43	.093	22.31
2	2	....	No. 10½ ore	41.07	.07	....
5	5	1	Ames tunnel ore	39.29	.059	28.66
3	2	2	Garden field and Ames tunnel mixed	42.75	.047	33.1
82	77	22	Average of all samples	48.69	.07	23.98

MINES

Introductory statement.—The available information on the iron mining industry in this district has been assembled and is given below. The mines were visited by the writer between 1925 and 1930. Very little information could be obtained in the field about some of them,

[83] Frazer, Persifor, Jr., The iron ores of the middle James River [Va.]: Am. Inst. Min. Eng. Trans., vol. 11, pp. 201-216, 1883.
[84] Op. cit., p. 214.

because the old workings have been abandoned for nearly fifty years. The writer has drawn freely from articles by Campbell, McDonald, Britton, Frazer, Holden, and others, from the Tenth Census report, and from personal communications.

By 1880 the different bands of ferruginous schist and iron ore occurring in the district were numbered from 1 to 25 with some intermediate half numbers. These numbers were apparently applied from place to place without any definite system.

The location of the mines described is shown on Plate 13.

Mount Athos area.—According to McDonald,[85] "At the southwest end of Mount Athos the Birmingham Iron Company have run a drift from the level of the railroad about 100 feet into the mountain, following the ore. . . . The ores are specular and magnetic, the magnetic predominating."

"Near the railroad the Birmingham Company have driven a tunnel from the southeast side to intersect the system. The last 50 feet of the tunnel is in ore (specular and magnetic)."

"In this same ore system, but west of the range above indicated, is a very rich and pure specular ore, which has been worked by the Birmingham Company, by a slope shaft, to a depth of 90 feet. A section at the bottom of shaft shows 18 inches to 2 feet of rich specular ore, 6 feet of lean ore, and on the 'foot' wall a seam of very rich crystalized pyrolusite several inches in thickness."[86]

Analysis of iron ore from Mount Athos, Campbell County, Virginia

(After Britton[87])

Ferric oxide	46.10
Ferrous oxide	8.75
Silica	38.93
Water	1.22
Alumina	3.98
Lime	.26
Magnesia	.17
Manganese oxide	.37
Phosphoric acid	.192
Undetermined and loss	.028
	100.000
Metallic iron	39.03
Phosphorus	.084

[85] McDonald, Col. Marshall, Semi-annual report of the Superintendent of the Virginia Military Institute, enclosing the report of a geological and mineral examination of a portion of the James River iron belt: 23 pp. and map, Richmond, 1879. Reprinted in the Virginias, vol. 1, no. 1, pp. 11-12, 1880.

[86] McDonald, Col. Marshall, op. cit., pp. 11-12.

[87] Britton, J. B., Analyses of Campbell and Appomattox counties, Virginia, iron and manganese ores and limestones: The Virginias, vol. 2, no. 11, pp. 170-171, 1881.

The ore was from the mill-dam opening on the southwest slope of Mount Athos. From a point about 45 feet above Archers Creek, and some 200 yards north of the Norfolk and Western Railway, a drift had been driven horizontally about 180 feet to the northeast. The ore-bearing stratum was 6 to 8 feet wide and dipped steeply to the southeast. The sample consisted of numerous fragments and fine material. The color of the material when pulverized was a light reddish-gray.

Three analyses of ores from Mount Athos, given by Campbell,[88] show that the metallic iron content ranges from 57.68 to 64.85 per cent, phosphorus from 0.001 to 0.048 per cent, and silica from 3.14 to 14.67 per cent.

Galts Mill area.—The Lone Pine mine was located about 1 mile northwest of Galts Mills, at the southwestern terminus of the Greenway-Riverville-Stapleton ore belt. The workings were on the west side of Stovalls Creek and on the northwest flank of Round Mountain. The ore was associated with quartz conglomerate. When worked in the fall of 1881, three drifts were driven into the hillsides and a small amount of ore was shipped. According to Campbell, the ore was lean and specular.

The following analyses of ore samples at this locality in March, 1881, were reported by Frazer:[89]

Analyses of iron ores from Lone Pine mine, near Galts Mill, Amherst County, Virginia

(N. A. Stockton, Analyst)

Source of Sample	Iron	Phosphorus	Silica
Head of lower drift	37.70	0.04	....
Across fall of middle drift	27.13	....	....
Upper drift	39.95	0.03	....
From dump	33.13	0.06	....
Specimens	33.59	....	....
	34.05	....	....
Float from top of hill west of vein	54.43	0.03	13.66

Chestnut Mountain tract.—The Chestnut Mountain tract, east of James River, was extensively prospected for iron ore in 1880.

Iron is said to have been mined from the quartzite ridge near the river just east of Stapleton from workings on the Ferguson and Isbell properties just south of Stonewall Creek. According to Mr. Isbell, the ore was carried on a wire cable across the river to the canal. Some

[88] Campbell, J. L., Geology and mineral resources of the James River Valley, Virginia, U. S. A., p. 49, New York, G. P. Putnam & Sons, 1882.
[89] Op. cit., p. 213.

ore was also reported shipped from a mine on the near-by property of the Birmingham Iron Company which was inaccessible in 1880.

Wreck Island Creek area.—Campbell,[90] describes the mines along Wreck Island Creek as follows:

"Near the mouth of Wreck Island Creek (locally called Rack Island), I found miners at work on a bed of tolerably pure magnetite, closely associated with a bed of white limestone (or marble). The prospecting was said to be in search of copper ore."

Stapleton area.—Most of the mining in the vicinity of Stapleton was carried on between 1880 and 1882 at the Maud View mine by Thomas Dunlap. The mine was located on a hill northeast of Porridge Creek about 1¼ miles north of Stapleton. The locality was one of the three most important ore-producing areas in the district.

The ore was found between beds of regionally metamorphosed quartzite conglomerate and slaty mica schist. The folds were mashed together so that the beds were nearly vertical. (See Fig. 11.) The strike of the main ore bed was N.20°E. The ore was slightly magnetic and was mainly martite and specularite. Two types were recognized: (1) Ore associated with quartzite which was said to have been especially rich in iron and to have consisted of specular hematite speckled with grains of magnetite and martite, and (2) a variety of ore, called "slate ore" by the miners, which consisted of mica schist highly impregnated with iron oxides. The first type contained mashed pebbles of blue quartz scattered through nearly pure ore. A thin section showed grains of quartz, around which were bent wisps of muscovite and hematite. Other samples of ore were nearly free of impurities. Only high-grade ore was shipped and considerable material of relatively good quality is still found on the mine dumps. In the second type, much of the fine slaty mica schist associated with the quartzite contained fine disseminations of martite and magnetite.

The workable part of the main vein is said to have ranged from 1 to 2 feet in thickness. Thin layers of quartzite and schist were found interlaminated with the ore. When this mine was examined by the writer in January, 1930, the workings were mostly filled, but at present it is the most accessible iron mine in the district. The main workings followed the western limb of a syncline which pitches southwest. The outcrop of this bed was followed up the hill by a series of drifts for a distance of 800 feet. At this point, the "vein" ended. The eastern limb of the ore bed was followed for a short distance, but does not appear to have been as profitable as was the western one. This pitching out of the ore beds appears to explain the statements of Campbell, McDonald, and others that the ore veins in this district were frequently interrupted or terminated by barren quartz chutes.

[90] Op. cit., p. 42.

Other tunnels were driven in less promising veins or beds in the vicinity, apparently with poor success. Some of these veins may have been the folded extensions of the main ore bed, as some of them were said to have been branches of the Maud vein; others may have been less ferruginous beds associated with the Maud vein. The western tunnel trended N. 70° E., and was excavated from the wall of the creek valley north of the Maud tunnel to intersect the latter at a distance of 196 feet from its opening in the valley. The tunnel was constructed with the intention of removing ore from the main vein below the other workings. Ore of low grade was marketed from this tunnel in 1881.

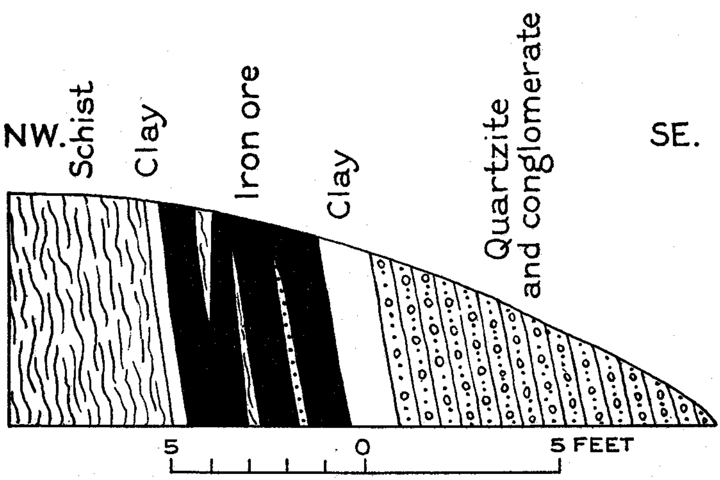


Figure 11.—Cross section at the Maud mines near Stapleton, Amherst County.

Kimball[91] reported that the average daily production of ore in this area in 1880 was between 50 and 75 tons. According to Frazer,[92] there was about 2,500 tons of ore in sight in this area in the spring of 1881.

On the east bank of Porridge Creek at the base of the hill in which the Maud mines are situated is a cut about 25 feet long. The foot wall is green, slaty, chloritic schist and the hanging wall is a quartzite conglomerate. Good ore was reported to have been taken from this cut.

According to Willis West, who mined ore in this district under the supervision of Mr. Dunlap, a shaft 20 feet deep was sunk about 1882 in a bed of ore in Round Mountain, and prospecting was also done on Little Round Top west of that point. Ore was taken also

[91] Kimball, J. P., The Greenway iron ore belt of the James River, Virginia: The Virginias, vol. 2, no. 1, pp. 2-5, 1881.
[92] Op. cit., p. 206.

from an opening in the quartzite ridge south of his house, about 1 mile southwest of the Maud mines.

The average shipments of ore from the Maud mines from January to March, 1880, averaged 63.43 per cent metallic iron and 0.141 per cent phosphorus. Some ore from the Maud mines was manganiferous. The following analyses of ores from the Maud mines made in 1881, taken from Frazer,[93] indicate ore of a somewhat lower grade than that shipped in 1880:

TABLE 4.—*Analyses of iron ores from the Maud mines near Stapleton, Amherst County, Virginia*

(N. A. Stockton, Analyst)

SOURCE OF SAMPLE	Date Sampled	Iron	Phosphorus	Silica
	1881			
Dump at end of track	March 14	52.18	0.14	....
Pile west of ore house	" 14	50.65	.11	19.35
From vein cut in west tunnel	" 19	56.02	.04	....
Large pile on wharf	" 3	47.30	....	....
Ore sent to Belmont Nail Co.	April 17	54.92	.07	....
Ore marked "Ore not washed"	" 24	45.47	.19	....
Ore marked "Washed ore No. 2"	" 24	48.65	.10	....
Ore marked "Washed ore No. 3"	" 24	53.31	.06	....
Fine ore washed	May 13	46.58[a]	.045[a]	......
Washed ore	June 2	49.79	.085	....
Received of Prof. Frazer	" 18	31.35[a]	.11	....
"Rough ore, washed"	" 21	49.3	....	....
"Western tunnel ore"	" 21	36.36	.095	....
200 tons of fine washed ore	July 25	51.89	.085	23.5
100 tons of coarse washed ore	" 25	46.76	.085	22.83
150 tons on west side of ore shed	" 25	52.95[a]	.065	16.33
60 tons of Western tunnel ore	" 25	37.52[a]	.175	31.00
100 tons of fine Maud ore	" 23	46.44[a]	.080	22.83
240 tons of Maud ore	" 23	49.63[a]	.075	20.33
4 tons of first class ore	" 25	48.22	.14	....
Black dirt	" 21	13.55	.055	....
Black dirt from Beulah tunnel	....	11.55	....	41.66

[a]Mean of two determinations.

Riverville area.—The most extensive mining operations in the district were carried on in 1880-1881 near Riverville, mainly in the bluffs west of the bend in James River. According to Kimball,[94] the daily output of the Riverville mines in 1880 was between 50 and 75 tons of ore. A standard gauge railroad was built from the canal wharf at Riverville up Cow Branch Run and into the ridge west of Saint James. There were many tunnels, shafts and pits along the course of this spur track. It is reported that in June, 1880, 150 men were engaged in 4 mines in this area. Frazer,[95] reported that 3,806

[93] Frazer, Persifor, Jr., The iron ores of the middle James River [Va.]: Am. Inst. Min. Eng. Trans., vol. 11, p. 213, 1883.
[94] Op. cit., pp. 2-5.
[95] Op. cit., p. 208.

tons of ore was in sight in 1881 at the Riverville mines. Near James River at Riverville were many pits, shafts and tunnels in "veins No. 10½, 11, and 13." The veins were only a few rods apart. According to McDonald,[96] several thousand tons of good ore had been taken from a single shaft in No. 10½ vein before January, 1880. The ore from veins Nos. 10½ and 11 was soft, specular hematite, and from vein No. 13, granular hematite and magnetite. Mining operations were carried on by Adams Scott and Company and the Dover Mining Company. Most of the ore was used in the furnace at Lynchburg.

When this locality was visited by the writer in the summer of 1928, three openings were found about 30 feet south of the Saint James-Allen Creek road. The coarser materials of the dump are fragments of mica schist with more or less hematite. Fragments of heavy fine-textured ore may still be picked up here.

Several shafts occur short distances apart in line with the strike of the schists. The rocks strike N. 40° E. and dip steeply to the southeast. The hanging wall is conglomeratic quartzite containing blue quartz grains and the foot wall is mica schist. Most of the ore appears to have been taken from the mica schist next to the quartzite. (See Fig. 12.)

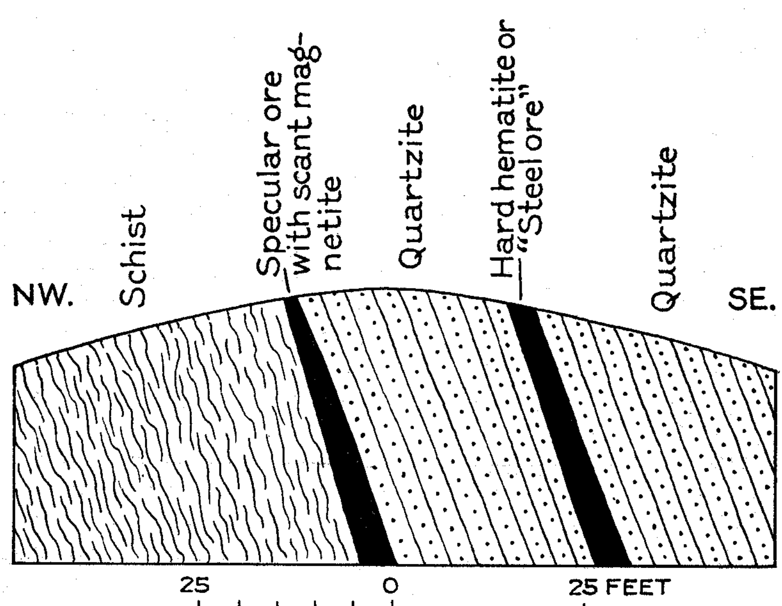


Figure 12.—Cross section at the Dover Company's mine at Riverville, Amherst County.

The northeast shaft was about 65 feet deep. About 6 feet to the southwest is a trench about 24 feet long and 10 feet deep, probably along the line of an old caved-in drift. About 30 feet to the southwest is a third opening 15 feet across at the top, about 6 feet wide at the bottom and about 30 feet deep. This shaft is probably more recent than the others.

In the bed of a small creek that follows the road from Riverville to Saint James, are good exposures of quartzite from which some ore is said to have been removed. The quartzite and enclosing mica schist dip 61° SE. The following section through the quartzite was measured by tape, from east to west.

Section of ore-bearing quartzite near Riverville

	Thickness Ft.	In.
1. Hanging wall of mica schist with small biotite porphyroblasts		
2. A "bed" of ore, of fine granular magnetite, with some martite and limonite		7
3. Hard quartzite conglomerate	12	
4. Massive, hard quartzite, containing ore and quartz veins	60	
5. Fine-grained, schistose quartzite	12	

A short distance to the southeast, the mica schist is intruded by quartz veins and lenses that in places carry much black tourmaline. Some lenses a foot or more in width are nearly pure tourmaline. A short distance northwest, towards Saint James, schist and quartzite have been prospected for iron ore. The quartzite is thoroughly impregnated with black tourmaline and large blocks are scattered over the hillside. No iron ore was found. The Canal tunnel or Canal cross-cut was driven from the canal level into the bluff through solid rock for 300 feet. This was done to strike the ore veins at a low level and to bring the ore out to the railroad that had just been completed.

West of Saint James and about 150 feet above the canal level at Riverville, a drift called the Hart tunnel was driven about 200 feet into the hill to intersect vein No. 6½. The vein was followed by drifts 200 feet to the southwest and 60 feet to the northeast. Barren areas of non-ferruginous rock are said to have been uncommon. Frazer[97] states, "On the northeast drift, at about 45 feet,

[96] Op. cit., p. 12.
[97] Op. cit., p. 207.

the ore turns to the eastward abruptly and runs out in a short distance. . . . "

Analyses of ore from the Hart tunnel made by Stockton,[98] from samples collected in the spring of 1881, showed the iron content to range from 30.60 per cent for the waste material to 56.92 per cent for the fine ore and a phosphorus content of from 0.02 per cent for the waste to 0.06 per cent for the fine ore.

Several shafts and tunnels were dug in the ridge west of Saint James. The Ames tunnel was a drift along vein No. 11. It is said to have been driven 500 feet and to have been stopped by a heavy fall of rock. According to Benton,[99] three main shafts had, by 1880, been carried to depths of 60, 115, and 105 feet, respectively, and drifts run from the shafts along the ore bed. Three varieties of ore were recognized. Micaceous specular and specular ore with many fine crystals of disseminated magnetite made up most of the deposit. A third variety called "steel ore" or hard hematite ore, of higher grade was shipped separately. Some barite was associated with the latter ore.

The following are analyses of ore from this tunnel made in the spring and summer of 1881 as reported by Frazer:[100]

Analyses of iron from the Ames tunnel, about half a mile west of Saint James, Amherst County, Virginia

(N. A. Stockton, Analyst)

	1	2	3	4	5	6
Metallic iron.......	37.22	32.14	38.88	38.79	48.51	42.26
Phosphorus........	0.11	0.025	....	0.05	0.075	0.035
Silica.............	....	....	....	....	28.66	....

The following analyses of samples collected by him from the Dover Company's mines on vein No. 11, about 1 mile northwest of Riverville, are reported by Benton:[101]

[98] Frazer, Persifor, Jr., The iron ores of the middle James River [Va.]: Am. Inst. Min. Eng. Trans., vol. 11, p. 212, 1883.
[99] Benton, E. R., Notes on the samples of iron ore collected . . . in Virginia: United States Tenth Census, vol. 15, pp. 267-268, 1886.
[100] Op. cit., p. 212.
[101] Op. cit., pp. 266-267.

Analyses of iron ore about 1 mile northwest of Riverville, Amherst County, Virginia

(E. R. Benton, Analyst)

	1	2
Sulphur	0.352	0.579
Phosphorus	.103	.061
Iron (metallic)	48.47	54.88
Silica	21.58	14.00
Ferrous oxide	6.03	13.67
Ferric oxide	62.35	63.01
Alumina	4.94	2.93
Lime	.28	.73
Magnesia	.37	.26
Iron disulphide	.320	.300
Barium oxide	1.18	2.11
Potassa	.99	.54
Soda	.14	.10
Carbonic acid	.21	.54
Sulphuric acid	.45	1.04
Phosphoric acid	.239	.141
Titanic acid	.07	Trace
Hygroscopic water	.07	.07
Water of composition	.85	.52
	100.069	99.961
Per cent of insoluble siliceous matter	28.53	20.71
Silica	21.58	14.00
Alumina (with trace of iron oxide)	4.12	2.92
Lime	.01	.05
Magnesia	.31	.21
Potassa	.91	.46
Soda	.11	.06
Phosphoric acid	.028	.002
Barium sulphate	1.32	3.04
	28.458	20.742

1. Specular hematite and magnetite from the heads of drifts in the main deposit.
2. Micaceous hematite and magnetite from the farther end of drifts, between shafts Nos. 2 and 3; also southwest of shaft No. 3.

An average of 18 samples from the Riverville mines reported by Kimball[102] gave 61.945 per cent metallic iron and 0.0875 per cent

[102] Kimball, J. P., The Greenway iron ore belt of the James River, Virginia: The Virginias, vol. 2, no. 1, p. 4, 1881.

phosphorus. The highest content of iron was 67.81 per cent and the lowest, 52.262 per cent. Phosphorus was reported absent from two samples and for all samples but three was much lower than the average given above. Omitting these three samples, the average phosphorus content of 15 analyses was 0.0266 per cent.

Allen Creek area.—According to Benton,[103] two veins were being opened along Allen Creek in 1880 east of the old Furnace vein which was then inaccessible. One was in "specular" ore with magnetite and the other in magnetite and martite, locally called "blue ore." The deposits were in mica schist and quartzite, and the ore beds dipped 60°-70° SE. At the southwest end of Buck Ridge on Allen Creek, an old tunnel and pits were found in quartzite.

A sample of hematite from the north slope of Buck Mountain analyzed by Stockton gave 42.30 per cent metallic iron and 0.03 per cent phosphorus.

Gladstone area.—Float magnetite is found on the property of Kirby Smith in Buckingham County opposite Gladstone. The late Dr. J. B. Weems, Chief Chemist of the Virginia Department of Agriculture and Immigration, reported to Mr. Smith an iron content of 70.50 per cent for this ore which indicates nearly pure magnetite. This magnetite body crosses the Bent Creek-Beckham road, about 1¼ miles southwest of the Smith property. It is about 8 inches thick and is interbedded with quartzite and quartz-muscovite schist.

About 1 mile to the east, on Cove Mountain, quartzite and quartz-mica schist carry some iron where they cross the county road.

Greenway area.—The old DeWitt or Greenway mines on the quartzite ridge about 2½ miles west of Greenway, were operated in the late seventies. Old workings are found southwest of the Greenway-Buffalo Springs road, and about half a mile east of Owens Creek. McDonald visited these mines a short time before 1880 and found that a shaft 80 feet deep had been sunk upon the ore vein (No. 16) and that several thousand tons of soft specular ore of fine quality had been shipped to the Westham furnace. According to Kimball,[104] the output of the Greenway mines in March, 1880, was between 50 and 75 tons daily, which could be readily increased to 100 tons by additional development.

Old reports advise that the mines were worked in 1880 by Naylor and Company of Philadelphia. There were two shafts, one of which was 205 feet deep. Operations extended for 600 feet along the strike of the ore which, including partings of schist, was said

[103] Benton, E. R., Notes on the samples of iron ore collected . . . in Virginia: United States, Tenth Census, pp. 264-265, 1886.
[104] Op. cit., pp. 2-5.

to be nearly 12 feet thick at the bottom of the mine. It was reported that the ore bodies thinned in places to mere streaks. According to reports current in the district, the mines were probably abandoned shortly after 1880. The old openings are now nearly filled; however, specimens of fine-grained quartzite ore may yet be found there.

The following section through the ore "vein," from the northwest to the southeast wall, is given by Frazer.[105] The vein is nearly vertical and appears to be the thickest ore-bearing vein found in the region.

Section of iron ore bed in Greenway (DeWitt) mines, about 2½ miles west of Greenway, Nelson County, Virginia

	Thickness Ft.	In.
Solid ore with a few wedgelike masses of quartzose matter		9
Barren, siliceous chlorite slate	1	4
Good ore		4
Barren rock		3
Good ore	2	6
Barren rock		6
Good ore	2	6
Lean ore	2	0
Thickness of ore	8	1
Barren rock	2	1

Two mines were opened on the Carter property on Mine Ridge northeast of the main Greenway shafts: (1) Church tunnel, about 1,600 feet to the northeast in a ravine, a cross-cut into the hillside to intersect vein No. 16, and (2) Lewis tunnel, nearly 1 mile northeast of the main mines, a cross-cut which was only partly completed in 1881. The vein encountered in Church tunnel was said to have been regular and to have been from 3 to 4 feet wide where opened for a distance of 300 feet. The ore was lean.

An average of 10 analyses of ore from vein No. 16 in the Greenway mines, given by Kimball,[106] shows 66.608 per cent metallic iron and 0.03 per cent phosphorus. The average shipment for December, 1879, contained 62.125 per cent metallic iron and 0.035 per cent phosphorus.

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105 Op. cit., p. 209.
106 Op. cit., pp. 2-5.

Analyses of several samples of Greenway ore made in 1881 by N. A. Stockton,[107] showed an iron content of from 41.64 per cent for fine washed ore to 59.64 per cent for a "specimen containing little quartz" and a phosphorus content of from 0.06 per cent for material taken from a "pile by the engine house" to .078 per cent for "Greenway lump ore en route to Charlotte furnace." The latter specimen contained 18.2 per cent silica. Although these analyses showed ore of good quality, the iron content was lower than that given in earlier analyses by Kimball.

The following analyses of samples from vein No. 16 in the Greenway mines were reported by Kimball:[108]

Analyses of iron ore from the Greenway mines, Nelson County, Virginia

	1	2
Ferric oxide	95.24	92.002
Phosphoric acid	.08	.052
Sulphur	....	.177
Silica	3.29	3.96
Manganous oxide	.09	....
Alumina	.53	1.839
Lime	.04	....
Magnesia	.07	....
Titanic acid	Trace	....
Water	.66	....
	100.00	98.030

1. Sampled by Thomas Dunlap. (Analysis by F. A. Genth.)
2. Sampled by J. P. Kimball. (Analysis by Booth, Garret and Blair.)

Several old pits on the property of James Sites about 1½ miles south of Greenway were examined. The ore in them, specularite and magnetite, occurs as disseminations and thin lenses in a fine-grained green mica schist and in places also in a crumpled gray-white quartz-mica schist that is near a quartzite in composition. The openings are nearly filled, but one of them is about 30 feet deep.

[107] Frazer, Persifor, Jr., op. cit., pp. 213-214.
[108] Op. cit., pp. 2-5.

ORIGIN OF THE DEPOSITS

Few opinions have been expressed in recent literature regarding the origin of these iron deposits. Campbell and other geologists, who visited the region in 1880-1882, generally regarded the deposits as sedimentary beds deposited with the enclosing rocks. According to Campbell,[109]

"The workable veins of magnetic and specular ores are probably referable to three or at the most four original horizons, now repeated several times by folds and faults represented in the section. There are minor veins, but they seem to be in some cases only branches of the larger ones, and in other cases only local in extent." He believed that the four conspicuous beds separated by schist occurred throughout the iron-producing section.

McDonald,[110] also believed that the ores were of sedimentary origin. He says:

"Whilst compounds of iron are conspicuous elements in the whole series, there are at least three well defined horizons of ore, at which the accumulation of iron sediments was in such large proportion to other materials as to constitute true iron strata, which are essentially continuous over considerable areas, though necessarily varying from point to point, with local conditions, in the richness and the thickness of the ore accumulations."

On the other hand, according to Frazer,[111] "All these ores show abundant evidence of their deposition by metasomatic action subsequently to the existence of the schists which enclose them." He believed that limonite may have replaced the mica and chlorite and was later converted to hematite by dehydration due to high temperatures.

Taber[112] described quartzite, containing hematite, magnetite and martite, from the James River gold belt in Buckingham County. In places, the quartzite is cut by tourmaline and gold-bearing quartz veins and shows slight mineralization by the vein-forming solutions. He described a bed of ferruginous quartzite about three-quarters of a mile southwest of Lantana, that was prospected for iron. The quartzite is cut by numerous irregular quartz stringers which in places contain plates of micaceous hematite. Near the veinlets, the quartzite appears to have been leached of some of its iron content.

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109 Campbell, J. L., Geology and mineral resources of the James River Valley, Virginia, U. S. A., p. 40, New York, G. P. Putnam and Sons, 1882.

110 McDonald, Col. Marshall, Report on a geological and mineral examination of a portion of the James River iron belt: The Virginias, vol. 1, no. 1, p. 13, 1880.

111 Frazer, Persifor, Jr., The iron ores of the middle James River: Am. Inst. Min. Eng. Trans., vol. 11, p. 210, 1893.

112 Taber, Stephen, Geology of the gold belt in the James River basin, Virginia: Virginia Geol. Survey Bull. 7, pp. 19-22 174-175, 1913.

It is quite natural that a sedimentary origin should be ascribed to iron ores interbedded with schist and not associated with igneous rocks, but it is thought that such an origin is unlikely for the iron deposits of this district.

These deposits bear certain resemblances to the iron deposits in the province of Minas Geraes, Brazil, to which Chamberlin and Harder,[113] have ascribed a sedimentary origin. The Brazilian deposits are bedded hematite. They contain much martite which is not entirely altered to hematite. The iron-bearing formation is the Algonkian Itabira quartzite. It lies under the Itacolumi quartzite, above the Caraca quartzite, and is separated from both formations by schist. Considerable variations in the thickness of the iron-bearing formation occur within short distances. The quartzite series is believed to represent delta deposits, the iron having been precipitated by bacteria.

If the deposits of the James River iron belt are of sedimentary origin, they must have been formed in somewhat similar manner. They do not resemble beach deposits in physical character or chemical composition. The pebbles of the conglomerate were originally well sorted, well rounded and more or less spherical. The iron is low in titanium and phosphorus. It is unlikely that a thick deposit of beach magnetite would contain little or no ilmenite or apatite.

The writer finds some evidence of an igneous origin for the iron deposits of this region and believes that they have replaced certain more soluble layers in the Mount Athos quartzite and the Cockeysville marble. The constant occurrence of the ore in quartzite and associated schist may signify that this formation was more permeable to the ore solutions, which may have been derived from the basic portion of a pre-Cambrian magma.

Small scattered lenses of granite pegmatite are found in a few places in the iron belt, and some quartz stringers carry hematite or ilmenite. These bodies are small, infrequent, and do not appear to be associated closely with the iron beds. At Riverville, quartz-tourmaline veins and lenses of almost pure black tourmaline cut the ore-bearing quartzite and schist.

On the Moore property along Wreck Island Creek, in Appomattox County, stringers of hematite, pyrite, and copper sulphides occur in white marble and mica schist. These minerals have been introduced with the vein quartz. According to Campbell,[114] a vein of magnetite occurs in this area. Available evidence does not seem sufficient to demonstrate that quartz-tourmaline veins or

[113] Harder, E. C., and Chamberlin, R. T., The geology of central Minas Geraes, Brazil: Jour. Geology, vol. 23, p. 397, 1915.
[114] Op. cit., p. 42.

recent granite differentiates are responsible for these magnetite deposits.

Marked changes in thickness within a few feet and the tendency of veins to divide and reunite are difficult to explain. Deposition of sand in one place and iron in another, with rapid changes in the nature of the deposits from time to time, may have caused some interlensing of iron, quartzite and schist.

Thin sections of fresh quartzite from the quarry at Mount Athos contain patches of calcite grains. In places the quartzite immediately below the Cockeysville formation is highly calcareous, as at Greenway and Norwood. At the Maud mines, the Cockeysville formation is partly replaced by magnetite. Limestone and calcareous schist on the west side of the mines are thoroughly speckled with small magnetite octahedra. It can not be said definitely that the Cockeysville formation is replaced by ore at Riverville, but important iron mines were located near and along the strike of the limestone. Analyses of the high-grade ores show a low content of calcium carbonate.

LIMONITE

General Features

Many deposits of limonite or brown hematite are reported from this district. They occur in pockets and belts at or near the surface, where they have been formed by long and thorough chemical weathering of limestone and crystalline schist. Along James River, belts of ore have been traced for several miles, generally in limestone belts.

These limonite ores were worked for the old furnaces before the magnetite and hematite ores were used. They are not directly associated with the latter deposits, which occur in quartzite and mica schist and have had a different origin.

The limonite is frequently admixed with more or less manganese oxide, and contains more phosphorus than the hematite and magnetite. Although the limonite ores did not make Bessemer steel, they are said to have made superior grades of foundry iron.

Limonite and turgite are especially abundant in the "Red Belt" east of Chestnut Mountain. Considerable ore was shipped from limonite deposits in the vicinity of Mount Athos to the Powhatan furnace near Richmond. The most important limonite deposits are discussed below.

Mines

Mount Athos area.—Much limonite, or brown hematite, has been mined in the vicinity of Mount Athos, especially east of Chestnut

Mountain. The following analyses of ores in this district are taken from a report by Britton.[115]

TABLE 5.—*Analyses of limonite ores from the vicinity of Mount Athos, Campbell County, Virginia*

(After J. B. Britton)

	1	2	3	4	5	6	7	8
Metallic iron	34.63	55.95	40.24	48.04	43.41	46.82	49.02	50.97
Oxygen with iron	14.73	23.79	17.14	20.50	18.52	19.93	20.93	21.72
Silica	31.31	7.08	25.80	15.17	19.96	9.39	16.05	11.46
Water	9.21	10.28	9.53	9.87	9.62	11.98	9.35	11.81
Alumina	5.36	1.03	3.69	4.88	5.26	3.93	3.01	2.00
Lime	.23	Trace	Trace	.06	Trace	.09	Trace	.11
Magnesia	.16	Trace	....	Trace	Trace	5.02	Trace	Trace
Manganese oxide	2.97	.32	1.30	Trace	1.62	1.55	Trace	Trace
Phosphoric acid	1.124	1.406	2.045	1.243	1.152	.984	1.559	2.40
Undetermined loss	.276	.144	.255	.237	.458	.306	.081	.53
	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00
Phosphorus	.491	.614	.893	.543	.503	.43	.681	1.048

1. Variable, siliceous, brown hematite from breast of open-cut, about 100 feet long, on north side of railroad.
2. Compact, brown hematite from vein 6 feet wide, in small opening on west side of public road.
3. Brown hematite from narrow cross-cut, 2 or 3 feet deep, on top of hill, showing vein 34 feet wide.
4. Composite sample of brown hematite, similar to 3 above, from shaft and surface opening at "Olney workings."
5. Brown hematite from old caved-in open-cuts.
6. Fine, compact, brown hematite from shallow cross-cut at base of a hill, showing body of ore near surface 10 feet wide.
7. Compact, brown hematite from shallow cross-cut showing body of ore 20 feet wide.
8. Brown hematite from shallow cross-cut on outcrop of vein, showing apparent width of 18 feet.

Stonewall Creek area.—In the Stonewall Creek area, east of Chestnut Mountain and between Stonewall furnace and the Norfolk and Western Railway, were many pits, tunnels and shafts, mostly in limonite and manganese oxides. In 1880, these properties were leased by the Birmingham Coal and Iron Company.

About 500 feet southeast of Chestnut Mountain and separated from it by slaty schist, is a tract that was designated as the "Red Belt." It extends from the railroad northeast to the old Stonewall

[115] Britton, J. B., Analyses of Campbell and Appomattox counties, Virginia, iron and manganese ores and limestones: The Virginias, vol. 2, no. 11, pp. 170-171, Nov., 1881.

furnace. The deposits are intermixed red and brown hematite. Turgite and limonite replace mica schist. The ores range in composition from nearly pure red turgite to nearly pure limonite. The limonite ores are richer in iron and contain more phosphorus.

A second belt of ore, called the "Pot Ore Belt," occurs a few hundred feet southeast of this belt. These ores are concentrations of limonite and manganese oxide derived from the weathering of blue marble and associated schist.

On the property of C. B. Blankenship of Concord, a considerable concentration of limonite is found in the schist. In June, 1925, when this locality was visited, a tunnel was found which had been driven about 50 yards into the schist. There were also numerous prospect pits and narrow open-cuts. Ore is said to have been shipped from this locality about 30 years ago.

The following analysis of limonite from Stonewall Creek, reported to have consisted of brown hematite and siliceous brown oxide and probably used in the old Stonewall furnace, is given by Rogers:[116]

Analysis of limonite ore from Stonewall Creek, Appomattox County, Virginia

Ferric oxide	76.00
Alumina	.50
Silica and insoluble	13.00
Water	10.00
Loss	.50
	100.00
Metallic iron	53.20

An analysis of ore from the Stonewall furnace given by Campbell,[117] shows a metallic iron content of 55.2 per cent, a phosphorus content of 0.26 per cent and a silica content of 7.14 per cent. An analysis of limonite ore from the old Stonewall mine by F. A. Genth shows 42.81 per cent iron and 0.478 per cent phosphorus.

The old Stonewall furnace was located at a prominent bend in Stonewall Creek, about 1 mile above its mouth. The ore used at the furnace was taken from the hill on the northeast side of the creek. It was limonite with some admixed manganese oxide, concentrated through the weathering of limestone.

[116] Rogers, W. B., A reprint of annual reports and other papers on the geology of the Virginias, pp. 527-528, New York, D. Appleton and Co., 1884.

[117] Campbell, J. L., Geology and mineral resources of the James River Valley, Virginia, U. S. A., p. 32, New York, G. P. Putnam's Sons, 1882.

The old Ross furnace was located in Campbell County, 2 miles south of the present James River bridge. In 1781, Jefferson reported that it was making 1,600 tons of pig iron annually. It was operated during the War between the States under the name of Oxford furnace. Local limonite was used.

Walker Ford area.—Nearly opposite Walker Ford limonite was mined from the "Nutall Vein." According to Campbell,[118] the deposit is not less than 12 feet thick, is associated with manganese, and is in the limestone belt. The old workings were filled by 1926.

Limonite has been mined also on the Christian property on the west side of the river.

Allen Creek area.—The Allen Creek area is the oldest mining area in the district. On Allen Creek, formerly called Elk Island Creek, about seven-tenths of a mile west of James River, was located the old Elk Creek charcoal furnace. (See Pl. 13.) It used local limonite ores and had the reputation of making the best pots and ovens in the country, and its metal was regarded to be the toughest that could be found. Later, local hematite and magnetite ores were mixed with the pot ores and used at the furnace.

The following analysis of amorphous, cellular, chestnut-brown limonite, half a mile above the mouth of Allen Creek, which was used in the old Elk Creek furnace, was made by Rogers.[119]

Analysis of limonite ore along Allen Creek, Nelson County, Virginia

Ferric oxide	84.00
Alumina	.85
Lime	Trace
Silica and insoluble	7.60
Water	7.10
Loss	.45
	100.00
Metallic iron	58.94

A partial analysis of brown hematite from near the old Elk Creek furnace, made by F. A. Genth, gave iron 44.50 per cent and phosphorus 0.850 per cent.

Gladstone area.—Ore of excellent quality was found on the property of W. S. Mundy, a short distance northwest of Gladstone. The following analyses of this ore were reported to Mr. Mundy by the Oriskany furnace of Lynchburg:

[118] Op. cit., p. 80.
[119] Op. cit., p. 528.

Analyses of limonite ore from W. S. Mundy property near Gladstone, Nelson County, Virginia

	1	2	3
Metallic iron	44.85	46.22	35.10
Manganese	4.96	.....	.....
Phosphorus	.92	.....	.....
Silica	12.92	.....	.....

1. Cross-vein sample.
2. Float-ore sample.
3. Hanging-wall slate.

New Canton area.—Three belts of limonite ores were worked at an early date near New Canton in Buckingham County. They extended from James River for an undetermined distance towards Buckingham Court House. A furnace using these ores was put into operation in 1835 at New Canton by F. B. Dean, Jr.[120] According to Campbell, its operations were suspended in 1848. During 1858 and 1859, large quantities of ore from this district were shipped to the Westham furnace 10 miles above Richmond. The ores at Bremo were worked by the Confederate Government during the War between the States. The following analysis of this ore was made by Britton:

Analysis of limonite ore from Bremo, Fluvanna County, Virginia

Metallic iron	49.11
Insoluble silica and silicates	21.38
Sulphur	None
Phosphorus	.71
Alumina	4.43
Lime	.07
Magnesia	.04
Manganese	Trace
Titanium	None

MANGANESE

INTRODUCTORY STATEMENT

Manganese is important in the manufacture of steel and for several other uses. Considerable manganese has been mined in Virginia, and deposits of manganese oxides of excellent quality in this district may come into prominence in the future. Some of them are nearly pure manganese oxide, whereas others are associated with limonite and rarely with other iron ores. The deposits occur in residual clay derived

[120] Quotation from the Richmond Courier in the Niles Register, July 25, p. 364, 1835.

from the weathering of crystalline schist and Cockeysville marble, and are generally near quartzite. The mines near Mount Athos and west of Warminster and Midway Mills, were worked at an early period and yielded a considerable part of the manganese produced in the State at that time. Considerable unmined manganese remains at these localities.

MINES

Campbell County.—South of the Norfolk and Western Railway at "the Arch," and on the west side of Archers Creek, was the Leet, or Whitman, manganese mine. It is now abandoned and the workings are inaccessible. The mine was in the Cockeysville marble belt and the hanging wall was quartzite. A shaft, said to be 200 feet deep, was sunk in the valley slope and a drift intersected it. According to Watson,[121] "Its production of high grade ores has been very large, probably ranking next to the Crimora mines, in Augusta County, in quality and quantity of ore produced. The ore is of the nodular or kidney type. The individual nodules show considerable variation in size and shape, and are generally assembled in the form of nests and pockets in a residual clay derived from a dark-colored micaceous schist. The ore is associated with iron."[122]

"Ore of much better quality than is indicated by the . . . analyses was mined; and during the early period of mining the ore was of such superior quality that most of it was shipped to England for use in chemical purposes."

The following description of the operations and samples collected by him in the spring and summer of 1881, which are believed to be from this property, are given by Britton:[123]

"Mine some three or four hundred yards south of the Norfolk & Western R. R. A drift running southwestwardly has been started well up on the side of the hill, and a penetration of some 300 feet had been reached. The average width of the ore-bearing stratum, the superintendent informed me, was about 4 feet. Work was going on at the time of my visit. The preparation for market was by hand-picking and washing with rocker and jig. About three hundred tons, I was told, had been prepared and shipped. The sample for analysis was taken from the platform at the railroad, where a little of the prepared ore had been left; consisted of 20 small pieces, and weighed 1 pound 1¾ oz. The mineral appeared to be chiefly pyrolusite. . . . A drift had been started at the base of a hill and carried southwardly about 250 feet. The ore-bearing stratum varied in width from 6 to 15 feet or thereabouts.

[121] Watson, T. L., Mineral resources of Virginia, p. 240, Virginia-Jamestown Exposition Commission, Lynchburg, Va., 1907.

[122] Analyses of ore from the Leet mine are given in Table 6.

[123] Britton, J. B., Analyses of Campbell and Appomattox counties, Virginia, iron and manganese ores and limestones: The Virginias, vol. 2, no. 11, pp. 170-171, November, 1881.

Considerable mineral had been taken out, but not any prepared for market. The sample for analysis was taken from a pile of picked lumps, and considered as fairly representing an average of what the carefully prepared product of the mine would be; consisted of 9 pieces, and weighed 2 pounds, 2½ oz. The mineral was pyrolusite with a little manganite."

Analyses of the samples are given in Table 6.

Weeks[124] gives the following production of ore from this mine:

Production of manganese ore from the Leet mine, Campbell County, Virginia

Year	Long tons
1880	104
1881	50
1882	130
1883	40
1884	76
1885	500
	900

TABLE 6—*Analyses of manganese ores from the James River iron and marble belt, Virginia*

	1	2	3	4	5	6	7	8	9	10
Manganese (metallic)	43.58	45.87	44.18	.....	.....	66.60	52.92	34.56	44.30	43.02
Manganese dioxide	.....	.....	.....	76.40	88.30	.....	.....	.....	.....	.....
Iron (metallic)	5.24	5.34	6.64	.....	.....	.28	2.53	22.57	3.67	4.24
Iron peroxide	.....	.....	.....	9.30	.47	.....	.....	.....	.....	.....
Phosphorus	.316	.257	.274	.....	.....	.174	.002	.08	.243	.182
Silica	7.15	7.77	7.73	10.96	5.54	.99	10.53	.....	17.45	18.51
Residue and loss	.....	.....	.....	3.34	5.69	.....	.....	.....	.....	.....

1. Manganese ore from Leet mine, on Archer Creek, Campbell County. (After Watson, T. L., Mineral resources of Virginia, p. 240, 1907.)
2. Idem.
3. Idem.
4. Manganese ore from Leet mine, on Archer Creek. (Analysis by J. B. Britton.)
5. Idem.
6. Manganese ore from prospect near Concord, Appomattox County. (Analysis by Froehling and Robertson.)
7. Idem.
8. Manganese ore from prospect near Stapleton, Amherst County. (After Weeks, J. D., Mineral resources of the United States for 1885, p. 311, 1886.
9. Manganese ore from Cabell mine, near Warminster, Nelson County. (After Weeks, J. D., Mineral resources of the United States for 1885, p. 312, 1886.)
10. Idem.

Appomattox County.—Manganese deposits are known in Appomattox County near Concord and east of James River on Chestnut Ridge, between Galts Mill and Stapleton.

[124] Weeks, J. D., Manganese: U. S. Geol. Survey Mineral Resources of the United States, 1885, p. 310, 1886.

According to Watson,[125] several openings near Concord, made prior to 1907, exposed good ore. Analyses of this ore, as reported by Froehling and Robertson, are given in Table 6.

On the Cabell estate, about three-fourths of a mile southwest of "White Rock" above Galts Mill, the local ridge has been prospected for manganese and brown hematite and some is said to have been shipped. An old opening was found in 1927 between quartzite in the hanging wall and mica schist in the foot wall. About 1 mile to the southwest along Chestnut Ridge, on Slippery Creek, pyrolusite has been taken from several pits that are now 10 to 30 feet deep. Quartzite forms the foot wall and mica schist the hanging wall.

Manganese ore was discovered in 1930 by J. W. Woodson, of Lynchburg, on the top of Chestnut Mountain, and some development work was done locally. Several small openings were made near the point at which the county road crosses Stonewall Creek, 2 miles east of Galts Mill, and a shaft was sunk near the creek. The property[126] is located along the Chestnut Mountain road in Appomattox County, a short distance from the Appomattox-Campbell county line, at a point where it runs parallel to James River and a distance of 1¼ miles therefrom. The deposit strikes N. 37° E., and is described as a replacement deposit in quartz mica schist. J. W. Woodson reports that the body of ore was found about 6 feet from the surface, where it is 2 feet wide, and that it had widened out to 6 feet at a depth of 14 feet from the surface. He reports that on December 1, 1930, a discovery was made of a second deposit of ore of good quality, along the top of the mountain, which was traced for about 1½ miles. The following analyses of samples from the first deposit are reported by Barnard and Ryan:

Analyses of manganese ore from Chestnut Mountain, Appomattox County, Virginia

(W. W. Cash, Jr., Analyst)

	1	2	3
Iron	1.44	4.35	29.31
Manganese	42.05	21.29	11.63
Phosphorus	.254	.122	.214
Silica	8.00	41.80	29.04

1. A picked sample of high-grade ore from vein near the surface.
2. An average sample of the replaced quartz-mica wall.
3. A typical sample of wad from the foot wall of the vein.

Amherst County.—Weeks[127] mentions deposits of manganese ore from Amherst County. An analysis of a manganiferous iron ore re-

[125] Op. cit., p. 239.
[126] Barnard, E. E., and Ryan, C. W., Unpublished report on the manganese ores of Chestnut Mountain to Mr. John W. Woodson, of Lynchburg, Va., Lynchburg, June 19, 1930.
[127] Op. cit., p. 311.

ported from a prospect near Stapleton Mills (now Stapleton) is given in Table 6. A manganese deposit is also reported by Weeks from Walker Ford.

Nelson County.—Considerable manganese was mined in the ridge between Midway Mills and Warminster, about 1½ to 2 miles west of James River. The ore occurs as pockets in residual clay, derived from the weathering of limestone and schist, and is associated with beds of mashed quartzite. The old workings are now inaccessible and the data regarding the mines have been taken from the report by Weeks.

West of Midway Mills, a quartzite band in the Wissahickon schist has been extensively prospected for manganese. A mine on the property of G. F. Simpson was worked in 1882 and yielded 1,200 tons of first-class ore, which was shipped to Liverpool, England. The ore is said to have been taken from a shaft which was carried below water level to a total depth of 165 feet. It is reported to have analyzed 70 per cent manganese oxide above water level and 80 to 85 per cent below water level.

The Frank Cabell mine, situated about 2 miles from Warminster, has not been worked since 1877. In 1868 and 1869, 5,000 tons of ore were shipped from this mine to Newcastle-on-Tyne. Two analyses are given in Table 6, and another by J. L. Campbell gave 81.25 per cent manganese dioxide.

The Bugley mine, about half a mile southwest of the Cabell mine and worked at the same time, yielded about 2,000 tons of ore.

The Davis mine is said to have produced about 1,000 tons of high-grade ore. Operations were suspended shortly before 1885. A complete analysis of a sample of this ore by S. W. McKown of the Briar Hill Coal and Iron Company, of Youngstown, Ohio, is given below:

Analysis of manganese ore from the Davis mine, Nelson County, Virginia

(S. W. McKown, Analyst)

Metallic manganese	57.16
Metallic iron	1.56
Ferric oxide	2.24
Alumina	1.13
Lime	1.22
Magnesia	2.28
Silica	1.12
Phosphoric acid	.43
Manganese dioxide	90.42
Phosphorus	.188
Water	1.25

ORIGIN OF DEPOSITS

The hydrated oxides of manganese are of secondary origin, having been precipitated by downward circulating meteoric waters. Small amounts of manganese occur in limestones and in crystalline schists. They may also occur in the silicates of the schists. Many iron deposits have had a similar origin and the two elements are closely related. The association of manganese oxides with limestones and quartzite is to be expected in Virginia. The deposits have been formed as a result of prolonged weathering, solution, and reprecipitation of the manganese-bearing compounds.

COPPER

GENERAL STATEMENT

Copper was mined in Amherst County and on Wreck Island Creek in Appomattox County before the Revolutionary War. During the iron boom of 1880, copper was mined by Thomas Dunlap, at two localities.

MINES

Norwood area.—On Joe Creek at Norwood, copper was mined from Catoctin greenstone, but the amount shipped from this locality is not known. Ore was taken from a large shaft, which, when visited in 1925, was nearly filled with blocks of greenstone that had been cast aside in mining. Pyrite and bornite occur in stringers throughout the greenstone. Quartz stringers are abundant.

The Glades area.—That section of the Glades near the west end of Buffalo Ridge in Amherst County has been rather extensively prospected for copper and some has been mined. Along the "Glade Road," near Mundys old mill, are many prospects and a few shafts along a zone of mineralization that strikes N. 55° W. A large inclined shaft, where most of the mining was done, is said to have been 300 feet deep. The ore was brought up by buckets and windlass.

The openings appear to be either in Lynchburg gneiss or at the contact between the gneiss and a fine, dense, dark-colored volcanic rock that has the appearance of an old flow, and which locally is generally altered to greenstone. Specimens on the dump show that the primary copper sulphide is bornite. The sulphide is generally altered to chrysocolla and in places to malachite.

The Lynchburg gneiss has been considerably altered in the mineralized zone. It contains veins of amphibole asbestos (tremolite) and large masses of long, bladed tremolite, nearly pure chlorite, granular chlorite, and quartz. The chlorite has been formed from the alteration of biotite. Lumps of chalky white, cellular silica and carbonate (probably calcite) containing chlorite and other minerals are common. These minerals are more or less stained with chrysocolla and malachite.

There are few historical records available of copper mining in this district. Robinson[128] says, "A copper mine was opened in this county [Amherst] on the west side of James River, but is not now wrought."

A note in December, 1880, issue of *The Virginias*[129] states that Colonel Thomas Dunlap shipped 30,000 pounds of copper ore December 2, 1880, from the mines in the Glades. The ore was hauled to Amherst. The mines were again leased about 1917-18 by the Buffalo Ridge Development Company, when the main shaft was cleared out, but no ore was shipped.

Beckham area.—Before the Revolutionary War, copper is said to have been mined east of Mineral (now Beckham) on Wreck Island Creek, near a large body of white marble on the property of Alonzo Moore. The marble is bounded on the east by Wissahickon mica schist which contains numerous stringers and lenses of vein quartz carrying pyrite and copper sulphides. A 40-foot tunnel was driven into the valley wall through schist and into marble. At the end of the tunnel, white and blue marble contain thin veins, stringers, and disseminations of pyrite, hematite and chalcopyrite. A sample of oxidized ore from the tunnel donated by Mr. Moore shows bornite, chrysocolla, limonite and chlorite.

According to Mr. Moore, there was an old smelter on the property of Joe Ferguson near by, before the Revolutionary War. The copper was floated down Wreck Island Creek to James River. Specimens of copper ore have been found at the site of this old smelter.

ORIGIN OF THE DEPOSITS

In the Virgilina district,[130] graphic intergrowths of chalcocite and bornite have crystallized where copper-bearing magmatic waters may have reacted with epidote and other silicates which contain iron in a ferric state.

Weed and Watson,[131] in discussing the origin of Blue Ridge copper deposits, conclude that the copper minerals are of secondary origin and were deposited by meteoric waters along joint planes in the rock.

No granite or pegmatite has been found associated with the copper deposits of the James River district, but mineralization has been produced by quartz veins at Norwood and in Appomattox County. The

[128] Robinson, Samuel, A catalogue of American minerals with their localities: p. 203, Boston, Cummings, Hilliard & Company, 1825.
[129] The Virginias, vol. 1, no. 12, p. 193, 1880.
[130] Laney, F. B., The geology and ore deposits of the Virgilina district of Virginia and North Carolina: Virginia Geol. Survey Bull. 14, pp. 83-85, 1927.
[131] Weed, W. H., and Watson, T. L., The Virginia copper deposits: Econ. Geology, vol. 1, no. 4, pp. 322-323, 1906.

deposits in the Glades show metamorphism similar to that produced by pegmatite in the Lynchburg gneiss several miles west. The original minerals are bornite and chalcopyrite. The deposits in the Glades were later oxidized and perhaps somewhat enriched.

WATER RESOURCES

WATER POWER

The possibilities for the development of water power in this region are important. Among the factors which determine the potential value of power development are the drainage area and flow of water of the stream above the proposed reservoir site, the continuity of the flow, accurate data regarding fluctuations in volume of flow, and the possibility of regulating the flow to insure constant volume. Whereas the rate of fall for the streams in the Piedmont region is less than in the Blue Ridge, the volume of flow is greater in the Piedmont. Between Lynchburg and Scottsville, James River has a fall of 240 feet in 67 miles, measured along the Chesapeake and Ohio Railway.[132] Above Scottsville, James River has a drainage area of 4,570 square miles. Extremes of discharge at Scottsville between February 26, 1925, and September 30, 1927, show a maximum discharge of 42,300 second feet on January 20, 1926, and a minimum discharge of 400 second feet on September 30, 1925.[133] The volume varies considerably from month to month and from day to day. This factor does not favor power development, where an even flow of water is desired. Smaller streams in the district have been used to run grist mills since the time of early settlement. The names of such villages as Galts Mill, Variety Mills, and Midway Mills indicate the early importance of mill sites. Some of these old mills are still run successfully.

SPRINGS AND WELLS

Good springs are especially numerous in the James Valley, partly because deep valleys have been cut in the rocks by tributary streams and partly because of the diversity in the physical character of the rocks. Limestone springs are rare in the marble belt. A typical hard water spring flows from blue, slaty marble at Greenway. There is a tendency for large springs to occur on the southeast side of quartzite beds. This is probably because the rocks dip to the southeast, and quartzite is more porous than the enclosing schists. Southeast of the quartzite, springs tend to issue from the northwest side of valleys cut in the softer rocks. Two springs of this type are similar in

[132] Grover, N. C., and Bolster, R. M., Hydrography of Virginia: Virginia Dept. Agr. and Immigration, Geol. Survey of Virginia, Geol. Ser., Bull. 3, Pl. 6, 1906.
[133] Dirzulaitis, J. J., and Stevens, G. C., Water resources of Virginia: Virginia Geol. Survey Bull. 31, pp. 147-251, 1927.

volume to large limestone springs, such as are found in the Valley of Virginia.[134] One is at "Old Tavern," about 1 mile northeast of the "Arch"[135] and near the Campbell-Appomattox county line. The other is in Brooks Hollow, on the property of Kirby Smith, just east of Gladstone in Buckingham County. A large spring about 1 mile north of Gladstone proves more than sufficient to supply the town with excellent water. The spring is about 65 feet above the town and rises on the west side of a diabase dike. Only a part of the water is piped to Gladstone. A spring of this size is unusual in the Piedmont province. Buffalo Springs, issuing from Wissahickon mica schist at the eastern base of Buffalo Ridge, is the best known spring in the region and was once the site of a famous resort. Ferric hydroxide from the spring is precipitated in the stream channels.

East of James River, dwellings built upon flat land between streams are generally supplied with water from wells. West of the river there are many springs. Soapstone contains much soluble mineral matter, especially carbonates, and water issuing from it should be tasted with caution. The Lower Cambrian arkosic quartzite is an ideal water-bearing rock, but its outcrops are rather narrow. It is porous, contains few soluble minerals, and supplies excellent "freestone water." Many families living on the belt of this rock to the northeast depend upon springs for their water supply.

Lynchburg is now supplied with water from a reservoir in Pedlar Gap in Amherst County. It was one of the first cities in the United States to build modern water works. The original water works were built in 1828-1829 at a cost of $50,000. A channel of James River around an island above the town was dammed and water was transferred by means of a canal half a mile long to the pump house at the river. From this place it was pumped to a reservoir of 400,000 gallons capacity, 253 feet above river level.

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[134] Collins, W. D., and others, Springs of Virginia: State Commission on Conservation and Development, Div. Water Resources and Power, Bull. 1, 55 pp., 1930.
Reeves, Frank, Thermal springs of Virginia: Virginia Geol. Survey Bull. 36, 56 pp., 1932.

[135] At the "Arch," the Norfolk and Western Railway passes over the county road to Lynchburg.

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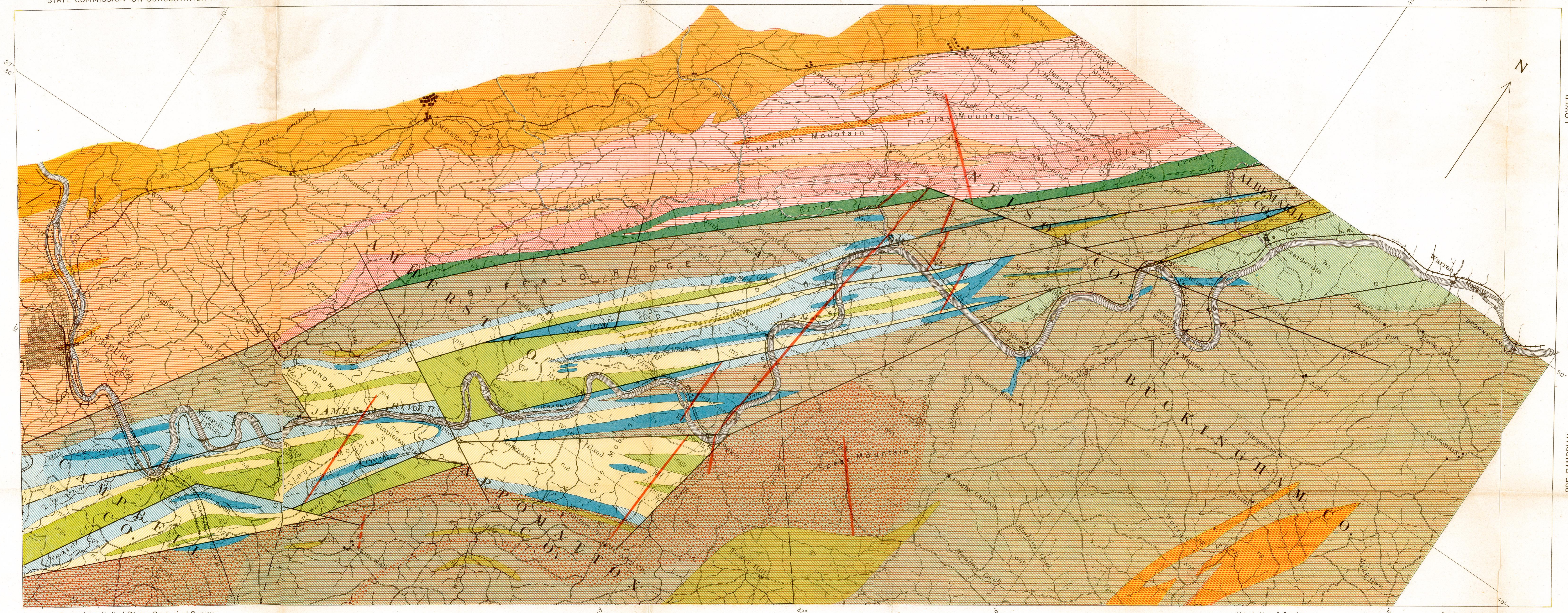
STATE COMMISSION ON CONSERVATION AND DEVELOPMENT

VIRGINIA GEOLOGICAL SURVEY
ARTHUR BEVAN, STATE GEOLOGIST

BULLETIN 39, PLATE I



Base from United States Geological Survey maps of Appomattox, Buckingham, Lexington (Buena Vista) and Lynchburg quadrangles. Surveyed in 1887-90.

Lith. A. Hoen & Co., Inc.

Geology by A. Sarcron
Surveyed in 1929

EXPLANATION

SEDIMENTARY

TRIASSIC

Ŧn — Newark group
(brown arkosic sandstone, red and olive-colored shale; greenstone; conglomerate near fault at Howardsville.)

UNCONFORMITY

LOWER CAMBRIAN

Єl — Loudoun formation
(arkosic quartzite and dark-colored slate.)

UNCONFORMITY

PRE-CAMBRIAN

lyg, was (wasq, gv) — Lynchburg gneiss and Wissahickon formation
(lyg, Lynchburg gneiss: biotite gneiss and schist. was, Wissahickon albite-chlorite-muscovite schist and phyllonite, garnetiferous facies shown by dots; thin quartzite beds, wasq; thin greenstone flows, gv.)

cv (Outcrops) — Cockeysville marble
(white, pink and blue marble and talcose schist.)

ma (Graphite schist) — Mount Athos formation
(quartzite and mica schist.)

IGNEOUS AND METAMORPHIC

TRIASSIC

Ŧd — Diabase dikes

PRE-CAMBRIAN

lgn — * Lovington gneiss
(granite and quartz monzonite biotite gneiss, intrusive into Lynchburg gneiss and hornblende gneiss.)

ss, hg — Soapstone and hornblende gabbro
(ss, soapstone, peridotite, and pyroxenite, including hornblende gneiss and hornblende gabbro, intrusive into Lynchburg gneiss and interfolded with Catoctin greenstone; hg, hornblende metagabbro associated with soapstone.)

cgv — Catoctin greenstone
(basalt flows west of the Catoctin Mountain Border fault, altered to greenstone schist.)

mgv — Mount Athos greenstone
(basaltic lava flows at base of Mount Athos formation, altered to greenstone schist.)

Faults
D—downthrow side of normal fault

*Should read Lovingston gneiss

GEOLOGIC MAP OF THE JAMES RIVER IRON AND MARBLE BELT, VIRGINIA

Scale $\frac{1}{125,000}$

0 1 2 3 4 5 6 Miles