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CONSERVATION AND DEVELOPMENT COMMISSION
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Wilbur A. Nelson, *State Geologist*

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Geology of the Gold-Pyrite Belt

of the

Northeastern Piedmont Virginia

By *John T. Lonsdale*

University, Virginia
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LETTER OF TRANSMITTAL

COMMONWEALTH OF VIRGINIA

Virginia Geological Survey

University of Virginia

Charlottesville, Va., February 24, 1927.

To the State Conservation and Development Commission:

Gentleman:

I have the honor to transmit and to recommend for publication as Bulletin 30 of the Virginia Geological Survey Series of reports a manuscript and illustrations of a report on the *Geology of the Gold-Pyrite Belt of the Northeastern Piedmont Virginia,* by John T. Lonsdale.

This report contains the results of an investigation of the geology and mineral resources of the gold-pyrite belt in northeastern Piedmont Virginia. The area involved comprises approximately 600 square miles in Culpeper, Fairfax, Fauquier, Orange, Prince William, Stafford, and Spotsylvania counties. The general geological features of the region and the origin of the gold, pyrite, copper, iron, graphite, and soapstone deposits found in the area are discussed in as much detail as possible. Building stones and road materials are considered briefly.

Virginia's pyrite deposits are among the most extensive in this country and have given her first rank among the domestic pyrite producing states. The area covered by this report constitutes an important pyrite reserve.

The report contains much valuable historical data relating to individual mining properties in the district.

Respectfully submitted,

WILBUR A. NELSON,
State Geologist.

Approved for publication:

State Conservation and Development Commission,
Richmond, Virginia, February 24, 1927.
E. O. FIPPIN, *Executive Secretary.*

TABLE OF CONTENTS

	PAGE
Introduction	1
Acknowledgments	1
Geography and history	2
Location	2
Topography	4
Drainage	4
Soil	4
Timber	5
Climate	5
Culture	5
History	6
Iron mining	6
Gold mining	6
Gold production	8
Pyrite mining	9
Pyrite production	10
Previous geologic work	11
Bibliography	12
Physiography	15
Introduction	15
Relief	15
Drainage	15
Physiographic history	16
Geology and petrography	18
Introduction	18
Sedimentary rocks	18
Triassic sedimentary rocks	19
Occurrence	19
Descriptions	19
Topography	19
Structure	20
Cretaceous sedimentary rocks	20
Occurrence	20
Structure and description	20
Igneous rocks	21
Igneous rocks of pre-Cambrian or Cambrian age	21
Granites	21
Locust Grove granite	22
Occurrence	22
Megascopic characters	22
Microscopic characters	22
Chemical composition and classification	22
Geologic age	23
Somerville granite	24
Occurrence	24
Variations and structure	24

Geology and petrography (continued)
Igneous rocks (continued)
Igneous rocks of pre-Cambrian or Cambrian age (continued)
Granites (continued)
Somerville granite (continued) PAGE
Megascopic and microscopic characters 24
Classification 25
Geologic age 25
Hornblende granite 25
Occurrence 25
Megascopic characters 25
Microscopic characters 26
Chemical composition and norm 26
Geologic age 27
Blue quartz diorite (and its pegmatite facies) 27
Normal quartz diorite 27
Occurrence 27
Relation to pegmatite 28
Megascopic characters 28
Microscopic characters 28
Chemical composition and classification 28
Structure 30
Geologic age 30
Pegmatite 30
Pegmatite facies 30
Megascopic characters 30
Microscopic characters 30
Chemical composition and classification 31
Diorites 32
Diorite gabbro complex 32
Occurrence 32
Diorite 32
Gabbro 33
Basic facies 34
Gradation 34
Porphyritic facies 35
Evidence of differentiation 36
Geologic age 36
Neapsco Run diorite 36
Occurrence 36
Megascopic characters 36
Microscopic characters 37
Chemical composition and classification 37
Geologic age 38
Locust Grove diorite 38
Occurrence 38
Megascopic characters 39
Microscopic characters 39
Geologic age 39
Resume 39
Igneous rocks post-Cambrian, probably post-Ordovician, in age 39
Granites and quartz monzonites of post-Ordovician age 39

Geology and petrography (continued)
Igneous rocks (continued)
Igneous rocks post-Cambrian, etc. (continued)
Granites and quartz monzonites, etc. (cont'd) PAGE
Stafford Store quartz monzonite 40
Occurrence 40
Megascopic characters 40
Microscopic characters 40
Chemical composition and classification 41
Geologic age 42
Fredericksburg granite (quartz monzonite) 42
Occurrence 42
Megascopic characters 42
Microscopic characters 43
Chemical composition and classification 43
Structure 44
Geologic age 45
Occoquan granite with its included aplite 45
Occurrence 45
Variation 45
Microscopic characters 46
Chemical composition and norm 47
Classification 48
Geologic age 48
Uses 48
Rhyolite 48
Occurrence 48
Megascopic characters 49
Microscopic characters 49
Classification and geologic age 49
Rhyolite porphyry 50
Occurrence 50
Megascopic characters 50
Microscopic characters 50
Geologic age 51
Pegmatites and aplites 51
Pegmatite from Fredericksburg quartz-monzonite 51
Occurrence 51
Megascopic characters 51
Microscopic characters 51
Pegmatite from Stafford Store quartz-monzonite 52
Occurrence 52
Megascopic characters 53
Microscopic characters 53
Pegmatite from Somerville granite 53
Occurrence 53
Aplite dikes 53
Igneous rocks of Triassic age 53
Diabase dikes 54
Occurrence 54
Megascopic characters 54
Detailed occurrences 54
Olivinitic diabase dikes 54
Non-olivinitic diabase dikes 55

PAGE

Geology and petrography (continued)
Metamorphic rocks 56
Metamorphic rocks of igneous origin 56
Fredericksburg gneiss 56
Occurrence 56
Megascopic characters 57
Microscopic characters 57
Chemical composition and classification 58
Geologic age 59
Amphibolite 59
Occurrence 59
Classification 59
Amphibolites near Hemp 59
Megascopic characters 59
Microscopic characters 60
Amphibolites near Richardsville 60
Megascopic characters 60
Microscopic characters 60
Geologic age 60
Greenstone schist 60
Occurrence 60
Description 61
Geologic age 61
Soapstone 61
Occurrence 61
Origin 62
Mineralization 62
Indiantown occurrence 63
Geologic age 63
Biotite-quartz feldspar schist 63
Occurrence 63
Megascopic characters 63
Microscopic characters 63
Geologic age 63
Metamorphic rocks of sedimentary origin 63
Introduction 63
Schists 64
Quartz schist with biotite and feldspar 64
Occurrence 64
Megascopic characters 64
Microscopic characters 64
Structure 65
Geologic age 65
Hornblende quartz schists often with chlorite 65
Occurrence 65
Megascopic characters 65
Microscopic characters 66
Structure 66
Sericite quartz schists often with epidote and chlorite 66
Occurrence 66
Megascopic characters 66
Microscopic characters 66
Structure 67
Geologic age 67

Geology and petrography (continued)
Metamorphic rocks (continued)
Metamorphic rocks of sedimentary origin (continued)
Schists (continued) PAGE
Garnetiferous quartz schists 67
Occurrence 67
Megascopic characters 67
Microscopic characters 67
Minor varieties 68
Arkosic quartzite (feldspathic) 68
Indiantown 68
Occurrence 68
Megascopic characters 68
Microscopic characters 68
Structural features 69
Geologic age 69
Neapsco Run 69
Occurrence 69
Megascopic characters 69
Microscopic characters 69
Classification 70
Quantico slate 70
Occurrence 70
Geologic age 70
Description 71
Microscopic characters 71
Structure 71
Relation to bordering rocks 72
Structure and metamorphism 73
Folding 73
Faulting 73
Regional metamorphism 74
Contact metamorphism 74
Veins and ore deposits 74
Igneous rocks 75
The mines of the district 76
Introduction 76
Gold mines and prospects 76
Culpeper County 76
Culpeper mine 76
Location 76
History 76
Geology 76
Love mine 77
Location 77
History 77
Geology 77
Embry mine 77
Location 77
History 77
Geology 77
Dry Bottom prospect 78
Location 78
Description 78

The mines of the district (continued)
Introduction (continued)
Gold mines and prospects (continued)
Culpeper County (continued) PAGE
Morgana mine 78
Location 78
History 78
Geology 78
Ellis mine 78
Location 78
History 78
Geology 78
Fauquier County 78
Bancroft mine 78
Location 78
History 78
Geology 79
Liberty mine 79
Location 79
History 79
Geology 79
Little Elliot and Randolph mines 79
Location 79
Kelly mine 79
Location 79
History 79
Geology 79
Franklin mine 79
Location 79
History 79
Geology 80
Other mines in Fauquier County 80
Orange County 80
Grasty tract 80
Location 80
History 80
Geology 80
Jones prospect 80
Location 80
History 80
Mines near Wilderness Run 81
Location 81
History 81
Vaucluse mine 81
Location 81
History 81
Geology 82
Melville mine 82
Location 82
History 82
Geology 82
Wilderness mine 82
Location 82
History 82
Geology 83

The mines of the district (continued)
Introduction (continued)
Gold mines and prospects (continued)
Orange County (continued) PAGE
Other Orange County mines 83
Prince William County 83
Greenwood mine 83
Spotsylvania County 83
United States mine 83
Location 83
History and geology 83
Other gold mines in Spotsylvania County 84
Stafford County 84
Eagle (Rappahannock) mine 84
Location 84
History 84
Geology 84
Horse Pin (Rattlesnake) mine 84
Location 84
History 84
Other mines in Stafford County 85
Iron properties 85
Pyrite mines and prospects 85
Cabin Branch mine 85
Location 85
History 85
Geology 86
Austin Run pyrite mine 89
Location 89
History 89
Geology 90
Soapstone quarries and prospects 90
Verdiersville soapstone quarries 90
Location 90
History 90
Geology 91
Origin of the gold and pyrite ores 92
Introduction 92
Gold deposits 92
Previous theories 92
Types of deposits 92
Gangue minerals 92
Ore minerals 93
Shape of the ore bodies 94
Pyrite deposits 95
Previous theories 95
Types of deposits 95
Gangue minerals 95
Ore minerals 95
Shape of the ore bodies 96
Origin of the ore bodies 96
Introduction 96
Mineral composition 97

Origin of the gold and pyrite ores (continued)
Pyrite deposits (continued)
Origin of the ore bodies (continued) PAGE
Shape and texture of ore bodies 98
Distribution of the ore bodies 99
Relation of gold veins to pyrite bodies 99
Geologic age of the deposits 100
Building stone and road materials 102
Building stone 102
Fredericksburg granite 102
Stafford Store granite 102
Occoquan granite 103
Other stones 103
Road materials 103
Gravel from Coastal Plain sediments 104
Road materials from the crystalline rocks 104

ILLUSTRATIONS

Plate 1. Geologic map of the pyrite-gold belt in Culpeper, Fairfax, Fauquier, Orange, Prince William, Spotsylvania and Stafford counties, Virginia .... In pocket

FACING PAGE

2. A, Gabbro from Rock Hill; B, Blue quartz diorite from Poplar Road 33
3. A, Fredericksburg granite from Cartwright and Davis quarry; B, Granite from Bellfair P. O. 43
4. A, Rhyolite one-half mile east of Hemp; B, Diabase dike with ophitic texture from Poplar Road 49
5. A, Fredericksburg gneiss from Cartwright and Davis quarry; B, Gneiss from Mott's Run 57
6. A, Greenstone schist from near Dumfries; B, Plumose chlorite from schist at Garrisonville pyrite mine 61
7. A, Quartz sericite schist from Missouri Mills; B, Hornblende quartz schist from Embry mine 67
8. Structure sections 73
9. A, Greenstone schist on Quantico Run at Dumfries; B, Shaft head and mill, Austin Run mine 90

PAGE

Figure 1. Index map showing location of area 3
2. Structural relations of Triassic formations 20
3. Geologic details of diorite-gabbro complex near Rock Hill.... 32
4. Plan of relations, ultrabasic rocks at Rock Hill 35
5. Relation of granite to schist near Occoquan 45
6. Relation of gneiss, quartz-monzonite, pegmatite and quartz veins near Falmouth 52
7. Geological details at Cabin Branch mine 87
8. Relation of pyrite to schist at Cabin Branch mine 88
9. Post-pyrite mineralization at Cabin Branch mine 89
10. Quartz lens in schist 94
11. Plan of pyrite lenses in Louisa County 96

The Geology of the Gold-Pyrite Belt of Northeastern Piedmont Virginia

By John T. Lonsdale.

INTRODUCTION

This report contains the results of an investigation of the geology and mineral resources of the gold-pyrite belt in northeastern Piedmont Virginia. The area involved comprises approximately 600 square miles in Culpeper, Fairfax, Fauquier, Orange, Prince William, Stafford, and Spotsylvania counties. The general geological features of the region and the occurrence and origin of the gold, pyrite, copper, iron, graphite, and soapstone deposits found in the area are discussed in as much detail as possible. Building stone and road materials are considered briefly since these are also of importance in the future development of the district. More detailed descriptions of them are found in publications of the Virginia Geological Survey or in reports soon to appear.

The field work upon which this report is based was done during June, July, and August, 1922, and during the same months in 1923.

The condition of the mining industry in the area under discussion is such that very little detailed information can be given on certain important phases of the ore deposits. The long period of idleness of many mines has rendered it almost impossible to state more than generalities as to the features of specific deposits.

ACKNOWLEDGMENTS

The writer is greatly indebted to the late Thomas L. Watson, State Geologist, who supervised the work, for the privilege of making the investigation, and for his timely advice and assistance throughout all stages of the work; also to Wilbur A. Nelson, the present State Geologist, under whose direction the report is published. The writer also wishes to acknowledge the efficient help rendered him by Messrs. D. H. Cardwell, J. W. Kisling, Jr., and E. R. Woolfolk who acted as assistants during a part of the field investigation. To the inhabitants of the region should be expressed the writer's appreciation of their hospitality and willingness to aid his work in any way within their power.

The traverse maps used as a base for the areal geologic mapping were two in number. One was made by C. M. Gravatt, R. Emmett, S. P. Holt, L. L. Stratton, and W. J. Cox, and is the northern part of the gold belt map published in 1921 by the Virginia Geological Survey. Geologic data on this part of the area are given but no map showing them accompanies the report. The data however will be incorporated in a revised gold belt map to be published by the Virginia Geological Survey. The other map was made in 1920 by A. A. Pegau and J. W. Kisling, Jr., and included the greater part of the area. Other acknowledgments are made in the body of the report.

GEOGRAPHY AND HISTORY

LOCATION

The region described in this report is situated in the extreme northeastern part of the State. It includes the southeastern part of Culpeper, Fairfax, Fauquier, and Prince William counties, the eastern part of Orange County, the northern part of Spotsylvania County, and all except the extreme eastern part of Stafford County, Virginia. The exact location of the area is shown in the index map (fig. 1). A large scale geologic map (pl. 1) inserted in the pocket at the back of this report, shows local details of geography, except those of the northeastern part of Spotsylvania County which will be found on the gold belt map previously mentioned.

The area is roughly triangular in shape, its base resting in an east-west direction on the Piedmont, Fredericksburg and Potomac Railroad,[a] and the two sides extending nearly to the Southern Railway on the west and the Richmond, Fredericksburg and Potomac Railway on the east. The triangular area thus described is approximately 20 miles wide at its base, and has a distance of approximately 60 miles from base to apex. It covers approximately 600 square miles.

The three railroads mentioned above, the Piedmont, Fredericksburg and Potomac,[a] the Southern Railway, and the Richmond, Fredericksburg and Potomac are accessible to the greater part of the area. The first is a narrow gauge line running from Fredericksburg to Orange, the second parallels approximately the western border of the area, and the third follows fairly closely the eastern border. These steam roads are supplemented by several good automobile roads. From Orange to Fredericksburg, an excellent road follows approximately the course of the narrow gauge railroad and bus service is maintained upon it between the two towns. The Richmond-Washington highway skirts the eastern edge of the area and is one of the main arteries of freight and passenger traffic, supplying many of the towns and villages. Fairly good roads are found from Fredericksburg to Warrenton, from Dumfries to Manassas, and from Occoquan to Manassas.

Fredericksburg lies 3 miles from the southeast corner of the area, Orange 10 miles from the southwest corner, and Washington and Alexandria 14 and 11 miles, respectively, from the northern corner of the area. Within the area proper, Dumfries and Occoquan are villages of approximately 300 inhabitants, but other larger settlements are lacking.

[a]The P. F. & P. narrow gauge line as shown on the geologic map (Plate 1, in pocket) and referred to in several places in this report, while known by this name at the time that Doctor Lonsdale did his field work, was taken over during the latter part of 1926 by John L. Williams & Sons, of Richmond, Virginia, and is now operated as a standard gauge line under the name of the Virginia Central Railway, connecting with the Southern and C. & O. railways at Orange and with the R. F. & P. Railway at Fredericksburg.

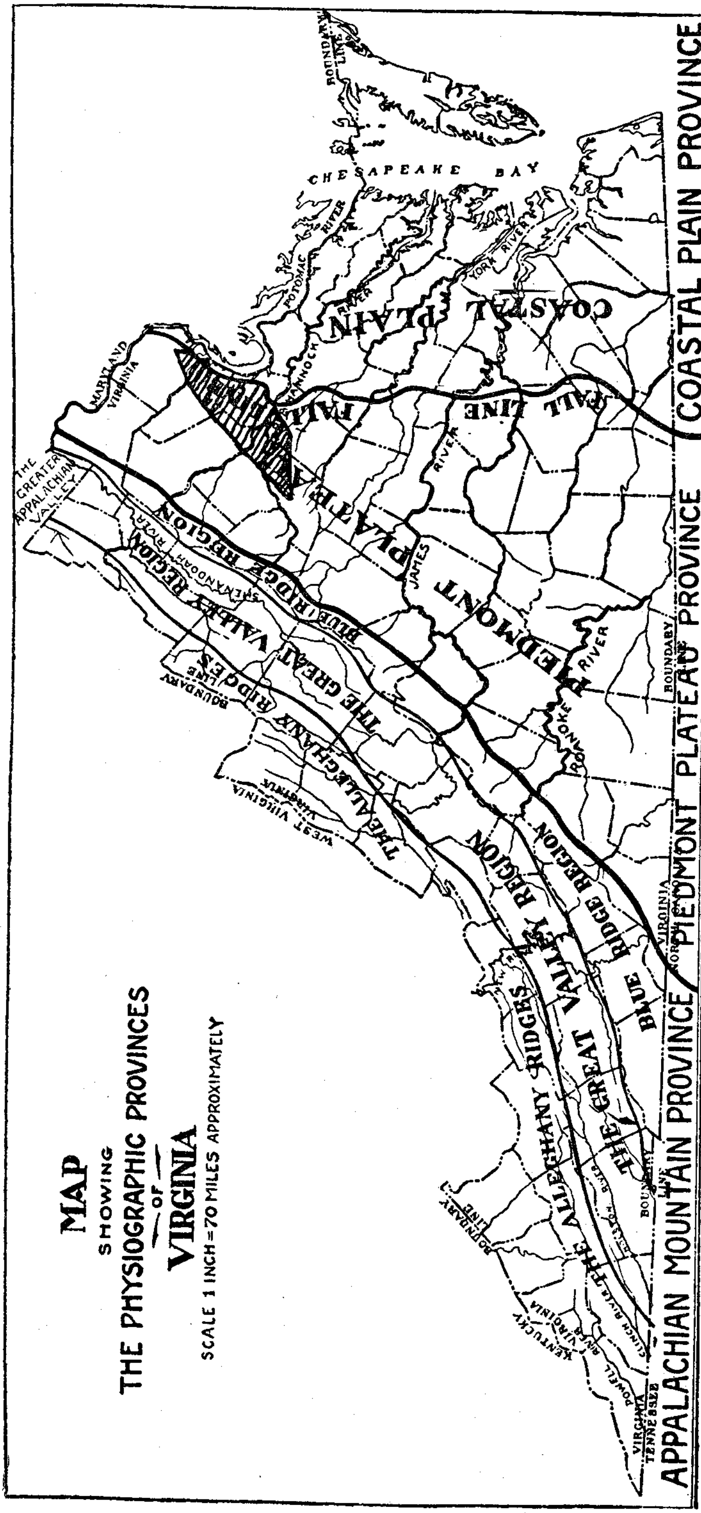

Figure 1. Index map showing location of area (shaded). Base after Watson, *Mineral Resources of Virginia*, 1907, p. 2.

Physiographically the area forms a part of the Piedmont Plateau and is bounded on the east by the Coastal Plain and on the west by the Triassic Plain. It lies in the narrow belt of crystalline rocks extending from Canada to Alabama and is an integral part of the gold belt of the southeastern Atlantic States.

TOPOGRAPHY

The topography of the district is uniform in its development. A panoramic view from any elevation gives the impression of a rolling plain which slopes gently eastward. Here and there on this plain streams have cut narrow valleys with steep walls. The greatest elevations, in the western part of the area, are about 450 feet above sea level. In the eastern part of the area the streams are at the level of tidewater, so that the land surface slopes to the east from 450 feet above sea level to practically sea level. There are no conspicuous hills or mountains in the district. The extension of this district into nearby areas does contain low mountains, but within this area nothing destroys the monotony of the panorama.

DRAINAGE

The district is drained by three river systems. These master streams, the Potomac in the north, the Rappahannock and Rapidan in the south, are large and important. In their lower reaches they are used extensively for water transportation. Into them empty many smaller streams which form a perfect drainage system for the district. The more important secondary streams are Occoquan Run, Aquia Creek, and Potomac Run. On most of the smaller streams water power is developed to operate the many grist mills of the region. Rappahannock River is the site of a hydro-electric plant which serves the city of Fredericksburg and is also connected with the system which furnishes power to the city of Richmond.

SOIL

The soils of the district are of two types, residual and transported. The residual soils are formed by the decay of rocks, and remain essentially in place above the rock from which they were derived. The transported soils are formed in a similar manner, but have been carried to new locations, usually the flood-plain bottom land along the streams, by the wash after rains and by streams.

The residual soils are of varying degrees of fertility because of a variation in the composition of the rocks, from which they were derived through decay. A rock containing potassium or phosphorus will on decay produce a richer soil than one lacking these elements, because both are strong soil enrichers. None of the rocks of the district contain noteworthy amounts of phosphorus but several, such as the granites, are well supplied with potassium through the presence of potash feldspars. The granites of the district then, because they contain potash feldspar, will on decay produce relatively fertile soils. Schists and basic igneous rocks, which contain smaller amounts of potash in feldspar, will produce soils less fertile than the granites. All of the residual soils of the district must be handled carefully in farming operations. Many abandoned fields now covered with second growth timber could have been retained as farm land if the proper land treatment had been used. Those derived from granite could have been saved most readily, but with the proper treatment, all could have been, and can be, retained as agricultural lands.

The transported soils are developed to a limited extent on the slight floodplains and river bottoms of the district. These soils, being mixtures of the decay of all of the rocks of the region, are usually fertile and are valuable farm lands. They are, however, subject to flood in freshets which sometimes occur during the crop growing season.

TIMBER

At one time the district contained magnificent forests of pine. A few of these original forests remain and in some sections second growth timber is large enough for lumbering purposes. The supply is more than sufficient for mining purposes and in most cases mine timber could be obtained at only short distances from the mines.

CLIMATE

The climate of the district is that characteristic of Piedmont Virginia. The greater part of the year is pleasant. The mean annual temperature is around 56° F. Temperatures as low as zero are very unusual in winter, and in summer the thermometer seldom reaches as high as 100°. Precipitation is abundant and well distributed throughout the year.

CULTURE

The country is not thickly populated and there are no large towns within the area. The raising of corn, wheat, and live stock are the principal industries. Lumbering in some sections is still important, though the products consist of ties and pulp wood rather than dressed timber. Fredericksburg is the principal market for these products. Mining once important is now entirely abandoned. Educational advantages and living conditions are constantly being improved in the district. In many sections consolidated schools are established and these are able to offer greater school advantages than ever before. The improvement of roads is constantly in progress and, with the advent of the automobile, conditions of life in the isolated inland parts of the district are much easier than was formerly the case. At the same time the farm products of the district are marketed in the cities at a greater advantage than was possible heretofore.

HISTORY

It is interesting to note that some of the pioneer attempts at mining, not only in Virginia but in North America, were made in this district. Some of the earliest iron mines, and the first blast furnace, were situated on Rappahannock River. It is recorded that near the same river the first authentic discovery of gold in Virginia was made.

In 1794, Thomas Jefferson described a lump of gold ore found in 1782 on the north side of Rappahannock River 4 miles below the falls. The ore yielded 17 pennyweight of gold.[1] The history of mining in this part of Virginia is of course intimately related to the history of mining in the entire southern Appalachians. Summaries of this history were made by J. D. Whitney[2] in 1854 and by Geo. F. Becker[3] in 1895.

IRON MINING

Iron mining antedated organized gold mining. In 1619 a bloom furnace was built in Chesterfield County, but the first blast furnace was built in 1714 at Germanna 13 miles up stream west of Fredericksburg. At this place (Germanna) Governor Spotswood maintained an elaborate establishment for mining and smelting iron ores. The settlement was inhabited by a group of German miners and the operations were extensive for that period. Ore was obtained from the territory now known as the "Wilderness." Another historic iron industry was located in Stafford County, near Mountain View. This was operated by Augustine Washington, father of George Washington, and a Mr. English. Interesting accounts of these ancient mining enterprises are given by W. H. Adams[4] and to them the reader is referred for further details. There are no figures available on the production of iron mining in the district.

GOLD MINING

The first gold mining company to be incorporated in Virginia operated in this district. According to Watson,[5] the Virginia Mining Company of New York, operated on the Grasty tract in Orange County between 1831 and 1834. This company paid $30,000 for a one-half interest in a 20 year lease on the tract. Silliman,[6] who visited this district in 1836, found con-

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1. Jefferson, Thomas, Notes on the State of Virginia, 2d Am. ed., Philadelphia, Nov. 12, 1794, p. 32.

2. Whitney, J. D., The metallic wealth of the United States, Philadelphia, 1854, pp. 114-134.

3. Becker, Geo. F., Reconnaissance of the gold fields of the southern Appalachians: 16th Ann. Rept. U. S. Geol. Survey, 1895, pt. III, pp. 253-258.

4. Adams, W. H., The first iron blast furnaces in America: Trans. Amer. Inst. Min. Engrs., vol. XX, pp. 196-215, sketch map, 1892.

5. Watson, Thomas L., Mineral resources of Virginia, Lynchburg, 1907, p. 549.

6. Silliman, Benjamin, Remarks on some of the gold mines and on parts of the gold region of Virginia. Founded on personal observations made in the months of August and September, 1836: Amer. Jour. Sci. and Arts, 1837, ser. I, vol. XXXII, pp. 98-130.

siderable mining activity. The Culpeper mine, at that early date, had nearly 600 feet of tunnels and shafts. Prospecting was being vigorously prosecuted and he was led to predict an era of extensive mining activity in this region. Whitney[7] reported the following mines as operating in 1854: Culpeper mine, Freehold Gold Mining Company, Liberty Mining Company, Gardiner gold mine, and the Marshall mine. Some of these were reported to be doing well and to possess good ore reserves. Another interesting account of the gold mining industry in this district was given for the year 1877 by Morton.[8] He reported five mines in operation, and one lately abandoned through mismanagement and the operations of the promoter of a "secret process" for recovering the gold. His note in this connection is applicable today. He says:

> The last attempt to work the mine was by one of those electro-chemical, process fellows that are always going to do wonderful things but always fail to do anything more than any of the rest of their pestiferous kin have done, that is, show off their wares and let their victim pocket his losses.

From the time of Morton's report until about 1890, the mining journals carry occasional news items about the Virginia gold mines. In most cases these relate details concerning the Rappahannock mine west of Fredericksburg. One shipment of "20 good sized bags of gold dust" was made from this mine in 1879.[9]

Active mining ceased about 1906 and only spasmodic attempts have been made since that time to resume operations. During the summer of 1922 a little prospecting was done near Morrisville and in 1923 the Wilderness mine was unwatered, and some development work done, but these are the only instances of mining activity in the entire district.

A summary of the history of the region shows that the mines reached their greatest development between 1835 and 1879. The war effectively stopped operations and results since that time have generally not been successful, though for a period of 10 years after the war considerable mining was done. The earlier (and most profitable) operations were conducted either on placer material or on the free-milling oxidized portions of the deposits. Labor was cheap, the process of recovery simple, and as a result the early operations were as a rule very profitable. After the Civil War the labor situation was changed, but still more disadvantageous was the exhaustion of the oxidized ores. As the workings penetrated below water level the ores were found to be highly pyritic, entailing in many cases a different kind of treatment. If stages in Virginia mining were to be named, this one should be called the stage of "Secret Processes." Metallurgically unsound and even fantastic schemes for separating the

7. Whitney, J. D., The metallic wealth of the United States, Philadelphia, 1854, pp. 114-134.

8. Morton, J. H., Gold mines of Virginia: Eng. & Min. Jour., vol. 24, 1877, p. 345.

9. Eng. & Min. Jour., 1879, vol. 28, p. 26.

gold from the pyrite were attempted, with the only result that could be expected. It is true that many of these failures were due to the fact that the knowledge of the proper treatment of sulphide ores was not advanced to the same state as today. In addition to this, it is a regrettable fact that many of the mines were unwisely managed by men lacking proper technical training. There are many instances of large expensive surface plants which should never have been built. Again, lack of capital has handicapped many of the mines.

Any future development of mining in this district must depend on the successful treatment of the sulphide ores. Inasmuch as the values contained in these ores are often low, exceedingly careful management and development are indispensable. Treatment of the ores should be in accord with present day methods of working sulphide bodies and only sound accurate engineering methods should be tolerated. Properly conducted, probably some of these deposits could be mined at a profit.

GOLD PRODUCTION

The figures on the gold production from Virginia do not show the production by different districts. It is impossible, therefore, to state just what part this district played in the total gold production of the State. It is probable that the returns from the district varied with the returns from other parts of the State but that a large part of the total production recorded was from this district. Available figures on production are given below.

Statistics of gold production in Virginia from 1829 to 1926, inclusive

Year	Amount	Year	Amount
1829	$ 2,500	1850	$ 65,991
1830	24,000	1851	69,052
1831	26,000	1852	83,626
1832	34,000	1853	52,200
1833	104,000	1854-1879	1,688,269
1834	62,000	1880	11,500
1835	60,400	1881	10,000
1836	62,000	1882	15,000
1837	52,100	1883	7,000
1838	55,100	1884	2,500
1839	57,600	1885	3,500
1840	38,995	1886	4,000
1841	25,736	1887	14,600
1842	42,163	1888	7,500
1843	48,148	1889	4,113
1844	40,595	1890	6,496
1845	86,783	1891	6,699
1846	55,538	1892	5,002
1847	67,736	1893	6,190
1848	57,886	1894	7,643
1849	129,382	1895	6,303

Statistics of gold production in Virginia from 1829 to 1926, inclusive, (Cont'd.)

Year	Amount	Year	Amount
1896	$ 4,435	1911	$ 3,064
1897	4,280	1912	218
1898	5,075	1913	604
1899	7,729	1914	429
1900	3,558	1915	534
1901	6,465	1916	885
1902	4,295	1917	1,343
1903	4,465	1918	400
1904	3,853	1919	.....
1905	4,982	1920	.....
1906	14,832	1921	763
1907	8,288	1922	706
1908	2,451	1923	.....
1909	3,750	1924	116
1910	888	1925	68
		1926	220
Total			$3,298,542

The above table was compiled from figures of the Director of the United States Mint, Mineral Resources of the United States, and Mineral Industry.

PYRITE MINING

Although only two mines in the district have produced pyrite, the value of their output exceeds the entire gold production of the region. The Cabin Branch mine, a subsidiary of the American Agricultural Chemical Company, located near Dumfries, was a very large mine. The other pyrite mine, variously known as the Austin Run mine, the Old Dominion Sulphur mine, and the Fer-Sul mine, while covering a number of years in its life, was not as extensive as the Cabin Branch mine. Both mines, however, produced considerable quantities of pyrite, as will be seen by the figures given below.

At a comparatively early date the existence of bodies of pyrite in Virginia was common knowledge among engineers. Mining operations on gold veins and on the gossan iron ores usually revealed bodies of pyrite at slight depths. When it was realized that these ores had a marketable value, mining operations were commenced. In Louisa County some of the largest pyrite mines in North America were developed. The extension of this pyrite mining into the area covered by this report was to be expected; conditions were similar and pyrite prospects were known. The first development was the Cabin Branch mine. This mine was discovered in 1889, and a large body of ore was proved and exploited from that time until 1920. In the years since the European War, native sulphur from the Gulf States has replaced pyrite in the acid industry which was its greatest use. This fact has caused most of the Virginia pyrite mines to cease operations. This is true of the Cabin Branch property.

At one time this mine had an extensive plant for treating and milling the ore. Railroad connections with tidewater were installed and altogether a very flourishing operation was in progress. Today all of the plant has been dismantled and only the dump remains.

The Austin Run mine is located on Austin Run near Garrisonville. This mine was opened in 1906 and operated intermittently until 1920. Its production was never great and legal and financial troubles further handicapped its operations. Its milling plant is still intact and could be put in operating shape with little trouble.

During the years 1906 to 1920 prospecting for pyrite was carried on in many localities, but no production was made from these efforts.

PYRITE PRODUCTION

The production for the Cabin Branch and Austin Run mines, as far as available, is given in the table below.

Statistics of production, Cabin Branch Mine

Year	Quantity produced Long tons	Quantity sold Long tons	Value
1908	16,948	15,566	$ 60,982
1909	(a)	(a)	(a)
1910	38,444	38,251	142,798
1911	35,304	33,601	126,941
1912	26,000	26,402	100,044
1913	10,840	11,329	43,129
1914	10,603	11,198	44,324
1915	(a)	(a)	(a)
1916	5,681	5,681	27,673
1917	19,785	19,785	160,061
1918	18,850	18,850	193,000
1919	14,339	14,339	208,324
1920	10,468	10,468	61,237

Statistics of production, Austin Run Mine

Year	Quantity produced Long tons	Quantity sold Long tons	Value
1908	None	None	None
1909	(a)	(a)	(a)
1910	500	None	None
1911	None	None	None
1912	Development work		
1913	None	None	None
1914	None	None	None
1915	(a)	(a)	(a)
1916	Development work		
1917	1,932	1,932 [b]	$15,630
1918	844	844	8,106
1919	None	None	None
1920	600 [c]	300	2,400

a. Statistics not available.
b. Tons reported sold amounted to 1,782, but value was given for 1,932 long tons produced, hence these figures are tabulated under "Quantity sold."
c. Value of tonnage produced (600 long tons) amounted to $4,800.

PREVIOUS GEOLOGIC WORK

Very little detailed geologic work has been published concerning this district. That portion of the gold belt lying in the James River Valley has been mapped and described by Stephen Taber in Bulletin VII of the Virginia Geological Survey. A geologic map of the gold belt between James River and the P. F. & P. Railway, has been published by the Virginia Geological Survey, but for the area north of the P. F. & P. Railway only a few small areas have been described. Early geologists visited the district from time to time, usually in connection with mine examination work, and some of these published theories as to the origin of the ores. In recent years the decline of mining activity and the lack of accurate maps have discouraged extensive work in the region.

There are a number of publications dealing with the gold regions of the southern Appalachians as a whole and certain of these refer to this district. The conditions found elsewhere in the gold belt are similar to those in this area, so that general papers are of considerable value. Short papers have appeared from time to time, usually dealing with individual properties or special metallurgical problems relating to the ores. A bibliography containing the principal papers which relate to the district will be found on pages 12 to 14, inclusive.

It is of interest and value to review the progress of the geologic work done in this region and to trace the evolution of ideas as to the nature of the rocks and ores. Some conceptions advanced in the early days have necessarily undergone great modification. Professor Wm. B. Rogers visited the gold belt, and in 1835 published a report entitled "Report of the Geological Reconnaissance of the State of Virginia." He considered all the rocks of the gold belt to be primary and that they graded westward into rocks of different character. He was quick to recognize that, while the gold veins in general conformed to the structure of the country rock in places, they do not conform to the prevalent structure. He was led to conclude quite rightly that the veins were not beds of the same age as the inclosing rocks, but were "veins of injection." [10] It is interesting to note that this early view as to the nature of the veins is essentially the view held today.

Silliman, in his article [11] in 1836, did not agree with Rogers as to the nature of the veins. He contended that they were not veins, but beds or layers conforming to the general structure of the country.

In 1854, Ansted advanced views opposed to those of Rogers. He believed that the veins represented original beds changed by chemical agencies

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10. Rogers, W. B., A reprint of the geology of the Virginias, New York, 1884, pp. 75-77.

11. Silliman, B., Remarks on some of the gold mines and on parts of the gold region of Virginia. Founded on personal observations made in the months of August and September, 1836: Amer. Jour. Sci. and Arts, 1837, ser. I, vol. XXXII, pp. 98-130.

into their present condition. The valuable materials were once disseminated through many beds, but by a process of segregation were collected into the present veins.[12] In the same year Whitney's book, entitled "Metallic Wealth of the United States," was published and contained descriptions of the mines of the district. He classified the gold veins as "segregation veins," formed by the elimination of the values from the surrounding rocks and their concentration in the veins.[13]

Perhaps the most complete account of the southern Appalachian rocks and gold ores is that of Becker.[14] He calls the veins true injection veins confirming Rogers' early observations on this point.

In 1894, the Fredericksburg Folio[15] of the United States Geological Survey, and in 1901 the Washington Folio[16] were issued, giving maps and descriptions of parts of the district.

In 1911, Thomas L. Watson and S. L. Powell[17] were able to establish the identical age of the Quantico and Arvonia slates. This is the most significant paper of recent years, because of its bearing on the age of the ore deposits which will be discussed in another place in this report.

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12. Ansted, D. T., The Alleghanies and the gold district of eastern Virginia: Scenery, Science and Art, London, 1854, chap. 3, pp. 287-292.

13. Whitney, J. D., Metallic wealth of the United States, Philadelphia, 1854, p. 83.

14. Becker, George F., Reconnaissance of the gold fields of the southern Appalachians: 16th Ann. Rept., U. S. Geol. Survey, 1894-5, Pt. III, p. 282.

15. Darton, N. H., Fredericksburg Folio, No. 13, U. S. Geol. Survey, 1894.

16. Darton, N. H. and Keith, Arthur, Washington Folio, No. 70, U. S. Geol. Survey, 1901.

17. Watson, Thomas L., and Powell, S. L., Fossil evidence of the age of the Virginia Piedmont slates: Amer. Jour. Sci. 1917, ser. IV, vol. XXXI, pp. 33-44.

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PHYSIOGRAPHY

INTRODUCTION

The State of Virginia is divided by physiographers into three divisions: (1) The Coastal Plain, extending from the fall-line at the head of tidewater to the edge of the continental shelf approximately 75 miles east from the present shore line; (2) the Piedmont Uplands, extending from the fall-line westward to the southeast foot of the Blue Ridge; and (3) the Appalachian Mountain province which contains the mountainous country in the western part of the State.

The Piedmont Uplands division of Virginia, which lies between the Coastal Plain and the Blue Ridge, varies in width from 40 to 175 miles. The district considered in this report lies in the northeastern part of the Virginia Piedmont Uplands and has a width of 40 miles. The general surface features of other parts of the Piedmont Uplands, both within and without Virginia, are found here. Low relief, well developed drainage, and great depths of residual rock decay are the outstanding features of the district.

RELIEF

There are no conspicuous elevations above the average surface of the region. This character is so pronounced that any extended view gives the impression of a gently sloping plain with only occasional depressions in its surface. Close examination of any considerable part of the district reveals the fact that its surface is not a true plain, but is gently rolling, broken by slight elevations and by narrow valleys. The roads of the region in general follow the upland surface, near the stream divide, taking advantage of its uniformly gentle slope. Roads which cross valleys are characterized at the crossing by sharp breaks in profile, emphasizing the narrow gorge like character of the valleys.

Stream divides attain approximately the same altitude. Connected, these upland surfaces would form a gentle plain sloping to the eastward. Before the streams cut their present valleys such a plain existed. This plain will be called the Piedmont Surface Peneplain represented today by the upland surface of the district. Depressions in the Piedmont Surface Peneplain are the present stream valleys. These vary in depth from 200 feet, in the case of the larger streams, to a few feet in the case of the smaller ones.

DRAINAGE

The principal streams of the region are Potomac and Rappahannock rivers, with Rapidan River as as important tributary of the latter. These flow for the most part in a southeasterly direction across the strike of the rock formations which is northeast-southwest. Bull Run, Aquia Creek, and Occoquan Run are streams of secondary importance maintaining also courses at right angles to rock structure. These streams are believed to be subsequent streams. Many smaller streams enter as tributaries into those already mentioned. The network of streams thus formed furnishes a nearly perfect drainage for the district. The drainage, while excellent, has not yet resulted in complete dissection of upland flats so that maximum roughness has not been attained. The district is in early maturity of the present cycle of erosion. The smaller streams in many cases flow along the structure of the rocks. Differences in resistance of the rock formations followed are in some cases expressed in the resulting valleys.

PHYSIOGRAPHIC HISTORY

The physiographic history of the district is only imperfectly known. Several cycles of erosion, partial or complete, are known to have occurred. To state completely the succession of physiographic events would entail correlation, by extensive field work, with other better known areas. In this report only the outstanding events of this history can be mentioned.

If the most prominent topographic feature, the Piedmont Surface Peneplain, is taken as a reference level, the physiographic history both prior and subsequent to its formation can at least be roughly outlined. This plain forms the floor upon which the earliest sediments of the Coastal Plain were deposited. This marks this peneplain as early Tertiary in age. G. W. Stose [18] believes that the general surface of the Valley of Virginia is also a peneplain developed at the same time and that it is to be correlated with the Harrisburg plain of Pennsylvania. Descriptions of the plains both above and below the Harrisburg in Pennsylvania have been made by F. Bascom [19] and emphasize this conclusion. The development, then, in early Tertiary times of an extensive peneplain is one of the essential facts in the physiographic history of the district.

In the district covered by this report there is no conclusive evidence of the formation of peneplains prior to the Piedmont Surface Peneplain, for there are no erosion remnants above its surface. A consideration of the physiographic features of neighboring districts shows, however, that such features must have existed. In the Valley of Virginia and in the Piedmont of Pennsylvania, at least three such peneplains were formed before the development of the Piedmont Surface Peneplain. These undoubtedly extended into this district. In the extensive erosion since that time all distinct evidence of these early cycles has been destroyed, as far as the district here considered is concerned.

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Since early Tertiary times there have also been breaks in the cycles of erosion with rejuvenation of the streams. Many of the streams are intrenched in narrow gorge-like valleys cut in a plain below the level of the Piedmont Surface Plain. This lower plain represents a cycle of erosion inaugurated since early Tertiary times and which proceeded until the streams reached a new base level. This cycle did not go to completion but was interrupted as is shown by the fact that the streams today are cutting narrow valleys below the levels which represent this second cycle.

GEOLOGY AND PETROGRAPHY

INTRODUCTION

Rocks belonging to each of the three commonly recognized groups—igneous, sedimentary, and metamorphic, are found in the district. These are of various geologic ages, ranging from pre-Cambrian schists and gneisses to Cretaceous sedimentary formations. Not all geologic periods between pre-Cambrian and Cretaceous are represented in the rocks of the district. Rocks of Silurian, Mississippian, Pennsylvanian, Permian, Jurassic, and Comanchean ages are nearly or entirely lacking. The blanks present in the geologic record render difficult the age determination of many of the rock bodies. Some igneous bodies are believed to intrude Ordovician slates. They accordingly are younger than Ordovician. The exact age of these rocks can not be stated because formations younger than Ordovician, to which they might be referred, are lacking.

Many of the rocks found in the district show the effects of metamorphism to a greater or smaller degree. Ancient pre-Cambrian terranes have suffered such intense metamorphism that the original character of the rock is entirely changed. Some granite bodies show a great development of gneissic structure, while others show only a slight banding and still others are massive. The youngest metamorphosed rock found in the district is Ordovician in age and is a slate. Its degree of metamorphism is very slight when contrasted with that of the pre-Cambrian schists and gneisses.

In the absence of other criteria the relative degree of metamorphism exhibited by the rocks is used in this report as a rough measure of the age of the rock. A granite at Fredericksburg is massive, hence very probably is younger than the youngest metamorphosed rock (Ordovician) in the area. It is realized, of course, that massive rocks like granite are more resistant to pressure and other metamorphic forces than some sedimentary ones. This fact is always considered in using extent of metamorphism as a criterion for determining the geologic age of the rocks of the district.

In the following descriptions the rock bodies are divided into sedimentary, igneous, and metamorphic. They are further divided as to geologic age and variety.

SEDIMENTARY ROCKS

The sedimentary rocks referred to here are found in narrow belts on the eastern and western flanks of the district forming its lateral limits. These rocks are found to lap up on the edges of the crystalline rocks in the central part of the district and are Triassic and Cretaceous in age. They are described in publications of the Virginia Geological Survey and hence will only be briefly mentioned here. Those on the western side of the district are Triassic in age, while those on the east are Cretaceous.

TRIASSIC SEDIMENTARY ROCKS

Occurrence.—As shown on the areal geology map, Triassic sedimentary rocks occur in the western part of the district. They are well exposed near Elk Run and Bristerberg and again southeast of Manassas near Broad Run. These exposures are but a small part of an extensive area of Triassic rocks which are described in Bulletin 29 of the Virginia Geological Survey.

Descriptions.—The Triassic sedimentary rocks occurring in this area are of three types—conglomerate, sandstone, and shale. The conglomerate occupies the lowest position, stratigraphically, of the three and is the basal member of the Triassic in this part of North America. It represents the first rocks to form when the Triassic seas occupied the present land positions. On the road between Somerville and Elk Run this phase of Triassic sedimentation is well exposed in cuts and in ditches at the sides of the road. An examination shows it to be dark red in color and to consist of pebbles, cobbles or even bowlders of various sorts bound together by a matrix of red clayey sandstone. The pebbles and cobbles vary in size from that of a BB. shot to over one foot in diameter. They consist of quartz, diabase or greenstone, and schist. The quartz cobbles are fresh and unaltered but the greenstones and schists are greatly decayed, being easily pulverized by the fingers. The cobbles are both angular and rounded, without reference to the kind of material composing them.

North of Elk Run, where Town Run crosses Haymarket road, the conglomerate is also exposed. At its lowest exposure here the conglomerate is as described above except that the pebbles and cobbles are smaller. Followed upward to levels above the valley bottom it is noted that the pebbles and cobbles are still smaller in size. At a level about 40 feet above the stream the conglomeratic character of the rock has entirely disappeared and is replaced by an even-grained, dark red sandstone. This phase of the Triassic, as shown by numerous traverses, is dominant in the region considered here.

Near Bristerberg beds of blue gray shale are found interbedded with the sandstone. These shaly beds carry considerable amounts of quartz sand grains and evidently are only shaly phases of the normal sandstone which itself is not extremely arenaceous.

West of Broad Run the sequence of the Triassic beds is much the same as that already described except that the basal conglomerate is not always present. This may be due to the nondevelopment of the conglomerate in this region or faulting may have removed it at the exposures shown.

Topography.—The topographic features of areas underlain by the above described rocks are characteristic. Flat monotonous stretches of chocolate brown land, known locally as the "Flat Lands," are always present. The clayey nature of the soil lends itself to the building of good dry weather roads, but in wet weather the opposite is true. In the winter months many roads traversing these areas are almost impassable.

Structure.—The structural relations of the Triassic rocks to the older crystalline ones are well shown, both in the district around Bristerberg and near Broad Run. The sedimentary rocks are found to dip to the northwest with angles less than 45° and to lap up on the surface of the crystalline rocks which dip to the southeast at high angles often more than 75°. The accompanying generalized diagram (fig. 2) illustrates the relation found in the two places.

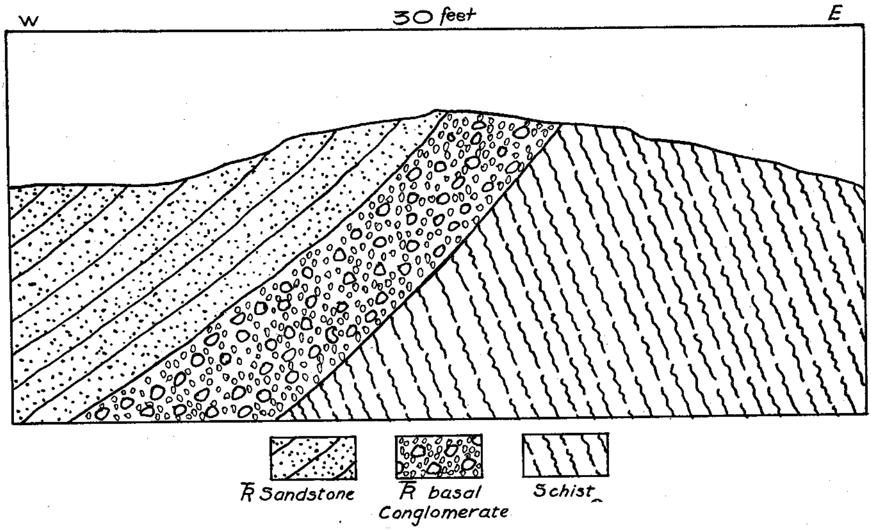


Figure 2. Structural relations of Triassic formations.

CRETACEOUS SEDIMENTARY ROCKS

Occurrence.—The Cretaceous sedimentary rocks occupy the same relative position on the eastern side of the district that the Triassic ones occupy on the west. The eastern edge of the areal geology map alternately passes either to the east or to the west of the Cretaceous-crystalline boundary. This results in small, more or less discontinuous, areas of the Cretaceous rocks appearing on the map. The boundary between the two types marks the fall-line, the head of tidewater and navigation.

Structure and description.—These younger sedimentary rocks lap upon the crystalline just as the Triassic rocks do on the west side of the district, but they dip gently to the eastward instead of the west and consist of alternating sandstones, shales, and gravels. The lowest member, which alone is represented on the areal map, is a white arkosic sandstone easily separated from the crystalline rocks both by color and texture. This formation has supplied much of the material used in constructing the Richmond-Washington highway, as it disintegrates into gravel suitable for highway construction. On Aquia Creek just outside the area here considered, a massive fine-grained member is being quarried for building purposes. The quarries, which were also worked in times past, supplied the stone for some of the public buildings in Washington. A description of this and of other Coastal Plain rocks will be found in Bulletin IV of the Virginia Geological Survey.

IGNEOUS ROCKS

Several types of igneous rocks occur in the district. As included here, only rock bodies in which the igneous character distinctly predominates over effects of metamorphism are considered as igneous in origin. In many of them banding and incipient gneissic structure are developed. As far as possible the igneous rocks are assigned to definite geologic ages. Rocks showing distinct foliation are placed under a general heading of pre-Cambrian or Cambrian, in conformity with past usage in this respect. This is indefinite, but a closer approximation is impossible. Some bodies, from field relations, are known to be younger than Ordovician. These are massive in structure, not only in fresh material but in weathered exposures. Other bodies whose field relations are obscure, but whose structure corresponds to those known to be post-Ordovician, are also classed as post-Ordovician. This may be erroneous in some cases, but it serves to emphasize the fact that these rocks are distinctly much younger than those classed as pre-Cambrian or Cambrian.

Under each group divisions are made, as far as seems practicable, into groups of similar types, as granites, diorites, etc. As distinct bodies of similar types are found in widely separated areas, locality names are assigned them merely to emphasize their geographical location and unity, as contrasted with other bodies of the same general composition.

IGNEOUS ROCKS OF PRE-CAMBRIAN OR CAMBRIAN AGE

These rocks include certain granitic, dioritic, and gabbroic bodies which exhibit distinct metamorphic effects. Foliation, either in the fresh material or in the weathered outcrop, is seen as evidence that these rocks were subjected to metamorphic forces prior to Ordovician times.

GRANITES

Three bodies of granite which are believed to be of the age mentioned above occur in the district. One of these is named the Locust Grove granite because of its typical development near Locust Grove in Orange County. Another is called the Somerville granite because of its typical development near Somerville, while a third found near Kellogs Mill is described here as a hornblende granite.

LOCUST GROVE GRANITE

Occurrence.—There is exposed in the vicinity of Locust Grove in Orange County a body of igneous rock corresponding in composition fairly closely to quartz monzonite. Outcrops are found in stream beds or in knobs protruding in the fields. The prominence of these "knobs" has led the inhabitants of the Locust Grove neighborhood to speak of this rock as "set tight." One-half mile east of Locust Grove fresh material of this rock has been produced by blasting for a road bed. At no other place is essentially fresh material found. This rock outcrops in a narrow belt from one-half mile to 2 miles wide, extending from a point south of the P. F. & P. Railroad, outside of this area, to a point about 1 mile above the mouth of Flat Run. The area involved is about 15 square miles.

Megascopic characters.—This quartz monzonitic rock is essentially massive, though there is a tendency toward the development of gneissic structure as seen in the fresh material. This, however, is not borne out by microscopic study of thin sections of the rock. In color the rock is light gray; its texture is unequigranular medium-grained. Recognizable minerals are quartz, feldspar and biotite. The biotite tends to form bands but only imperfectly so, as this mineral is scattered through the entire rock in fairly equal amounts.

Microscopic characters.—Under the microscope, quartz, orthoclase, albite-oligoclase, epidote, biotite, muscovite, chlorite, garnet, and zircon were recognized.

The quartz is abundant, developed largely as interstitial material in small anhedral grains. The feldspar, both orthoclase and albite-oligoclase, is developed in larger crystals than the quartz. The orthoclase exhibits Carlsbad twinning, the albite oligoclase pericline twinning. Biotite is present in scattered shreds which are almost entirely chloritized. Muscovite as sericite is found as the alteration product of feldspar. Garnet is present in sporadic crystals and zircon is seen as minute crystals.

Chemical composition and classification.—The chemical composition of this rock, with its norm, is given below.

Chemical analysis of Locust Grove Granite
(PENNIMAN & BROWNE, *Analysts.*)

	Per cent
SiO_2	76.71
Al_2O_3	12.39
Fe_2O_3	1.21
FeO	1.29
MnO	0.07
TiO_2	0.16
BaO	Trace
CaO	1.88
MgO	0.07
K_2O	2.18
Na_2O	4.09
P_2O_5	Trace
	100.05
Norm.	
Il	.30
Or	12.79
Ab	34.58
An	9.17
Mt	1.86
Hy	1.10
Q	40.14
MnO	.07
	100.01

The feldspar ratios for the rock are as follows:

Orthoclase	12.79
Albite	34.50
Anorthite	9.17
Total plag.	43.75
Ab_nAn_m ratio	3.7 : 1 = Oligoclase
Or: Plag. ratio	1 :3.4

Under the Quantitative System the position of this rock is: I. 3.″ 2. 4 (Alsbachose.)

In the Qualitative System the rock is closely related both to granite and to quartz monzonite. The feldspar content as to kind and amount, falls midway between that typical of each of the rocks.

Geologic age.—The position of this rock in the geologic column is problematical. There are no rocks of exactly known age to which it can be referred in comparison. It intrudes, on both flanks, the crystalline schists which are of Cambrian or pre-Cambrian age. Pegmatites associated with it intrude a still older igneous rock to the west. With such data only approximations can be made. That it is definitely younger than pre-

Cambrian seems clear, but how much younger is doubtful. It is relatively massive, only slightly foliated, which warrants the conclusion that the rock is not one of the oldest granites of the district. For the purposes of this report it is best perhaps to consider the age of the rock as undifferentiated pre-Cambrian or Cambrian, as there is no trustworthy evidence for any other statement of its age.

SOMERVILLE GRANITE

Occurrence.—Extending from a point not far from the Morganna mine on Rappahannock River to near Cromwell, a body of igneous rock outcrops in a belt about 1½ miles wide. The length of the belt is about 12 miles, so that the total area involved is approximately 20 square miles. Excellent outcrops of this rock are found on Rappahannock River, on Rock Run and on Deep River. In the rest of the area, the great depth of rock decay masks the exposures of this rock. Along Rappahannock River and in the vicinity of Somerville, a number of the once active gold mines were grouped, either within or near the exposed border of this intrusive mass.

Variations and structure.—As mapped in this report, this rock body shows considerable variation in character from place to place. Near Somerville the exposures show a coarse-grained biotite muscovite granite essentially massive, and quite pegmatitic in character. In other localities, as for example on Rappahannock River and on Rock Run, the rock shows considerable banding and development of a gneissic character. Even in these places, however, the mineralogical character is quite similar, being essentially a mica granite. In the coarser grained facies of this rock individual quartzes and feldspars often reach dimensions of one-fourth inch while in the finer grained varieties the crystals are much smaller. Three sets of joint planes have been observed in the rock as follows: (1) N-S, dip 50° W. (2) N-S, dip 40° E. and (3) N. 75° E., dip 50° W.

Megascopic and microscopic characters.—The color of the rock varies from a light gray to medium gray. Glassy quartz, feldspar, biotite, and muscovite are identified in the hand specimen. Under the microscope the rock is seen to contain in addition, magnetite, leucoxene, zircon, and apatite.

Quartz is abundant occurring in two generations. One represented by larger grains is apparently contemporaneous with feldspar, while a second generation occurs as interstitial material, and evidently is later than the former. Both generations are anhedral. The feldspar consists of orthoclase and plagioclase which corresponds to albite-oligoclase. Orthoclase is present in large subhedral crystals, untwinned or twinned after the Carlsbad law. The albite-oligoclase exhibits polysynthetic twinning. Orthoclase is in excess of plagioclase. Biotite is abundant in shreds and flakes, but is largely chloritized. Muscovite is developed mainly as the secondary sericite.

Magnetite is present in a number of fair sized grains. This mineral is titanium-bearing as shown by the border of leucoxene developed around grains. This alteration, in some cases, has gone to completion. Zircon and apatite are present as a few small crystals.

Classification.—Chemical analyses of this rock are not available. Its mineralogical characters mark it as closely related to granite, but slightly intermediate in character. It resembles in this way the rock at Locust Grove. Its characters place it as between the true granite and true quartz monzonite, though probably more closely related to granite.

Geologic age.—This rock is pre-Cambrian or Cambrian in age. It lacks the extensive metamorphism of the oldest pre-Cambrian igneous rocks, but shows some development of gneissic character. In this respect it fairly closely resembles the granite of Locust Grove in Orange County. As a matter of fact the granite around Somerville lies in the strike of the mass at Locust Grove and, considering their mineralogical and structural similarity, it is possible that the two are closely related.

HORNBLENDE-GRANITE

Occurrence.—On Potomac Run southwest of Mountain View, outcropping for a distance of 2½ miles upstream from Kellog's Mill, is a small stock-like body of hornblende-granite. Excellent exposures are found along the stream to a point one-fourth mile north of the point where the south branch of Potomac Run crosses the Poplar Road. At this place the contact of this granite and the Fredericksburg gneiss is seen. The lateral extent of the hornblende-granite on either side of Potomac Run is difficult to place accurately, because of heavy underbrush and deep rock decay.

Megascopic characters.—The hornblende-granite is a greenish gray rock medium to coarse-grained, essentially massive, except for joints, and showing considerable textural and mineralogical variation from place to place. In the majority of exposures the texture is granitic with feldspar, hornblende, and quartz as recognizable minerals. In such cases the hornblende, while prominent, is not in excess of quartz. In other exposures hornblende has increased at the expense of feldspar and quartz, and the rock more nearly corresponds to a hornblende-syenite. Most extensive exposures of the rock show small fine-grained, dike-like bodies intruding the coarser grained rock. These seldom reach 1 foot in width and are usually only 2 or 3 inches wide. These bodies commonly taper off until they are lost as recognizable units. These fine-grained masses or stringers are of the same color as the main rock mass and have the same mineral composition. They are regarded as the last portion of the mass to crystallize.

Microscopic characters.—Under the microscope feldspar, hornblende, quartz, magnetite, epidote, and biotite are recognized.

The feldspar in all sections studied is practically entirely orthoclase, exhibiting Carlsbad twinning and the polarization typical of this mineral. It is possible that certain portions of the rock carry plagioclase but, if so, the amount is exceedingly small.

Hornblende is developed in slender prismatic crystals, varying in abundance from amounts less than quartz and feldspar to a position of first importance. Quartz, like hornblende, is variable. It is developed in smaller grains than the feldspar or hornblende. In sections in which quartz is in small amounts or lacking the rock corresponds to a hornblende-syenite. Magnetite is developed to a considerable extent, partly as a primary constituent and partly as the alteration product of hornblende. The magnetite is titanium-bearing, as shown in certain cases by alteration rims of leucoxene. Epidote is extensively developed as the alteration product of the feldspar. Biotite is present in a very few scattered brown pleochroic shreds.

Chemical composition and norm. — A chemical analysis of the rock, together with norm, is given below.

Chemical analysis of hornblende granite on Potomac Run southwest of Mountain View

(PENNIMAN & BROWNE, *Analysts.*)

	Per cent
SiO_2	51.24
Al_2O_3	15.54
Fe_2O_3	3.21
FeO	6.12
TiO_2	0.44
MnO	0.07
CaO	11.13
MgO	7.66
K_2O	0.27
Na_2O	1.16
P_2O_5	0.06
H_2O	0.75
CO_2	2.44
	100.09

Norm.

	Ap	0.34
	Il	0.76
	Or	1.67
	Ab	9.96
	An	36.14
	Mt	4.64
	Di	14.59
	Hy	20.10
	Q	8.70
Not used	H_2O	.75
	CO_2	2.44
		100.09

The feldspar ratio is as follows:

Orthoclase	1.67
Plagioclase	46.10
Total feldspar	45.77
Ab_nAn_m ratio	1:3.6 = Bytownite
Or-plag. ratio	1:27

In the Quantitative Classification this rock is classed as follows:

"III. 4. 4(5). 4-5.

Geologic age.—The age of this rock can not be definitely stated. It intrudes the pre-Cambrian granite-gneiss developed at Hemp as shown near where Potomac Run crosses the Poplar road. The contact at that place is plain and metamorphic effects have resulted in the alteration of the gneiss to a marked degree. The particulars of this metamorphism are discussed elsewhere. On the east border the hornblende-granite cuts greenstone, probably also of pre-Cambrian age. The massive character of the rock suggests a much younger age than pre-Cambrian and, while proof is lacking, it is possible that the hornblende-granite may be as young as post-Ordovician. It is, however, in the absence of conclusive evidence, assigned to the undifferentiated Cambrian and pre-Cambrian.

BLUE QUARTZ-DIORITE (AND ITS PEGMATITE FACIES)

NORMAL QUARTZ DIORITE

Occurrence.—In the eastern part of Stafford County, and extending across Rappahannock River into Spotsylvania County, there occurs a very distinctive dioritic rock marked by the presence of blue quartz. Good exposures of this rock are found only in a few places, but the presence of blue quartz in the rock decay serves as a reliable indicator by which the rock can be traced. Fresh outcrops of quartz diorite are found in Stafford County on the Poplar road near Coakley, where blasting has revealed the rock in an excellent manner. Occasionally badly weathered exposures are found along the Richmond-Washington highway south of Garrisonville, and also along the Warrenton road in the vicinity of Storck Post Office. The area in which this rock occurs is 16 miles long and averages 2½ or 3 miles in width. A smaller occurrence of an identical rock is found in Spotsylvania County near Haislip and, since this occurrence is in line with the main mass, it seems likely that the two belong to the same parent mass. As will be shown later it is probable that this rock is one differentiate of a magmatic complex which centers around Rock Hill in Stafford County.

Relation to pegmatite.—One very striking feature of this rock mass is its association with pegmatite facies. The pegmatite is present in unusually large amounts and occurs not as dikes but as lenses or segregation-like bodies in the main mass. In exposures found of this quartz diorite, it is invariable that no single area is composed of normal quartz diorite alone or of pegmatite alone. While the normal rock is somewhat in excess in the total mass, yet the pegmatite comprises a large part of it. This fact has been of especial value in mapping the rock, for the blue quartzes are much larger in the pegmatite than in the normal rock and are much more readily identified. Bodies of irregular shape are very common, being developed in the normal facies in every conceivable direction and shape. Boundaries between the two rocks are, in some cases, sharp and definite, but in others very indefinite if not actually gradational. One contact of the pegmatite may be sharp, but a foot away the coarse-grained rock changes gradually into fine-grained dark colored diorite. The pegmatitic areas are small, rarely exceeding two feet in width and usually much smaller. Because of this intimate relationship between the quartz-diorite and its pegmatite, the two are discussed together.

Megascopic characters.—The quartz diorite is dark gray in color and is medium- to fine-grained equigranular in texture. A close examination reveals small lighter areas which are caused by the feldspars. Feldspar, quartz, and hornblende are recognized in the hand specimen. An occasional quartz grain is deep blue in color, but in this type the greater part of the quartz is whitish in color. The hand specimens appear perfectly massive.

Microscopic characters.—Under the microscope hornblende, often in euhedral development, and with perfect prismatic cleavage, was identified. The color is green and the mineral is strongly pleochroic. Alteration to chlorite, magnetite, and epidote is quite extensive. Plagioclase feldspar predominates over orthoclase, which is present in only a few Carlsbad twins of subhedral outline. The plagioclase, which is andesine, shows both albite and pericline twinning. This mineral is extensively altered to epidote. Biotite is present as a few scattered shreds often intergrown with hornblende. Magnetite is very largely the alteration product of hornblende, but there are present scattered grains which are primary in origin. Epidote is present in grains and prisms as the alteration of hornblende and feldspar, and chlorite is present as the alteration of hornblende.

Chemical composition and classification.—A chemical analysis of the normal quartz diorite is given below, together with the norm calculated from it.

Chemical analysis of normal quartz diorite

(PENNIMAN & BROWNE, *Analysts.*)

	Per cent
SiO_2	56.21
Al_2O_3	17.59
Fe_2O_3	3.41
FeO	5.96
TiO_2	0.49
CaO	9.66
MgO	2.20
MnO	0.06
K_2O	0.46
Na_2O	2.05
P_2O_5	0.19
CO_2	0.82
H_2O (comb.)	0.95
	100.05

Norm.

	Il	.91
	Ap	.34
	Ab	17.29
	Or	2.78
	An	37.53
	Mt.	4.87
	Di	7.88
	Hy	8.95
	Q	17.58
		98.13
Not used	H_2O	.95
	CO_2	.82
	MnO	.06
		99.96

The relatively low percentage of silica and potash and the preponderance of lime over soda, are notable points of the analysis. The relation of the feldspars is as follows:

Orthoclase	2.78	
Albite	17.29	
Anorthite	37.53	
Total feldspar	57.60	
Total plagioclase	54.82	
Ab_nAn_m ratio	1:2.1	= Labradorite
Or-plag. ratio	1:19	

In the Quantitative System this rock is designated by the following symbol:

II. 4. 4. 4(5). Bandose,

while in the Qualitative System it is classed as a quartz diorite.

Structure.—Structurally this rock is massive, except for numerous joints which are quite closely spaced. In the few exposures of fresh material, these joints systems were found to be three in number with the following orientations: (1) N. 20° W., dip 82° E., (2) N. 70° E., dip 71° S., (3) N. 70° E., dip 32° E.

Geologic age.—The age of this rock can not be determined exactly from the data in hand. It is placed tentatively in the undivided Cambrian and pre-Cambrian. Its relation to surrounding rocks and its massive character suggest the possibility of a much younger age. It undoubtedly intrudes metamorphic rocks of Cambrian and pre-Cambrian age, but conclusions beyond this are not warranted.

PEGMATITE

Pegmatitic facies.—The pegmatitic phase of the quartz diorite differs from the normal phase in color and texture and, to a less extent, in mineralogical composition. The color is white or light gray flecked with subordinate greenish areas caused by the presence of hornblende. Many of the quartzes are colored blue, lending a bluish tint to some surfaces. The texture is much coarser than the normal type, being coarse-grained unequigranular. Individual crystals of quartz attain dimensions of nearly one-half inch, though the majority of them are nearer one-fourth inch in greatest dimension. Light colored minerals are much more abundant than in the parent rock.

Megascopic characters.—In the hand specimen quartz, feldspar, hornblende, and epidote are readily identified. The quartz, usually blue in color, predominates. Epidote appears as a yellowish film on the edges of feldspar crystals.

Microscopic characters.—Under the microscope the following minerals are recognized: Quartz is present in anhedral grains often containing minute inclusions of rutile needles. Feldspar, both plagioclase and orthoclase, is developed. The plagioclase is twinned after the albite law and is andesine. Orthoclase is scantily developed. The plagioclase is altered extensively to epidote. Tourmaline is found as a few pleochroic prisms. Hornblende is euhedral to subhedral and is altered to magnetite and chlorite. Some magnetite is primary but most of it, as indicated above, is secondary after hornblende. The minerals, with the exception of tourmaline and rutile, are seen to be the same as those of the parent rock. The relative amounts are quite different, since hornblende is less abundant in the pegmatite and quartz is more abundant.

Chemical composition and classification. — A chemical analysis and norm calculated from it are listed below.

Chemical analysis of pegmatite phase of quartz diorite
(PENNIMAN & BROWNE, *Analysts.*)

	Per cent
SiO_2	61.37
Al_2O_3	17.75
Fe_2O_3	1.96
FeO	4.35
TiO_2	0.39
CaO	7.80
MgO	0.71
MnO	0.06
K_2O	0.45
Na_2O	2.96
P_2O_5	0.28
CO_2	0.45
H_2O (comb.)	1.50
	100.03

Norm.

	Il	.76
	Ap	.67
	Or	2.22
	Ab	25.15
	An	33.92
	Mt	3.02
	Di	2.38
	Hy	6.02
	Q	23.88
		98.02
Not used	CO_2	.45
	MnO	.06
	H_2O	1.50
		100.03

It is to be noted that, compared with the parent rock, silica and soda are in greater abundance than in the normal rock. All through, the analysis confirms the microscopical examination of the rock. In computing the feldspar ratios from the norms, the following results are obtained:

Orthoclase	2.22	
Albite	25.15	
Anorthite	33.92	
Total feldspar	61.29	
Total plagioclase	59.07	
Ab_nAn_m ratio	1:1.3	= Basic andesine or acid labradorite
Or-plag. ratio	1:26	

In the Quantitative System the rock is classified as follows:

II. 4. 4. "5. Bandose.

DIORITES

DIORITE GABBRO COMPLEX

Occurrence.—In the area between Roseville and Tackitt's Mill there is an occurrence of a complex of igneous rocks of several closely related types. Because two of the most prominent members of the complex are diorite and gabbro, it will be designated the diorite-gabbro complex. The field relation of the rocks composing this series suggests that they are probably derived from a common source or magma by processes of differentiation.

The area involved is approximately 20 square miles. The minute details of the occurrence of the several facies can not be represented on the map because of poor exposures. The accompanying sketch map (fig. 3) delineates the relations that are believed to exist in that part of the area where exposures exist. The area covered extends from near Garrisonville to a point about 3 miles southeast of Heflin. Between Tackitt's Mill and Roseville, and again northwest of Taluca, the rocks are well exposed, but at other points exposures are very poor. The complex nature of the body of igneous rock is best seen near Rock Hill midway between Roseville and Tackitt's Mill.

Diorite.—An investigation of the area shows that the most abundant rock type is dioritic in character. In ditches along the road from Davis Store to Tackitt's Mill, and again between Davis Store and Rock Hill, this rock is exposed. This rock is for the most part equigranular, medium-grained, and greenish gray in color. Its essential minerals are hornblende and plagioclase feldspar, corresponding to andesine and labradorite in composition. In this type there are found occasionally nests or lenses much coarser grained, which are pegmatitic in character. These correspond to the finer-grained facies in mineral composition, with the exception that an occasional grain of quartz is observed in them. Extensive alteration of these two phases has resulted in the development of epidote and zoisite, so that the original character of the rock is at times difficult to determine.

The blue-quartz diorite described on page 27 is thought to be a part of the magmatic complex. Since it has already been discussed in some detail only its relations to the other facies will be considered here.

Next in prominence to the dioritic facies is the development of gabbroic rocks. Two of these are found inclosed in the main dioritic mass. One is at Rock Hill, the other near Taluca. There are some slight differences between the two occurrences, but they are distinctly of the gabbroic type as will be seen from the following description of them.

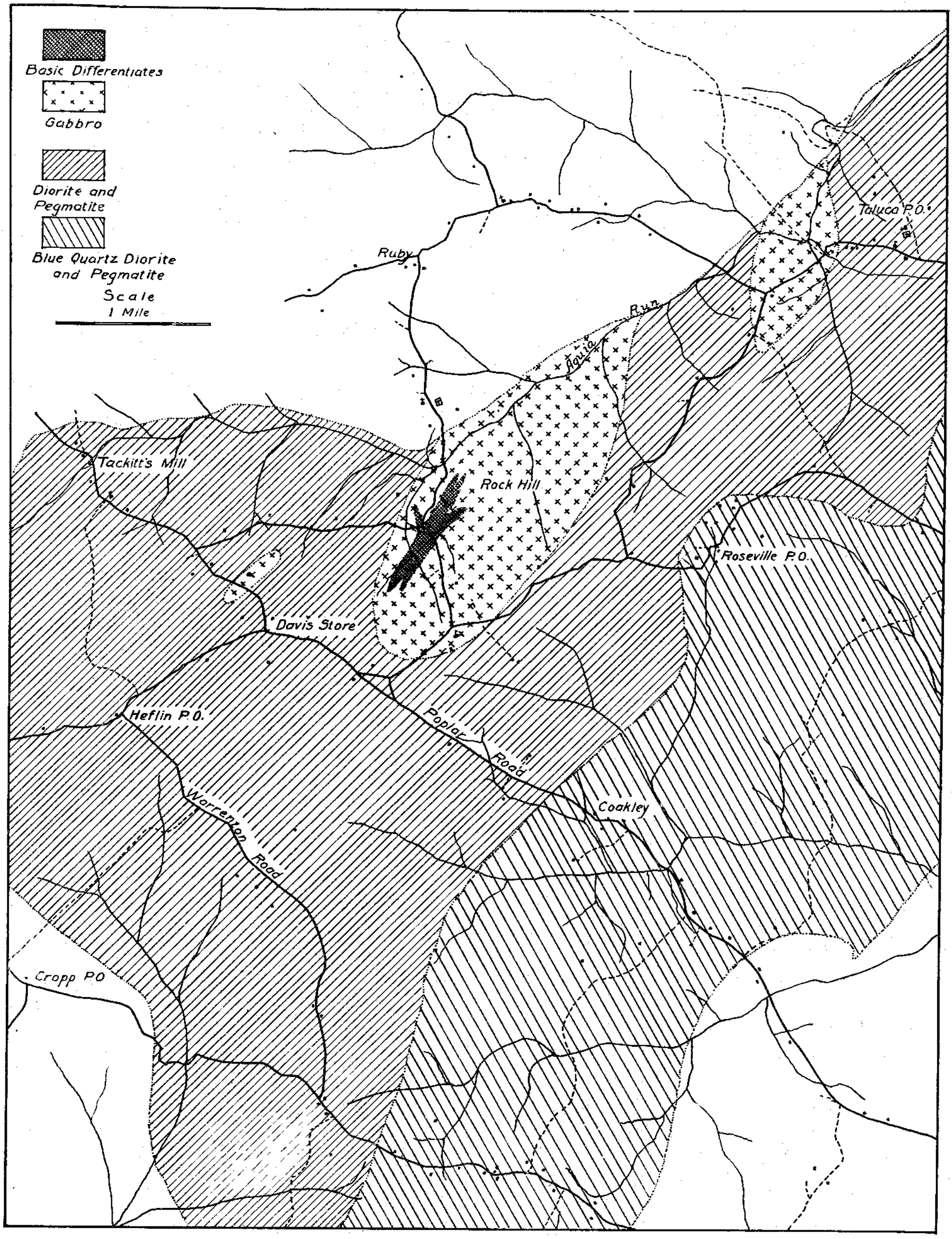
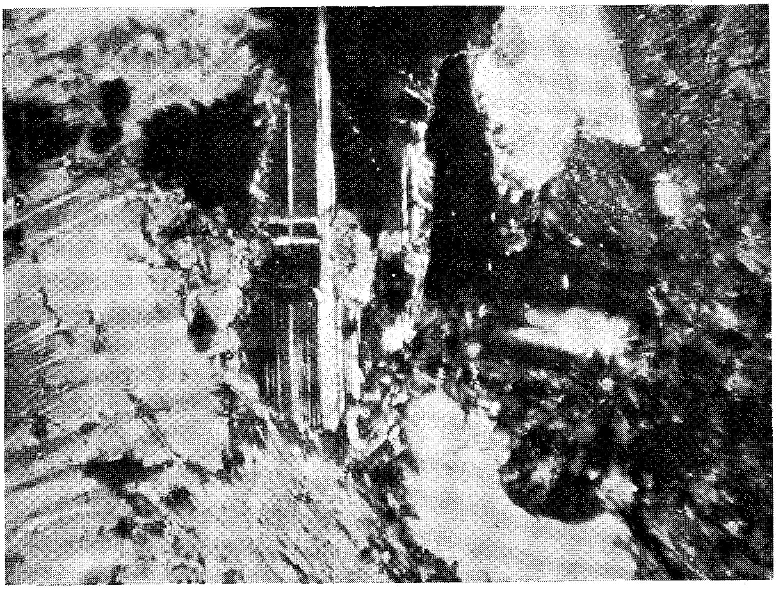
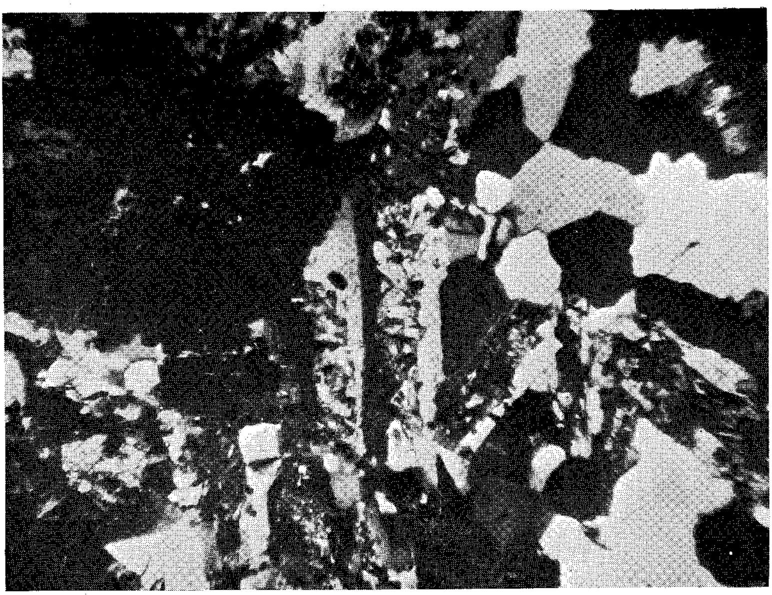


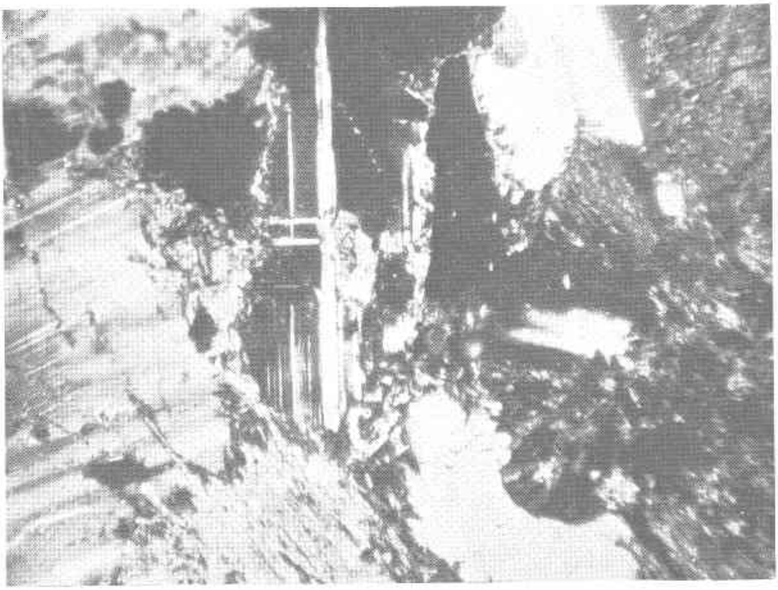
Figure 3. Geologic details of diorite gabbro complex near Rock Hill.



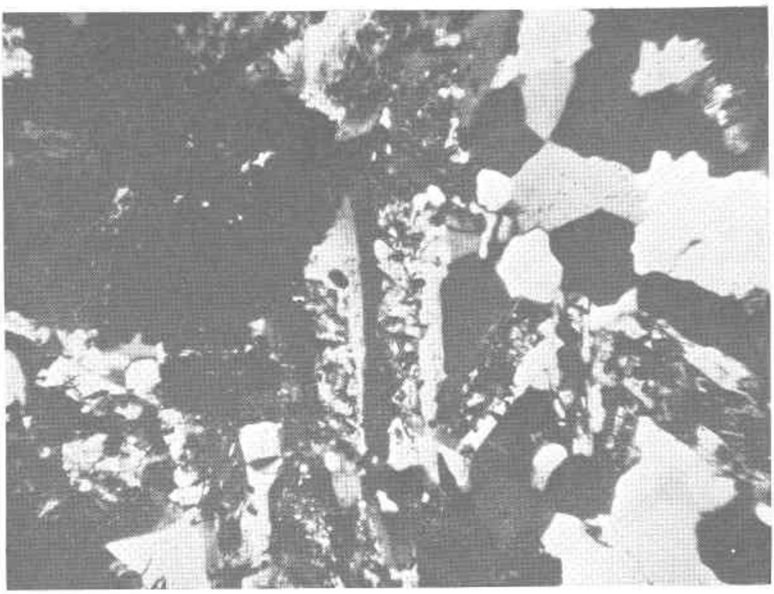
A. Gabbro from Rock Hill. X 46 crossed nicols.



B. Blue quartz diorite from Poplar Road. X 82 crossed nicols.



A. Gabbro from Rock Hill. X 46 crossed nicols.



B. Blue quartz diorite from Poplar Road. X 82 crossed nicols.

Gabbro.—The gabbro as developed at Rock Hill is equigranular, medium- to coarse-grained, and is of a very uniform medium gray color. It is massive and very tough. Its minerals are feldspar corresponding to labradorite and anorthite, with the latter in greatest abundance, diallage, hypersthene, hornblende, uralite, and magnetite. Primary hornblende is developed to a considerable extent, while uralite is formed from the alteration of diallage and is fairly abundant. The feldspars are in greatest abundance and constitute a large part of the rock. Plate 2, A, is a photomicrograph of a thin section of this rock.

A few specimens of pegmatite from the gabbro were found. These were much coarser than the gabbro and consisted essentially of two minerals, feldspar and hornblende, but contained in addition occasional grains of blue quartz.

The chemical composition of the gabbro as developed at Rock Hill is given below, together with its norm.

Chemical analysis of gabbro from Rock Hill

(PENNIMAN & BROWNE, *Analysts.*)

	Per cent
SiO_2	48.61
Al_2O_3	19.01
Fe_2O_3	2.12
FeO	4.85
TiO_2	0.16
CaO	14.28
MgO	8.56
MnO	0.02
K_2O	0.20
Na_2O	0.88
P_2O_5	0.12
CO_2	0.47
H_2O (comb.)	0.70
	99.98

Norm.

Ap	0.34
Il	0.46
Or	1.11
Ab	7.86
An	46.98
Di	18.51
Hy	19.38
Mt	3.02
Q	1.26
Not used	1.19
	100.11

The feldspar ratio for the analysis is as follows:

Orthoclase	1.11	
Albite	7.86	
Anorthite	46.98	
Total plagioclase	54.84	
Total feldspar	55.95	
Ab_nAn_m ratio	1:5.9	= Anorthite
Or-Plag. ratio	1:49	

The quantitative expression for this rock is:

III." 5. (4)5. (4)5. Auvergnose.

The type of gabbro developed near Taluca is very similar to that described above. Feldspars of the same composition are the most prominent minerals. Diallage is absent from this rock which is its main difference from the preceding one. Hypersthene is next to feldspar in abundance and is essentially the only primary mafic constituent. A few crystals of primary hornblende were observed, but these are in far smaller amounts than hypersthene. Some uralite is developed around borders of the hypersthene. Magnetite is present in scattered grains. The secondary minerals are the same as in the first type. This rock has the same texture and granularity as the preceding one, but its color is dark greenish, with a shade of brown observable.

Analyses of this type are not available, but it clearly falls into the gabbroic class of igneous rocks, being essentially basic feldspar with hypersthene and hornblende as mafic minerals.

Basic facies.—Developed at Rock Hill are the facies of this group of rocks which show it to be a complex series with common origin. At this place outcrops are sufficiently numerous and fresh to reveal the character of the rock. The main rock mass is the gabbro already described, but inclosed within this gabbro are several types of rocks more closely related to peridotites. These areas of basic rocks, while not delineated in their entire extent, are believed to be gradational from and into the gabbro. The areal expression on a large scale is shown in figure 4, page 35.

In this occurrence as can be seen from the sketch, areas of ultrabasic types can be found but they are not sharply separated from the normal gabbro. In all cases gradational types are found with a complex interfingering relation.

Gradation.—Since the ultrabasic facies or differentiates in this series are gradational, a great variation in character can be observed in the specimens. The most abundant of these corresponds to the gabbro in mineral composition, but it differs in the relative amounts of the minerals. This is the only absolute difference. The gabbro consists of predominant anor-

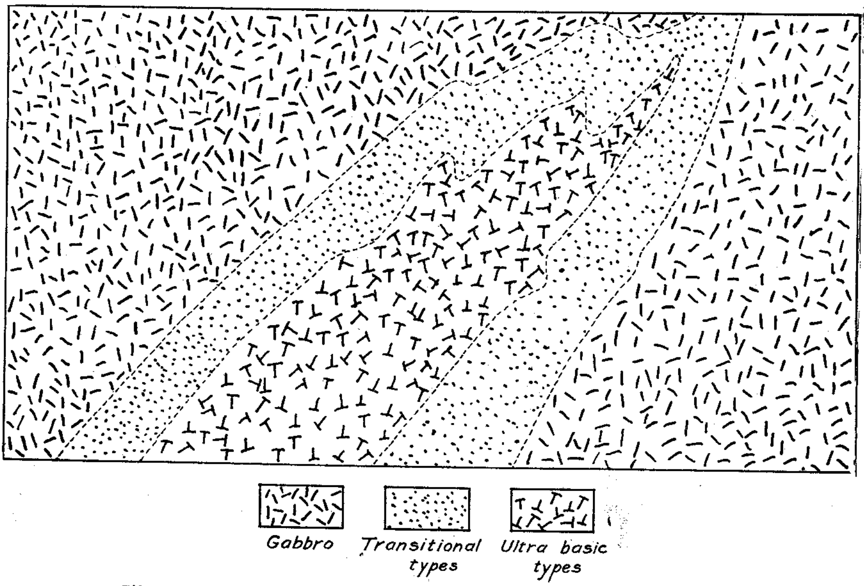


Figure 4. Plan of relations, ultrabasic rocks at Rock Hill.

thite feldspar with diallage, hypersthene, and hornblende. The more basic type has the same minerals with a different order of importance to be expressed as follows: Diallage, hypersthene, hornblende, and anorthite feldspar. This rock corresponds to a pyroxenite. In the specimens represented by the above description, the megascopic appearance of the rock corresponds to and varies with the mineral composition. It is brownish with the metalloidal luster of the pyroxenes very well developed. Feldspars, if observed, are present in very small proportions.

Every gradation between the ultrabasic pyroxenite and the typical gabbro may be observed. Even on the basis of color alone the character of these gradational types can be told, for all shades between the even gray of gabbro and the brown of the pyroxenite exist. Sections show that the difference in the rocks are only changes in the proportions of the minerals, so that as feldspar increases in amount, at the expense of pyroxene, the rock approaches the gray of the gabbro and *vice versa*. While these gradational types are common, they are not present in the same abundance as the more basic types and represent a zone between the gabbro and pyroxenite.

Porphyritic facies.—Developed within the boundaries of the basic differentiate as a whole are narrow bodies and lenses of a basic porphyritic rock which are believed to represent a final product of differentiation and crystallization. These lenses perhaps correspond in occurrence to the pegmatites of more acid igneous rocks. These are dark brownish green in color with a porphyritic texture. There is present a fine-grained groundmass in which are imbedded phenocrysts of pyroxene mainly hypersthene, and to a less extent of hornblende. The ground mass is aphanitic, while the phenocrysts attain dimensions of one-fourth inch in extreme cases. Feldspar is entirely lacking both in the ground mass and among the phenocrysts. The essential mineral composition is that of the non-porphyritic facies already described, except that feldspar is lacking. This rock is to be classed as a porphyritic pyroxenite with minor amounts of hornblende.

Evidence of differentiation.—The evidence that suggests differentiation as the cause of the rock variation seen here has already been indicated. The presence of blue quartz in the blue-quartz diorite and in the pegmatite of the gabbro is a mineral characteristic so unusual that it points to a common origin. The field relationship of the more basic types to the gabbro admits of no other explanation. The gradation between them is so well shown that the close relationship of the two rocks is apparent. It is evident therefore that the blue-quartz-diorite is related to the gabbro and that the gabbro in turn is related to the basic facies. The relation of the diorite to the other varieties is not so plainly shown but the occurrence of the whole group in an apparent unit seems to indicate such a relation.

If this evidence is sufficient to establish the relation in origin of the several varieties of rocks, the whole occurrence furnishes a very interesting example of differentiation. The parent magma was apparently dioritic in composition and the end products of the process of differentiation were blue-quartz-diorite and pyroxenite. The presence of blue quartz in this district is also of interest because it suggests a relationship of the rocks considered here to those of Nelson County many miles distant.

Geologic age.—The geologic age of this igneous complex is Cambrian or pre-Cambrian. Pegmatites believed to be post-Ordovician in age intrude the series and the series in turn cuts schists that are of either Cambrian or pre-Cambrian age. While fresh material of these rocks appears massive, foliation is well shown in weathered material.

NEAPSCO RUN DIORITE

Occurrence.—One mile northeast of Minnieville Post Office and 5 miles northwest of Dumfries, along Neapsco Run, there are outcrops of a small body of dioritic igneous rock. Although the exact boundaries of this rock are difficult to establish, the evidence obtainable indicates that it has the shape and relations of a stock. The area covered by its outcrop is small, being only 1½ square miles.

Megascopic characters.—This rock is massive dark green in color. The texture is fine to medium-grained and there is considerable variation in mineral composition from place to place. The minerals recognized in the hand specimen are hornblende, feldspar, biotite, and quartz. Hornblende is very prominent and is present in all specimens, as is feldspar. Biotite is sparsely disseminated through the rock, but is also segregated, in some cases, into small areas when this mineral is the predominant one. Quartz in general is lacking or present in small amount, except for segregation areas where the rock consists entirely of this mineral. These segregation areas are lens-shaped and do not exceed 1 inch long and half as wide.

Microscopic characters.—Under the microscope the following minerals are seen: Feldspar, hornblende, quartz, biotite, magnetite, titanite, apatite, epidote, zoisite, and chlorite.

The feldspar is andesine with, in addition, very small amounts of orthoclase. The andesine has been extensively altered to epidote. Hornblende is green pleochroic, often in slender crystals. In some specimens it is greater in amount than feldspar. Quartz is present in anhedral grains and is practically lacking in many specimens. Biotite is variable in amount, some sections revealing none of this mineral, while others show it abundantly developed but subordinate to feldspar and hornblende. Magnetite is present as a few scattered grains. Titanite is quite extensively developed in small crystals, often with the lozenge shape of this mineral. Apatite is present in a few crystals, some of large size showing well developed prismatic habit. Epidote and zoisite are abundantly developed as secondary minerals in most sections. The zoisite is *"clinozoisite"* showing oblique extinction and ultra-blue interference colors. Chlorite has developed slightly as the alteration of biotite and hornblende.

Chemical composition and classification.—A chemical analysis of this rock is given below, together with the norm calculated from it.

Chemical analysis of Neapsco Run diorite

(PENNIMAN & BROWNE, *Analysts.*)

	Per cent
SiO_2	49.75
Al_2O_3	14.19
Fe_2O_3	1.89
FeO	7.33
TiO_2	0.48
CaO	8.99
MgO	10.27
MnO	0.06
K_2O	0.99
Na_2O	1.79
P_2O_5	0.16
CO_2	2.31
H_2O (comb.)	1.75
	99.96

Norm.

Il	0.91
Ap	0.34
Or	6.12
Ab	15.20
An	27.52
Mt	2.78
Di	13.24
Hy	28.73
Ol	0.98
	95.82
	2.31 } Not used
	1.75 } Not used
	99.88

It is to be noted that this analysis shows the rock to be relatively low in silica, potash, and soda, and high in iron, lime, and magnesia. The rock is essentially calcic. Its classification causes it to be named diorite, but the specimens high in quartz correspond more nearly to quartz diorite. The feldspars calculated from the analysis are given below.

Orthoclase	6.12	
Albite	15.20	
Anorthite	27.52	
Total plagioclase	42.72	
Total feldspar	48.84	
Ab_nAn_m ratio	1 :1.8	= labradorite
Or-plag. ratio	1 :6.9	

The Quantitative expression for the rock is as follows:

III. 5. 4. 4. Auvergnose.

Geologic age.—As is the case with many of the rock bodies in this district, the age of the diorite can not be definitely fixed. It intrudes schists of Cambrian and pre-Cambrian age, hence is younger than these. Its apparently massive character suggests that the rock is much younger than Cambrian, but direct evidence is wanting, and it is assigned here to the undivided Cambrian and pre-Cambrian.

LOCUST GROVE DIORITE

Occurrence.—In Orange County, closely paralleling the development of granite near Locust Grove, is a narrow body of dioritic rock. It extends from a point 1 mile east of Verdiersville on the P. F. & P. Railway, to a point 1½ miles southwest of Flat Run Post Office, a distance of 8½ miles. The greatest width of exposure of the rock does not exceed 1 mile and the average width is approximately one-half mile. The area involved by the exposures of this rock is about 5 square miles. The best outcrops of the diorite are found on Mine Run west of Locust Grove and one-half mile north of Locust Grove.

Megascopic characters.—This rock is medium-grained equigranular in texture, and of a medium green color which in many specimens is speckled on account of the feldspars being kaolinized. Hornblende largely chloritized, as well as feldspar, is present in abundance.

Microscopic characters.—Under the microscope the diorite is seen to consist for the most part of feldspar, hornblende, and occasional grains of quartz. Feldspar is largely andesine with minor amounts of orthoclase. Hornblende is abundant, but is altered extensively to chlorite and magnetite. Alteration products are kaolinite, epidote, chlorite, and magnetite.

Geologic age.—This rock is probably pre-Cambrian in age. It appears to have suffered considerable metamorphism as shown by foliation. It is definitely older than the Locust Grove granite, for pegmatite dikes belonging to that rock are found intruding the diorite. The Locust Grove granite is believed to belong in the Cambrian or late pre-Cambrian, largely on account of its relatively massive structure and freedom from extensive metamorphism. The diorite being older can probably be safely considered as pre-Cambrian in age.

RESUME

In the foregoing descriptions of rocks assigned to the undivided pre-Cambrian or Cambrian, it is to be noted that, in many cases, the evidence of geologic age is not conclusive. Rocks such as the blue quartz diorite and hornblende granite which are essentially massive rocks are included here. The possibility must be kept in mind that such rock bodies may be of an age much younger than that assigned them, even though conclusive evidence is lacking.

IGNEOUS ROCKS POST-CAMBRIAN, PROBABLY POST-ORDOVICIAN, IN AGE

Included in this group are bodies of igneous rocks which are distinctly younger than those previously described. Certain of them can be demonstrated to be of undoubted post-Ordovician age. Others, whose field relations are not such as to admit of the exact determination of age, are so similar in structure and physical aspects that they are believed to be of the same age. Embraced here are several bodies of granite, quartz monzonite, and some dike rocks of acid character.

GRANITES AND QUARTZ MONZONITES OF POST-ORDOVICIAN AGE

Three bodies of massive and unmetamorphosed igneous rock are found in the district. These are found near Fredericksburg, Stafford Store, and Occoquan. Two of them, the Fredericksburg body and that of Stafford

Store, are strikingly similar both mineralogically and chemically. They are believed to be closely related, though no areal connection exists between them. These rocks for the most part are intermediate in composition, that is, they are quartz monzonites rather than true granites. They are called granites in the general heading, because they conform to the popular conception of this rock. In the descriptions which follow the exact classification of each rock is given.

STAFFORD STORE QUARTZ MONZONITE

Occurrence.—Developed typically near Stafford Store Post Office in Stafford County, is a large body of granitic rock corresponding to quartz-monzonite in composition. Extensive bluffs of this rock form the banks of Chopowamsic Creek at Bellfair Post Office, good exposures exist east of Onville on Aquia Creek, and occasional expósures are found in much of the territory around Stafford Store. The area covered by the rock is about 60 square miles. Its northern limit is about 2 miles from the Cabin Branch mine at Dumfries, and its southern limit is near Tackitts Mill. It is in contact on the east with schist, greenstone, sandstone and diorite; on the west with schist; and on the south with diorite and gabbro. The decay of this rock is quite different from any of the rocks with which it is in contact. A deep red highly micaceous product in which numerous minute quartz grains are found is quite characteristic. This fact has been of considerable aid in the mapping of the quartz monzonite.

Megascopic characters.—In the hand specimen the quartz monzonite appears medium gray in color, with an equigranular medium-grained texture. Occasionally segregation areas of quartz or biotite are seen. These attain a maximum size of 2 inches in greatest dimension. Recognizable minerals are quartz, feldspar, biotite, and muscovite.

Microscopic characters.—Under the microscope the rock is seen to consist essentially of feldspar, quartz, biotite, muscovite, magnetite, epidote, sericite, apatite, zircon, titanite, and garnet. Only the first four of this group of minerals are present in considerable amounts. Epidote, sericite, and a part of the magnetite are secondary in origin. The texture is granitic.

The feldspar includes both orthoclase and plagioclase. Orthoclase is present either untwinned or in Carlsbad twins. The plagioclase is oligoclase-andesine and is present with polysynthetic twinning after both albite and pericline laws. Quartz is present in numerous anhedral grains. Biotite is seen as numerous scattered flakes and shreds highly pleochroic and often carrying inclusions of apatite and zircon. Muscovite is in part primary and in part secondary (sericite) from the alteration of the feldspars. Magnetite when primary is present in euhedral crystals or grains. Biotite in altering has yielded numerous minute grains of the mineral. Apatite and zircon are developed in a few minute crystals occurring as inclusions in biotite. Titanite is present in a few irregular grains. Garnet is present in a very few anhedral crystals, often larger than any other rock constituent. The appearance of the rock under the microscope is shown in plate 3, B.

Chemical composition and classification.—A chemical analysis of this rock, together with the norm calculated from it, appears below.

Chemical analysis of Stafford Store quartz monzonite

(PENNIMAN & BROWNE, *Analysts.*)

	Per cent
SiO_2	62.63
Al_2O_3	17.63
Fe_2O_3	1.44
FeO	4.25
TiO_2	1.37
CaO	2.18
MgO	1.81
MnO	0.08
K_2O	3.77
Na_2O	2.59
P_2O_5	0.31
CO_2	0.59
H_2O (comb)	1.30
	99.95

Norm.

Il	2.74
Ap	.67
Or	22.24
Ab	22.01
An	8.90
C	6.02
Mt	2.09
Hy	8.72
Q	24.60
Not used CO_2	.59
Not used H_2O	1.30
Not used MnO	.08
	99.96

The feldspars calculated from the norms are as follows:

Orthoclase	22.24
Albite	22.01
Anorthite	8.90
Total plag.	30.91
Total feldspar	53.15
Ab_nAn_m ratio	2.4:1
Or-plag. ratio	1:1.3 = Andesine

In the Quantitative Classification this rock is designated by the following symbol:

(I) II. "4. 2. 3. (Adamellose).

Under the old system the rock corresponds to quartz monzonite.

Geologic age.—In age this rock is probably younger than Ordovician (Cincinnatian). In the Quantico slates of Dumfries, near the Cabin Branch pyrite mine, there are found stringers and bands of granitic material. These are thought to be related in origin. Likewise, near the head of Quantico Run, the rock shows evidence of intruding the Ordovician slates. The relation of this rock to the ores of the district will be discussed elsewhere. This rock is probably to be correlated with the quartz monzonite at Fredericksburg. There is a striking similarity between them, so much so that hand specimens can not be told apart. Mineralogically they are also in quite close agreement, both being biotitic granitic rocks corresponding closely to quartz monzonites.

FREDERICKSBURG GRANITE (QUARTZ MONZONITE)

Occurrence.—This rock has been described by Watson[20] as quartz monzonite. It has been quarried to a considerable extent near Fredericksburg and is one of the best Virginia building stones among the siliceous crystalline rocks.

The quartz monzonite occurs in the southeastern part of the area covered by this report. Its best exposures are found along Rappahannock River in both Stafford and Spotsylvania counties. The bluffs on either side of the river above Falmouth for nearly 4 miles are composed largely of this rock. Since the area included in this report does not include Falmouth and Fredericksburg, the entire extent of the occurrence of this rock does not appear on the map. Quarries opened and formerly operated are situated 3 miles northwest of Fredericksburg in Spotsylvania County. The quartz monzonite is not separated from the Fredericksburg granite-gneiss described elsewhere, because such a separation is impracticable.

Megascopic characters.—The rock is fine-grained, phanerocrystalline, equigranular in texture, and is dark bluish gray in color. Uniformity of texture and color marks its development over wide areas. This has had a direct bearing on the value of the stone for monumental purposes. Individual crystals of the quartz-monzonite average 0.5 millimeters in size. The minerals recognized by the unaided eye are feldspar, quartz, biotite, and muscovite. Quartz and feldspar predominate, biotite being subordinate. The biotite is uniformly distributed through the rock, giving to the mass a characteristic blue gray color. Muscovite appears as scanty white flakes much smaller in amount than the biotite.

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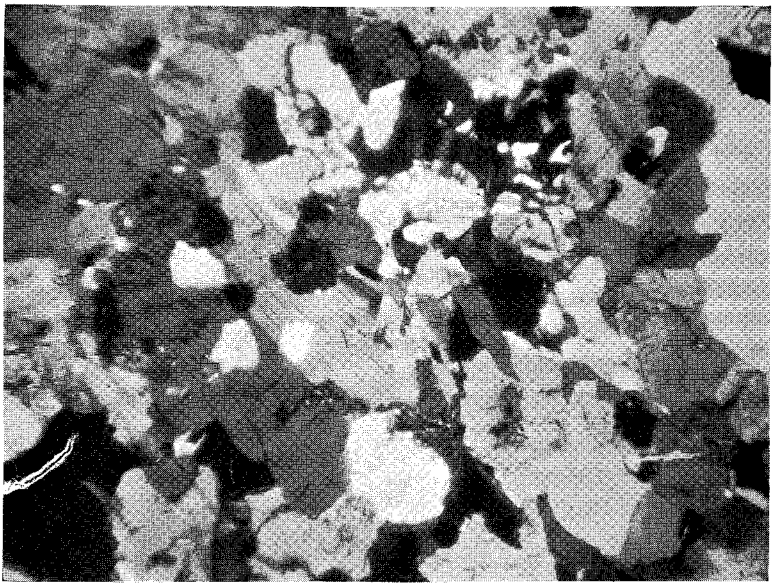
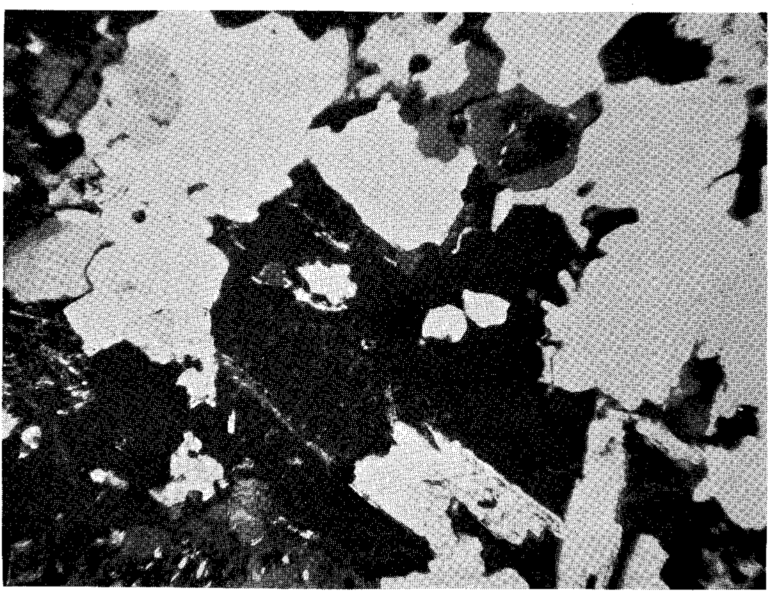
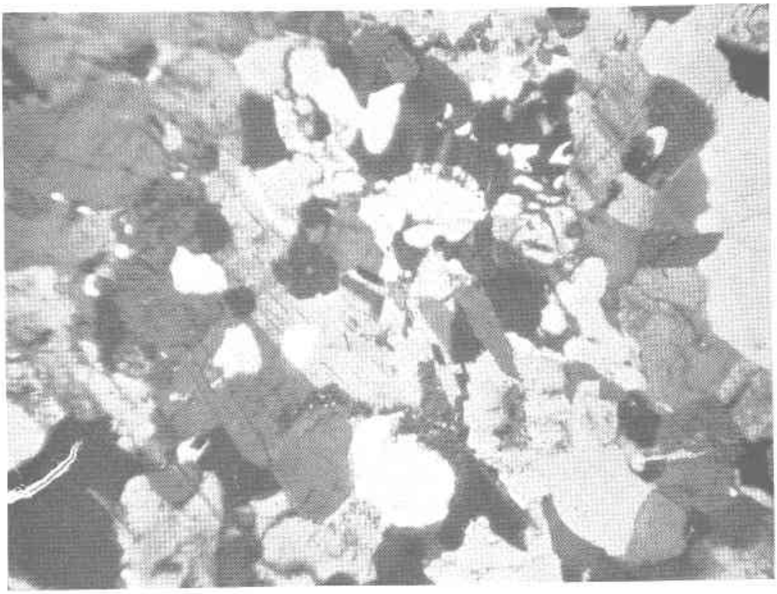
20. Watson, Thomas L., Granites of the Southeastern Atlantic States: Bull. No. 426, U. S. Geol. Survey, 1910, p. 16.



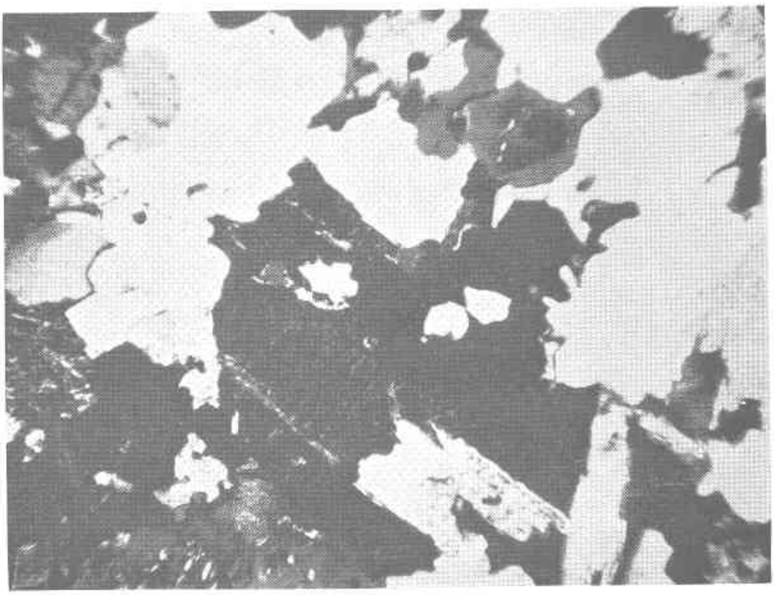
A. Fredericksburg granite from Cartwright and Davis quarry. X 82 crossed nicols.



B. Granite from Bellfair P. O. X 82.



A. Fredericksburg granite from Cartwright and Davis quarry. X 82 crossed nicols.



B. Granite from Bellfair P. O. X 82.

Microscopic characters.—A microscopical study of thin sections of the quartz-monzonite shows the following features: The essential minerals are feldspar, quartz, biotite, and muscovite. Accessory minerals include apatite, zircon, and rutile. Secondary minerals are epidote, kaolinite, and calcite. The texture is finely granitic and there is an absence of pressure effects.

Both orthoclase and plagioclase (oligoclase) feldspar are present. The orthoclase is present in anhedral or subhedral grains showing Carlsbad twinning. In rare instances graphic intergrowths of this mineral with quartz occur. The plagioclase exhibits albite twinning with fine closely spaced laminae. Determination of indices of refraction of the plagioclase shows its correspondence to oligoclase.

Quartz is abundant, developed in anhedral colorless grains, often filled with irregular dust-like inclusions. Biotite appears as shreds or flakes showing perfect cleavage and intense pleochroism. Inclusions of apatite and zircon are common. In some cases this mineral is bleached to a nearly colorless condition, when it resembles muscovite. Muscovite is both primary and secondary. In the first case colorless flakes are observed, in the second irregular shreds adjacent to the mineral from which it was derived. In a few instances this mineral is intergrown with quartz. Apatite, zircon, magnetite, kaolinite, epidote, and calcite are present in very small amounts. Plate 3, A, shows a thin section of the rock.

Chemical composition and classification.—An analysis of the quartz monzonite, with its norm, is given below.

Analysis of Fredericksburg dark blue gray granite—Cartwright and Davis quarry.

(W. M. THORNTON, JR., *Analyst.*)

	Per cent
SiO_2	69.48
Al_2O_3	13.95
Fe_2O_3	2.82
FeO	1.70
MgO	1.10
CaO	2.81
Na_2O	3.65
K_2O	3.45
H_2O (comb.)	0.54
TiO_2	0.47
MnO	0.03
CO_2	Trace
P_2O_5	0.49
	100.49

Norm [21]

Quartz	28.32
Orthoclase	20.57
Albite	30.92
Anorthite	11.40
Hypersthene	2.80
Ilmenite	0.91
Magnetite	4.18
Apatite	1.01
Not used H_2O	.54
Not used MnO	.03
	100.68

From this analysis, it will be seen that the rock conforms rather closely to the characters of quartz monzonite. Silica and alumina are abundant, soda and potash nearly equal in amount, and lime less than either soda or potash. The amounts of the other oxides are also characteristic of this type of rock. A computation of the feldspars of the rock gives the following result:

Orthoclase	20.57	
Albite	30.92	
Anorthite	10.29	
Total plagioclase	41.23	
Total feldspar	61.75	
Ab_nAn_m ratio	2.9:1	= oligoclase-
Or-plag. ratio	1:2	andesine

The position of this rock in the Quantitative System is as follows:

I″. 4. 2. 3(4). Toscanose [22]

According to the Qualitative System of classification based on amounts and kinds of quartz and feldspar, the rock is seen to be a quartz monzonite.

Structure.—The quartz monzonite is a perfectly massive rock, except for joints which occur in it from place to place. No evidence is seen that it participated in the metamorphism which took place in this region. The joint systems are three in number, generally occurring quite widely spaced.

In the Fredericksburg quarries Watson [23] found the orientation of the joints to be (1) N-S., dip 40° E., (2) N. 60° E. to N. 80° E., dip 10°-30°, and (3) N. 20° W. to N. 80° W. Pegmatites are extensively developed in the rock, but their relation to the quartz monzonite will be discussed in another place in the report.

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21. Washington, H. S., Chemical analyses of igneous rocks published from 1884 to 1913, inclusive, with a critical discussion of the character and use of analyses: Prof. Paper 99, U. S. Geol. Survey, 1917, p. 171.
22. Washington, H. S., op. cit.
23. Watson, Thomas L., Bull. 426, U. S. Geol. Survey, 1910, p. 108.

Geologic age.—This rock is believed to be younger than late Cambrian in age. It intruded the undoubted pre-Cambrian gneiss at Fredericksburg from which it can not be separated areally. It also intruded pre-Cambrian and Cambrian schist along Rappahannock River. Furthermore it is completely free from pressure effects which characterize many of the rocks of this region, even those as young as Ordovician in age.

OCCOQUAN GRANITE WITH ITS INCLUDED APLITE

Occurrence.—As mapped, this body of igneous rock is the greatest in areal extent of any of the igneous rocks of the district. Exposures of the rock are not continuous, as there are bodies of schist intervening. It is believed, however, that these discontinuous bodies are united at no great depth beneath the surface. Excellent exposures of this granite are found on Occoquan Run, from Occoquan village to the forks of Bull Run, at Davis Ford bridge over Occoquan Run, at Blands Ford bridge, and at numerous other places throughout the area. One narrow belt of this rock, separated from the main mass, extends from Buck Hall to near Independent Hill, where it is separated by only a narrow body of schist from the main mass of the rock. The area covered by this rock mass is approximately 100 square miles. It is to be noted that small bodies of schists are included in places in the area mapped. These are small very subordinate areas and represent remnants which erosion has not completely removed from the top of the granite. Larger areas of schist, which distinctly divide areas of the granite, appear on the map as such.

The relation of the granite to the crystalline schist is shown in figure 5 accompanying. That the schist is only a relatively thin capping to the granite is shown at Wolf Run Shoals where the remaining band is less than one-fourth mile wide.

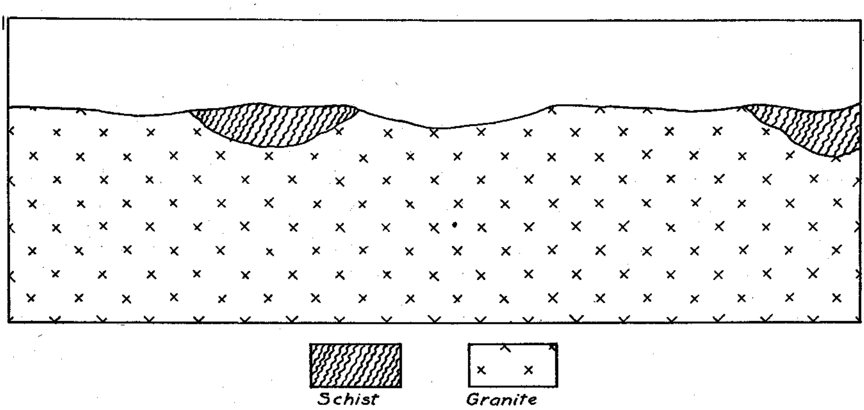


Figure 5. Relation of granite to schist near Occoquan.

Variation.—The Occoquan granite is marked by considerable variation in its composition and texture from place to place. In all developments it is highly siliceous in nature, as shown by an unusually large content of quartz. As exposed at Bland's Ford which is perhaps typical of the greater portion of the rock, this granite is distinctly coarse-grained and sheeted mainly horizontally. The color is irregular greenish gray, with feldspar and quartz in coarse grains as the recognizable minerals. Darker constituents are not identified by the unaided eye. The quartz and feldspar grains frequently exceed one-fourth inch in dimension. Slight variations from this type are common. One shows the presence of recognizable biotite, and in others a greater amount of green mineral is common. In the quarry at Occoquan, not far from the border of this rock, variation is shown within narrow limits. Here the rock is highly siliceous and distinctly sheeted. The very small amounts of dark minerals present are arranged in thin bands separating the wider bands of quartz and feldspar. The prevailing color is a speckled greenish gray. In the same quarry face bands or narrow dike like bodies, not to be separated from the main type, are developed. These are very fine-grained, a very faint pink in color, and resemble quartzite. In these narrow bands of fine-grained rock, only a very few specks of biotite disseminated through the mass represent dark colored constituents.

A microscopic study of numerous sections of the granite reveals that all portions of it are igneous in character, but that variation in amounts of the essential minerals is common. In the Blands Ford specimens and in all specimens from the central part of the mass quartz, while abundant, is in approximately the usual proportion for granites. In the specimens from the Occoquan quarry, however, quartz is unusually abundant. The fine-grained masses are essentially quartz and feldspar corresponding closely to alaskite, while the coarser grained specimens are also highly siliceous in character. It seems probable that this variation in this rock, especially near its eastern border, is due to special causes. The fine-grained bands are believed to be in the nature of aplitic bodies developed in the final stages of the consolidation of the magma which produced this rock, while the coarse-grained highly siliceous rock at Occoquan probably represents a pegmatitic border phase. At Occoquan this rock is in contact with Ordovician slates. In the Arvonia belt a quartzite bed is developed at the base of the slates. This is missing at Occoquan and there is a possibility that the highly siliceous border of the granite represents a combination of igneous rock and quartzite.

Microscopic characters.—Under the microscope the minerals recognized in the granite are feldspar, quartz, biotite, muscovite, zircon, magnetite, epidote, calcite, and chlorite. Of these epidote and chlorite are secondary.

The feldspar consists of orthoclase, microcline, and albite. All three species are in large grains. The orthoclase exhibits Carlsbad twinning or is untwinned, the microcline exhibits the cross hatching characteristic of this mineral, and albite is very finely twinned after the albite law. Epidotization has altered this last mineral to a considerable extent. In the case of the fine-grained aplitic phase of the rock the same development of the feldspars is characteristic, except that the individuals are much smaller. Quartz is very abundant in all specimens of the rock, a maximum being reached in the case of the aplitic and pegmatitic facies at Occoquan. It is anhedral in development, the grains being of the same size as the feldspars.

Biotite extensively chloritized is a subordinate mineral in all facies of the rock. It is far less developed in the specimens from Occoquan than in those from the vicinity of Blands Ford. In the former case only a very few minute shreds occur, while in the last cases cited the amount of biotite reaches a maximum of several per cent of the area of the rock. Muscovite is largely sericitic in its development, though primary muscovite occurs in flakes to about the same extent as biotite. Sericite has developed in the alteration of the feldspar minerals. Zircon and magnetite as primary minerals are exceedingly scanty. A few scattered crystals and grains occur. Magnetite, as a secondary product from the alteration of biotite, is fairly common in slides carrying appreciable biotite. A very few small prisms of apatite are also found. Epidote, calcite, and chlorite are secondary minerals developed in all of the slides to a very limited extent.

Chemical composition and norm.—A chemical analysis, together with norm, is listed below.

Chemical analysis of Occoquan granite

(PENNIMAN & BROWNE, *Analysts.*)

	Per cent
SiO_2	72.19
Al_2O_3	14.60
Fe_2O_3	1.33
FeO	1.39
TiO_2	0.28
MnO	0.03
CaO	3.59
MgO	0.57
K_2O	1.06
Na_2O	3.23
P_2O_5	0.08
H_2O	0.60
CO_2	0.97
	99.92

Norm.

Ap	0.34	
Il	0.61	
Or	6.67	
Ab	27.25	
An	16.96	
C	1.84	
Mt	1.86	
Hy	2.32	
Q	40.56	
H_2O	.60	Not used
CO	.97	Not used
MnO	.03	Not used
	100.01	

The feldspar ratio is as follows:

Orthoclase	6.67
Plagioclase	44.21
Total feldspar	50.88
Ab_nAn_m ratio	1:1.6
	= Andesine
Or.-plag. ratio	1:6.

In the Quantitative Classification this rock is classed as follows:

I.″ 3. 3. 4.

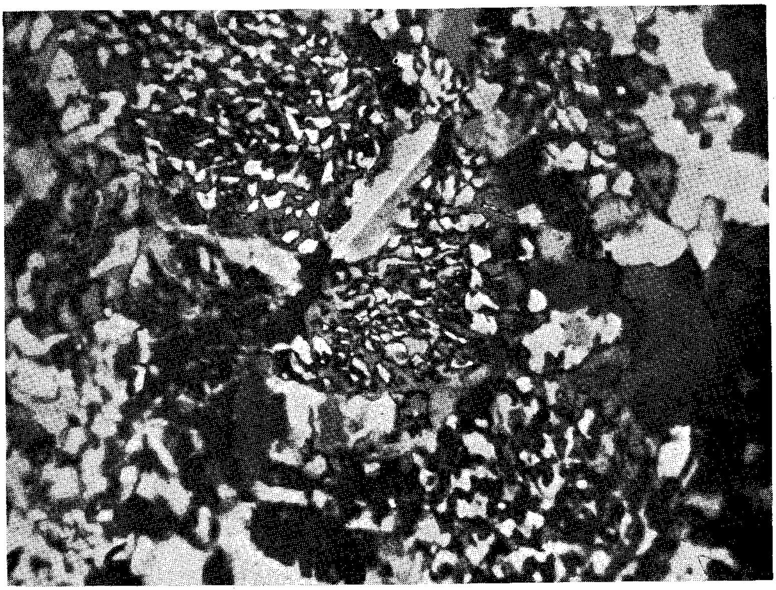
Classification.—A consideration of the essential minerals of this rock and of their relative proportions classifies it as a granite. Quartz is abundant, while orthoclase and microcline, the potassium feldspars, are in greater abundance than the plagioclase feldspars. It may be pointed out that this rock is not a common type in the Piedmont province, since many of the rocks found here are more nearly related to intermediate types such as quartz monzonite.

Geologic age.—The age of this rock is not definitely established. At Occoquan there is some evidence suggesting that the granite intrudes the Quantico slate. If this is true the rock is younger than the slate. In the absence of absolute proof of the age relationship, the granite is shown on the map as belonging to the undivided pre-Cambrian and Cambrian. The discussion, however, groups it with the younger igneous rocks.

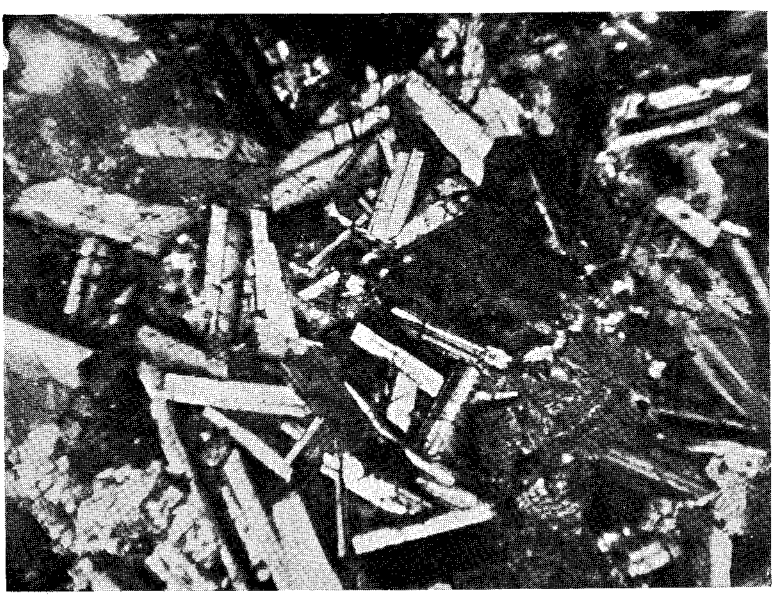
Uses.—The sheeting of this rock renders it unfit for many of the building stone uses. It is, however, admirably suited for use as rubble for filling breakwaters and piers. It has been used for this purpose in many of the riparian structures along Potomac River. The rock thus used was obtained from the quarry at Occoquan and shipped by water to the points where used.

RHYOLITE

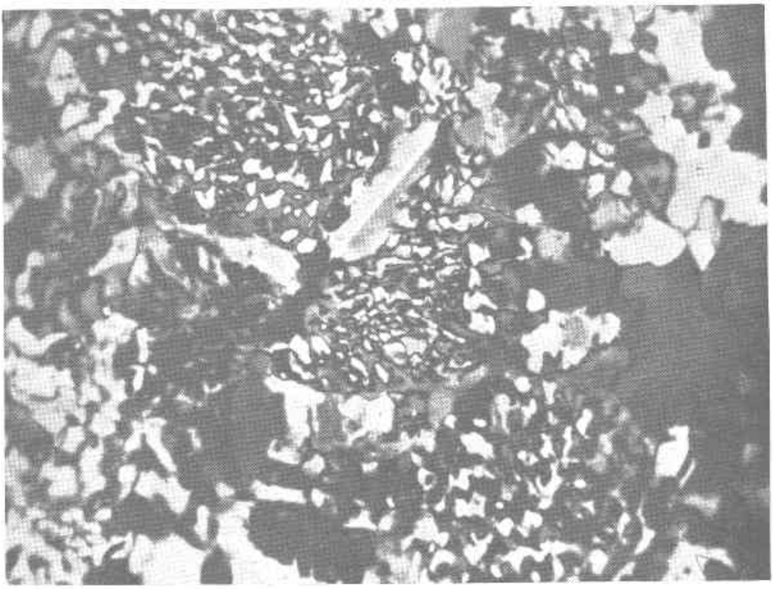
Occurrence.—One-half mile east of Hemp, on the Warrenton road, there is exposed a small body of rhyolite. It occupies a position between amphibolite on one side and granite on the other and has the form of a dike. The dike is 25 feet wide and strikes N. 35° E. It stands nearly vertical between the diorite and granite, and can be traced a few yards on either side of the road where the deep decay obscures its outcrop.



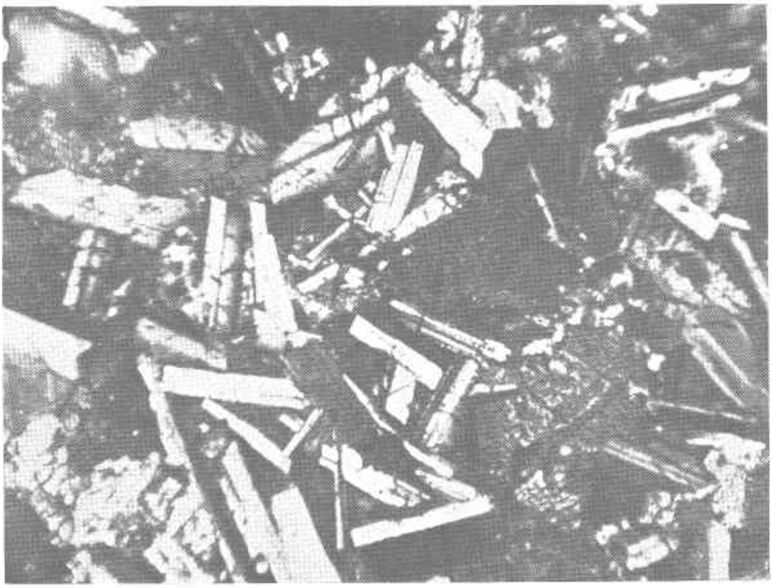
A. Rhyolite one-half mile east of Hemp. Micrographic texture well shown. The large crystal in upper center is orthoclase. X 150 crossed nicols.



B. Diabase dike with ophitic texture from Poplar Road. X 46 crossed nicols.



A. Rhyolite one-half mile east of Hemp. Micrographic texture well shown. The large crystal in upper center is orthoclase. X 150 crossed nicols.



B. Diabase dike with ophitic texture from Poplar Road. X 46 crossed nicols.

Megascopic characters.—The rhyolite of which the dike is composed is dull white to cream colored. The freshest material obtainable shows a faint pinkish cast. Its volcanic character is evident even in the hand specimen. It is seen to consist of a fine-grained paste in which are imbedded bodies of much coarser grain. The largest of these bodies slightly exceed one-eighth inch in length. Some of these phenocrysts are seen to be quartz, but others are feldspar.

Microscopic characters.—Under the microscope the volcanic character of this rock is still more emphasized than in the hand specimen. The minerals constituting the rock are feldspar, quartz, biotite, muscovite, magnetite, and zircon. A very fine-grained paste of quartz and feldspar incloses large crystals of the same minerals.

The feldspars and quartz are present in the rock in a very striking manner. Quartz in all cases is anhedral in development, but is present as phenocrysts, as small grains in the paste or matrix and graphically intergrown with the feldspars. There is a complete gradation in size from the minute grains of the paste to those of the phenocrysts. Many of the bodies, which appear as phenocrysts of quartz in the hand specimen, are revealed by the microscope to be intergrowths of quartz and feldspar. In these intergrowths the resulting pattern is either the typical graphic texture or one which is arborescent in its appearance.

The feldspars present in the rock are orthoclase and albite-obligoclase. The orthoclase is in greater abundance. It occurs as individuals twinned or untwinned, but rarely as large as the quartz grains and as intergrowths with quartz. The orthoclase texturally plays the same role as quartz, that is phenocryst, matrix or intergrowths. Many of the individual crystals are beautiful euhedral ones. The plagioclase in the rock is albite-oligoclase. Separation of individual feldspars is very difficult, so that the plagioclase feldspar can not be definitely referred to one species. The plagioclase feldspar is present in the paste to a very limited extent and also as phenocrysts and intergrowths with quartz. Albite and pericline twinning are both to be observed.

Biotite is a minor constituent of the rock being greenish in color and present as a few scattered shreds. Muscovite is present in exceedingly small amounts. Magnetite is present in small grains and crystals, some with euhedral development. One or two minute crystals of zircon were observed as inclusions in biotite.

Plate 4, A, shows a thin section of the rock. The micographic development is shown as well as large crystals of feldspar.

Classification and geologic age.—This rock is a rhyolite, the age of which cannot be definitely stated. It intrudes rocks of pre-Cambrian or Cambrian age, but is much younger. Its absolute lack of metamorphism marks it as probably post-Ordovician in age, for it is impossible to conceive of so small a rock body of such character withstanding the intense metamorphism that took place in this region.

RHYOLITE PORPHYRY

Occurrence.—Two miles southeast of Hemp and one-fourth mile west of Horsepin Run there is exposed a small dike of rhyolite porphyry. Although this rock is different in certain phases from the rhyolite east of Hemp, it is probable that they are closely related. The facts that both are completely massive and unmetamorphosed, that they are only 2 miles apart and that one is approximately the continuation of the strike of the other are suggestive of this relation. When it is considered further that they are chemically quite similar, though texturally unlike, it seems that the two are probably parts of the same mass or, if distinct masses, have a common origin.

Megascopic characters.—The rhyolite porphyry is a massive, dark bluish gray rock which weathers to a white chalky clay. It is composed of an aphanitic paste or groundmass in which are imbedded scattered phenocrysts of glassy bluish quartz and of feldspar. The largest quartz phenocrysts are slightly less than one-eighth inch in greatest dimension, and appear slightly rounded in outline. The feldspar phenocrysts are more elongated and angular than those of quartz, and attain lengths of one-eighth inch as a maximum. In a surface of the rock 1 inch square 20 phenocrysts were counted, showing the relative abundance of matrix and phenocrysts.

Microscopic characters.—Under the microscope this rock is seen to be typically porphyritic in texture. The phenocrysts of quartz and feldspar are many times larger than the grains of the groundmass which in places are so small as to be cryptocrystalline. The minerals identified were orthoclase, quartz, hornblende, magnetite, garnet, and zircon.

Orthoclase occurs both as phenocrysts and as a constituent of the groundmass. As phenocrysts, beautiful twinned crystals of perfect euhedral outline are developed. In the groundmass minute difficultly recognizable grains of the mineral are seen.

Quartz occurs in three sizes of grains: (1) As large phenocrysts showing, in some cases, subhedral development, many of which are corroded and resorbed; (2) as the finest cryptocrystalline matrix; and (3) also in anhedral grains of somewhat larger size which characterize parts of the matrix.

Hornblende is abundant in the matrix of the rock. It is developed in small slender needle-like crystals of bluish green color or in fibrous aggregates. These occupy all the space of the matrix and are oriented in all possible directions. Around the borders of phenocryst the crystals of hornblende are often concentrated into a perfect mat.

Magnetite is present as scattered anhedral grains. Garnet is developed in a very few crystals showing the outline of the rhombic dodecahedron. A very few grains of zircon were observed in the matrix of the rock.

Geologic age.—This rock is probably to be correlated with that of the rhyolite near Hemp. It is totally unmetamorphosed and hence is much younger than the foliated rocks of this district, some of which are Ordovician in age. As in the case of the rhyolite, it seems likely that the rhyolite porphry is younger than Ordovician.

PEGMATITES AND APLITES

Throughout the district covered by this report pegmatites and aplites are developed in association with some of the igneous rocks. The pegmatite found associated with quartz diorite near Roseville is discussed with that rock, but other pegmatites found are discussed below. In the descriptions below the pegmatites and aplites are assigned to the parent rock from which they are believed to have been derived.

PEGMATITE FROM FREDERICKSBURG QUARTZ-MONZONITE

Occurrence.—In the quarries northwest of Fredericksburg and in exposures along Rappahannock River, dikes of pegmatite are found developed with the quartz-monzonite already described. These dikes are narrow bodies which sharply intrude the older rocks. The widths of the dikes seldom exceed two feet and are frequently much narrower. The relation of the dikes to the older rocks is shown in the accompanying diagram (fig. 6).

Megascopic characters.—These pegmatite dikes are coarse-grained unequigranular. Individual crystals attain dimensions of 2 inches and vary from this size down to small grains. The color of the rock is light, but not uniform. Certain portions are pink, others pale green, and others black because of the uneven texture present. Feldspar, quartz, and biotite are recognizable in the hand specimen. Part of the feldspar is pink in color, while the remainder is light green. The feldspars attain the greatest size among the minerals of the rock. Quartz is in smaller grains than the feldspars, and in some cases is megascopically intergrown with them. Biotite occurs in large crystals about 1 inch in diameter or in scattered grains.

Microscopic characters.—The microscopic characters of the rock are as follows:

The feldspars are orthoclase, microcline, albite, and oligoclase, microcline being least abundant. The feldspars are partly graphically intergrown with quartz. This structure is not characteristic of the rock as a whole, but only of isolated areas. Quartz is anhedral and abundant. Biotite occurs in scattered flakes much less abundant than either quartz or the feldspars and in smaller crystals. Muscovite is seen as a few

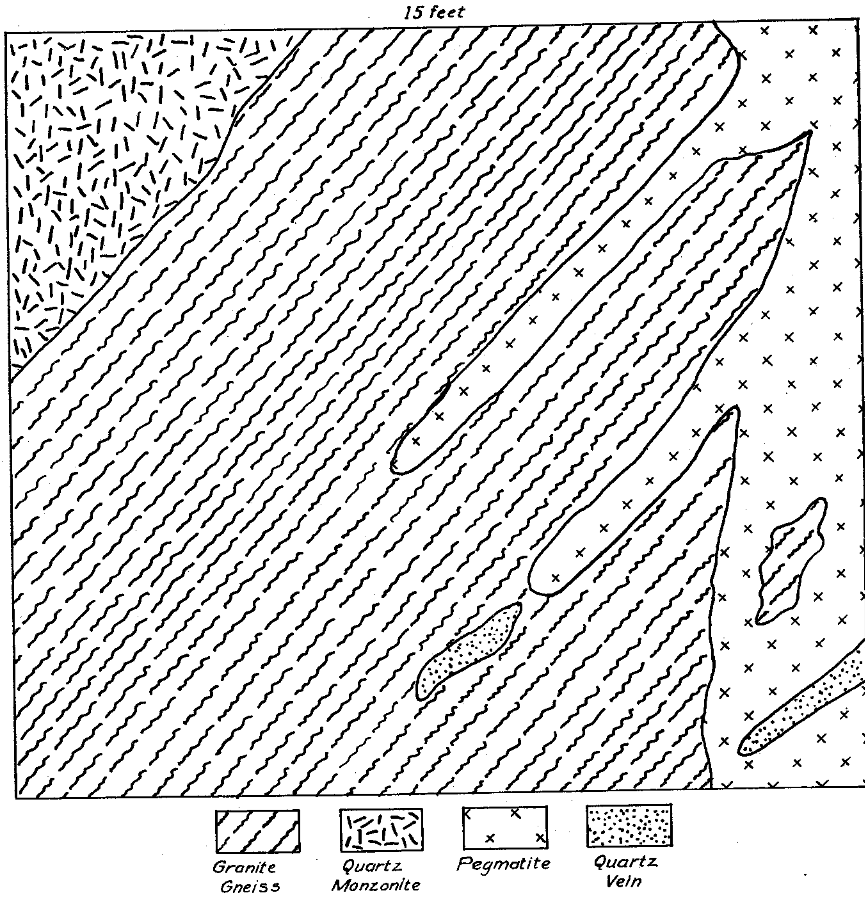


Figure 6. Relation of gneiss, quartz-monzonite, pegmatite and quartz veins near Falmouth.

scattered flakes. Zircon is present as a very few minute crystals. Tourmaline is found in minute crystals usually included in quartz.

This mineral composition, together with the texture, is characteristic of pegmatite. Tourmaline is an especially significant mineral in this connection. Although analyses are not available, the pegmatite is plainly much higher in silica than the parent rock, as shown by abundance of quartz and feldspars and smaller amounts of the ferromagnesian minerals.

PEGMATITE FROM THE STAFFORD STORE QUARTZ-MONZONITE

Occurrence.—On the marginal portions of the quartz-monzonite found around Stafford Store, dikes of pegmatite are extensively developed. These are seldom more than 1 foot in width and are not separately shown on the map. On the road from Davis Store to Rugby these dikes are numerous. They are found cutting the complex of basic rocks developed in this vicinity, but are clearly related to the quartz-monzonite and not to the basic series.

Megascopic characters.—These pegmatite dikes are relatively fine-grained. Very few of the individual crystals attain dimensions of one-half inch, much smaller sizes being the rule. The pegmatitic character, however, is established from the mineral content and the field relation of these dikes. The minerals recognized in the hand specimen are pink feldspar, quartz, and muscovite.

Microscopic character.—Under the microscope the rock is seen to be composed essentially of quartz and feldspar. The feldspar is both orthoclase and microcline with small amounts of albite. These occur in larger crystals. Quartz is of two generations, one contemporaneous with feldspar in large grains, the other later and interstitial in position. The quartz and feldspars are not graphically intergrown, though small areas suggest an irregular intergrowth. Muscovite is present as a few primary shreds and flakes, and more abundantly as sericite from the decomposition of the feldspars.

PEGMATITE FROM SOMERVILLE GRANITE

Occurrence.—Near the Franklin mine small dikes of pegmatite are occasionally encountered. These are usually too small to be represented on the map. At the fork of the roads just east of the Franklin mine, one such body is found. Its relation to the parent mass is seen when it is considered that the boundary of the main granite mass is only 300 yards distant. This dike is about 10 feet wide, entirely massive, and composed of quartz, feldspar, and muscovite. The texture is coarse, and graphic intergrowths can be seen even in the hand specimen.

APLITE DIKES

In many of the localities mentioned for pegmatites aplitic bodies are also developed. These are small and less abundant than the pegmatites. These rocks like the pegmatites are developed in such relations as to suggest that they were the last products of crystallization of the magma. They are apparently contemporaneous with pegmatites from the same rocks. In all cases they are fine-grained, and composed essentially of quartz, feldspar and muscovite. The difficulty of obtaining fresh material from these bodies renders complete descriptions of them impossible. They are encountered in the following localities:

(1) On road from Davis Store to Ruby derived from Stafford Store quartz-monzonite; (2) on P. F. & P. Railroad near Reynolds derived from Locust Grove granite; (3) on Bull Run derived from Occoquan granite.

IGNEOUS ROCKS OF TRIASSIC AGE

Certain dike rocks of diabasic nature occur throughout the district.

These are assigned to the Triassic, on the basis of correlation with similar rocks elsewhere in Virginia and other parts of the eastern United States.

DIABASE DIKES

Occurrence.—These rocks commonly known as "trap" rock are found to a limited extent over all of the district. They occur as narrow dikes and belong to the great series of Triassic dike rocks found cutting the older rocks over a large part of the Atlantic slope. In the area covered by this report these dikes are found cutting all rocks except those of the Coastal Plain.

The dikes vary in width from 1 foot to over 100 feet, and can be traced along the strike from a few feet to over a mile in exceptional cases. They usually conform to the structure of the region and, in many cases, also to the structure of the rocks which they intrude. In some cases, however, the dikes are found to cut across the foliation of the intruded schists. The strikes observed for the dikes are, with few exceptions, in the northeast quadrant.

Megascopic characters.—The diabases found within the area mapped vary in color from dark green to nearly black, and in texture from medium fine-grained to ophitic. In a majority of cases the texture is characteristically ophitic. In the occurrences where ophitic texture is not seen the mineral composition is quite different. The essential minerals of the diabase dikes are plagioclase feldspar (labradorite), augite, hornblende, and magnetite with or without olivine. Accessory minerals, usually secondary, are chlorite, limonite, serpentine, calcite, and biotite.

DETAILED OCCURRENCES

Below are listed details of the occurrences of the more prominent of these dikes, together with description of the types found. Undoubtedly there are more of these rocks in this region than listed here, but their small areal extent and depth of decay cause them to be overlooked.

Olivinitic diabase dikes.—Two olivinitic diabase dikes are found in the district: (1) On the Haymarket road south of Bristerberg 1 mile north of Town Run and (2) 1½ miles north of Germania Bridge. These dikes are 35 and 25 feet wide, respectively, with strikes of N. 10° E. and N. 30° E. The two bodies are of slightly different appearance in the hand specimen, but are much alike microscopically. The first is dark greenish gray in color with ophitic texture which can be seen by the unaided eye. The second is dark gray in color and is much finer grained.

Under the microscope these rocks are seen to consist of labradorite, augite, olivine, magnetite and serpentine. The feldspar is present in lath-shaped euhedral crystals. Augite is colorless anhedral, and is the second mineral in point of abundance. Olivine is a minor constituent largely altered to magnetite and serpentine. In many cases only a central unaltered portion of the olivine is left in a pseudomorph of serpentine. Magnetite is both primary and secondary. Augite and olivine together form a matrix in which the feldspars are imbedded, showing a marked ophitic development. Plate 4, B, shows the microscopic details of one of the diabase dikes.

Non-olivinitic diabase dikes. — These are much more abundant than olivinitic types and occur in many localities. One dike occurring 1 mile east of Parker on the P. F. & P. railroad will be described as typical also of the other occurrences listed below. This dike is 25 feet wide and stands nearly vertical in schist. Its strike is N. 30° E. The rock is dark gray in color with a very fine-grained texture. Under the microscope it is seen to contain labradorite, augite, magnetite, and chlorite. Labradorite is present in lath-shaped crystals imbedded in a matrix of augite. The augite is subhedral and exhibits a faint reddish color. A few intergrowths of this mineral with labradorite were observed. Magnetite is both primary and secondary, in the former case being the first mineral to form in the rock. Chlorite is entirely secondary. The texture is markedly ophitic.

Listed below are other occurrences of non-olivinitic diabase dikes together with brief notes concerning them.

1. One mile south of Mt. Holly at intersection of roads, 30 feet wide, strike N. 30° E.

2. Two miles south of Bristerberg, 35 feet wide, strike N. 10° E.

3. One-half mile north of Canova, 100 feet wide, strike N. 35° E. Contains a few shreds of biotite.

4. One-fourth mile east of Richards Ford, 25 feet wide, N. 45° E.

5. One mile southwest of Stafford Store, 60 feet wide, strike N. 30° E.

6. One-half mile east of Indiantown, 20 feet wide, strike N. 35° E. Much altered.

7. One-half mile west of Indiantown, 30 feet wide, strike N. 35° E.

8. One mile southeast of Melville mine, 50 feet wide, strike N. 30° E. Much altered.

9. One-fourth mile south of Vaucluse mine, 120 feet wide, strike N. 30° E. Much altered.

10. One and one-half miles west of Richardsville, 25 feet wide, strike N. 20° E.

11. One-half mile upstream from Martins Ford on Rappahannock River, 20 feet wide, strike N. 10° E. Much altered. Carries quartz and calcite.

12. Near Love Gold Mine, 75 feet wide, strike N. 32° E. Much altered.

13. Forks of road at Elk Run, 20 feet wide, strike N. 30° E.

14-15. One-third mile north of Franklin Mine. Two dikes 300 yards apart. (1) 60 feet wide, strike N. 40° E., (2) 25 feet wide, strike N. 20° E. Both much altered.

16. Near Coakley Post Office, 25 feet wide, strike N. 35° E.

17. One and one-fourth miles northeast of Buck Hall.

18. Two miles southwest of Clifton.

19. At Evans Ford on Bull Run, 300 feet wide, strike N. 45° E.

20. One-fourth mile west of Davis Ford on Occoquan Run, strike N. 15° E.

21. One mile above mouth of Wolf Run, strike N. 10° E.

22. On Occoquan Run one mile above Davis Ford.

METAMORPHIC ROCKS

Metamorphic rocks occur extensively throughout the area. They are of many kinds and have been derived from both igneous and sedimentary rocks. Granite-gneisses, schists of several types, arkosic quartzites, amphibolites and slates are among the types represented. These rocks range in age from pre-Cambrian through Cambrian to Ordovician. Only one group, the Quantico slates, can be assigned to a definite geologic age. This determination was made by Watson and Powell,[24] on fossil evidence, and admits of no question. All other bodies of metamorphic rocks, with the exception of soapstone which is of indeterminate age, are assigned indiscriminately to Cambrian or pre-Cambrian, since there is no trustworthy basis of separation. As far as possible the different types are divided as to the nature of the original rock, that is, igneous or sedimentary. In some cases it is impossible to state the nature of the original rock.

METAMORPHIC ROCKS OF IGNEOUS ORIGIN

Some of the metamorphic rocks in the district are of undoubted igneous origin. Among these may be mentioned gneiss once granite, greenstone which was originally basaltic in nature, amphibolite originally a basic dike rock, certain schists which resulted from the alteration of granites and soapstone originally basic igneous rock. These are discussed below.

FREDERICKSBURG GNEISS

Occurrence.—Embraced in an area extending as far as 8 miles south-

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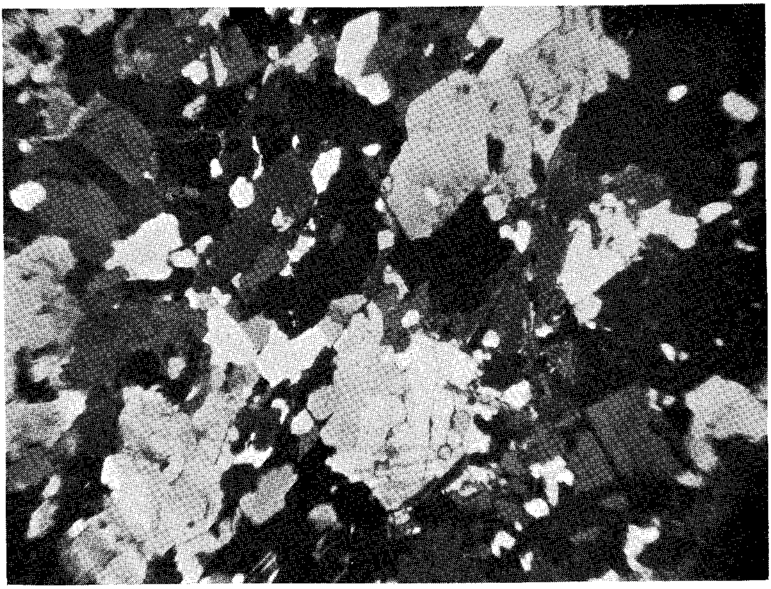
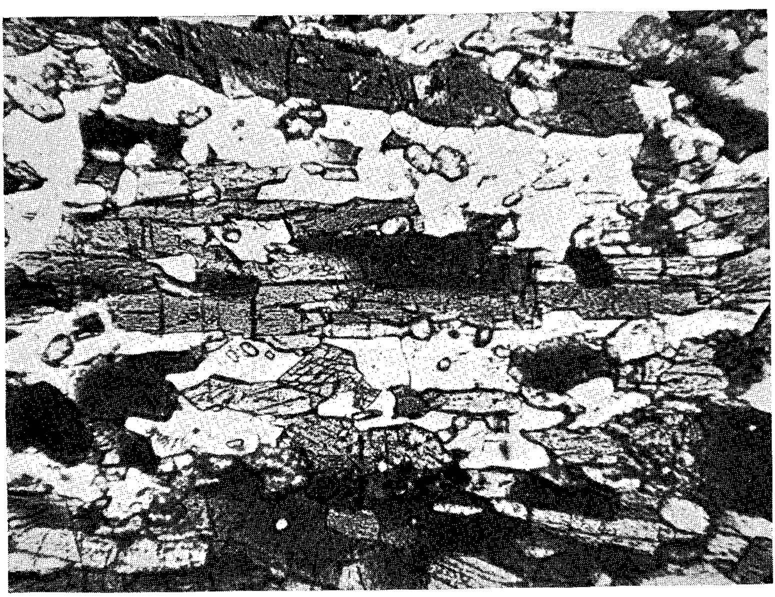
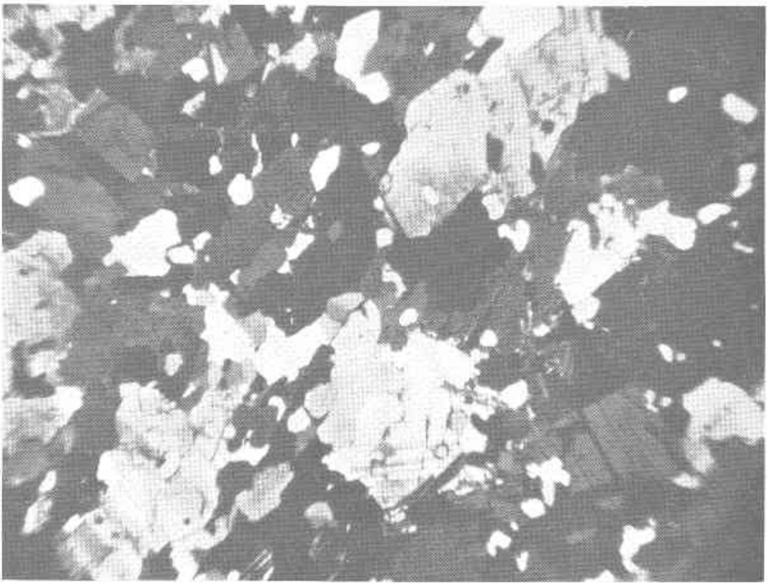
24. Watson, Thomas L. and Powell, S. L., Fossil evidence of the age of the Virginia Piedmont slates: Amer. Jour. Sci., 1911, vol. XXXI, pp. 33-44.



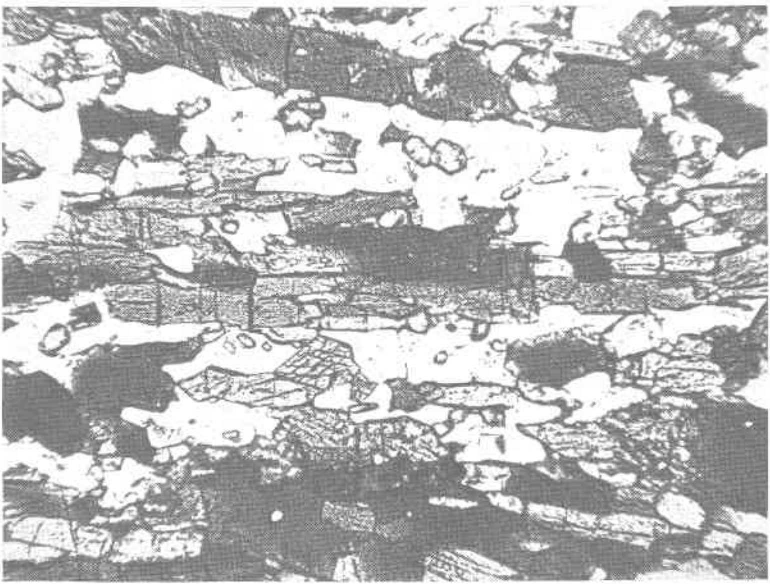
A. Fredericksburg gneiss from Cartwright and Davis quarry. Feldspar, biotite and quartz are the essential minerals. X 26 crossed nicols.



B. Gneiss from Motts Run. The light bands are quartz, the dark amphibole. X 46.



A. Fredericksburg gneiss from Cartwright and Davis quarry. Feldspar, biotite and quartz are the essential minerals. X 26 crossed nicols.



B. Gneiss from Motts Run. The light bands are quartz, the dark amphibole. X 46.

west and 8 miles northwest of Fredericksburg, the country rock to a large extent is granite-gneiss. The best exposures of the gneiss are found in the quarries northwest of Fredericksburg, in cuts along the P. F. & P. Railroad near Aldrich, on Motts Run northeast of Chancellorsville, and in the immediate vicinity of Hemp. This rock shows considerable variation from place to place and portions of it may possibly be of sedimentary origin.

Megascopic characters.—The greater portion of the rock is foliated or banded, in which one set of bands is composed of light colored minerals and the other of dark colored minerals. In general the light bands are wider than the dark, attaining in some cases widths of several millimeters. The minerals recognized in the hand specimen are quartz, biotite, feldspar, and hornblende. The rock, as typically developed, is distinctly coarse-grained. In the Motts Run locality a local phase of the rock is very much finer-grained, individual bands being less than a millimeter in width. The rock in this locality is dark greenish gray in color. In cuts on the P. F. & P. Railway near Aldrich, the gneiss is seen to be light gray in color because of larger portions of the light colored minerals, though its minerals and texture are identical with the gneiss of the Fredericksburg locality. Around Hemp the gneiss is light gray and highly siliceous. Plate 5 shows thin sections of the gneiss from near Fredericksburg and from the Motts Run locality.

Microscopic characters.—Under the microscope the rock is seen to contain the following minerals: Feldspar, quartz, hornblende, biotite, zircon, apatite, epidote, muscovite, magnetite, calcite, and titanite. The feldspar includes both orthoclase and plagioclase. Orthoclase is subordinate to plagioclase and occurs in irregular grains. Plagioclase is oligoclase near andesine showing polysynthetic twinning. Quartz is present in anhedral grains of very irregular outline often filled with minute inclusions, some of which are needle-like suggesting rutile. Biotite is present as brown strongly pleochroic flakes and shreds partly altered to chlorite and contains in places inclusions of apatite and zircon. The hornblende present in the rock is green and pleochroic exhibiting subhedral to euhedral development. There is considerable variation in the amount of this mineral, for in some specimens it is the principal mafic mineral, while in others it is subordinate in amount. Apatite and zircon are contained as inclusions in hornblende. Zircon occurs both as inclusions in biotite and hornblende, and interstitially in irregular grains in very small amounts. Apatite is present as a few prisms and grains. Epidote, while quite abundant in the rock, is secondary in origin, resulting from the alteration of the feldspars. Muscovite largely of secondary origin is present in a few shreds. A few grains of calcite, magnetite, and titanite are encountered and around Hemp garnet and pyrrhotite are also found in the rock.

The mafic minerals are arranged in bands alternating with the salic ones giving the foliated appearance so characteristic of the hand specimens. Crinkling and bending of the feldspars testify to the metamorphism undergone by the rock.

Chemical composition and classification. — The table below gives the chemical composition and norm of this rock as developed near Fredericksburg.

Chemical analysis of Fredericksburg gneiss
(W. M. THORNTON, JR., *Analyst.*)[25]

	Per cent
SiO_2	68.45
Al_2O_3	10.00
Fe_2O_3	5.71
FeO	2.59
MgO	3.26
CaO	6.20
Na_2O	1.98
K_2O	1.18
H_2O (comb.)	0.80
TiO_2	0.20
MnO	0.05
CO_2	Trace
P_2O_5	0.25
	100.67

Norm

Or	7.23	
Ab	16.77	
An	14.73	
Q	37.92	
Di	11.02	
Mt	7.66	
Hy	3.10	
Il	0.46	
Ap	0.67	
He	0.48	
MnO	.05	Not used
H_2O	.80	Not used
	100.89	

The feldspars as computed from the norms are given below.

Orthoclase	7.23	
Albite	16.77	
Anorthite	14.73	
Total plag.	31.50	
Total feldspar	38.73	
Ab_nAn_m ratio	1.13:1	= Andesine.
Or.-plag. ratio	1:4.3	

25. Washington, H. S., op. cit., p. 333.

The foregoing norm permits the following designation of the rock under the Quantitative System: [26]

II. 3. 3. 4.

Under the Qualitative System the original unaltered rock was probably close to a quartz-monzonite.

Geologic age.—This rock is the oldest unit in the Fredericksburg area. It is intruded by the massive quartz-monzonite of the region described elsewhere, and is probably older than many of the schists which occur to the west. These facts, together with the extensive dynamic metamorphism undergone by the rock, mark it as pre-Cambrian in age. More minute details as to its relations to other rocks of the area will be found under the discussion of pegmatites.

AMPHIBOLITE

Occurrence.—In the district four occurrences of amphibolite have been found. They have the form of dikes and have undergone considerable metamorphism. These amphibolite dikes are found (1) One-half mile east of Hemp outcropping across the Warrenton road for a width of 200 yards: (2) one-fourth mile west of Hemp extending from the Marsh road northeast through the Warrenton road with a width of 25 yards; (3) one mile northeast of Richardsville, and (4) two miles northeast of Germania Bridge, two miles northwest of Richardsville. In the last two localities the excessive tangle of underbrush combined with poor outcrops prohibits accurate delineation of the dikes.

Classification.—These rocks in each instance are amphibole quartz mixtures without feldspar. Hornblende is the most prominent mineral and most of the quartz is secondary. Such circumstances render it difficult to place definitely the origin of these rocks. As far as composition is concerned, they may have been derived from either sedimentary or igneous sources. The form of the body in each case is dike-like, which suggests that they were probably of igneous origin. The four separate bodies are briefly described below. The two near Hemp are apparently identical, and will be described together.

AMPHIBOLITES NEAR HEMP

Megascopic characters.—The amphibolite bodies near Hemp are dark grayish green rocks of fine-grained texture. They are jointed and foliated to a considerable extent. The foliation is in the structure of the region, and while its effect is marked in all weathered specimens, some fresh material appears essentially massive. There has been apparent differential action in this respect, for variation is seen across the strike of

26. Idem.

the rock body. Some areas are highly foliated, while others are essentially massive.

Microscopic characters.—The minerals identified in the amphibolites near Hemp are hornblende, quartz, biotite, magnetite, epidote, pyrite, and hematite.

Hornblende is the most abundant mineral and occurs in green to bluish green slender crystals exhibiting strong pleochroism. Definite orientation of hornblende crystals is lacking though a tendency in this direction is observed. Quartz is next to hornblende in abundance. The two minerals constitute over 90 per cent of the rock as it now exists. This mineral is present in small anhedral grains arranged imperfectly in bands to correspond with the rough orientation of the hornblende. Much if not all of the quartz is believed to be secondary in origin. Biotite is found in an exceedingly few scattered flakes. Magnetite is present in scattered grains, mostly developed from the alteration of hornblende. In a few cases this mineral has altered to hematite. Epidote, secondary in origin, is present to a limited extent. A few scattered grains of pyrite encountered in the rock were introduced into the rock subsequent to its formation.

AMPHIBOLITES NEAR RICHARDSVILLE

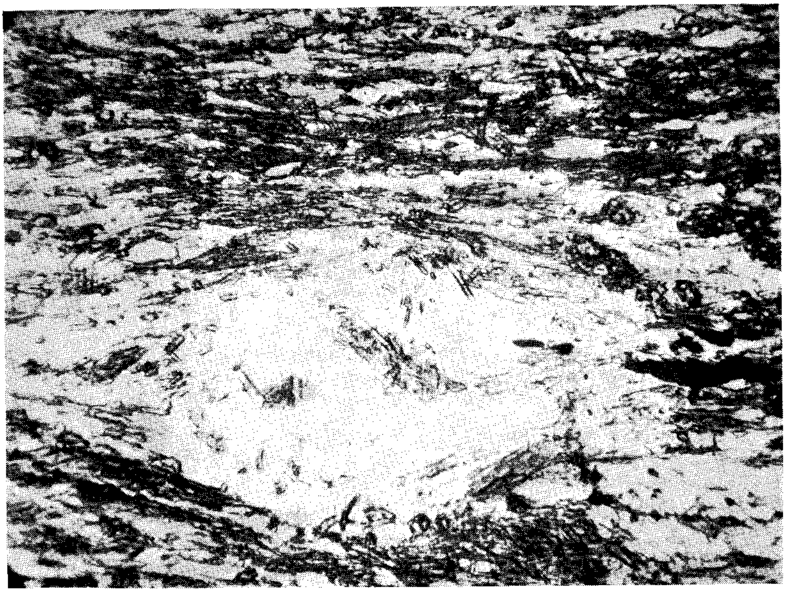
Megascopic characters.—The two bodies of amphibolite northwest and northeast of Richardsville differ from those already described mainly in texture. They are coarser grained being in some cases fairly coarse-grained. A "salt and pepper" effect is produced in these rocks through contrast of areas of quartz with those of hornblende.

Microscopic characters.—The microscopic features of the rocks are essentially the same as in the bodies previously described. Hornblende and quartz are the essential minerals with very few accessories other than secondary ones. Titaniferous magnetite is present in these bodies, as shown by the development of leucoxenitic borders about the grains of this mineral.

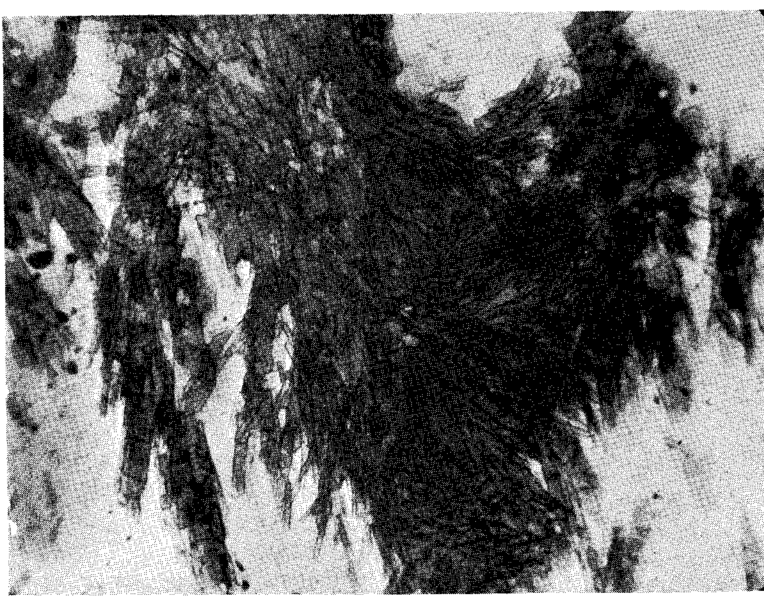
Geologic age.—The age of the amphibolites can not be definitely stated. They are apparently younger than the inclosing rocks, since probably the amphibolites were originally dikes which intruded these rocks. The rocks cut are crystalline schists and gneisses which are generally referred to pre-Cambrian or Cambrian age. The amphibolitic bodies, in the absence of conclusive evidence, are assigned to undivided pre-Cambrian and Cambrian.

GREENSTONE SCHIST

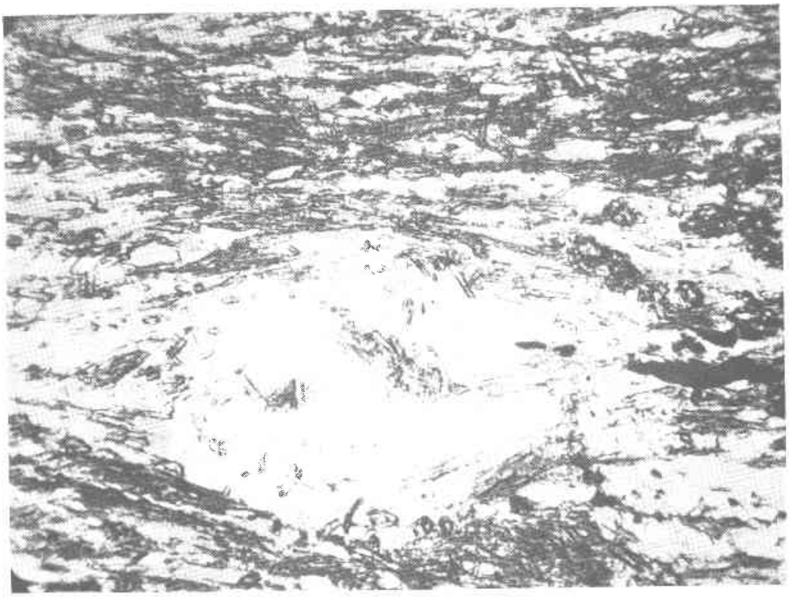
Occurrence.—In certain parts of the district there occur areas of greenstone schists. These differ so widely from the other rocks with which they are associated, that a separate legend is used to represent them on



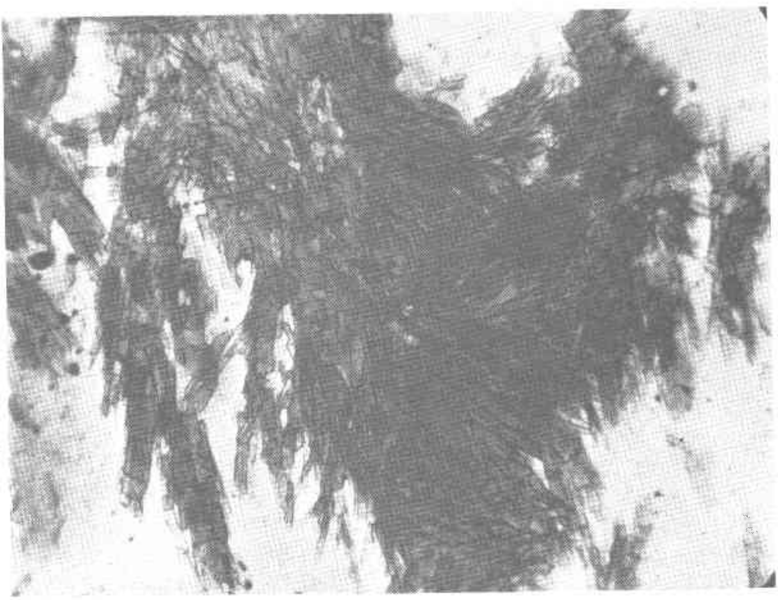
A. Greenstone schist from near Dumfries. The lighter colored body in the center of the field is a quartz eye. X 82.



B. Plumose chlorite from the schist at the Garrisonville pyrite mine. X 82.



A. Greenstone schist from near Dumfries. The lighter colored body in the center of the field is a quartz eye. X 82.



B. Plumose chlorite from the schist at the Garrisonville pyrite mine. X 82.

the map. These rocks are well exposed near the Cabin Branch mine at Dumfries, a short distance northeast of Garrisonville, at Kellogs Mill and at Burr Hill. Although there is some variation in these rocks among the localities mentioned, in general they are quite similar in character and occurrence.

Description.—The greenstone schists are very finely foliated and very fine-grained in texture. In fresh exposures a massive appearance is characteristic, but weathered specimens show the foliation in a striking fashion. Just east of the Cabin Branch mine, near Dumfries, the bed of Quantico Creek is made of the greenstone. Plate 9, A, shows the exposure at this place. Here prominent ledges abound showing to all appearances a dense igneous rock. Close examination, however, shows foliation, the strike of which varies from N. 20° E. to N. 50° E., while the dip is from vertical to 80° W. They are thus seen to be steeply dipping, closely folded rocks, conforming to the general structure of the country.

In color these rocks are a dark uniform green, though the bodies at Dumfries and Kellogs Mill show some lighter areas which resemble amygdaloidal cavities of basalt. The greenstones consist of hornblende, quartz, chlorite, epidote, zoisite, feldspar, and magnetite, with a part of the quartz secondary in origin. The ultimate origin of these rocks was very probably igneous and of basaltic type, since there are remnants of igneous rocks present. Plate 6, A, shows a thin section of the greenstone from Dumfries.

Geologic age.—The age of the greenstone is probably pre-Cambrian. In many parts of Virginia bodies of greenstone are found and are generally assigned to Algonkian age. The close similarity of these bodies to the greenstone developed in this district suggests the same age. In this district there is no definite evidence upon which to determine the age of the rocks. They are associated with schists of various ages and with much younger granites.

SOAPSTONE

Occurrence.—In three areas within the district small bodies of soapstone have been located. Their occurrences are: (1) One mile northeast of Verdiersville; (2) two miles northeast of Verdiersville; and (3) one-half mile southeast of Indiantown on Rapidan River. The total area involved in the three occurrences is less than 1 square mile. At the Indiantown occurrence, the inclosing rock is schist, while at the other two occurrences it is diorite. The two bodies near Verdiersville have been worked for soapstone in the past, but at Indiantown only a little prospecting has been done.

These bodies of soapstone occur in the form of dikes or lenses. The relations to the surrounding rocks are not always clear, but at Verdiersville the form and shape are typical of a dike, that is, narrow slender bodies. At the old workings of these deposits, excellent exposures show the relation of the deposit to the inclosing rocks. The soapstone is not homogeneous throughout, but alternates to a greater or less degree with chloritic bands. In the portions of the deposit which are predominantly soapstone, the rock is massive gray in color with a very fine-grained texture. In the majority of specimens the rock is a mixture of talc and calcite, with small amounts of magnetite and scattered grains of pyrite. The rock is soft and is easily worked into the various shapes demanded by the trade.

Origin.—In the borders of the deposit and in certain of the quarry faces at Verdiersville, the rock is seen to differ from the above description. In some instances a gradation from the soapstone to this bordering rock can be traced. It is believed that the soapstone has originated from the alteration of this rock. The igneous rock may represent true dikes in the diorite mass, or may be more basic portions of the diorite itself. The last condition seems probable since the soapstone bodies are surrounded by diorite. One type of the original rock, intermediate between the soapstone, is dark bluish-green in color, altered extensively to talc and chlorite but showing an original igneous texture and a few feldspar crystals. Other specimens correspond more closely to either the soapstone or original rock. Fresh specimens of the original rock were not obtained, but from the partially altered specimens it seems probable that the original rock was a peridotite composed chiefly of magnesian silicates, with feldspar in subordinate amounts. In part the alteration produced chlorite rather than soapstone, since contemporaneous with the soapstone are large areas of almost pure chlorite-bearing schistose rock.

Mineralization.—In the Verdiersville deposits a certain amount of mineralization has occurred since the formation of the soapstone. There are numerous small veins found in many of the quarry faces. These have filled fissures in the soapstone, but have also to a certain extent replaced the soapstone. These veins are of two types. One is composed of magnetite and calcite, in which magnetite occupies the walls and calcite the center of the fissure. The other type consists of calcite, siderite, and talc. In this case calcite and siderite occupy the center of the fissure, with talc developed on either wall. The talc is highly foliated crystalline in character and is arranged with its cleavage perpendicular to the fissure wall. This mineralization subsequent to the formation of the soapstone is of a type not produced by surface or descending solutions. The presence of magnetite indicates that hot solutions formed the veins. The presence of a younger granite near by suggests that the solutions had their origin from that body. Both types of veins are small never exceeding a few inches in width, but destroying the value of considerable areas of soapstone by their presence.

Indiantown occurrence.—The deposit at Indiantown is not well exposed. Only the surface part of the deposit could be observed, which corresponded to the Verdiersville deposits but was in general more highly foliated. Certain specimens cut from this rock, however, are practically identical with the Verdiersville rock.

Geologic age.—The age of these soapstone bodies is uncertain. The igneous bodies from which the soapstones were derived intrude Cambrian or pre-Cambrian rocks. The age of the formation of the soapstone from these intrusive rocks can not be stated.

BIOTITE-QUARTZ FELDSPAR SCHIST

Occurrence.—At the Wilderness mine one-fourth mile northeast of Wilderness Post Office, the wall rock of the mine is a schist of igneous origin. Its areal extent can not be determined, for good outcrops do not exist. The field relations suggest that this occurrence is a part of a deeply buried igneous mass whose covering of sedimentary schists has been removed by erosion. The strike of its foliation is N. 28° E. and the dip is 82° to the eastward.

Megascopic characters.—This rock is dark gray in color and finely foliated. Quartz is recognized in the hand specimen but other minerals, with the exception of pyrite, are too small to be identified. The pyrite occurs as disseminated crystals.

Microscopic characters.—Under the microscope this rock is seen to contain feldspar, quartz, biotite, chlorite, calcite, pyrite, and magnetite in the order of abundance as listed.

Feldspar is the most prominent mineral present. It is predominantly of the orthoclase variety, and occurs in such relations with quartz and biotite as to suggest an original igneous texture. A few grains are found in which the feldspar is graphically intergrown with quartz. Quartz is subordinate to feldspar in amount and occurs in irregular grains. Biotite is present in numerous shreds and flakes, a few of which are altered to chlorite. Calcite is present in a very few scattered grains as the alteration of feldspar. Magnetite and pyrite occur as scattered grains formed subsequent to the mass of the rock. The presence of graphic intergrowths, together with the relations of the minerals present, seems to establish this rock as the metamorphic equivalent of a granitic igneous rock.

Geologic age.—This rock can be assigned only to the pre-Cambrian. Its great metamorphism and relations to the other rocks of the district suggest this conclusion.

METAMORPHIC ROCKS OF SEDIMENTARY ORIGIN

INTRODUCTION

In addition to those already described, there are extensive areas of metamorphic rocks in the district, which were derived originally from sedimentary rocks. These include crystalline schists of several varieties, arkosic quartzites, and slates. Of these the schists are most abundant and alone occur over an area greater than 300 square miles. These metamorphic rocks belong in geologic age either to the undifferentiated Cambrian and pre-Cambrian or to the Ordovician. Only the Quantico slates are positively known to be of the latter age. Structurally, all of these rocks occur under similar conditions. They are tightly folded, highly foliated, and occur in belts in a northeast-southwest direction.

SCHISTS

As stated above crystalline schists are extensively developed in the area. They form a complex into which the various younger igneous masses have been intruded. Throughout the region in which these rocks occur, extensive areas are found in which good rock exposures do not exist. Only in favored localities, as for example, stream beds or mines, is fresh material obtainable. As a consequence it is possible that varieties of schist other than those described here occur in the district. The commonest and most abundant types are the ones listed here. They include: (1) Quartz schists with biotite and feldspar, (2) hornblende quartz schists often with chlorite, (3) sericite quartz schists often with chlorite or epidote, and (4) garnetiferous quartz schists with biotite.

QUARTZ SCHIST WITH BIOTITE AND FELDSPAR

Occurrence.—At a number of localities in the district, the schist developed is characterized as being high in quartz with noteworthy amounts of biotite and feldspar. Exposures of this type of rock are especially well developed (1) on La Rogue Run near Doswell Chapel in Spotsylvania County, (2) at Missouri Mills 2 miles south of Joplin Post Office, (3) on Austin Run one-half mile southeast of the Austin Run mine, and (4) on Neapsco Run 3 miles west of the Richmond-Washington Highway. These are the best developed occurrences, but other areas of quite similar rocks are known. At Rogers Ford the rock is of this type.

Megascopic characters.—The rocks from those widely separated localities exhibit a general similarity in appearance, though differing in minor details. All are dark gray finely foliated rocks in which quartz is the major constituent. Biotite is variable in amount being very slightly developed at La Rogue Run, while quite pronounced in specimens from Neapsco Run. Feldspar is not identified in the hand specimen.

Microscopic characters.—The mineral assemblage found in these rocks under the microscope corresponds closely in the different localities. The minerals present are quartz, biotite, feldspar, chlorite, garnet, zircon, calcite, apatite, magnetite, pyrite, epidote, and hornblende. Only the first three are present in all specimens in noteworthy amounts. Feldspar, quartz, and biotite are invariably present in such amounts and relations as to suggest the sedimentary origin of the rock. In a few cases the feldspar has been recrystallized as metacrysts around which the foliation has been adjusted.

Chlorite and calcite are secondary in origin, the first derived from biotite, the second from feldspar. Garnet is a minor constituent not present in sufficient amounts to qualify the classification of the rock. It is present in anhedral grains. Zircon, apatite, and magnetite, for the most part, are residuals which were in the original rock and have been carried over into the metamorphic product. They are slightly developed. Some magnetite is of a later origin related to the mineralization of the district. Pyrite is variable in amount and, in most cases, is a subsequent mineral.

Structure.—These schists conform to the general structure of the region. At La Rogue Run the strike is N. 10° E., at the Austin Run occurrence it is N. 33° E., dip 50° E., and at Missouri Mills N. 25° E., with a vertical dip.

Geologic age.—On the basis of lithologic character and structure, these rocks can not be grouped later than Cambrian in age and may be pre-Cambrian.

HORNBLENDE QUARTZ SCHISTS OFTEN WITH CHLORITE

Occurrence.—Rocks which are essentially hornblende quartz schists with minor constituents are found in four localities in the district: (1) At the Austin Run mine, (2) 2 miles northeast of Locust Grove, and (3) on Bull Run at Evans Ford. At the Austin Run mine the wall rock is schist of this description, varying however in hornblende content. The Locust Grove occurrence is not well exposed and little is known of its exact character. On Bull Run an extensive development of this rock is found, but it is of a slightly different character from those already mentioned.

Megascopic characters.—These rocks are greenish gray to dark green in color and are foliated with variation in the degree of foliation. The specimens from the immediate wall rock at the Austin Run mine show lenses of quartz interleaved with darker hornblendic material. Specimens at a distance from the ore deposit show hornblende arranged in plumose aggregates and a diminution in the amount of quartz. The specimens from near Locust Grove are dark green in color, high in hornblende and chlorite, and carry visible crystals of magnetite. The Bull Run development corresponds more closely to a phyllite than to schist. It is dark greenish gray in color, shows highly developed foliation, and possesses good slaty cleavage.

Microscopic characters.—As among previously described types, variation in the mineral composition exists, but their correspondence as a whole to the type indicated is quite close. The minerals found in these schists are quartz, hornblende, chlorite, epidote, magnetite, zoisite, and pyrite. Quartz, hornblende, and chlorite are the main constituents of the rock. In most specimens quartz is abundant found as grains of various sizes. A fine mosaic is typical of large areas of the slides. Though variable, quartz is the most prominent mineral. Hornblende is present either as small perfectly oriented crystals, alternating with quartz, or as plumose aggregates also perfectly oriented in one plane. Chlorite is secondary after hornblende. Epidote and zoisite are sparingly present and are alteration products from other minerals. Magnetite and pyrite are in most cases younger in age than the mass of the rock. In the specimens from the Austin Run mine pyrite is abundant, but is a part of the mineralization of the ore deposit. A thin section of hornblende largely altered to plumose chlorite is shown in plate 6, B.

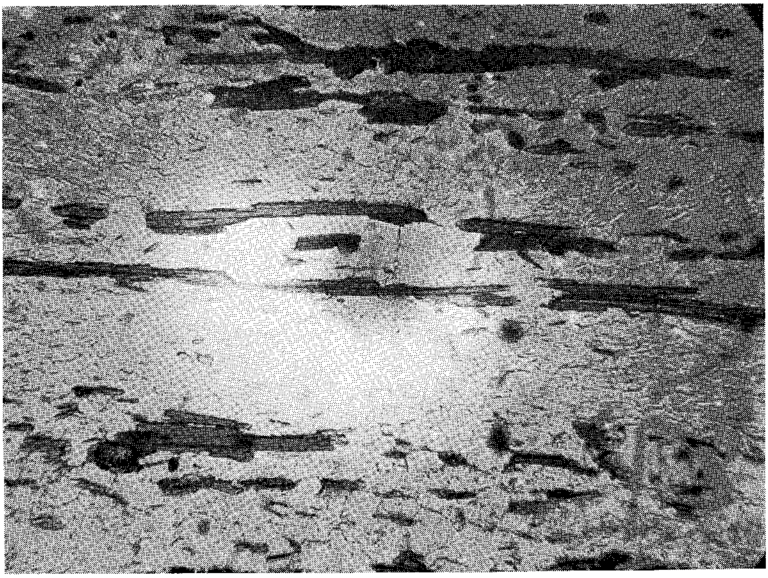
Structure.—The following strikes and dips have been determined for these rocks: Austin Run mine, N. 33° E., dip vertical; Bull Run, N. 30° E., dip 75° W.

SERICITE QUARTZ SCHISTS OFTEN WITH EPIDOTE AND CHLORITE

Occurrence.—Quartz schists, characterized by the presence of sericite, and often epidote and chlorite occur at several localities in the district. Along Rapidan River west of Richardsville and at the mines near Richardsville, this type of schist is predominant. At Wolf Run Shoals west of Occoquan there is also an extensive development of this type. It is likely that at many places, where only weathered material can be obtained, this type of schist prevails. Much of this weathered material shows the presence of sericite and quartz and, while the complete mineral assemblage can not be stated, it seems probable that many such areas of schist also belong to the sericitic quartz variety.

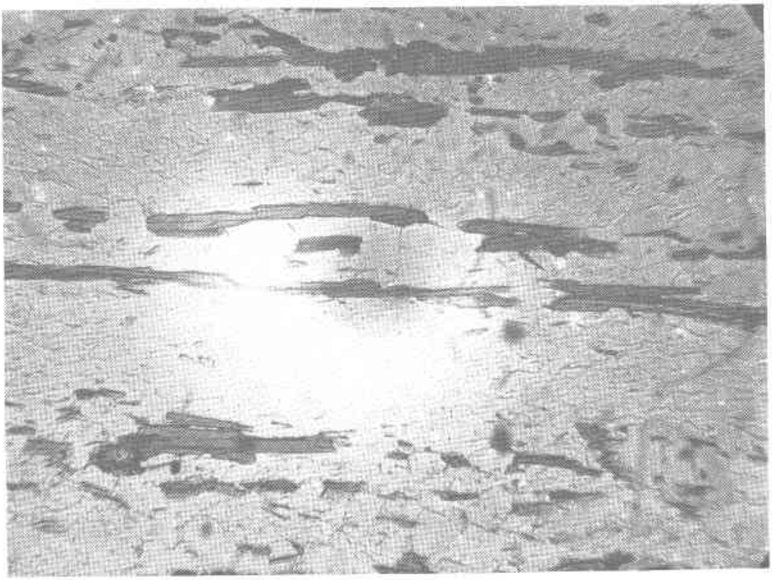
Megascopic characters.—Fresh unweathered specimens of these schists are dark gray in color, sometimes exhibiting a greenish cast. From these colors they grade in weathered material to light grays, finally resulting in red clays and soils carrying flakes of mica. The texture for the most part is foliated conforming to true schist, but some specimens approach banded arkoses or quartzites. Near Richardsville, and again near Sumerduck, rocks which are included here as schists of this type show some characters of arkoses, but of finely banded arkoses. These, however, grade laterally into true sericitic quartz schists and will be included here.

Microscopic characters.—A microscopic study of these rock reveals the presence of quartz, sericite, biotite, chlorite, calcite, epidote, zircon, pyrite, and magnetite. These are variable in amounts in different specimens, and

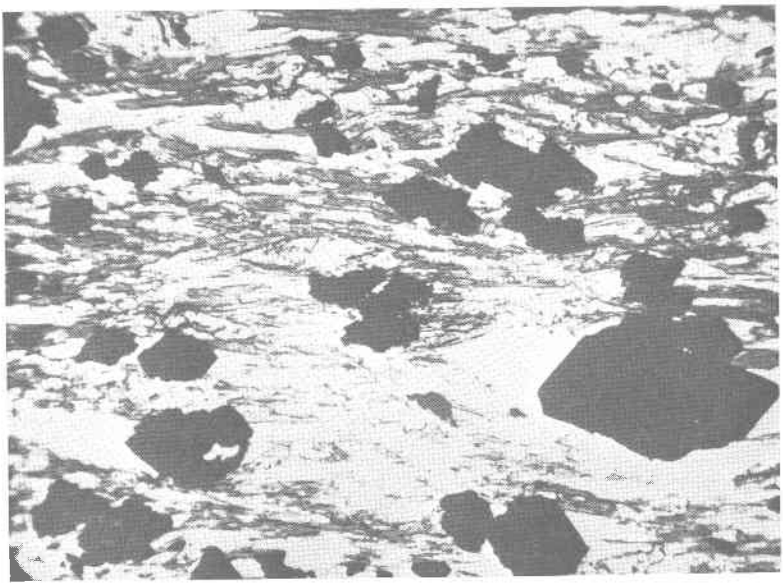


A. Quartz sericite schist from Missouri Mills. The schistose structure is well shown. X 82.

B. Hornblende quartz schist from the Embry mine. The black minerals are pyrite replacing hornblende and quartz. X 82.



A. Quartz sericite schist from Missouri Mills. The schistose structure is well shown. X 82.



B. Hornblende quartz schist from the Embry mine. The black minerals are pyrite replacing hornblende and quartz. X 82.

in some cases all are not present. The assemblage, however, is characteristically of the sericitic quartz type. Variation in texture is shown in the thin sections. Some specimens are highly and perfectly foliated, while others show this feature less perfectly. Quartz is the most abundant mineral and is arranged in definite bands separated by bands of the other constituents. Sericite, biotite, and chlorite form alternating bands with quartz in which their orientation in many cases is perfect. These are variable in relative amounts. Calcite and epidote vary in amount and probably represent alteration of small amounts of feldspar once present in the rocks. In the case of the specimens from the Embry mine calcite is very abundant, but is a part of the mineralization of the mine. Zircon is present in only a few scattered grains. Magnetite and pyrite vary in amount in these rocks. In specimens taken near mines they reach considerable proportions of the rock, but are usually subsequent in age to the formation of the rock. In some of these specimens the magnetite is the alteration product of pyrite. A small amount of magnetite is found as a residual mineral carried over into the metamorphic rock. The high amounts of quartz and the texture mark these rocks as being originally sediments which have undergone metamorphism. Sections of quartz schists are shown in Plate 7.

Structure.—The structure of these sericitic quartz schists is the same as those already described. Strikes are in the northeast quadrant averaging about N. 35° E., while dips range from vertical to 45° to the east.

Geologic age.—On the same basis as the schist already considered, these must also be assigned to undifferentiated pre-Cambrian and Cambrian in age.

GARNETIFEROUS QUARTZ SCHISTS

Occurrence.—At the Eagle mine in Stafford County the wall rock is schist in which garnet is a prominent constituent. Other localities show also the development of this type, but in only minor amounts.

Megascopic characters.—This rock in fresh specimens is dark gray, almost black, in color, with a very finely developed foliation. Weathered materials are of greenish gray color. Quartz and garnet are recognized in the hand specimen.

Microscopic characters.—The minerals found in this type of schist are quartz, biotite, garnet, hornblende, magnetite, and tourmaline. Quartz is the predominant mineral, arranged in bands in which the grains of the mineral are of differing sizes. Biotite occurs as scattered flakes, but is fairly abundant. Garnet is abundant in large anhedral reddish crystals. Hornblende is present only as a few scattered grains. Magnetite is seen as irregular grains. An occasional crystal of bluish pleochroic tourmaline is found.

MINOR VARIETIES

In addition to the schists which can be placed in the classification given above, there are some which differ quite widely and which merit special mention. Near Doswell Union Chapel, for example, the rock is characterized by quartz, feldspar, chlorite, and epidote. Feldspar and epidote are raised to a prominence not found in other schists of the district. Outwardly this schist appears very similar to others and actually differs from them only in the proportions of the minerals present. In a similar fashion some of the rock found at the Cabin Branch mine differs from the listed types. These variations are not deemed of sufficient importance to warrant separate classification. It must be borne in mind that the foliated rocks of sedimentary origin may vary as the sediments from which they came varied in composition. To list and describe every variation as a separate type of rock is beyond the scope of this report.

ARKOSIC QUARTZITE (FELDSPATHIC)

In two areas in this district exposures of arkosic quartzites are found. Both are of slight extent and represent lenses of this material interbedded with the crystalline schists. One area is at Indiantown in Orange County, while the other is on Neapsco Run in Prince William County 1½ miles upstream from the Richmond-Washington Highway. The two occurrences are described below.

INDIANTOWN

Occurrence.—The occurrence at Indiantown is restricted to the rather deep valley of Russell Run in the immediate vicinity of the village. Here this rock is found in bold bluffs and ledges traceable one-half mile upstream from the village. The width of the exposure, on an average, is 300 yards. On either side the inclosing rock is quartz sericite schist, to the structure of which the quartzite conforms. The strike of the quartzite rock is N. 40°-45° E., and the dip is essentially vertical.

Megascopic characters.—The greater part of this rock is a medium gray, fine-grained, foliated material. Quartz and feldspar are recognized, but present in small grains. Scattered through the exposure are small bands in which the minerals are of greater size. These are distinctly foliated, but their similar character is evident at a glance. Quartz and feldspar grains constitute the greater part of this type, and even in the hand specimen these minerals are seen to be flattened and elongated parallel to the foliation of the rock. The maximum size of the grains is slightly less than one-eighth inch. A considerable proportion of the quartz grains are of a blue color.

Microscopic characters.—Under the microscope the rock is seen to be foliated with alternating bands of unlike minerals. Quartz is the most abundant mineral present and, with very small amounts of feldspar, constitutes one series of bands. Sericite and biotite, the latter altered to chlorite, constitute a second series of bands which alternate with the first. These are subordinate in amount to quartz. Scattered grains of magnetite, zircon, and apatite are found throughout the rock. In places the alteration of feldspar has produced grains of epidote and calcite.

Structural features.—This rock has been subjected to considerable pressure effects shown in the flattening of the minerals in the rock in a common plane which has resulted in well developed foliation. In addition to these generally observed effects, there are evidences of folding within the mass itself. Below the dam at Indiantown beds or layers of the coarser quartzite were observed less than 2 feet wide in which smaller divisions a few inches wide would be distinctly folded or crenulated. This effect faded out laterally into bands with essentially straight boundaries. Apparently the smaller folded bed was less competent to withstand pressure, and alone suffered minor folding not seen in the mass as a whole.

Geologic age.—The age of this arkosic quartzite is either Cambrian or pre-Cambrian. Interfolded with schists it corresponds to them in age but, since the schists can not be assigned to a definite geologic age, the quartzite must also share in this relation.

NEAPSCO RUN

Occurrence.—On Neapsco Run, 1½ miles above the point where this stream is crossed by the Richmond-Washington Highway, there occurs a lens-like body of arkosic quartzite. The measured outcrop of this rock is 300 yards wide and of unknown length. There is reason to believe that the width of the exposure does not cover the total exposure of this rock, since the borders of the exposure are marked by decay.

Megascopic characters.—The rock is dark gray in color, with a fairly fine-grained texture. It is distinctly foliated with darker minerals concentrated into bands alternating with those composed of lighter colored ones. Quartz, feldspar, and biotite are recognizable in the hand specimen. The biotite occupies definite bands and is of uniform granularity, but quartz occurs to a certain extent as metacrysts exceeding one-eighth inch in diameter and possessing in some cases a characteristic blue color. The fact that these quartz grains are rounded attests their clastic origin.

Microscopic characters.—Under the microscope this rock is seen to consist of quartz, feldspar, and biotite with a few accessory minor constituents. Quartz is the most abundant mineral and is present in fairly large grains most of which exhibit strain effects. Some smaller individuals appear to have resulted from recrystallization during pressure and are free from anomalies. The quartz grains are roughly arranged in bands with feldspar. The feldspar in most crystals is extensively altered to calcite and epidote. It is present in crystals of even greater magnitude than quartz and, like quartz, seems in most cases to be residual in the rock and to have undergone pressure. Certain feldspar grains fail in the orientation and have apparently been recrystallized to their present condition of metacrysts. Biotite is the third mineral in importance in the rock and occurs in numerous flakes and shreds. This mineral exhibits a definite orientation and collection into bands or foliæ. Chlorite has developed to a slight extent as an alteration of this mineral. Calcite and epidote are abundant, being the alteration products of feldspar. Zircon and apatite are present in an exceedingly small number of minute grains and crystals.

Classification.—The high quartz content and the presence of apparently clastic quartz mark this rock as sedimentary in origin. It contains large amounts of feldspar, but the feldspars are considered to be residual in nature. Their presence suggests that the original sediment from which this rock was derived was an arkose.

QUANTICO SLATE

Occurrence.—In certain parts of the district a discontinuous belt of carbonaceous slates of Ordovician age occurs. Good exposures of these rocks are found on Occoquan Creek, on Neapsco Creek, on Powells Creek, on Quantico Creek, on Potomac Run, on Wilderness Run south of Wilderness Post Office, at Chancellorsville, at the Graphite mine northeast of Chancellorsville, and at Brock Road beyond the southern boundary of the district. Streams which flow across the strike of the rocks furnish the best exposures and the majority of the above occurrences are of this type. These slates were named by Darton [27] after Quantico Creek in Prince William County. They occur as a discontinuous belt running for 40 miles in a northeast-southwest direction, and rarely exceeding 1 mile in width. In many localities in the northern part of the belt, Cretaceous sedimentary rocks cover the slates resulting in discontinuous outcrops. The Quantico slate is in contact with the Cretaceous sedimentary rocks or with the older crystalline rocks. In the Dumfries section and others, the slates are in sharp contact on the west with greenstone, but in other places the contact rock is mica schist.

Geologic age.—The age of the Quantico slate can be placed as Ordovician (Cincinnatian). This was determined by Watson and Powell [28] in 1911, on the basis of fossils found in the Powells Creek section. These investigators were also able definitely to correlate the Quantico slate with the slates of the Arvonia district.

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27. Darton, N. H., Folio No. 13, U. S. Geol. Survey, 1894, p. 4.
28. Watson, Thomas L., and Powell, S. L., Fossil evidence of the age of the Virginia Piedmont slates: Amer. Jour. Sci. 1917, ser. IV, vol. XXXI, pp. 33-44.

With two exceptions, the exposures of slate found in the district covered by this report lie in the same strike and structure. Fossils were found by Watson and Powell only in the Powells Creek section, but the areal location and structural relations existing between the several occurrences establish beyond question that most of the areas of slate mapped as Quantico are to be correlated with the Powells Creek section. Two small areas of graphitic slate at Chancellorsville and at the Graphite mine are located in positions slightly out of the prevalent structure of the belt. These occurrences are located a few miles to the east of the main belt, but in a parallel position. Based on lithologic character, it seems probable that these areas are also to be correlated with the Quantico slate. It is possible that faulting has accounted for their present position.

Description.—Considerable variation exists in the material found in the slates. A large part is undoubtedly of terrigenous nature, but considerable thicknesses of pyroclastic material have also been identified. In certain sections, also, dikes of igneous rock are found conforming to the structure of the slate. Large portions of the slate are characterized by the presence of graphite. In the section at Dumfries, graphite is reported as representing 3 per cent of the total composition of the rock, and an attempt was made to mine the mineral. The graphite-rich phases of the slate are black in color, exceedingly fine-grained, and very thinly foliated. Occurrences of this type of the slate are also well developed on Powells Creek and near Agnewville. Lenses and pockets of pyrite found at this last locality were prospected, but without success. Pyrite is a common mineral in many occurrences, but no workable deposits of this mineral have been found in the slate. The highly graphitic type of slate grades insensibly into one carrying less graphite and of coarser grain, resembling phyllite or fine-grained schist.

In many of the sections there are beds or layers of much lighter color than the graphitic type and, though altered, their pyroclastic nature is evident. The presence of unchanged or slightly altered glass in thin sections shows the nature of these beds.

Microscopic characters.—Thin sections of the non-graphitic slate showed quartz, sericite, chlorite, and zircon. Graphitic specimens show essentially the same minerals with the admixture of graphite. Watson and Powell [29] also identified altered rhyolite interbedded with the slate. This rock contained quartz, sericite, biotite, chlorite, magnetite, tourmaline, apatite, zircon, and glass. Just east of the railroad bridge over Occoquan Run is a small body of this character.

Structure.—The structure of the Quantico slate conforms to the structure of the older crystalline rocks of the district. In general the strike

29. Watson, Thomas L., and Powell, S. L., op. cit., p. 40.

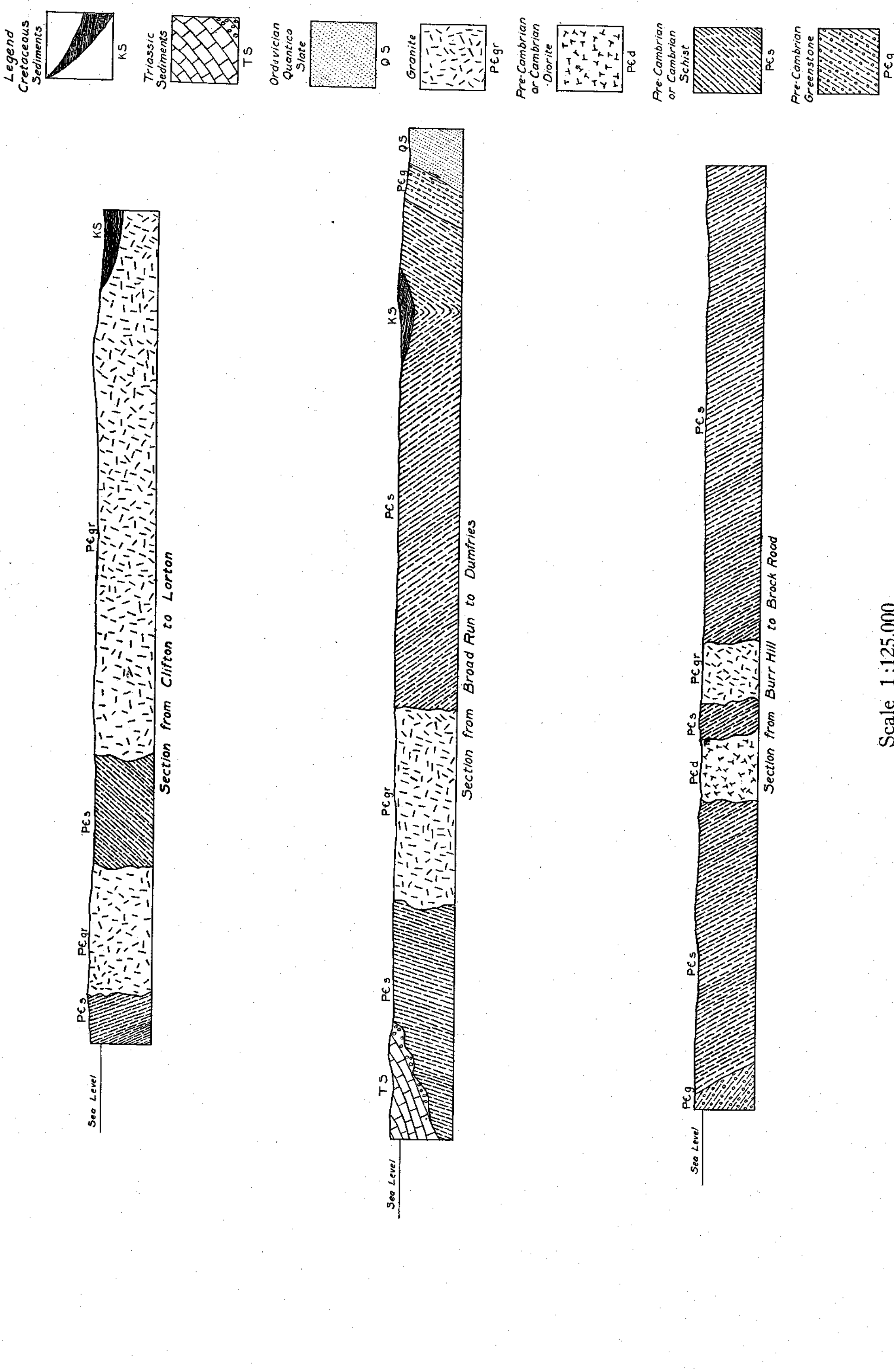
is northeast and the dip is to the west. There are, however, variations from place to place in the different sections. Numerous accurate determinations of strike and dip were made and tabulated by Watson and Powell.[30] Their figures appear below.

Determination of Strike and Dip of Quantico Slate

Name of Section	Strike	Dip
Occoquan Creek	N. 40°-45° E.	70° N. W. to vertical.
Marumsco Creek	N. 35°-42° E.	Nearly vertical.
Powells Creek	N. 20° E.	50-70° N. W. to vertical.
Quantico Creek	N. 30°-35° E.	75° N. W. to vertical.
Aquia Creek	N. 25°-40° E.	70° N. W. to vertical.
Austin Run	N. 30°-45° E.	80° N. W. to vertical.
Accakeek Creek	N. 38°-60° E.	80° N. W. to vertical.
Potomac Creek	N. 50° E.	35°-59° N. W.
Wilderness, 1 mile west	N. 20° E.	Nearly vertical.
Brock Station	N. 38° E.	Vertical.
Shady Grove	N. 25° E.	Vertical.

Relation to bordering rocks.—In the Dumfries section and at Kellogs Mill, the slates are in contact with greenstones which is undoubtedly much older in age, probably pre-Cambrian. The contact is sharp without gradation. Although the evidence is not conclusive, it seems possible that faulting localized at this point caused the present position of the rocks.

30. Op. cit., p. 37.


Legend
Cretaceous Sediments
KS
Triassic Sediments
TS
Ordovician Quantico Slate
QS
Granite
PЄgr
Pre-Cambrian or Cambrian Diorite
PЄd
Pre-Cambrian or Cambrian Schist
PЄs
Pre-Cambrian Greenstone
PЄg
Section from Clifton to Lorton
Section from Broad Run to Dumfries
Section from Burr Hill to Brock Road
Sea Level
Scale 1:125,000

STRUCTURE AND METAMORPHISM

FOLDING

Close folding is a universal feature of the metamorphic rocks of the district. The axis of folding in all cases has been roughly parallel to the Blue Ridge, that is, in a northeast-southwest direction, varying from N. 10° E. to N. 50° E. The folding along this direction has resulted in very steep dips varying from 26° to vertical. The directions of dip may be either to the east or to the west. If the dips as found are studied, it is found that throughout the central part of the district they are toward the east, while in the extreme eastern and western parts, westward dips were found. This condition is shown in the accompanying structure sections (pl. 8). The sections show a series of schists from west to east intruded by igneous rocks. Two major folds are shown, one with its axis central in the east end of the sections, the other with its axis at the west end of the sections. Faulting is shown at the contact of the Quantico slate with schist.

The folding represented here affects all rocks up to and including those of Ordovician age. The pre-Cambrian and Cambrian schists wherever found always exhibit this feature as does also the Quantico slate of Ordovician age. Many dips found in the slate are practically vertical. The Triassic and Cretaceous sedimentary rocks, on the other hand, did not share in the crustal movements recorded in the folding. These rocks are found in essentially horizontal positions or lapping up on the closely folded older rocks. We have then recorded in the rocks evidence of crustal deformation which affected rocks as young as Ordovician, but which did not extend into Triassic and Cretaceous times.

FAULTING

No direct evidence of faulting is found in the region. Outcrops are of such a discontinuous nature that such evidence is difficult to find. Likewise mine workings are not accessible so that underground evidence is also unavailable. Watson [31] noted small cross faults in the Cabin Branch mine, but no other instance has been noted.

The relation of the Quantico slate to the older rocks does, in some localities, suggest the possibility of faulting. At Dumfries this formation (Quantico slate) is found dipping steeply to the westward in contact with rocks that are probably pre-Cambrian in age. The contact is perfectly sharp. Such a position suggests faulting, for the rock normally in contact with the slates is Cambrian in age. It is to be noted further that in

31. Watson, Thomas L., Mineral resources of Virginia, Lynchburg, 1907, p. 193.

the Arvonia district, for example, the basal member of the Quantico slate formation or its equivalent is a quartzite. This member is not found in the district covered by this report. This fact taken with the relation of the slates to older rocks, as at Dumfries, suggests a faulted contact which is so represented in the structure sections.

REGIONAL METAMORPHISM

All of the older rocks of the district exhibit evidences of metamorphism (anamorphism). The degree of metamorphism shown, while depending to a certain extent upon the nature of the original rock, is a rough measure of the age of the rock affected. The undoubted pre-Cambrian rocks are highly metamorphosed, being found today as gneisses and schists whether of igneous or sedimentary nature originally. Rocks believed to be Cambrian in age, especially igneous rocks, do not exhibit marked gneissic structure or schistosity. Rough banding, however, is observed and some true schists are of this age. The Quantico slate has a well developed slaty cleavage, but has plainly undergone less alteration than the neighboring schists. Some of the igneous rocks believed to be younger than Ordovician are truly massive and show no evidence of anamorphic effects.

Under the microscope the nature of the metamorphism undergone is well shown. Orientation of mineral grains or crystals and partial recrystallization are seen to be the essential changes. In the case of some schists, this orientation attains a high perfection, while in others the effect is not so marked. Recrystallization into new minerals is a common feature of the rocks, especially in the gneisses and schists. Rocks which originally were sediments, such as impure sandstones, limestones or shales, are now found as sericite quartz schists, biotite epidote quartz schists or amphibole quartz schists. It is plain that in such cases, the constituents of the original rock have been recrystallized and rearranged into their present condition. Fracturing and optical distortion are also frequently noted as evidence of regional metamorphism.

CONTACT METAMORPHISM

Evidences of contact metamorphic effects in the region are not abundant, largely because contacts are obscured. Whatever phenomena are present can be divided roughly into two classes, those associated with the veins and ore deposits, and those more closely associated with the rock masses.

VEINS AND ORE DEPOSITS

Many of the veins show a development of contact metamorphic effects. This usually takes the shape of replacement of the walls by the vein solution. The commonest result is the development of pyrite and, to a slighter extent, of quartz and other minerals in the wall rock. In the case of the pyrite deposits, the entire ore assemblage, as at the Cabin Branch mine, suggests a contact metamorphic deposit. The ores are replacements of schists, and the development of epidote and garnet, while not abundant, is not an uncommon feature.

IGNEOUS ROCKS

Contact metamorphic effects undoubtedly exist at the contact of the igneous rock bodies with other rocks. In most cases, however, these contact zones are not exposed. On Potomac Run, the contact of the hornblende granite with older granite gneiss is exposed. The result of the intrusion as far as metamorphic effects are concerned was the impregnation of the gneiss with hornblende. The gneiss is normally free from hornblende, but here at the contact a transition zone can be observed in which hornblende and, to some extent, quartz have been added to the older rock. The typical contact assemblage of minerals is not developed.

THE MINES OF THE DISTRICT

INTRODUCTION

Descriptions of the mines and prospects found in the district are given below. Complete history is lacking for nearly every mine because most of them have been abandoned for many years. Only one mine, the Wilderness mine, was operating in 1923, and since then it has also shut down. The descriptions not only of gold mines and prospects, but also of pyrite and other minerals, are considered here. These will be grouped according to metal or mineral mined and by counties.

GOLD MINES AND PROSPECTS

CULPEPER COUNTY

CULPEPER MINE

Location.—Two miles south of Richardsville and one-half mile northeast of Rapidan River.

History.—This mine was being actively operated in 1836 and was last worked about 1905. Between these dates it was operated intermittently with greatest activity before the Civil War. When visited by Silliman [32] in 1836, the ores being worked were above ground water level, and were opened by a shaft 57 feet deep together with 531 feet of tunnels, adits, and cross cuts. The vein was reported to be from 8 to 30 feet wide and to divide and reunite along its course. Silliman also reported that the company was erecting a dam across Rapidan River to furnish power to operate the mine. In 1854, according to Whitney,[33] the mine employed 24 men and operated with expenses of $120 per week. A twelve stamp mill and two Chilean mills were used in treating the ore. The mine produced 3400 dwts. of gold in seven weeks.

According to Mr. Smith of Richardsville who worked at this mine, the most profitable operations were just before the Civil War and in the early resumption of mining afterward. In the last development of this property there were two shafts 100 and 120 feet deep, and an open cut about 40 feet deep. The ores were pyritic and were worked by jaw crusher, grinding mill, tables, and amalgamation after first being roasted. The vein, according to Mr. Smith, was 30 feet wide and averaged $6.00 per ton over its entire width. Pockets carried values as high as $100 per ton.

Geology.—The country rock at the Culpeper mine is a very finely foli-

32. Silliman, B., Culpeper gold mine, Virginia: Am. Jour. Sci., 1837, ser. I, vol. XXXII, p. 185.
33. Whitney, J. D., Metallic wealth of the United States, 1854, p. 126.

ated dark gray sericite quartz schist. On exposure it weathers to a light gray. This rock strikes N. 32° E. and dips steeply, practically vertically, to the east. The vein conforms for the most part to this structure and is a strong massive quartz vein. The old workings are not accessible, but the dump shows numerous specimens of the vein material. Pyrite is an important vein mineral and is abundantly disseminated in all specimens. Sericite is present in small amounts and occasional areas of kaolin suggest the original presence of feldspar. Free gold is sometimes seen not only in the oxidized specimens but also in pyritic ones.

LOVE MINE

Location.—One-half mile northeast of Culpeper mine.

History.—This property was operated before the Civil War and also since that time. Its last operations were about 1905. Some very rich ore was found and considerable surface working was carried on in addition to the underground mining. One shaft about 120 feet deep was sunk.

Geology.—Owing to the exceedingly poor outcrop and condition of the workings, little can be said concerning the geology of this property. The country rock is similar to that found at the Culpeper mine and both properties are believed to be on the same vein.

EMBRY MINE

Location.—One-half mile south of Culpeper mine.

History.—The story of this mine is much the same as the two preceding. Located on the same vein, it was worked before and after the Civil War with fair success, but yielded, just as did the others, to the difficulties of working the ores found below water level. Two shafts 140 and 100 feet deep were sunk and were connected by levels. The ore was milled by a battery of ten stamps, tables, and amalgamation. A part of the old mill is still standing.

Geology.—The country rock at the Embry mine is a dark greenish gray, finely foliated, hornblende quartz schist. Magnetite and calcite are abundantly developed as impregnations in the schist. These are probably a part of the vein mineralization. Part of the magnetite is titaniferous and part has altered from pyrite which is present sparingly in the wall rock. Calcite replaces hornblende and magnetite replaces both hornblende and calcite. The vein here also carries magnetite to a considerable extent. Concentrates from the tables show a high percentage of this mineral and former workers here recall this to be a general condition. The old workings are so badly caved that no idea of the vein itself could be gained.

DRY BOTTOM PROSPECT

Location.—Two miles southeast of Richardsville, 1½ miles south of the Richardsville-Richards Ford road.

Description.—This property was never actually operated but was only a prospect. Several shallow shafts and test pits were sunk. The country rock is sericite quartz schist. No evidences of vein formation nor ore were found as the old openings are very badly caved.

MORGANA MINE

Location.—On west side of Rappahannock River half way between Martins Ford and Ellis Ford.

History.—Notes on the history of the property are lacking. It is reported to have sunk one shaft 128 feet deep which encountered the water table at about 60 feet. The ruins of the old mill indicate that a six stamp mill with tables and amalgamation were used to treat the ore.

Geology.—Evidence of the vein or veins of this mine was not seen. The shaft was sunk in granite described elsewhere as Somerville granite.

ELLIS MINE

Location.—On west side of Rappahannock River near Ellis Ford.

History.—This mine has not been operated since 1904, but previous to that time was worked intermittently, with greatest activity about 1877. At that time 35 men were employed. A 10 stamp mill, with Frue vanner and arrastra, was used to treat the ore. The main shaft was 110 feet deep, while the vein was developed for 300 feet along its strike. The ore from the lower workings was highly pyritic but easily concentrated to yield $175 per ton. In 1877 there were 200 tons of ore on the dump. This mine in its most active days purchased ore from near-by properties. Today nothing remains but caved shafts and a few scattered pieces of machinery.

Geology.—The country rock is sericitic quartz schist. The vein conforms generally to the structure of the schist, the strike of which is N. E.-S. W. The dump shows little evidence of mineralized vein matter, only occasional specimens with pyrite being found.

FAUQUIER COUNTY

BANCROFT MINE

Location.—On Summerduck Run two miles southwest of Morrisville.

History.—This mine, as far as known, has not operated since 1902, but was active as far back as 1877. At that time, according to Morton,[34] there were four shafts with connecting levels and ore to the amount of 500 tons averaging from $13 to $15 per ton in value was on the dump.

Geology.—The country rock is quartz schist. No evidence as to the mineralization can be obtained because of a lack of exposures.

LIBERTY MINE

Location.—Three and one-half miles southwest of Morrisville on Rock Run.

History.—Little is known of the history of the property. In 1922 a little prospecting was done apparently without much result.

Geology.—Old workings and new prospect openings are in schist close to granite.

LITTLE ELLIOT AND RANDOLPH MINES

Location.—Three miles southeast of Morrisville on Marsh Road. Authentic information not obtainable.

KELLY MINE

Location.—Two miles southwest of Summerduck.

History.—This mine has been operated intermittently over a long period. In 1879 it was reported to have yielded from $700 to $1,000 a week profit. It was last worked about 1904. A large and elaborate mill was built and still remains in good shape. Originally a stamp mill with tables and amalgam plates, it was remodeled to use the cyanide process for treating the ores, but with what success is not known.

Geology.—The mine is located in an area of schist dipping steeply to the eastward and showing a northeast-southwest strike. Several veins were reported, but could not be observed because of caved ground.

FRANKLIN MINE

Location.—Three miles east of Morrisville.

History.—This mine was opened shortly before the Civil War and last worked about 1904 or 1905. It had over 700 feet of underground workings and a 20 stamp mill for treating the ore. It was described in 1877 as having been worked in a desultory manner for 40 years, during which time 100,000 tons of $12 ore were mined. At that time, 1877, the mine was caved and flooded. Ten samples, taken at a later date, are reported to have given an average value of $24.24 per ton. In 1901 and 1902, 1,000 tons of tailings were cyanided with little success.

34. Morton, J. H., Gold mines of Virginia: Eng. and Mng. Jour., 1877, vol. 24, p. 345.

Geology.—This mine is located in schist near the border of the Somerville granite. Lindgren described the deposit as a strong fissure in diorite accompanied by an intrusion of diabase. The diabase was observed by the writer at the time of his visit (1922), but he was unable to observe the diorite.

OTHER MINES IN FAUQUIER COUNTY

Mention of the Kidwell, Waterman, Wykoff, Kirk, and Leopold mines in the Morrisville district is found in the literature. The exact location of these is not known; probably some of them are among the properties mentioned above, but known now under different names.

ORANGE COUNTY

GRASTY TRACT

Location.—This tract of mineral land extends northward from St. Just Post Office along Mine Run nearly to the Orange Pike, including an area of over 900 acres.

History.—Several mining companies have at various times attempted to exploit this property. The first incorporated gold mining company in Virginia, the Virginia Mining Company of New York, operated here between 1831 and 1834. The last operation was about 1910 by the Piedmont Mining and Metallurgical Company of Philadelphia. Companies operating between these periods were the Chancellorsville-Freehold Mining Company of London, England, 1853-1857, the Chicago-Virginia Gold Mining Company, 1879-1881, American Gold Mining Company, 1881-1883, and the Gold Run Mining Company. According to Watson,[35] from whose account most of these facts are taken, these companies sunk 12 shafts for a total of 578 feet and drove 1,400 feet of drifts and cross cuts. The Freehold Company mentioned above was reported in 1854 to have traced one vein 20 feet wide 1½ miles on the surface. Several thousand tons of ore are believed to have been taken out by these companies with reported values of from $6 to $32 per ton. The Piedmont Mining and Metallurgical Company, the last to operate here, reported values from $4.13 to $201.67. At least three veins, from 3 to 5 feet wide, are reported to have been found by this company.

Geology.—The veins in the Grasty Tract are found either in schist or in granite, as the contact between the Locust Grove granite and schist passes through the property. The veins carried quartz, pyrite, and chalcopyrite.

JONES PROSPECT

Location.—Two miles southeast of Indiantown on Russell Run.

History.—A small amount of prospecting was done here in 1915. Two

35. Watson, T. L., Mineral resources of Virginia, 1907, pp. 555-557.

shafts 30 feet and 26 feet deep, respectively, were sunk on a 3 foot vein in schist. Values of $32 per ton were reported. The strike of the schist and vein is N. 45° E. and the dip, which is high, is to the east.

MINES NEAR WILDERNESS RUN

Location.—North and northeast of Wilderness Post Office and comprising the area between Wilderness Run and Flat Run.

History.—Many attempts at prospecting and mining have been made in this area both before and since the Civil War. Some producing properties have been developed, the most important of which are the Vaucluse and Melville. Others are the Partridge and Wilderness mines.

VAUCLUSE MINE

Location.—About 3 miles east of Indiantown and 1½ miles south of Rapidan River.

History.—The Vaucluse mine was opened in 1832 and in 1843 had a plant valued at $70,000. Several companies were identified with the mine in its long history. In 1854 the Liberty Mining Company of England, capitalized at £1,000,000, had purchased this and the Grymes mine for £50,000. The average yield of the ore was $8 per ton. Six shafts were sunk and in 1853 a mill run of 80 days produced 556 ounces 6 dwt. of gold of a fineness of 943½. In December, 1853, 50 tons of ore were crushed daily. Previous to 1852, the mine had been worked by two open cuts 60 feet deep, 75 feet wide, and 120 feet long.

As early as 1847 this mine maintained an elaborate plant (one of the earliest on this continent) for the separation of gold from quartz and pyrite. According to Nitze,[36]

The machinery consists of a condensing Cornish mining engine of 120 horse-power; the mill-house contains 6 large Chilean mills; the cast-iron bed plate of each is 5 feet 6 inches in diameter, and on it are two cast iron runners of the same diameter, the total weight of the mill being 6,200 pounds. The ores, on arriving at the surface, are divided into two classes: 1. The coarse and hard ore for the stamps: 2. Slate and fine ore for the Chilean mills. This is done by means of a large screen. The very large pieces are first broken by a hammer before they are fed to the stamps. All of the ores are ground with water, each mill being supplied with hot and cold water at pleasure. Twelve inches from the top of the bed-plate there is a wide, open mouth, from which the turbid water escapes to tanks. On the south side of the steam engine is the stamp house and amalgamation mill, containing 6 batteries of 3 stamps each; these stamps with the iron head of 125 pounds weigh 350 to 380 pounds each. Each battery is supplied with water and at each blow of the stamp a portion of the fine ore passes out of the boxes through the grates to the amalgamation room. Here are stationed 18 small amalgamation bowls of cast iron, 30 inches in diameter. The bowls are supplied with runners which move horizontally; in the

36. Nitzs, H. B. C. and Wilkens, H. A. J., Gold mining in North Carolina, etc.: Bull. 10, N. C. Geol. Survey, 1897, p. 34.

center of these runners is an eye or opening like that in the runner of a corn mill. The ground or finely-stamped ore, gold and water pass into this eye, and by the rotary motion of the same are brought into contact with the quicksilver deposited in the center, forming amalgam. From the amalgamators, the pulp passes through 3 dolly-tubs or catch-alls, acting as mercury and gold tubs. After this the whole mass passes to the strikes or inclined planes, where the sulphurets are deposited and the earthy matter washed away. These sulphurets were formerly treated in two heavy Mexican drags or arrastras, but not answering so good a purpose, they have been altered into three heavy Chilean mills.

Part of the operation at this property consisted of surface washing. No recent work has been done here, and at the time of the writer's visit in 1922, the old machinery was scrapped.

Geology.—The country rock is a sericite quartz schist which was described by early writers as "talco micaceous schist." Contained in this are numerous veins and stringers of auriferous pyritic quartz. The auriferous belt in places is 30-40 feet wide. The gold and pyrite were also found impregnating the schist in which the veins were inclosed.

MELVILLE MINE

Location.—One and one-half miles northeast of the Vaucluse mine.

History.—Extensive development has been carried on at this mine which has had a long history. Much surface working was done at one time and, in addition, considerable underground mining. At the time of the writer's visit in 1922, experiments as to the best method of treating the sulphide ores were being carried on. Crushing, roasting, and cyaniding are among the methods used, the results of which are not known.

Geology.—The country rock at the Melville mine consists of variable schists which in places approach arkosic quartzites in composition. Quartz and sericite are the prominent minerals. In the coarser facies blue quartz grains are seen resembling very closely the rock described from Indiantown a few miles distant. The veins consisted of massive quartz impregnated with abundant pyrite and a very little chalcopyrite.

WILDERNESS MINE

Location.—One-half mile north of Wilderness Post Office and 1¼ miles south of the Vaucluse mine.

History.—Development work was carried on at this mine in 1923 by the Wilderness Mining and Milling Company, W. C. Kuper, Manager, Wilderness Post Office. Operations were carried on about four months ending in the autumn of 1923. Since that time nothing has been done. This company first worked the property about 1911, acquiring 101 acres of land together with a mill. The mill, destroyed by fire in 1911, has not been rebuilt, and no work has been done on the property to date. In its earlier efforts the company sunk a shaft 100 feet deep and drove drifts 385 feet long. Abandoned older workings are found evidencing the work done prior to 1911. The present work has been to sink the shaft to the 125-foot level, to drift 190 feet on the 100-foot level, and to start a drift on the 125-foot level.

The equipment consists of a steam hoist and two pumps. When visited by the writer, 12 men were employed in two shifts, 4 men working underground and 2 at the surface. All drilling was by hand. Water level is at 60 feet below the surface and the pumps were used a part of each day. Usually 7 hours pumping during each day was sufficient to keep the shaft clear of water. The pumps are of 100 gallons capacity.

Geology. — This property is in dark quartz feldspar-bearing schists of igneous origin, described elsewhere in this report, pp. 66-67. The strike is N. 28° E. and the dip is 83° to the east. The vein varies from 4 to 13 feet in width and conforms to the strike and dip given above. Values are reported from $10 to $48 per ton. An assay made by a "chemical assay method" gave $170 per ton, as opposed to values of $16 obtained from the same ore by fire assaying.

OTHER ORANGE COUNTY MINES

The Partridge, Orange Grove, Greenwood, and Randolph are other Orange County mines and prospects whose exact locations and histories are not known.

PRINCE WILLIAM COUNTY

GREENWOOD MINE

Only one gold property is known in Prince William County. This is one-half mile southeast of Independent Hill and has been abandoned more than 20 years. Two vertical shafts were sunk and considerable trenching was done. This property is on granite. No evidence of mineralization was seen.

SPOTSYLVANIA COUNTY

UNITED STATES MINE

Location.—On Rappahannock River near the United States ford.

History and geology.—This is one of the very old mines of the region being worked prior to 1837. In 1836 it was reported by Silliman [37] as producing $600 per week and employing 40 to 50 men. The vein was about 2 feet wide and often showed free gold. Stamps and Chilean mills were used to crush the ore, and amalgamation was used to recover the values. The values reported were 1 pennyweight of gold to 100 pounds of

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37. Silliman, B., Remarks on some gold mines and parts of gold regions of Virginia, etc.: Amer. Jour. Sci., 1837, vol. XXXII, pp. 98-130.

ore. The vein is in schist and, besides the usual quartz and pyrite, carried sphalerite, galena, chalcopyrite, pyromorphite, and vanadinite.

OTHER GOLD MINES IN SPOTSYLVANIA COUNTY

Other gold mines in this County, some of which are located on the map, (pl. 1 in pocket), are the Ramsey, the Bell, the Smith, the Gardiner, and the Marshall. All of these have long been abandoned and, as far as known, never had a great production, although some reports state that the Marshall in 1854 had obtained $300,000 up to that time and had workings 100 feet deep. The Gardiner mine in 1854 was erecting a mill to crush ore. The Bell, Ramsey, and Smith mines have been abandoned for more than 30 years. Good showings of ore are reported to have been found at these places. All three are near granite. No vein material was seen.

STAFFORD COUNTY

EAGLE (RAPPAHANNOCK) MINE

Location.—Fourteen miles northwest of Fredericksburg near the junction of Rapidan and Rappahannock rivers.

History.—This is one of the older properties established before the Civil War and also one of the largest. It was operated by several different companies with variable success, but has been abandoned for many years. Its workings extended several hundred feet and reached more than 200 feet in depth. The mine was probably first worked about 1834, for Clemson in 1835 visited a Rappahannock mine in this neighborhood. From 1879 to 1886 mining magazines carried news items from this mine, indicating considerable activity. These items for one year (1879) mention workings 85 feet deep, a 3½ foot vein, and the number of men employed as 30. In 1885 ore to the extent of 10,000 tons was reported blocked out on three levels. The ore carried $10 per ton and 50 per cent of the gold was free. Eleven nuggets weighing from 1 to 18 dwt. were reported in 1886 and, in the same year, the occurrence of a streak of galena in the vein was noted. Altogether the mine had a long career and a considerable production.

Geology.—The veins found on this property lie in a garnet biotite quartz schist which is dark gray in color and finely foliated. A few microscopic crystals of tourmaline were found in this rock. Its strike is N. 45° E. and the dip is 85° E. Vein specimens are massive quartz showing abundant pyrite and scanty galena.

HORSE PIN (RATTLESNAKE) MINE

Location.—One and one-half miles southeast of Eagle mine.

History.—This mine was abandoned in 1894 and shows practically no evidence today of ever having been operated. The country rock is schist. The old workings are reported to have been 605 feet long and to have reached a depth of 250 feet.

OTHER MINES IN STAFFORD COUNTY

Other gold mines in Stafford County were the Monroe and Lee mines which were in the same neighborhood as the Horse Pin, though their exact locations are not known. No details of their histories are available.

IRON PROPERTIES

The iron mines are of interest more from a historical than from any other standpoint. There were three furnaces in the district all working ores obtained from the area. None of the furnaces have been worked since the Civil War and at least one was abandoned before the Revolutionary War. The three furnaces were the Germania furnace established in 1714 near the present Germania Bridge, the Washington furnace established by Augustine Washington, father of George Washington, near Mountain View in Stafford County, and the Catherine furnace 3 miles west of Chancellorsville in Spotsylvania County. The Germania and the Catherine furnaces were supplied with ore mined for the most part from the Wilderness region. Evidence of this early mining can be seen today in the shape of very old surface pits. The ores were all gossan ores derived from the oxidation of the pyritic bodies which occur in the district. The Washington furnace obtained its ore from the immediate vicinity of the furnace on Accakeek Run. This was abandoned in 1753, though the supply of ore was not exhausted according to available information. Probably bodies of gossan ores could still be found in the district where these furnaces were operated.

PYRITE MINES AND PROSPECTS

Two large mines which returned considerable productions of pyrite were developed and operated in the district until recently. Today both are idle. Several prospects from which no production was made were also developed during the war period, and were located in the Wilderness region near Chancellorsville, near Agnewville, and on Marumsco Run. In all of these cases pyritic bodies were found but of too low grade to justify their further development. The two large mines will be described below.

CABIN BRANCH MINE

Location.—One and one-half miles northwest of Dumfries in Prince William County.

History.—This mine was opened in 1889, but steady production was not established until several years later. Steady production was maintained from 1908 to 1919, while in 1920 the mine was abandoned and the machinery scrapped. It was last operated by the American Agricultural Chemical Company.

The mine was connected by a narrow gauge railroad with the R. F. & P. Railway and with water shipping facilities at Barrow Siding about 6 miles from the mine. Development was by three shafts, two of which were vertical and the third inclined. These were called No. 1, No. 2, and No. 3, in which No. 2 shaft was inclined. These penetrated the ore body to depths of over 1,000 feet.

A large mill was operated at one time, but has been scrapped since. In general the product was divided into three classes, lump, spall, and fine. Lump was first grade ore requiring no sorting, spall was first grade ore broken to pass a 2.5 inch ring and freed from fines by screening. Fine ore was under three-eighths inch. In the milling practice at the Cabin Branch mine the ore from the hoist was dumped on a 2.5 inch grizzly, oversize going to a lump storage bin. Hand sorting separated slate from first class lump which went to a spalling floor. The finer impure ore went to a roll-jaw crusher. The larger lump was broken by hand, and shipped without further treatment. The undersized from the grizzly was treated in a 3-compartment Hartz jig. Clean pebble ore was shipped as such. Middlings from the jig were treated by roughing rolls of two grades, and were finally treated in 2-compartment jigs.

Geology.—The accompanying sketch map (fig. 7) shows the geology at the Cabin Branch mine. At the mine itself schists which are biotitic and carry quartz, hornblende, feldspar, and occasionally garnet and epidote, are the country rock. Passing eastward a narrow belt of greenstone, probably altered basalt, is encountered and this is succeeded in turn by the graphitic Quantico slates which carry in places stringers of decomposed granite. To the northwest at a distance of 2 miles, the massive Stafford Store quartz monzonite is found. Stream divides are plastered over with Cretaceous sediments.

Dips are to the west at this property and vary from 26° to nearly vertical. The inclined shaft No. 2 of the mine which followed the ore down the dip varied greatly in its grade, being nearly horizontal in some cases. Faulting is not evidenced at the surface, but cross faults were reported by observers who had access to the workings. The sharp contact of the Quantico slate (Ordovician) with pre-Cambrian greenstone may represent fault conditions.

The ore body was sharply separated from its inclosing walls. The width varied from 5 to 10 feet, and marked rolling or change in the amount of dip was common. The strike of the ore body was N. 10-20° E. The length of the lens-like body developed at the Cabin Branch mine exceeded 1,000 feet. The No. 1 and No. 2 shafts caught the ore near the surface, while No. 3, which was situated down the dip, caught the ore several hundred feet underground.

The ore minerals consist mainly of pyrite. Minor amounts of pyrrhotite, chalcopyrite, galena, and sphalerite are also found. Analyses showed small amounts of gold and silver, but these were not recovered. At one time some of the ores here were hand sorted for chalcopyrite and a matte was produced from them. The gangue consists of hornblende, chlorite, biotite, epidote, garnet, quartz, tourmaline, and calcite. A large part of the ore is a mixture of quartz, calcite, and pyrite resulting in a friable mass. Other portions are essentially pure pyrite throughout which are found areas of chloritic schist suggesting unreplaced residuals. A study

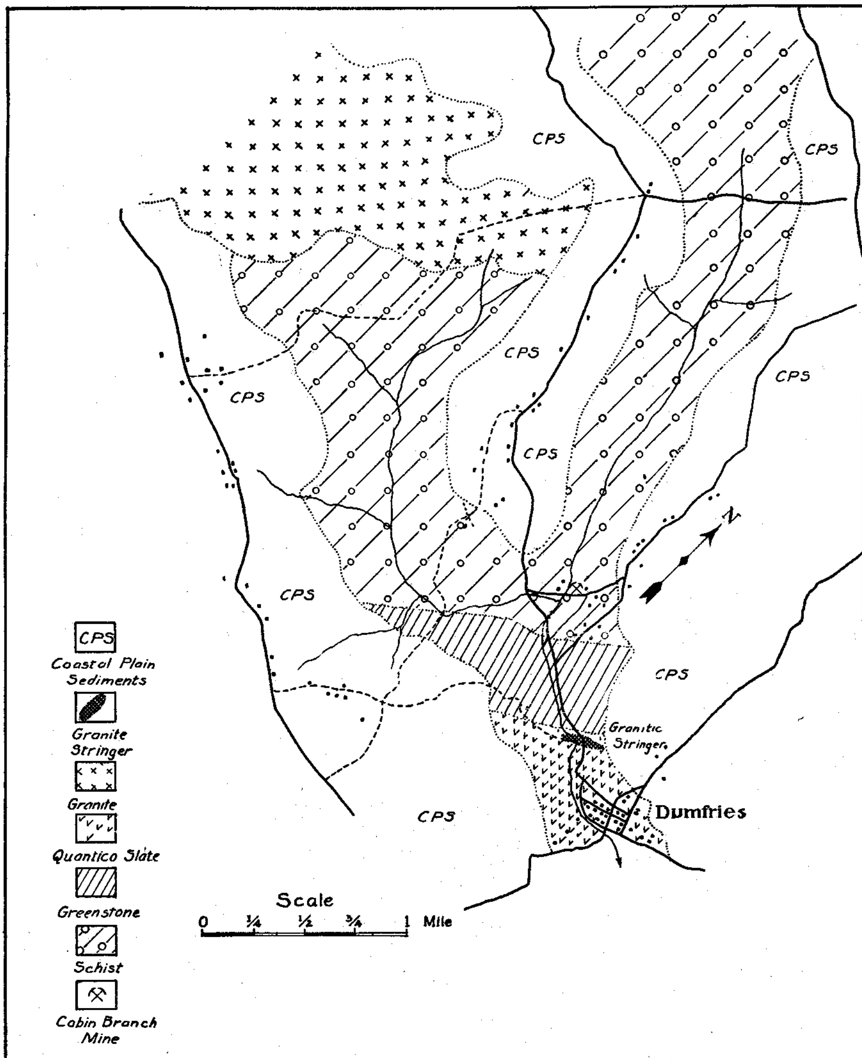


Figure 7. Geological details at Cabin Branch mine.

of thin sections shows that biotite, epidote, and garnet, together with some quartz, were minerals of the schist and were produced by metamorphism. These all antedated most of the pyrite in formation. Pyrite, quartz, and tourmaline are related in time of formation and are subsequent to the minerals mentioned above. Calcite and a second generation of quartz were introduced subsequent to the main mineralization and probably much later. Of the earlier gangue minerals quartz and chlorite, biotite and hornblende are the most abundant. Epidote and garnet are not commonly developed. The sketch accompanying (fig. 8) shows the relation of the pyrite to the schist which is the country rock. It seems probable that pyrite replaced the schists, since numerous examples of residuals are found in the ores and replacement is shown in the slides. In general the pyrite follows the structure of these original rocks, but in some cases has been itself folded subsequent to formation.

The calcite quartz portions of the deposit are, for the most part, veinlets which cross the previously existing structure. One of them is sketched in figure 9. These are noted most abundantly at No. 3 shaft. In some cases they cut the pyrite. The minerals composing these veinlets or lenses were deposited in successive stages, the order of deposition being calcite, chlorite and quartz. They show thus evidence of being formed in open space, and were probably formed much later than the pyrite body itself.

The presence of tourmaline in the ore at the Cabin Branch mine is of

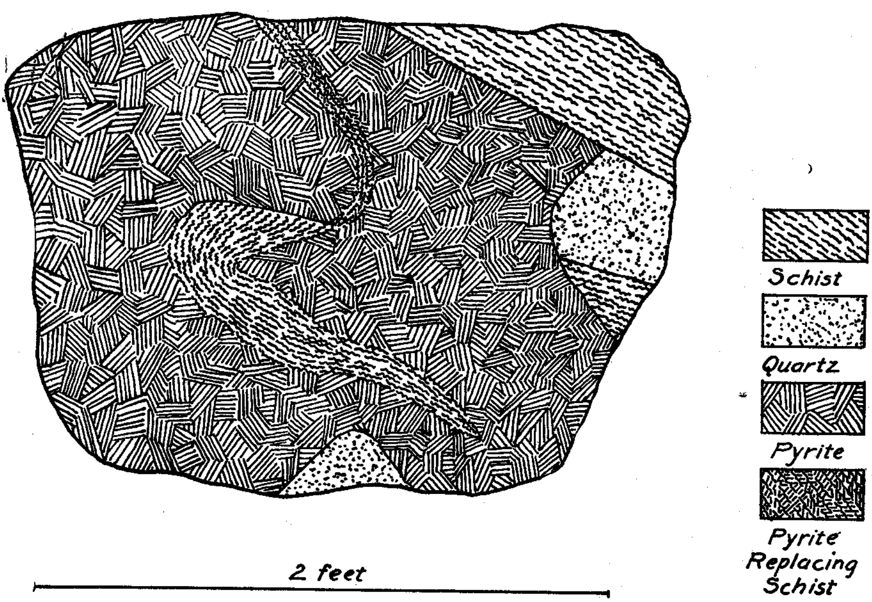


Figure 8. Sketch of ore specimen at Cabin Branch mine. Pyrite replacing schist is shown.

significance. This mineral is commonly believed to be formed only through igneous agencies at high temperature. This suggests a magmatic origin for the ore body. It is to be noted also that less than 1 mile distant from the mine stringers of granitic material are found in the Quantico slates, and that to the west only a little farther away massive igneous rocks are found.

AUSTIN RUN PYRITE MINE

Location.—One and one-half miles south of Garrisonville P. O. in Stafford County.

History.—This mine was opened about 1908 and produced irregularly until 1920, since when it has not been operated. Its production is given elsewhere in this report. Several companies have operated this property and, after being forced into the hands of receivers, reorganization has occurred once. The Austin Run Mining Company, the Old Dominion Pyrite Company, the Western Pyrite Company, and the Fer-Sul Company are among those which controlled the mine during the period from 1908 to 1920.

The mine was developed by one shaft 650 feet deep which entered verti-

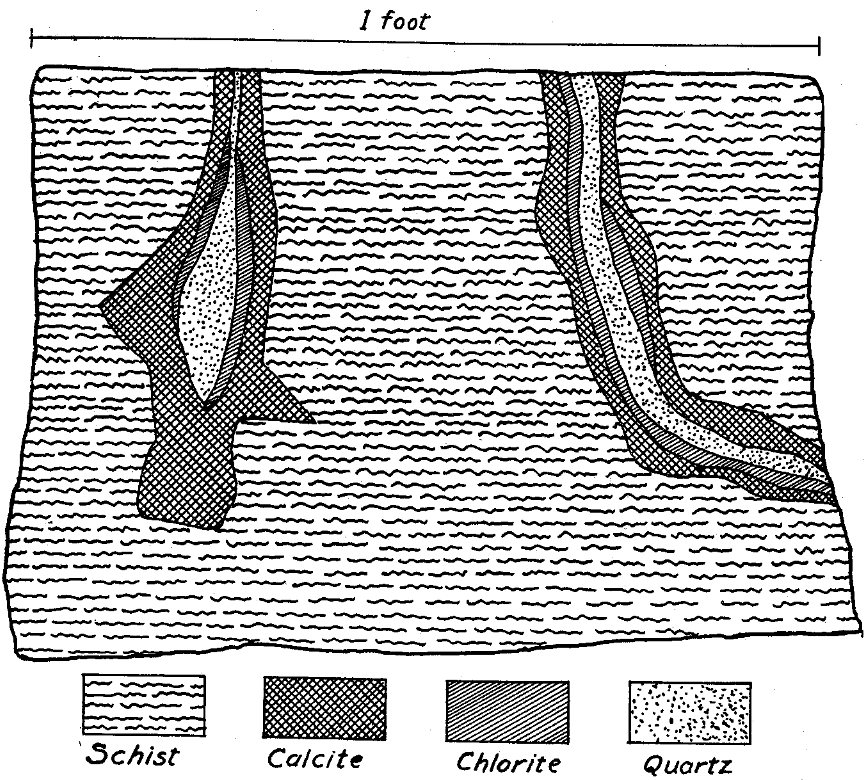


Figure 9. Sketch illustrating post-pyrite mineralization at Cabin Branch mine.

cally for 350 feet and then became inclined. When this mine was visited the shaft was filled with water, so that the workings could not be entered. A large modern pyrite mill was built at the property, and is still in good condition. It is shown on Plate 9, B. The flow sheet shows a large jaw crusher, 10 ball mills, and 6 tables. The exact treatment of the ore is not known.

Geology.—The country rock at this mine is a hornblende quartz schist which in places contains chlorite, epidote, and garnet. In some instances the chlorite is plumose. This rock is finely foliated, the strike of the schistosity being N. 33° E. and the dip 50° E. The original sedimentary nature of the rock seems evident.

Judging from the dump at this mine and from information furnished by those who were underground when the mine was operated, the ore body was not one distinct mass. The ore occurred in lenses and stringers over a width of several feet. In some places small areas were composed almost entirely of pyrite, but for the most part the ore was a mixture of schist and pyrite in which the whole mass was mined. Specimens can be found which show only occasional fine stringers of pyrite in schist, while others show more pyrite than schist. Examination of thin sections of the ore shows that pyrite replaced the amphibole and chlorite of the original rock and apparently was not accompanied by other minerals.

In some portions of the mine, calcite was reported by observers. On one level the late Doctor Watson [38] observed a large vug, filled with pure calcite, which was found to contain water. Specimens on the dump show this mineral with chlorite, but always in such condition as to suggest that the calcite was formed subsequent to the ore body.

SOAPSTONE QUARRIES AND PROSPECTS

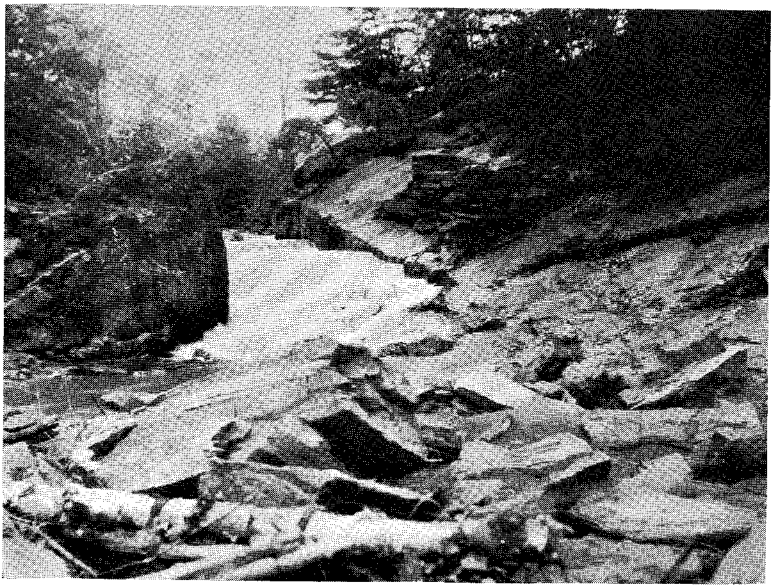
Prospecting on soapstone bodies has been carried on to a very slight extent at Indiantown, but the only instance of production of this material is near Verdiersville where quarries were worked for several years. They will be described below.

VERDIERSVILLE SOAPSTONE QUARRIES

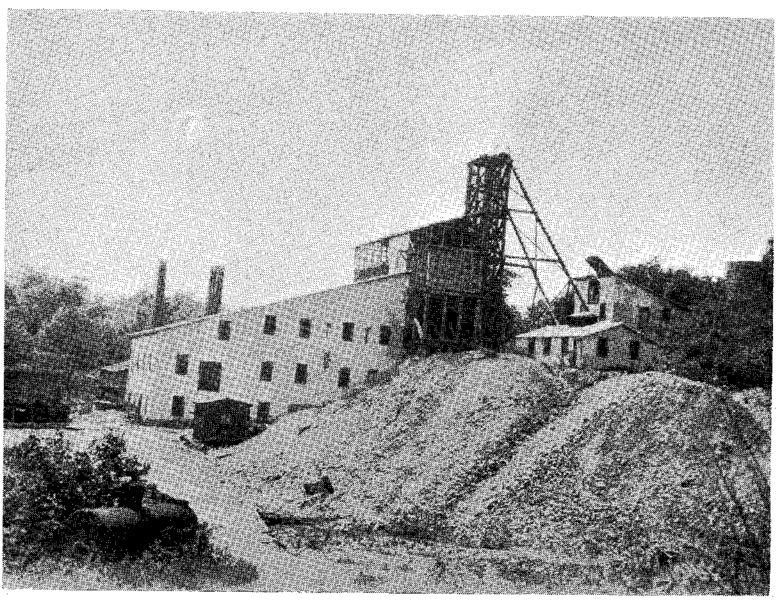
Location.—One mile northeast of and 2½ miles northeast of Verdiersville.

History.—The two quarries mentioned here about 1½ miles apart were worked by the same company, but the date which the work started is not known. At the quarry nearest Verdiersville, which was the larger, a plant for working the stone was erected, but was destroyed by fire about

38. Watson, Thomas L., Personal communication.



A. Greenstone schist on Quantico Run at Dumfries.



B. Shaft head and mill, Austin Run mine.

A. Greenstone schist on Quantico Run at Dumfries.

B. Shaft head and mill, Austin Run mine.

1916. The pit at this place was 100x100x50 feet. The pit at the other quarry was much smaller.

Geology.—As shown elsewhere in this report, pp. 61-62, the soapstones are in the form of dike-like bodies in diorite and are the result of superficial alteration of basic rocks. Chlorite is extensively developed and causes large portions of the rock to be unfit for use. A series of veins containing magnetite and calcite are found cutting the stone in place. For more detailed descriptions of these deposits, the reader is referred to the discussion of soapstones on pp. 61-63.

ORIGIN OF THE GOLD AND PYRITE ORES

INTRODUCTION

In considering the origin of the gold and pyrite ores which occur in the district, it is necessary to point out that not all of the evidence needed can be found in this region. The fact that in no case are underground conditions subject to inspection and that even dumps at the old mines have lost much of their value as evidence, makes it very difficult to discuss this problem adequately. When other districts are considered in conjunction with this district, however, it is found that there is available a considerable mass of evidence which warrants certain conclusions as to the origin of the ore deposits. The deposits of gold, while quite different in occurrence from those of pyrite, are grouped with them in parts of the discussion, because they are believed to be closely related in genesis.

GOLD DEPOSITS

PREVIOUS THEORIES

Among the early geologists who examined the gold veins of the region, two opposing views were held as to their origin. One group, of which Rogers was perhaps the leader, held that the veins were injected into the country rock by igneous agencies, and that, while the veins in general conformed to the structure of the rock in places, they cut across the schistosity. Another group of earlier geologists believed that the veins were syngenetic, deposited at the time of the formation of the original rock. Silliman, Ansted, Credner and others may be cited as advocates of this view. In more recent times, Becker, Lindgren, Graton, Watson, and Taber have shown conclusively that only the first view is tenable for the gold veins of the southeastern Atlantic States.

TYPES OF DEPOSITS

The gold deposits of the district occur in distinct veins accompanied, in many instances, by a certain amount of replacement. This replacement is seen usually as an impregnation of the wall rock by auriferous pyrite. Taber [39] described gold deposits in James River valley formed chiefly through replacement, but in the district covered by this report such deposits, while possibly existing, are not accessible to examination.

GANGUE MINERALS

The gangue minerals of the gold ores, found in the course of the field

39. Taber, Stephen, Geology of the gold belt in the James River Basin: Bull. VII, Va. Geol. Survey, 1913, p. 209.

work for this report, do not include the complete list of those found elsewhere in the Southeastern Atlantic States. The condition of the workings and the lack of fresh material account for this in part. The minerals actually found are supplemented here by additions from the numerous tables which have been compiled from time to time. The most abundant and important gangue minerals are quartz, feldspar (albite, oligoclase, andesine), muscovite, sericite, biotite, chlorite, tourmaline, and cyanite. To these may be added actinolite, barite, calcite, garnet, hornblende, sillimanite, and talcite which have been noted by various observers in the mines of this and other southeastern Atlantic gold districts. Some of the latter minerals are of doubtful occurrence, while others are secondary or represent inclusions of wall-rock in the veins. Of the more important gangue minerals, quartz is the most prominent and is always present. It varies from the variety known as milky quartz to clear transparent material. It is coarsely crystalline, but shows no crystal faces. Strain effects are sometimes noted and inclusions are common. In the weathered dumps of the district feldspar was not seen, but specimens were found showing kaolinite probably derived from this mineral. Taber [40] found in fresh material taken from below water level in the James River Valley mines that feldspar was always present and in some cases constituted 10 per cent of the vein matter. He identified the mineral as ranging from albite-oligoclase to andesine and did not find potash feldspar in a single instance. The presence of kaolinite in the weathered specimens found here is believed to indicate that feldspar also occurred in the veins of this district. Biotite, chlorite, sericite, muscovite, garnet, and hornblende, while noted occasionally in the ores, are believed to be independent of the ores in origin. Tourmaline, frequently found in the veins, is very prominent in some specimens.

ORE MINERALS

In point of abundance the ore minerals of the gold veins present a rather simple assemblage. Over 90 per cent of the group is made up of pyrite. To this may be added gold, chalcopyrite, galena and sphalerite. Occasional references are found in the literature to magnetite, pyromorphite, pyrrhotite, tennantite, tetradymite, chalcocite, copper, molybdenite and others. These were found in only a few mines distributed throughout the southeastern Atlantic States and were present in very small amounts.

Pyrite, as stated above, was the most abundant mineral—occurring at all of the mines. This mineral carried values in gold and probably was the principal source of the metal. It is found in granular aggregates or, in some instances, in well defined crystals both in the veins and in the wall rock. It does not commonly constitute a very large part of the vein.

40. Taber, Stephen, op. cit., p. 213.

Native gold occurred at all the mines to a limited extent, but is rarely met with today because the dumps have been thoroughly picked over. In the oxidized portions of veins it was not uncommon to find splendid specimens of the metal. The writer examined several such specimens which came from the Culpeper mine. Colors can usually be obtained by panning around any of the old mines.

Chalcopyrite was the second sulphide in importance. In most of the vein specimens small amounts of this mineral mixed with pyrite could be observed. As far as known, no gold mines in the district attempted to recover the copper values. Sphalerite and galena were found in specimens from the Eagle (Rappahannock) mine. They occurred in small amounts in scattered specimens. These minerals, however, have been reported from many southeastern gold mines.

SHAPE OF THE ORE BODIES

Figure 10, accompanying, illustrates in an ideal way the characteristic shape of the gold veins. It is taken from conditions found near Burr Hill in Orange County. As can be seen the fundamental shape is that of a lens. The lenses are found in the field to vary in size from a few inches or even less in length to several hundred yards. Underground operations showed that the lenses or veins were not continuous either in depth or along the strike. When the ore body pinched out, another lens might or might not be found directly beneath or on the continuation of the strike. In many cases ore bodies overlapped, with intervals of barren country rock between.

Evidence of open space in the ore bodies is lacking. The veins occupy areas in schists, whose foliæ are flexed around the thinner edges of the lens. Banding and crustification are notably absent. While the lens

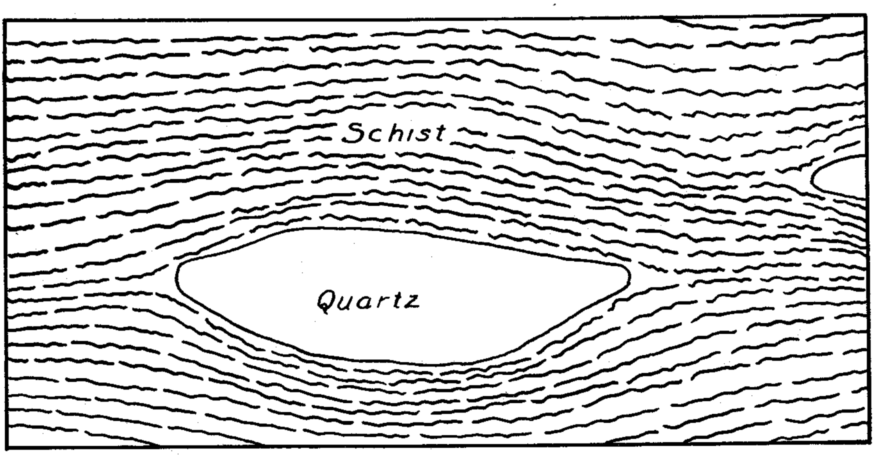


Figure 10. Quartz lens in schist.

sketched is shown confined within the structure of the schist, there are cases in which the veins cut across the schistosity proving the vein to be younger than the inclosing rock. Even in the case of veins which do not cut schistosity the absence of metamorphic effects in the veins suggests strongly that they are younger than the schists.

PYRITE DEPOSITS

PREVIOUS THEORIES

As with the gold deposits, many of the earlier geologists believed the pyrite deposits to be syngenetic in origin. Since the time in which these men worked, F. L. Nason, T. L. Watson and others have expressed the belief that many of the deposits, especially those of Louisa County, represent replacements of limestone. Doctor Watson [41] pointed out that, in the lower levels of some of the Louisa County mines, definite horizons of crystalline limestone have been replaced by pyrite and that these limestones grade laterally into mica schists. He found in addition that some of the pyrite bodies are intermediate between replacements and vein deposits.

TYPES OF DEPOSITS

As indicated above the pyrite deposits are for the most part replacements. In the district involved in this report the replaced rock was not a limestone but was a sediment yielding through metamorphism a garnet-epidote-biotite-hornblende-schist rather than limestone. Some pyrite deposits elsewhere in the Piedmont appear to occupy fracture zones and are of a type intermediate between replacements and true veins.

GANGUE MINERALS

The gangue minerals found in the deposits of pyrite are quartz, calcite, hornblende, garnet, chlorite, biotite, epidote, and tourmaline. For the most part these minerals are to be referred to the original country rock, to alterations of minerals of the original country rock or to a mineralization subsequent to the ore formation. The alteration of the limestone lenses in Louisa County produced garnet and hornblende. At the Cabin Branch mine, garnet and epidote are fairly abundant gangue minerals, while biotite and chlorite are undoubtedly unreplaced residuals from the original rock. Quartz and calcite are sometimes related to the mineralization of the pyrite, but frequently are present in subsequent veins and lenses.

ORE MINERALS

The ore minerals of the pyrite deposits are pyrite, sphalerite, chalcopy-

41. Watson, Thomas L., Personal communication.

rite, galena, pyrrhotite, and magnetite. In only a few of the pyrite deposits do ore minerals other than pyrite attain notable proportions. At the Cabin Branch mine chalcopyrite was developed to a considerable extent in some parts of the ore from which, after hand sorting, matte was produced. In the majority of cases minerals other than pyrite are present in grains sparsely disseminated through the ore. The pyrite is either with crystal development or is granular in nature. The crystal ore which shows the cube or its modifications is coarser than the granular type, which is frequently a fine-grained mass essentially pure pyrite.

SHAPE OF THE ORE BODIES

The essential shape of the pyrite bodies, like the gold, is that of a lens. The pyrite lenses in some cases were found to be over 1,000 feet long. In most cases the pyrite lenses, since they are replacements, inherit their shapes from previously existing rock bodies. In this they differ from the gold veins. The sketch (fig. 11) accompanying, shows conditions as found in Louisa County. There is a marked similarity to the arrangement of the gold veins.

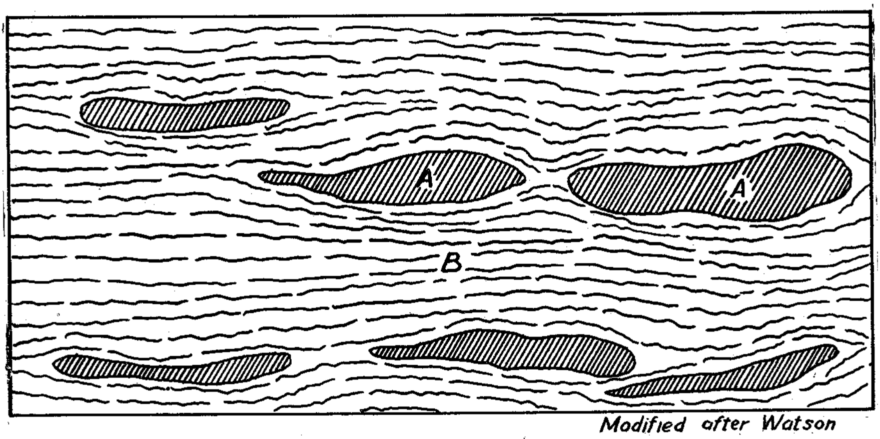


Figure 11. Plan of pyrite lenses in Louisa County.

ORIGIN OF THE ORE BODIES

Introduction.—Any reasonable explanation of the origin of the gold and pyrite deposits of the district must take into account four conditions: (1) The mineral composition, (2) the shape and texture of the ore bodies, (3) distribution of ore bodies in relation to the rocks of the district, and (4) relation of the gold veins to the pyrite bodies. A consideration of these factors should warrant conclusions as to the source of the materials found in the ores, the physical conditions under which they were formed, their relation or lack of relation to the rock formations of the region, and their geologic age.

Mineral composition.—A review of the lists of minerals found in the ore deposits shows two quite similar assemblages. In the gold veins by far the greater part of the vein is seen to consist of quartz, pyrite, feldspar, and gold. On an average probably all other minerals represent less than 1 per cent of the mass. Tourmaline, while present in small amounts, has been noted frequently and is believed to be of significance in this discussion. In the pyrite deposits the assemblage exclusive of residual or altered minerals of the original rock consists of pyrite and quartz. Sphalerite, chalcopyrite, and galena are more important than in the gold veins, reaching commercial importance in some cases, but on the whole are unimportant. Tourmaline again has been noted in these bodies as was the case with the gold veins. In addition pyrrhotite, which is considered a significant mineral, has been noted. Garnet, epidote, hornblende, biotite, calcite, and part of the quartz are present abundantly as gangue minerals. They are believed to be either residual minerals or secondary minerals resulting from the alteration of the original rock. They are of value in considering the mechanics, or rather the physical chemistry, of the formation of these ores, but not in establishing the ultimate source of the ore minerals. In the pyrite bodies quartz is much less prominent than in the gold veins and pyrite is much more pronounced. It should be stated also that small amounts of gold are usually present in the pyrite bodies.

The two mineral assemblages shown are seen to be similar in that the abundant minerals are common to each, though in different proportions. On the one hand, there is a quartz-feldspar-pyrite-gold assemblage with tourmaline, while on the other, there is one of pyrite with quartz, tourmaline, and pyrrhotite. If quartz were decreased in the one case and increased in the other, the assemblages would correspond quite closely. As far as these considerations go, the two types of ores, gold and pyrite, could have been derived from the same source.

It is useless to review here the evidence that has led to the belief that epigenetic ore bodies of the kind found here are formed by deposition or precipitation from solution with or without replacement of the wall rocks. This belief is one of the fundamental maxims of modern economic geology. The solutions which produce such deposits are in general of two types: (1) Related directly to igneous magmas and deriving their mineral content from the magmas, and (2) unrelated to magmas and deriving their mineral content, immediately at least, from sources other than magmas. The minerals deposited from such solutions are, under given conditions, in each case typical and characteristic. An examination of the gold and pyrite deposits considered here reveals the presence of minerals which suggest the type of solution from which they were derived. Quartz and pyrite are known to occur through a wide range of physical conditions and are found in deposits related to both types of solutions mentioned above. Their presence can not be used as a criterion in this connection. Tourmaline, feldspar, and pyrrhotite, on the other hand, are commonly believed to be minerals formed only in connection with igneous influences or environments. These minerals have been noted frequently in the deposits considered here and their presence suggests strongly, if indeed it does not prove, that the solutions from which these deposits were derived were of the first type mentioned above, that is, related directly to magmas and deriving their minerals from magmas.

Shape and texture of ore bodies.—A consideration of the shape and texture of the ore bodies is important in that from it and the mineral associations of the ores can be drawn conclusions as to the physical conditions under which the deposits were formed. The shape of the ore bodies has already been discussed at some length. It is seen to be characteristically lens-shaped or bulbous. In the case of the gold veins this is an inherent character, for veins are found which were not formed by replacement through which the shape could be inherited. In the case of the pyrite bodies, the lens shape in the Cabin Branch mine and in the Austin Run mine is to be ascribed to replacement and hence is inherited. Texturally the ores show no evidence that open space existed in which they were deposited. Crustification and banding are entirely absent, and no successive stages of mineral deposition can be demonstrated.

From what is known of past physiographic and geologic conditions, it is believed that great thicknesses of sedimentary and metamorphic rocks have been removed by erosion to reveal the veins and pyrite bodies in their present positions. It is believed by many that sedimentary formations of Paleozoic age found today west of the Blue Ridge once extended across the present Blue Ridge position into the Piedmont. Some observers estimate the thickness of removed sediments in other districts as from many thousands of feet even up to several miles. This condition, together with the shape and texture of the ore bodies, indicates that they were formed at great depths below the surface existing at the time of their formation. It has been frequently observed in gold veins in various parts of the world that deposits which could clearly be proven to have formed at great depths have a pronounced development of the lens or bulbous shape and show an absence of crustification or banding. These factors taken together seem to warrant the conclusion that at least the gold veins of the district were formed at great depths.

The pyrite lenses inherit their shapes from the replaced rock. Their bulbous shape, therefore, does not furnish a criterion as to the depth at which they were formed. The erosional conditions with regard to the pyrite bodies, however, are the same as for the gold veins, so that on this basis it seems evident that the pyrite bodies also were formed at great depths.

If, finally, the minerals found in the deposits of gold and pyrite are again considered, there would seem to remain no doubt as to the conclusions drawn above. Again, feldspar, tourmaline, and pyrrhotite, together with garnet, are significant minerals. These indicate conditions in which temperature and pressure were relatively high. Such conditions are believed to be ideally developed at great depths beneath the surface of the earth.

Distribution of the ore bodies.—If the distribution of the mines and prospects of this and neighboring districts is studied, it will be found that the ore deposits are confined to a narrow belt or belts. The mines, for the most part, are located between walls of schist, but the belt of mines is close to bodies of igneous rock. This condition holds true throughout the southeastern Atlantic states and has been pointed out by many observers.

The igneous rock bodies which roughly parallel the ore deposits are of several kinds and ages. The majority of them, perhaps, are to be referred to granites or quartz monzonites, though more basic types are known. Some of them have undergone pronounced metamorphism and are undoubtedly of pre-Cambrian age. The gneiss at Fredericksburg could be mentioned in this connection. Others are less metamorphosed, being massive rather than gneissic, and can probably be assigned to the Cambrian. Finally, some bodies of granite rocks are distinctly massive and probably are younger than Ordovician. The three generations of rocks are shown at Richmond, Virginia, in a single quarry, where their relations have been pointed out by Watson.[42]

The ore bodies are believed to be related genetically to certain of these igneous rocks. Their composition and shapes indicate their derivation from some igneous sources; their proximity to the rocks mentioned here shows that they must have been derived from this source. In a few localities, pegmatites of the youngest granite can be definitely traced into quartz veins which, though unmineralized, are essentially the same as those carrying ores. Such a relation is figured elsewhere in this report under the discussion of pegmatities, p. 51. These facts, taken together with the fact that such minerals as feldspar and tourmaline are found in the ore bodies, would seem to show that they are derived from igneous magmas.

Relation of gold veins to pyrite bodies.—In the preceding discussion the similarities existing between the pyrite deposits and the gold veins have been pointed out. It has been shown that both are deposits precipitated

42. Watson, Thomas L., Granites of the Southeastern Atlantic States: Bull. 426, U. S. Geol. Surv., 1910, pp. 82-88.

from solutions related to igneous rocks, and that the solutions involved were of a similar nature. It has been further shown that both are related to the same belt of igneous rocks. It remains to be seen if still other relations between them can be established—whether or not they can be referred to the same period of mineralization and to the same magmatic source.

In discussing these points it is again found that not all of the evidence needed can be observed in the field today. Recourse must be had to the work which has been done in the past as well as to the data obtainable today.

One fact is noted at once: All of the pyrite bodies carry small values in gold and the minerals of the pyrite deposits are similar to those of the gold veins. Much more significant and probably conclusive is the fact that observers who were underground while the mines were operating, found undoubted quartz-gold veins associated with the pyrite bodies in a manner which indicated contemporaneous deposition for the two. Throughout the district also the two types of deposits are found inclosed in the same kinds and ages of rocks. But further than this, on Neapsco Run, for instance, veins carrying pyrite and gold are found cutting Ordovician slate which also carried bodies of pyrite not of commercial grade. Such relations are thought to show that both gold and pyrite deposits are younger than Ordovician and, since there is only one igneous mass younger than Ordovician from which they could have been derived, it is probable they are of the same age, and are derived from the same source.

It should be pointed out, however, that some gold veins, as, for example, those near Locust Grove in Orange County, are found in positions which suggest that they may have been derived from igneous rocks of Cambrian or earlier age. For the veins in the eastern part of the district and for the pyrite deposits, a much younger rock must be sought for their source as indicated above.

Geologic age of the deposits.—The essential facts concerning the geologic age of the ore deposits have already been mentioned. Further attention is called to them to properly emphasize the point. As already shown, some of the gold veins and all of the pyrite deposits can be related genetically only to the younger igneous rocks of the region. The field evidence seems to be conclusive that these younger igneous rocks were formed subsequent to the Quantico (Ordovician) slates. It follows, of course, that the gold and pyrite deposits so related are also younger than Ordovician. This relationship is most apparent in the Cabin Branch pyrite deposits and in the gold deposits grouped in close proximity to the younger igneous rock near Fredericksburg. A partial check on this conclusion is found in Louisa County where the schists inclosing pyrite bodies were, on fossil evidence, found to be younger than

Middle Cambrian. Besides the positive fact of the close relation of both pyrite and gold veins to the younger rock near Dumfries, it must be recalled also that pegmatites from the younger rock at Fredericksburg are definitely traced into quartz veins. Not so tangible, but nevertheless quite convincing to the field observer at least, is the fact that the majority of the quartz veins throughout the entire area are not metamorphosed. Repeated observation of this condition leads the observer to feel, even in the absence of other evidence, that the quartz veins are much younger than the schists inclosing them, many of which are of Cambrian age.

Reference to the areal geology map, Plate 1, shows that in Orange County near Locust Grove, and in Culpeper and Fauquier counties there are several gold mines which are situated at considerable distances from the known exposures of post-Ordovician igneous rocks. These mines are located close to the boundaries of igneous rocks probably of Cambrian age. The possibility must not be ignored that such mines may owe their mineralization to epochs of activity occurring in Cambrian time. The veins at these mines, however, do not differ in structure and texture from those definitely connected with the younger rocks.

BUILDING STONE AND ROAD MATERIALS

BUILDING STONE

At the time the field work for this report was done, no production of building stone was being made in the area. This was not due to the lack of suitable stone because excellent material exists, but was probably due to the present condition of the quarrying industry in relation to markets and transportation. Building stone quarried in the area must compete with the New England granites and marbles and with the stone of Richmond and other southern quarries.

The markets are found in the larger cities. The large, well established quarries have an advantage in this connection. There is, however, a possibility of the development of the building stones of the area, and for this reason a section on building stone is included in the report.

FREDERICKSBURG GRANITE

The Fredericksburg granite has been quarried extensively in the past, but is not being worked at the present time. The quarries were located northwest of the city along the banks of Rappahannock River. Any resumption of the industry will probably be in the same general locality because of the transportation facilities available.

The stone at Fredericksburg is excellent both for dimensional and monumental purposes. It has an even gray color, very pleasing in effect, and finishes well. Dimensional material would perhaps not be of the largest size, but a considerable amount of such material is available. Of the Fredericksburg stone Watson says:[43]

> The granite is cut by several sets of joints so spaced as to admit of the stone being quarried in blocks of any size. The strike of the principal joint planes in the quarry openings is north-south dipping 40° E.; N. 60° to 80° E., dipping 10° to 30°; and 20° to 80° W. Pegmatites are abundantly developed in places and occasion considerable waste in quarrying.
>
> The granite is quarried exclusively for the monument trade. . . . The granite takes a fine polish, the durability of which is favored by the uniformly small size of the biotite scales.

STAFFORD STORE GRANITE

The granite (quartz monzonite) found near Stafford Store is quite similar to the Fredericksburg stone. All that can be said of the value of the former for building stone is true of the latter. It has not been quarried, but its similar composition suggests that the stone has commercial possibilities. The question of dimension material can be answered only after quarrying has been done.

43. Watson, T. L., Granites of the Southeastern Atlantic States: Bull. 426, U. S. Geol. Survey, 1910, p. 108.

The location of the Stafford Store rock is its greatest handicap. No railroad is accessible and furthermore no good automobile road leads from it to rail transportation. This fact will probably prevent the development of this stone for many years to come.

OCCOQUAN GRANITE

The Occoquan granite has already been mentioned in another place in this report. It has been quarried for rubble and other rough stone purposes. An immense supply exists with water transportation at hand. Markets which could be reached include Washington, Baltimore, and Philadelphia. The stone is probably too extensively sheeted for dimension material, but it is possible that a certain amount of monument stock could be secured.

Another possibility suggests itself with regard to this stone. It could be made to yield excellent paving blocks. With cheap water transportation available, it is possible that this could be made into a profitable enterprise. Although the Occoquan quarry has been idle for some years, it is felt that eventually operation may be resumed, since the quarry is so suitably located with reference to transportation and to markets.

OTHER STONES

Other stones which are suitable for building stone purposes occur in the district. Their location, however, makes doubtful their utilization in the near future. Situated inland from water and rail transportation, such occurrences are under a distinct handicap as far as present development is concerned. Of these stones possibly the blue quartz diorite is the best. This stone would finish into a very attractive stone for monumental purposes. It is probably too closely jointed for the production of dimension material.

ROAD MATERIALS

The location of road material is a question of utmost importance today. Practically every state in the Union is committed to a program of road building and road improvement. In this respect Virginia is keeping pace with her sister states. Since road building is a local problem the location of suitable materials must be considered here.

Several types of modern roads are being built today. These include the gravelled roads, concrete roads, water bound macadam roads and asphalt bound macadam roads. The selection of a particular type of road depends to some extent upon the local material available. The ideal condition is that under which a road can be built or improved by the use of materials alongside or nearby the road. When this condition exists the minimum cost for a given type of road construction should result.

In the area covered by this report, a number of improved roads have been built. These are constructed largely of local materials and are of the gravelled type. The most important of these roads is the Richmond-Washington Highway which is a state highway. The road from Fredericksburg to Orange is second only to the Richmond-Washington Highway, while other improved roads are the Popular Road, the Warrenton Road and others.

All of the roads already mentioned have been improved by the use of material which occurred nearby. It is evident that an abundant supply of such material exists sufficient to provide for an extensive road betterment campaign.

GRAVEL FROM COASTAL PLAIN SEDIMENTS

The formations of the Coastal Plain, especially those of Cretaceous age, furnish an abundant supply of gravel suitable for road construction. Detailed descriptions of these formations are found in Bulletin IV of the Virginia Geological Survey. For the present purpose it is sufficient to state that the supply of material is abundant and well suited. Reference to Plate 1 will show the location of the formations in question.

It will be seen from Plate 1 that the gravels of the Coastal Plain occur only in the extreme eastern limits of the district. The margin of the formation passes alternately in and out of the area. Accordingly these road materials are available for only a limited territory. Roads running northeast and southwest in the eastern part of the district could be surfaced with these gravels, and this has been done in the case of the Richmond-Washington Highway previously mentioned. The east-west roads pass beyond areas of the gravel a few miles from the eastern margin of the district and could be surfaced with the gravel only with the additional cost of fairly long hauls.

The gravel formations considered here require very little treatment or preparation for use. Many of the beds are essentially pure gravel of a size suited for road building purposes. In certain cases it has been found best to screen the material to secure an even graded product of the best size. In this case the cost is still relatively low, since portable screening machines simple in operation are used. The roads when graded, surfaced with gravel and packed are excellent. Furthermore materials for repair are always at hand.

ROAD MATERIALS FROM THE CRYSTALLINE ROCKS

The problem of road materials in the parts of the district underlain by crystalline rocks is quite different from these already mentioned. Since by far the greater part of the district falls in this category, the problem is of some importance. In these areas the surface is covered by a deep mantle of residual rock decay, with a few alluvial deposits in stream valleys. The alluvial deposits are ordinarily not of a sort adapted to road building purposes so that practically the only source of road materials is the residual decay mentioned above.

The rocks of the district from which the residual material was derived are generally of two sorts, igneous rocks of granitic nature and schists derived largely from sedimentary rocks. The residual decay over such rocks may be fairly similar or totally dissimilar. In the case of granites high in feldspar content and with only a small amount of quartz, a red clayey soil results. In the case of schists with abundant quartz, a sandy clayey soil is the product left after weathering. An increase in the amount of quartz in the granite or a decrease of the same mineral in schist produces weathering products quite similar. In very few cases is the soil left suitable for road building purposes until it has been modified by a process of natural concentration.

If a residual accumulation over a quartz schist be taken as an example, the process by which the road material is formed can be understood. Such a weathered rock will contain quartz, mica in the form of sericite, and a number of indeterminate clayey minerals. In an area of such materials a few localities will be found in which the accumulation is suitable for road building. This material differs from the above in containing a higher amount of quartz and less mica and clay. It is a slightly clayey sandy loam. It is usually found on knolls or small hills. In such localities the finer mineral particles have been washed away by rainwater until the resulting soil is concentrated with respect to quartz. It is this soil which furnishes the best road material in the greater part of the district.

From the above description, it is seen that material suitable for road building purposes can be formed from either granitic decay or the decay of schists. The granites must be high in quartz, and probably as a whole yield far less suitable material than the schists. The most likely locations for suitable materials without regard to kind of rock are the low knolls or hills which occur in the district. These are not of sufficient steepness to allow rapid runoff after rain which would remove all soil, but are sufficiently steep to allow the removal of the clay particles leaving the quartz portion behind.

The material thus made available is used without treatment or preparation. The top soil with vegetation is scraped away and the underlying material spread over the road bed to be improved. Since the material is very fine the resulting road is at first exceedingly dusty. However after settling and wetting by rainfall, a firm closely bound mass results. The quartz sand and fine gravel accumulate at the top of the body and, within a few weeks, produce an excellent gravelled road. Such roads require considerable attention for proper maintenance but, as a whole, are excellent and relatively economical.

The sandy soil described above represents practically the only source of road material over the greater part of the district. It is abundant and usually can be found within short distances of any road improvement project. Its location is merely a matter of prospecting the knolls and low hills.

INDEX

Acknowledgments, 1.
Amphibolites near Hemp, 59-60.
Richardsville, 60.
Analysis, Fredericksburg gneiss, 58.
Fredericksburg granite, 43.
gabbro from Rock Hill, 33.
hornblende granite on Potomac Run southwest of Mountain View, 26.
Locust Grove granite, 23.
Neapsco Run diorite, 37.
normal quartz diorite, 29.
Occoquan granite, 47.
pegmatite phase of quartz diorite, 31.
Stafford Store quartz monzonite, 41.
Aplite dikes, 53-54.
Aplites, pegmatites and, 51-53.
Arkosic quartzite (feldspathic), 68-70.
Indiantown, 68-69.
Neapsco Run, 69-70.
Austin Run pyrite mine, 89-90.
statistics of production, 10.
Bancroft mine, 78-79.
Basic facies, diorite gabbro complex, 34.
Bell mine, 84.
Bibliography, 12-14.
Biotite-quartz feldspar schist, 63.
Blue quartz diorite, 27-32, 103.
Building stone, 102-103.
Cabin Branch pyrite mine, 85-89.
statistics of production, 10.
Catherine furnace, 85.
Chemical composition and classification, Fredericksburg gneiss, 58.
Fredericksburg granite, 43.
Locust Grove granite, 22-23.
Neapsco Run diorite, 37-38.
Normal quartz diorite, 28-29.
pegmatite, 31.
Stafford Store quartz monzonite, 41.
and norm, hornblende-granite, 26-27.
Occoquan granite, 47-48.
Classification, amphibolite, 59.
and geologic age, rhyolite, 49-50.
Neapsco Run arkosic quartzite, 70.
Occoquan granite, 48.
Somerville granite, 25.
Climate, 5.
Coastal Plain sediments, gravel from, 104.
Contact metamorphism, 74-75.
Cretaceous sedimentary rocks, 20-21.
Crystalline rocks, road materials from, 104-105.
Culpeper County, 76-77.
Culpeper mine, 76-77.
Culture, 5.
Description, Cretaceous sedimentary rocks, 20-21.
Dry Bottom prospect, 78.
greenstone schist, 61.
Quantico slate, 71.
Triassic sedimentary rocks, 19.
Diabase dikes, 54-56.
Differentiation, evidence of, diorite gabbro complex, 36.
Dikes, aplite, 53.
diabase, 54-56.
non-olivinitic diabase, 55-56.
olivinitic diabase, 54-55.
Diorite, blue quartz, 103.
gabbro complex, 32-36.
Diorites, 32-39.
Dip, Quantico slate, 72.
Distribution of ore bodies, 99.
Drainage, 4, 15-16.
Dry Bottom prospect, 78.
Eagle (Rappahannock) mine, 84.
Ellis mine, 78.
Embry mine, 77.
Evidence of differentiation, diorite gabbro complex, 36.
Faulting, 73-74.
Fauquier County, 78-80.
Folding, 73.
Franklin mine, 79-80.
Fredericksburg gneiss, 56-59.
megascopic characters, 57.
granite, 102.
(quartz monzonite), 42-45.
quartz monzonite, pegmatite from, 51-52.
Gabbro, 33-34.
Gangue minerals, gold deposits, 92-93.
pyrite deposits, 95.
Gardiner mine, 84.
Garnetiferous quartz schists, 67.
Geography and history, 2-15.
Geologic age, amphibolites near Richardsville, 60.
biotite-quartz feldspar schist, 63.
diorite gabbro complex, 36.
Fredericksburg gneiss, 59.
Fredericksburg granite (quartz monzonite), 45.
greenstone schist, 61.
hornblende granite on Potomac Run southwest of Mountain View, 27.
Indiantown arkosic quartzite, 69.
Locust Grove diorite, 39.
Locust Grove granite, 23-24.
Neapsco Run diorite, 38.
normal quartz diorite, 30.
Occoquan granite, 48.
ore deposits, 100-101.
Quantico slate, 70-71.
quartz schist with biotite and feldspar, 65.
rhyolite porphyry, 51.
Geologic age, sericite quartz schist, 67.
soapstone, 63.
Somerville granite, 25.
Stafford Store quartz monzonite, 42.
Geology and petrography, 18-72.
Austin Run pyrite mine, 90.
Bancroft mine, 79.
Cabin Branch mine, 86-89.

Culpeper mine, 76-77.
Eagle (Rappahannock) mine, 84.
Ellis mine, 78.
Embry mine, 77.
Franklin mine, 80.
Grasty tract, 80.
Kelly mine, 79.
Liberty mine, 79
Love mine, 77.
Melville mine, 82.
Morgana mine, 78.
Vaucluse mine, 82.
Verdiersville soapstone quarries, 91.
Wilderness mine, 83.
Germania furnace, 85.
Gneiss, Fredericksburg, 56-59.
Gold and pyrite ores, origin of, 92-101.
deposits, 92-95.
mines and prospects, 76-85.
mining, 6-8.
production, 8-9.
veins, 94-95.
Gradation, diorite gabbro complex, 34-35.
Granite, Fredericksburg, 102.
hornblende, 25-27.
Locust Grove, 22-24.
Occoquan, 103.
Somerville, 24-25.
Stafford Store, 102-103.
Granites and quartz monzonites of post-Ordovisian age, 39-51.
of pre-Cambrian or Cambrian age, 21-27.
Grasty tract, 80.
Gravel from Coastal Plain sediments, 104.
Greenstone schist, 60-61.
Greenwood mine, 83.
Hemp, amphibolites near, 59.
History, 6-9.
Austin Run pyrite mine, 89-90.
Bancroft mine, 78-79.
Cabin Branch mine, 85-86.
Culpeper mine, 76.
Eagle (Rappahannock) mine, 84.
Ellis mine, 78.
Embry mine, 77.
Franklin mine, 79.
Grasty tract, 80.
Horse Pin (Rattlesnake) mine, 84-85.
Jones prospect, 80-81.
Kelly mine, 79.
Liberty mine, 79.
Love mine, 77.
Melville mine, 82.
Morgana mine, 78.
physiographic, 16-17.
United States mine, 83-84.
Vaucluse mine, 81-82.
Verdiersville soapstone quarries, 90-91.
Wilderness mine, 82-83.
Hornblende granite, 25-27.
quartz schists, 65-66.
Horse Pin (Rattlesnake) mine, 84-85.
Igneous rocks, 21-56, 75.
of pre-Cambrian or Cambrian age, 21-39.
of post-Cambrian, probably post-Ordovician, age, 39-53.
of Triassic age, 53-56.
Indiantown occurrence, arkosic quartzite, 68-69.
soapstone, 63.
Iron mining, 6.
properties, 85.
Jones prospect, 80-81.
Kelly mine, 79.
Kidwell mine, 80.
Kirk mine, 80.
Lee mine, 85.
Leopold mine, 80.
Liberty mine, 79.
Little Elliott mine, 79.
Location, area, 2-5.
Austin Run mine, 89.
Bancroft mine, 78.
Cabin Branch mine, 85.
Culpeper mine, 76.
Dry Bottom prospect, 78.
Eagle (Rappahannock) mine, 84.
Ellis mine, 78.
Embry mine, 77.
Franklin mine, 79.
Grasty tract, 80.
Horse Pin (Rattlesnake) mine, 84.
Jones prospect, 80.
Kelly mine, 79.
Liberty mine, 79.
Little Elliott mine, 79.
Love mine, 77.
Melville mine, 82.
Morgana mine, 78.
Randolph mine, 79.
United States mine, 83.
Vaucluse mine, 81.
Verdiersville soapstone quarries, 90.
Wilderness mine, 82.
Locust Grove diorite, 37-39.
granite, 22-24.
Love mine, 77.
Marshall mine, 84.
Megascopic and microscopic characters, Somerville granite, 24-25.
characters, amphibolites near Hemp, 59-60.
amphibolites near Richardsville, 60.
biotite-quartz feldspar schist, 63.
diabase dikes, 54.
Fredericksburg gneiss, 57.
Fredericksburg granite, 42.
garnetiferous quartz schists, 67.
hornblende granite, 25.
hornblende quartz schists, 65.
Indiantown arkosic quartzite, 68.
Locust Grove diorite, 39.
Locust Grove granite, 22.
Neapsco Run arkosic quartzite, 69.
Neapsco Run diorite, 36-37.
normal quartz diorite, 28.
pegmatite, 30.

pegmatite from Fredericksburg quartz-monzonite, 51.
pegmatite from Stafford Store quartz-monzonite, 53.
quartz schist, 64.
rhyolite, 49.
rhyolite porphyry, 50.
sericite quartz schists, 66.
Somerville granite, 24-25.
Stafford Store quartz monzonite, 40.
Melville mine, 82.
Metamorphic rocks, 56-72.
of igneous origin, 56-63.
sedimentary origin, 63-72.
Metamorphism, contact, 74-75.
regional, 74.
structure and, 73-75.
Microscopic characters, amphibolites near Hemp, 60.
amphibolites near Richardsville, 60.
biotite-quartz feldspar schist, 63.
Fredericksburg gneiss, 57-58.
Fredericksburg granite, 43.
garnetiferous quartz schists, 67.
hornblende-granite, 26.
hornblende quartz schists, 66.
Indiantown arkosic quartzite, 68-69.
Locust Grove diorite, 39.
Locust Grove granite, 22.
Neapsco Run arkosic quartzite, 69-70.
Neapsco Run diorite, 37.
normal quartz diorite, 28.
Occoquan granite with its included aplite, 46-47.
pegmatite, 30.
pegmatite from Fredericksburg quartz-monzonite, 51-52.
pegmatite from Stafford Store quartz-mozonite, 53.
Quantico slate, 71.
Microscopic characters, quartz schist with biotite and feldspar, 64-65.
rhyolite, 49.
rhyolite porphyry, 50-51.
sericite quartz schists, 66-67.
Somerville granite, 24-25.
Stafford Store quartz monzonite, 40-41.
Mineralization, soapstone, 62.
Mineral composition, gold and pyrite deposits, 97-98.
Mines of district, 76-91.
Morgana mine, 78.
Monroe mine, 85.
Neapsco Run arkosic quartzite, 69-70.
diorite, 36-37.
Non-olivinitic diabase dikes, 55-56.
Norm, Fredericksburg gneiss, 58.
Fredericksburg granite, 44.
gabbro from Rock Hill, 33.
hornblende granite on Potomac Run southwest of Mountain View, 27.
Locust Grove granite, 23.
Neapsco Run diorite, 38.
normal quartz diorite, 29.
Occoquan granite, 48.
pegmatite phase of quartz diorite, 31.
Stafford Store quartz monzonite, 41.
Normal quartz diorite, 27-30.
Occoquan granite, 103.
with its included aplite, 45-48.
Occurrence, amphibolite, 59.
biotite-quartz feldspar schist, 63.
Cretaceous sedimentary rocks, 20.
diabase dikes, 54-56.
diorite gabbro complex, 32.
Fredericksburg gneiss, 56-57.
Fredericksburg granite, 42.
garnetiferous quartz schists, 67.
greenstone schist, 60-61.
hornblende granite, 25.
hornblende quartz schists, 65.
Indiantown arkosic quartzite, 68.
Locust Grove diorite, 37-38.
Locust Grove granite, 22.
Neapsco Run arkosic quartzite, 69.
Neapsco Run diorite, 36.
normal quartz diorite, 27-28.
Occoquan granite with its included aplite, 45.
pegmatite from Fredericksburg quartz-monzonite, 51.
pegmatite from Stafford Store quartz-monzonite, 52-53.
Quantico slate, 70.
quartz schist with biotite and feldspar, 64.
rhyolite, 48.
rhyolite porphyry, 50.
sericite quartz schist, 66.
soapstone, 61-62.
Somerville granite, 24.
Stafford Store quartz monzonite, 40.
Triassic sedimentary rocks, 19.
Olivinitic diabase dikes, 54-55.
Orange County, 8-83.
Orange Grove mine, 83.
Ore bodies, shape of, 94-95.
minerals, gold veins, 93-94.
pyrite deposits, 95-96.
Origin of gold and pyrite deposits, 96-101.
soapstone, 62.
Partridge mine, 83.
Pegmatite, 30-31.
facies, quartz diorite, 30.
from Fredericksburg quartz-monzonite, 51-52.
from Somerville granite, 53.
from Stafford Store quartz-monzonite, 51-53.
Pegmatites and aplites, 51-53.
Petrography, geology and, 18-72.
Physiographic divisions of Virginia, 51.
history, 16-17.
Physiography, 15-17.
Piedmont Surface Peneplain, 16-17.
Porphyritic facies, diorite gabbro complex, 35-36.
Previous geologic work, 11-12.
theories, origin gold deposits, 92.
origin pyrite deposits, 95.

Prince William County, 83.
Pyrite bodies, shape of, 96.
deposits, 95-101.
mines and prospects, 85-91.
mining, 9-10.
production, 10.
Quantico slate, 70-72.
Quartz monzonite, Stafford Store, 40-42.
monzonites, granites and, post-Ordovician age, 39-53.
schist with biotite and feldspar, 64.
Ramsey mine, 84.
Randolph mine, 79.
Rappahannock mine, 84.
Rattlesnake mine, 84.
Regional metamorphism, 74.
Relation of gold veins to pyrite bodies, 99-100.
normal quartz diorite to pegmatite, 28.
Quantico slate to bordering rocks, 72.
Relief, 15.
Resume, igneous rocks of pre-Cambrian or Cambrian age, 39.
Rhyolite, 48-50.
porphyry, 50-51.
Richardsville, amphibolites near, 60.
Road materials, 103-105.
building stone and, 102-105.
from crystalline rocks, 104-105.
Schist, greenstone, 60-61.
quartz, 64-65.
Schists, crystalline, 64-68.
garnetiferous quartz, 67.
hornblende quartz, 65-66.
minor varieties, 68.
sericite quartz, 66-67.
Sediments, Coastal Plain, 104.
Sedimentary rocks, 18-21.
Sericite quartz schists, 66-67.
Shape and texture, ore bodies, 98-99.
of gold veins, 94-95.
pyrite bodies, 96.
Slate, Quantico, 70-72.
Smith mine, 84.
Soapstone, 61-63.
quarries and prospects, 90-91.
Soils, residual, 4-5.
transported, 5.
Somerville granite, 24-25.
pegmatite from, 53.
Spotsylvania County, 83-84.
Stafford County, 84-85.
Store granite, 102-103.
quartz-monzonite, pegmatite from, 52-53.
quartz monzonite, 40-42.
Statistics, gold production, 8 9.
pyrite production, Austin Run mine, 10.
Cabin Branch mine, 10.
Strike, Quantico slate, 72.
Structural features, Indiantown arkosic quartzite, 69.
Structure and metamorphism, 73-75.
Structure, Cretaceous sedimentary rocks, 20-21.
Fredericksburg granite, 44.
hornblende quartz schists, 66.
normal quartz diorite, 30.
Quantico slate, 71-72.
quartz schist, 65.
sericite quartz schists, 67.
Triassic sedimentary rocks, 20.
Texture, shape and, ore bodies, 98-99.
Timber, 5.
Topography, 4.
Triassic sedimentary rocks, 19-20.
Transportation facilities, 3.
Triassic sedimentary rocks, 19-20.
Types of gold deposits, 92.
pyrite deposits, 95.
United States mine, 83-84.
Uses, Occoquan granite, 48.
Variation, Occoquan granite, 45-46.
Variations and structure, Somerville granite, 24.
Vaucluse mine, 81-82.
Veins and ore deposits, 74-75.
Verdiersville soapstone quarries, 90-91.
Washington furnace, 85.
Waterman mine, 80.
Wilderness mine, 82-83.
Run, mines near, 81.
Wykoff mine, 80.


MINES AND QUARRIES
GOLD
2 Prospect
3 Grasty
4 Dickey
5 Jones Prospect
7 Partridge
8 Wilderness
9 Vaucluse
10 Melville
11 Love
12 Culpeper
13 Embry
14 Dry Bottom
15 Ellis
16 Morgana
17 Kelly
18 Bancroft
19 Liberty
20 Randolph
21 Little Elliot
22 Franklin
23 Eagle
24 Horse Pin
33 Greenwood
PYRITE
27 Garrisonville
28
29 Joplin Prospect
30 Cabin Branch
31 Agnewville Prospect
IRON
26 Washington
COPPER
25 Elk Run Prospect
SOAPSTONE
1
6 Indiantown
GRANITE
32 Occoquan
CHIEFLY DIKES AGE DOUBTFUL
So
Soapstone
Rhy
Rhyolite
In part rhyolite porphyry as dikes.
CRETACEOUS
Ks
Cretaceous and younger sedimentary rocks of Coastal Plain undivided.
TRIASSIC
Trd
Diabase
As dikes.
Trs
Triassic Sedimentary rocks undivided
ORDOVICIAN AND POST-ORDOVICIAN
Lgr
Later Granite
Quartz monzonite Post-Ordovician in age.
Oqs
Quantico Slate
Graphitic in part. Includes some pyroclastic material.
UNDIFFERENTIATED PRE-CAMBRIAN AND CAMBRIAN
PCqd
Quartz Diorite
Restricted to quartz diorite containing blue quartz.
PCdg
Diorite Gabbro Complex
Includes diorite gabbro and more basic facies in intimate association.
PChgr
Hornblende Granite
PCd
Diorite
PCaq
Arkosic Quartzite
Occurs as lenses in the crystalline schists.
PCa
Amphibolite
PCg
Greenstone Schist
Probably of Pre-Cambrian Age.
PCgr
Granite and Gneiss
Includes granites (partly quartz monzonite) and gneiss. In Fredricksburg area includes some Post-Ordovician quartz monzonite. Gneiss is Pre-Cambrian, but some of the granites are probably Cambrian. Granites largely biotite granites. Intruded by pegmatites and include some small bodies of schist
PCc
Crystalline Schists
Chiefly micaceous (sericitic) including chloritic, quartzitic, garnetiferous and hornblendic varieties. Intruded by pegmatites.
VIRGINIA GEOLOGICAL SURVEY
UNIVERSITY OF VIRGINIA
WILBUR A. NELSON, DIRECTOR
A GEOLOGIC MAP
OF THE
PYRITE-GOLD BELT IN CULPEPER, FAIRFAX, FAUQUIER, ORANGE, PRINCE WILLIAM, SPOTSYLVANIA, AND STAFFORD COUNTIES
VIRGINIA
1 ½ 0 1 2 3 Miles
BASE TRAVERSED BY J. W. KISLING, Jr. AND A. A. PEGAU
GEOLOGY BY JOHN T. LONSDALE, J. W. KISLING, Jr., D. H. CARDWELL, AND E. R. WOOLFOLK
1927
FAIRFAX CO.
PRINCE WILLIAM CO.
STAFFORD CO.
FAUQUIER CO.
CULPEPER CO.
ORANGE CO.
SPOTSYLVANIA CO.
BOUNDRY LINE
RAPPAHANNOCK RIVER
RAPIDAN RIVER
CEDAR RUN
P. F. and P. Narrow Gage R. R.