COMMONWEALTH OF VIRGINIA

VIRGINIA CONSERVATION COMMISSION

VIRGINIA GEOLOGICAL SURVEY

ARTHUR BEVAN, *State Geologist*

Bulletin 64

Commercial Granites and Other Crystalline Rocks of Virginia

By

EDWARD STEIDTMANN

UNIVERSITY, VIRGINIA
1945

COMMONWEALTH OF VIRGINIA

VIRGINIA CONSERVATION COMMISSION

VIRGINIA GEOLOGICAL SURVEY

ARTHUR BEVAN, *State Geologist*

Bulletin 64

Commercial Granites and Other Crystalline Rocks of Virginia

By

EDWARD STEIDTMANN

UNIVERSITY, VIRGINIA
1945

COMMONWEALTH OF VIRGINIA
Division of Purchase and Printing
Richmond
1945

VIRGINIA CONSERVATION COMMISSION

William A. Wright, *Chairman,* Richmond

L. E. Lichford, *Vice-Chairman,* Lynchburg

James Ashby, Stafford

C. S. Carter, Bristol

Edward W. Lauck, Luray

George Prince Arnold,
Assistant Commissioner, Richmond

Richard A. Gilliam,
Executive Secretary and Treasurer, Richmond

FOREWORD

The field work upon which this report is based was conducted mainly during the summers of 1941 and 1942, and the manuscript and illustrations were submitted to the printer on June 5, 1945, during the administration of Dr. Arthur Bevan as State Geologist, for publication. Because of unprecedented difficulties and delays, beyond the control of the Virginia Geological Survey, this Bulletin was not printed and delivered to us until the date stamped below.

The Commonwealth of Virginia and the Virginia Geological Survey suffered a great loss in the untimely death, on May 25, 1948, of Colonel Edward Steidtmann, the author of this Bulletin.

On September 1, 1947, the undersigned was appointed State Geologist of Virginia to succeed Dr. Arthur Bevan who resigned on that date.

WILLIAM M. MCGILL,
State Geologist.

Virginia Geological Survey,
Box 1428, University Station,
Charlottesville, Virginia,
December 15, 1948.

LETTER OF TRANSMITTAL

COMMONWEALTH OF VIRGINIA
VIRGINIA GEOLOGICAL SURVEY
UNIVERSITY OF VIRGINIA

CHARLOTTESVILLE, VA., June 5, 1945.

To the Virginia Conservation Commission:

GENTLEMEN:

I have the honor to transmit for publication as Bulletin 64 of the Virginia Geological Survey, the text and illustrations of a report on the *Commercial Granites and Other Crystalline Rocks of Virginia,* by Colonel Edward Steidtmann, Professor of Geology at the Virginia Military Institute.

The field work for this report was done by the author while seasonally employed by the State Geological Survey. It was the purpose of this investigation to make a study of the industrial uses of granites and other crystalline rocks in the Piedmont and Blue Ridge provinces of Virginia. Especial attention was given in the course of the field work and in the preparation of the report to undeveloped areas of these rocks which may have future commercial possibilities. To this end, a number of road traverses were made in different parts of the Piedmont and Blue Ridge provinces.

As this report has been prepared in part for quarrymen and other laymen interested in the stone industries, it contains a discussion of some of the elementary features of granites and of the economic factors to be considered in undertaking new quarry operations.

Respectfully submitted,

ARTHUR BEVAN,
State Geologist.

Approved for publication:
Virginia Conservation Commission,
Richmond, Virginia, June 12, 1945.
R. A. GILLIAM, *Executive Secretary and Treasurer.*

CONTENTS

ILLUSTRATIONS

TABLES

Commercial Granites and Other Crystalline Rocks of Virginia

By Edward Steidtmann

ABSTRACT

The commercial granites and certain other crystalline rocks discussed in this report crop out in parts of the Piedmont and Blue Ridge provinces. They are classified, on the basis of physical characteristics, into six groups: (1) Massive, quartz-bearing intrusive rocks, including granite, quartz monzonite, granodiorite, and quartz diorite; (2) gneissic and schistose granite, granodiorite, and quartz diorite; (3) greenstone of extrusive origin, now more or less foliated; (4) basic, dark-colored intrusive rocks which are foliated; (5) massive intrusive diabase (Triassic); and (6) unakite in more or less dikelike bodies. The location and extent of many of these bodies of rocks are shown on the Geologic map of Virginia, published in 1928.

The physical properties and inherent structures of granite which influence the usability of the stone; approved tests for dimension stone and crushed rock; and economic factors essential to the selection of quarry sites and the successful operation of commercial quarries are discussed in some detail.

The varied types of rock examined along traverses across the granite areas of the State are described in the text, and the location of the outcrops and local quarries shown on accompanying sketch maps. Petrographic data on the rocks examined along each traverse and chemical analyses of stone from a number of quarries are given in a series of tables.

Information is given on commercially active quarries and several former producers of dimension stone. A number of prospective quarry sites are listed and the potential reserves of granite and other crystalline rocks suited for the production of dimension stone, crushed rock, and special uses are discussed.

INTRODUCTION

PURPOSE AND SCOPE OF REPORT

The purpose of this report is to give information regarding the granites of Virginia and some of the crystalline rocks areally related to them. The data herein presented have been obtained from detailed field studies by the writer and from earlier reports, together with laboratory tests made on samples of granite and other rocks collected for such purposes.

FIELD WORK

The field study upon which this report is based covered all of the producing and most of the inactive granite quarries of the State. A general survey of all the granite resources of the State also was attempted. Exposures of granite were studied along 10 different highways which cross the granite areas of the Piedmont and Blue Ridge provinces of the State. About 1,200 samples of granite and other rocks were collected on these road surveys for detailed study.

LABORATORY STUDIES

The mineral content, grain, color and other physical and chemical characteristics of the samples collected in the field were studied and tabulated in the laboratory. These tabulations are the principal basis of a brief summary dealing with the nature of several of the granite bodies which are shown on the Geologic map of Virginia, published by the Virginia Geological Survey in 1928. The petrographic studies and physical tests were made in the laboratories of the Department of Civil Engineering of the Virginia Military Institute.

ACKNOWLEDGMENTS

The studies of the writer were authorized by Dr. Arthur Bevan, State Geologist of Virginia, and were made under the auspices of the Virginia Geological Survey. The writer was assisted in the field by Mr. Chamberlin Ferry of Washington and Lee University. Professor Robert A. Marr of the Virginia Military Institute supervised the physical tests of samples collected by the author. The tests were made by Cadet D. M. Erskine of the Department of Civil Engineering. The descriptions of certain quarries in the Charlottesville area, as indicated,

are by Arthur A. Pegau and William M. McGill. The manuscript and illustrations for the report were edited by William M. McGill, Assistant State Geologist.

The writer has drawn freely upon all available reports dealing with his subject. No present-day study of stone could be carried far without the work of Oliver Bowles, J. R. Thoenen, and others of the U. S. Bureau of Mines. The principal earlier reports consulted in the preparation of this report are those of the late Thomas L. Watson, former State Geologist of Virginia. A list of reports and papers consulted in this study is given under "References."

GENERAL FEATURES OF GRANITE

DEFINITION

Granite is a compact, granular, plutonic, igneous rock composed of alkali feldspars, quartz, minor amounts of soda-lime feldspars, and other minerals. The soda-lime feldspars range from albite to oligoclase. As a rule, granite also contains iron-bearing silicates, such as biotite and hornblende. Granitic rocks in which soda-lime and potash feldspars are about equally abundant are called quartz monzonites. Granodiorites contain a considerable excess of soda-lime feldspars. Granitic rocks which contain plagioclase feldspar and negligible amounts, if any, of potash feldspar are quartz diorites. Some of the granitic formations of Virginia, notably in the central part of the Piedmont province and in parts of the Blue Ridge, are quartz monzonites. Granodiorites and quartz diorites are common in parts of the Blue Ridge. The use of these rocks for structures is not affected by their feldspar content. Common accessory minerals besides mica and hornblende include augite, hypersthene, magnetite, apatite, garnet, zircon, and pyrite. Granites contain about 65 to 75 per cent feldspar, and about 15 to 30 per cent quartz. The proportions by weight and by volume are nearly the same.

CHARACTER

Every individual grain or particle of a crystalline rock, such as granite, is a mineral. Minerals determine the decorative value of a rock. The size, shape, and color of individual mineral particles, as well as their arrangement, determine the pattern of the rock and affect its strength. A relatively fine-grained granite generally is stronger and more durable than one of coarser grain.

Granite is an intrusive igneous rock that has crystallized from a magma below the earth's surface. Magma is a solution of silicates and other liquid as well as gaseous materials. The magma from which rocks such as granite are derived, not only contains the granitic materials but also steam and other gases. The gases escape when granite solidifies. In some cases the released gases deposit valuable minerals in the openings of the earth's crust.

MINERALS

GENERAL PROPERTIES

Each mineral has a sufficiently definite composition to be expressed by a chemical formula. Physical properties of minerals usually vary within very narrow limits. Minerals commonly vary greatly in color. These variations in color may be due to finely dispersed foreign matter, to differences in composition, to structural differences, and to other undetermined causes. What gives the Amazon stone of Amelia, Virginia, its beautiful green color is yet to be determined. Professor Karl Przibram of Vienna says that the blue color of some salt crystals is due to irradiation by radioactive elements, followed either by heating or compression.[33] Such discoveries suggest that other color variations of minerals may in some cases be due to a similar cause.

Hardness.—The hardness of a mineral is commonly measured by its resistance to scratching by certain selected minerals used as a scale or measure of hardness. For determining hardness, the Mohs' scale is used. It consists of the following minerals, from softest to hardest: 1, talc; 2, gypsum; 3, calcite; 4, fluorite; 5, apatite; 6, feldspar; 7, quartz; 8, topaz; 9, corundum; and 10, diamond. Each member scratches minerals which are below it in the scale (softer). The scale can be used only for determining relative hardness.

Crystal forms.—Nearly all minerals are crystalline and exhibit distinctive and definite internal structures. Crystalline substances are composed of regularly arranged particles. When not hindered by other objects, growing crystalline substances develop crystal faces. The faces are related to regularly arranged atoms and form the outer bounds of the atomic structure.

Cleavage.—Some minerals have the ability to part or split along parallel surfaces. This property is called cleavage. When present it is always parallel to certain crystal faces of the mineral. Every fragment of a cleavable mineral, however minute, has the power to cleave.

Fracture surfaces.—Fractures in a mineral which are not parallel to crystal faces are called fracture surfaces and not cleavage. The shape of such fracture surfaces is more or less distinctive for each kind of mineral.

Specific gravity.—The specific gravity of rocks and minerals generally varies within narrow limits. It is the weight of the rock or mineral divided by the weight of the volume of water which it displaces. Since quartz and feldspar have a specific gravity of about 2.6, it follows that this figure is close to the specific gravity of any granite. The weight of granite, as thus indicated, averages close to 165 pounds per cubic foot.

FELDSPAR

Feldspar is the name given to a series of closely related silicate minerals, having similar, but not identical, physical and chemical properties. Feldspars are sixth in the Mohs' scale of hardness. Those found in granite vary in specific gravity from about 2.57 to 2.65. They cleave along two surfaces, either at right angles to each other or nearly so.

When seen in cross section, as on polished surfaces, the feldspars of granite are commonly rectangular in outline. In a porphyritic granite, large feldspar crystals are embedded in a matrix of smaller grains. The larger crystals are rather evenly spaced. On smooth surfaces, the larger grains commonly form either rectangles or hexagons. In the stongest granites, feldspar grains do not exceed 0.05 inch in diameter. Coarse-grained granites are relatively weak.

The principal feldspars of granite include microcline, orthoclase, and gradations between albite and oligoclase. Andesine is sometimes present in quartz monzonite. The feldspars are best distinguished by the petrographic microscope.

QUARTZ

Quartz is the hardest, least soluble, and therefore the most durable of the major minerals of granite. It is composed of silica, lacks cleavage, and has a shell-like fracture. The quartz of granite is irregular in shape and fills the interstices between feldspars. It is the last mineral to crystallize from the magma. Quartz in granite generally varies in color from light to dark; however, blue, violet and purple varieties occur in certain granites of Virginia. These colors are ascribed to the presence of minute amounts of finely divided titanium oxide.

BIOTITE

Biotite is the dark-colored mica present in many granites, generally varying from brown to black. It is a complex silicate of iron, potassium, magnesium and aluminum, with water. The atomic ratio of these metals is variable. Biotite is one of the first minerals to crystallize, and therefore is commonly embedded in other minerals of granite, notably feldspar. In some granites biotite has a very marked effect on the color. The blue color of some granites is ascribed to the occlusion of small mica particles in white feldspar. As a rule, granites do not have more than 5 per cent biotite, but in granites in which the grain has been crushed, rolled, and reoriented as a result of great lateral pressure in the earth's crust, the mica content may run as high as 15 to 20 per cent. Such metamorphosed granites are called gneisses and schists. In gneisses, the light- and dark-colored minerals are more or less separated into a layered and banded arrangement in which the long and flat sides of mineral particles have a considerable degree of parallel alignment. Schists, like gneisses, result from the orientation of rock materials in response to great one-sided pressure. They have the parallel alignment of mineral particles common in gneisses but show no banding. Biotite flakes can be distinguished from hornblende grains, in that the former can be easily shredded by a knife blade.

Biotite affects the strength, color, and durability of granite. It is soft and easily decomposed by surface waters. Its relative abundance and arrangement have much to do with the general appearance of a rock. Granites in which biotite occurs in nearly spherical lumps are termed orbicular granites. A granite from Craftsbury, Vermont, has this characteristic. The biotite orbicles disintegrate easily and are undesirable in monumental stone.

MUSCOVITE

Muscovite is a colorless or nearly colorless mica. It is a complex silicate of potassium and aluminum, with water. In granite it is generally less common than biotite; however, in some granites, it is the only mica. As a rule it occurs with biotite, to which it is similar in composition except that it contains neither iron nor magnesium. In granites muscovite has about the same kind of grain and distribution as the dark-colored mica. Like biotite it is abundant in some granites in which the grain has been crushed, rolled, and more or less recrystallized as a result of great lateral pressure. Muscovite does not decompose easily.

HORNBLENDE

Hornblende, a member of the amphibole group, in some granites, constitutes the only dark-colored mineral; in others, it is associated with biotite. Hornblende commonly forms minute dark-brown to black needles or prisms, generally not more than 0.2 inch in length. It is cut lengthwise by two oblique cleavage surfaces and is nearly as hard as steel. In composition it is a silicate similar to biotite, but it contains very little alkali and has a notable amount of lime. It also contains water. In certain granitic rocks of the Blue Ridge, hornblende is closely associated with biotite and hypersthene. Locally it takes their place in these rocks. As in biotite, certain constituents of hornblende replace each other, and, like biotite, hornblende often changes to chlorite, which near the surface decomposes into red clay. This alteration generally takes place too slowly to affect the use of hornblende-bearing rocks for structural purposes.

AUGITE

Augite, a member of the pyroxene group of silicates, present in some granites, resembles hornblende in composition, hardness and color, but it is far less common in granite than is hornblende. It is commonly more stubby than hornblende and has two rather indistinct cleavages that cut each other at angles of nearly 90 degrees. The alteration products of augite are about the same as those of hornblende.

HYPERSTHENE

Hypersthene, a ferrous magnesium silicate, like augite, generally is rare in granite and has about the same color, grain, and hardness as augite. When present, it plays about the same rôle as hornblende, biotite, or augite. As a rule it is one of the first minerals to crystallize from the parent granitic magma. However, in the hypersthene-bearing granitic rocks of the Blue Ridge it is closely associated with the quartz between the feldspars, and is a late mineral. On weathering, hypersthene decomposes into a soft, reddish-brown, iron oxide. Alteration to serpentine, talc, magnetite, and carbonates is not uncommon in the deeper parts of the earth's crust.

Magnetite

Nearly all granites contain a small amount of magnetite, usually less than 1 per cent. Magnetite is a hard, black, weather-resistant, magnetic oxide of iron. It does not occur in quantity sufficient to affect the use of the rock for dimension stone.

Garnet

Garnets in the form of tiny reddish crystals are not uncommon in granite, but generally they are not sufficiently abundant to be of any practical importance. Although their composition is complex and variable, they are harder than steel and most varieties do not alter easily. They are silicates of various elements, including aluminum, magnesium, iron, and manganese.

Pyrite

Pyrite is present in many granites, generally as minute crystals about the size of a pin head. It is a hard, yellow sulphide of iron, occurring both as a primary and as a secondary mineral. When exposed to weathering, pyrite changes to hydrous iron oxide and has been known to give rise to unsightly reddish-brown blotches of limonite. Normally pyrite occurs in granite in amounts insufficient to affect the use of the rock.

COLOR

The color of granite depends mainly upon that of the feldspars and quartz present. Shades from white to gray, dark-gray, and bluish-gray are common. Some varieties are flesh-colored, pink to deep-red. The quartz monzonites and granodiorites of the Blue Ridge generally are dark-gray to bluish or greenish. Commonly colors are due to inclusions of iron oxides, mica, and other substances within the dominant minerals. Fresh feldspar has a nearly glassy appearance. A dull luster is proof of decay, thus granites containing decayed feldspar will not take a polish.

TEXTURE

Granite consists of a closely knit interlocking mass of grains, nearly devoid of intergranular openings. Polished surfaces of granite indicate that its grains generally fall into three principal classes. The first class constitutes only a small part of the granite. The grains of this class are largely or entirely bounded by crystal faces. To this class belong such minerals as magnetite, biotite, and hornblende which are the first to crystallize. The feldspars form the second class of grains and compose most of the rock, generally occurring as imperfect crystals. In porphyritic granites some feldspar grains are larger and more perfectly faceted than others. The larger feldspars crystallized before the smaller ones in the enclosing matrix. Quartz forms the third class of grains. It lacks crystal faces and fills the remaining interstices in the granite. In exceptional cases, hornblende, biotite, or hypersthene are in close association with quartz. Certain granitic rocks of the Blue Ridge described in this report are in this class.

Since all the grains of granite are crystalline, that is they are bodies whose atoms have a regular pattern, it follows that the mobility of the atoms in the magma must have been great enough to permit them to move to their assigned places. It appears that they were able to take their oriented positions, not because they moved rapidly through the magma, but because they were in motion during a long period of time. This mobility was conditioned in part by temperature. Granitic magmas cool slowly. Since all granites are formed beneath the earth's surface, no one has ever seen granite in the process of solidification. Slow cooling means that the crystallization temperatures—the conditions under which the atoms move into regularly oriented positions with inter-atomic spaces—are maintained during long periods of time. As evidenced in the treatment of metals, prolonged heating produces large grains and rapid cooling or quenching results in the production of fine grains.

Granites which crystallize under great one-sided lateral pressure develop more or less elongated, aligned grains. Granites formed in this way are called primary gneisses. The development of gneissic and schistose structure as a result of lateral pressure acting upon solidified granites and other rocks has been discussed. The process involves the slicing, granulation, and rolling out of grains into thin sheets. In some cases it also involves the development of new grains or even entirely new minerals. Rocks reorganized under such conditions commonly show an increased amount of mica, hornblende, and similar minerals.

The reorganization of granites by dynamic conditions usually lessens their usefulness for building and decorative purposes. Granite gneisses are rarely used for dimension stone since generally they lack the uniformity of grain and color pattern required for such uses. They often are used for crushed stone, riprap and similar purposes. Schistose granites have scant use in construction work.

FORMS

The size and shape of most granite masses are not clearly known. These bodies are only partly exposed by erosion; neither the deepest cuts of man nor those of nature reveal their full extent. Depending upon their size, shape, and relation to other rocks, granite bodies are classified as batholiths, stocks, sills, laccoliths, dikes, necks, and by other names. Dimension stone is obtained mainly from batholiths and to some extent also from stocks, laccoliths and sills. Dikes generally are too narrow to be workable. Crushed stone, however, has been prepared from all types of granite bodies.

Batholiths are large masses extending to considerable depths. In some cases their unroofed parts underlie thousands of square miles. Stocks are similar to batholiths but smaller. Sills are sheetlike masses injected between the stratiform structures of other rocks. Granite sills are far less common than are basalt sills.

Laccoliths are dome-shaped. They cause the strata of overlying masses to be arched upward. Most laccoliths do not exceed five miles in diameter.

Dikes are inclined, sheetlike masses of igneous rocks. They cut across bedding and foliation. Narrow dikes make granite unsuitable for use as dimension stone, since in large granite bodies dikes break the continuity of both the strength and pattern of the rock. They also cause waste of materials and add to the cost of quarrying. In quarries worked for crushed stone the presence of dikes generally is of no consequence. Necks are the frozen vents or feeders of volcanoes. They usually contain fragmental materials, such as inclusions of wall rock from the formations cut by the neck. Fragmental materials in necks are formed also by volcanic explosions and by subsidence.

STRUCTURES

The structural features of granites include: miarolitic cavities; foreign inclusions; segregations and schlieren, rift, grain and head; joints and faults; veins and dikes.

Miarolitic Cavities

Miarolitic cavities are small openings usually not more than an inch in diameter, lined with tiny crystals. The crystals are mostly of common minerals of the granite, such as quartz, but may include tourmaline, fluorite, and topaz. No miarolitic cavities were seen in the granites of Virginia except in the Boscobel quarry west of Richmond. Their presence indicates that the magma did not crystallize under severe compressive conditions, and that crystallization was accompanied by shrinkage due to escaping gases.

Foreign Inclusions

Fragments of foreign rock are in places present in the parts of a granite body near the contact of the granite with the rock into which it was injected. The abundance of such fragments varies greatly in different instances. Near the contact the fragments are angular and well defined; farther away inclusions lose their sharp definition and grade into the enclosing rock. Foreign inclusions are undesirable in dimension stone, since they interfere with the separation of suitable blocks and spoil the grain and color pattern of the rock.

Schlieren

In a granite, streaky dark-colored patches with indistinct boundaries are called schlieren. When they have the same minerals as the enclosing rock, they are thought to be due to segregations from the magma. When they differ from the enclosing rock, they generally are interpreted as having been formed by the action of the magma upon foreign inclusions. Segregations such as the biotite knots in the granite of Craftsbury, Vermont, have been discussed under "Biotite."

Sheet Structure

Most granite bodies show what is called sheet structure. Sheets are nearly horizontal, wavy, parting surfaces or joints. Near the surface of the earth they are commonly not more than 2 or 3 feet apart, but generally at greater depths, they are more widely spaced. Under a hill, the structure usually conforms to the swell in the land surface. Sheet structure has been noted at depths greater than 200 feet. The cause of sheet structure is uncertain.

It can not be ascribed to temperature changes caused by the sun since the structure extends to such great depths. It has been ascribed to shrinkage of the granite body due to loss of heat and also to unloading due to erosion of overlying rocks. Many granites are under a condition of stress when exposed by quarrying. Tools have become wedged by rock expansion. Cut blocks have expanded and dangerous "rock bursts" have occurred in quarries having sheet structure. Such strained conditions may be the cause of sheet structure.

Sheeting, if not too closely spaced, is an aid to quarrying. Generally a quarry floor is opened on a sheeting surface if one is present. If none is present, the quarry floor is made artificially by drilling, blasting and wedging. As a rule the artificial floor is made to slope towards the quarry pit in order to aid the removal of block stone.

RIFT, GRAIN, AND HEAD

Rift, grain, and head designate the easiest, intermediate, and hardest surfaces of splitting of the rock of a quarry. Rift is the "easiest way." A rift surface has the smoothest feel and normally is vertical or nearly so, but in some instances, it is horizontal. It is essentially constant in direction and dip in any quarry. The grain is the second best surface of splitting. It is horizontal where the rift is vertical. The head, which generally is vertical, is the "hard way." It takes the best polish and retains it longer, but is the hardest surface to finish. Most quarries exhibit all three surfaces, but some rocks are devoid of any superior surface of splitting.

Rift in its most obvious form is due to a faint alignment of the minerals in the plane of the rift. The dark-colored minerals usually show this alignment more clearly than do quartz and feldspars. The rift surface is the first to show decay.

In certain of the granites of New England, Dale[7] found that rift is related to microscopic fractures which cut the quartz grains and in places extend into the feldspars. These fractures are nearly parallel plane surfaces. He found that the grain was caused by a similar, but less distinct, set of fractures at right angles to the rift fracture. Both fractures were aligned with sheets of fluidal cavities which antedate the quartz grains, since they extend from grain to grain across intergrain boundaries.

The alignment of fluidal cavities, fractures, and minerals which cause rift indicates that the rock was deformed by one-sided pressure during crystallization. It also shows that the magma did not transmit pressure equally in all directions, like a liquid.

Finding the rift is one of the first steps in opening a quarry. Rift is used not only in separating large blocks from the ledge, but in subdividing them if need be. Some quarries, however, show no rift.

Granite breaks more easily when compressed in the direction of the rift than across it. The difference in pounds per square inch needed to produce rupture in each instance amounts to about 11 per cent of the greater strength. The compressive strength in either direction is so much greater than that required in structures built of granite, that this difference has no practical bearing.*

A marked rift tends to lessen the durability of granite. Water seeping into the rift and into the cavities that cause rift, in some cases produces decay. It would be interesting to know if the unusually deep, incipient decay of some granite bodies is related to the action of ground waters along rift surfaces and in microscopic cavities.

JOINTS

Joints are fracture surfaces whose length may be as much as several hundred feet along the outcrop. The length and depth of joints are unknown, since they can not be seen throughout their extent. On the surface they commonly form gaping fractures. In depth, their walls generally are pressed tightly together. Many joints are vertical or nearly so. Horizontal joints or sheets in granite have been discussed.

Joints with essentially the same strike and dip generally occur in a quarry at fairly regular intervals, thus forming a set of joints. The interval between joints may vary from a few inches to more than 50 feet. Quarries commonly have more than one set of joints. As a rule, one of the sets is more distinct than all others. In the granite quarries of Virginia the most prominent set of joints commonly extends in a northeasterly direction, with, locally, a set of secondary importance extending in a northwesterly direction. Their alignment is related to regional compression of the rocks of the Appalachian region by forces acting in a northwesterly direction.

FAULTS

Fault surfaces are fractures along which slipping of rock masses has taken place. In granite bodies, faults are indicated by closely spaced fractures; zones of crushed rock commonly recemented with vein material, mostly quartz; severed and dislocated veins and dikes; and by polished and grooved slip surfaces. In quarries producing dimension stone, faults, whether large or small, are harmful. They break the rock into unsuitable pieces, stimulate decay, and spoil the grain and color pattern. In crushed stone quarries, faulting generally is unimportant but intense faulting may cause the rock to yield too large a percentage of "fines."

Veins

Veins are more or less tabular, sheetlike bodies which fill joints and fault surfaces or replace wallrocks adjacent to fractures. The minerals of veins were deposited by subsurface solutions. Most of the vein material consists of the following: quartz, barite, carbonates, and sulphides. Variations in grain size and grain pattern, and in the proportion of mineral constituents, generally distinguish veins from igneous rocks. Veins in granite, even "hair-line" veins no thicker than tissue paper, affect the quality of granite and may prevent its use for dimension stone.

INJECTION

All granites crystallized from magmas. Studies of the structure of granite bodies exposed by erosion confirm this conclusion and also disclose that all the larger granitic bodies displace previously existing rock masses. The continuity of certain rock structures adjacent to granite batholiths and stocks is broken by the granite body which has displaced them. Generally granite bodies have been injected in zones of weakness, along the contact surfaces between geologic structures.

CONTACT PHENOMENA

The results of the interactions, both chemical and physical, along the contact between an intrusive magma and the invaded rock are called contact phenomena. The effects generally are most marked in the invaded rock rather than in the intrusive body. Limestones show more contact effects than other rocks. In most cases these effects do not extend more than 300 feet from the contact surface.

The effects developed within the invaded rock may involve changes in grain size, in pore space, and in mineral content. Both loss and gain of constituents may take place. In the intrusive rock the border zone may differ from the interior in mineral content, in the proportion of mineral constituents, in grain size, in pattern, and in porosity. Border zones of the intrusive mass are apt to be variable in grain size and pattern. They may also contain inclusions derived from the intruded rock.

In Virginia, contact zones of granites are rarely exposed. None have been reported as showing notable contact effects. Decomposition due to weathering has also masked these effects.

The border zones of granite bodies generally are not well suited for dimension stone because of the variable grain and color pattern and the presence of foreign inclusions.

DISINTEGRATION AND DECAY

The disintegration and decay of exposed granite by weathering processes are due mainly to the action of freezing water, volume changes resulting from temperature variations, and chemical and attendant physical changes caused by water and substances dissolved in it.

Water increases about 10 per cent in volume when it freezes. In confined places, as in the intergranular openings in rocks, it exerts a pressure of about 1.04 tons per square inch upon the confining walls. Granite has so little pore space, generally less than 0.13 per cent, that it is not damaged readily by freezing water. The effect is greatly increased by the presence of cracks, hence every precaution is taken in quarrying dimension stone to avoid the development of incipient cracks.

Granite expands when heated and contracts on cooling. For a rise of one degree Fahrenheit the expansion amounts to about 0.000045 inch per linear foot. The different minerals in granite expand unevenly and each mineral particle expands unevenly with respect to its unlike crystal directions. The adjustment of granite is also complicated by the fact that granite is a poor conductor of heat. Adjacent parts of a granite body not more than an inch apart may expand quite differently. These unequal changes in volume may lead to rupture.

The magnitude and rapidity of the temperature changes needed to break granite and other rocks are not clearly defined. Blackwelder[1] found that most igneous rocks withstand rapid temperature changes of 392° F., without producing visible fractures. This test is at least 3 times as severe as that of actual daily temperature changes on the earth's surface. He also found that a certain granite could withstand slow temperature variations of 800° C.

Fire tests have shown that temperatures below 400° C. have no disruptive effects on most rocks. The greatest injury in granite develops at about 800° C.; however, injurious effects of a milder nature are noticed at about 500° C. These injurious temperatures are related to inversion temperatures of quartz.

All minerals of a granite are attacked to some extent by surface and ground waters. The rate of decomposition is usually increased by the presence, in the water, of dissolved carbon dioxide, oxygen, and, in most cases, other substances including organic acids and salts. Quartz and muscovite are among the most resistant minerals. Feldspars react with water and some of its dissolved constituents. They expand, partially dissolve, and leave a residue of white clay. The iron-bearing silicates, biotite and hornblende, also swell when acted upon by ground water. They partially dissolve and leave a residue of red clay. A residual mantle of clay tends to form on all exposed granite bodies. The upper foot or two of the residue is generally porous, structureless, and dark-colored, the color being due to humus. At greater depths the decayed material still shows the texture of the granite from which it was derived. This zone of decayed rock grades downward into fresh granite. In most of the quarries of New England the residual mantle is lacking because of relatively recent glacial scraping. In quarries in the Southeastern States, the removal of the overlying residue and partially decayed rock constitutes an added cost of quarry operation.

In Virginia, the greatest thickness of residual material is about 100 feet. At producing quarries, however, the mantle generally is not more than 15 feet thick, and commonly near the eastern boundary of the Piedmont region, because of its partial removal by erosion, is very thin. In some quarries of this region, the overburden consists mainly of transported sand and gravel. The most extensive outcrops of fresh granite are found along the eastern border of the Piedmont province and in the Blue Ridge.

GROUND WATER

The surface of the zone of saturation, or the water table, in granite and similar rocks, is generally undulating like the land surface but less so. The water table commonly descends towards local streams or lakes.

Fresh granite contains relatively little ground water unless it is cut by open joints or faults. The intergrain pore space of granite commonly is less than 0.35 per cent of the total volume of the rock. Most of the ground water pumped from granite is obtained from the surficial part of the bedrock where the rock has been partially decomposed and where joints are most abundant. Most water wells in granite are less than 500 feet deep. Of 33 wells in granite in the Richmond area, studied by Sanford,[20] 60 per cent yielded more than 25 gallons of water per minute, and only 2 were dry. About 80 per cent of the wells were successful. Cederstrom[6] reports a yield of 380 gallons per minute from a well in South Richmond which penetrates 564 feet of granite. Another well 4 miles south of Richmond, with a yield of 360 gallons per minute, was bottomed in granite at 354 feet.

The flow of ground water into granite quarries that have been excavated below the level of the water table normally is slow, thus generally pumping is not a large item of quarry operating expense. The inflow of surface water is apt to be more serious than the inflow of ground water.

USES

Granite is used in the form of crushed rock, riprap, rubble, and dimension stone.

Crushed stone is produced in definite sizes specified by the buyer. It is used in road building, concrete aggregate, and as railroad ballast. Riprap consists of extremely coarse fragments used in building piers, shore protections, dams, and other kinds of river and harbor installations in which heavy pieces of rock are needed to resist waves, tides, and currents.

Rubble consists of fragments of variable size having at least one good face. It is used for retaining walls, basement walls, and occasionally for residences. Concrete has displaced rubble to a large extent.

Dimension stone includes paving block, sewer block, and building and monumental stone. According to compilations by the U. S. Bureau of Mines, the total value of granite dimension stone, including rubble, produced in the United States in 1941 was $10,831,476. About 23 per cent of this was building stone. Since 1941 production has declined, due to the war. The value of production for 1943 was reported as $7,991,454.

GRANITE AREAS IN VIRGINIA

GENERAL STATEMENT

Granite bodies underlie portions of the Piedmont and Blue Ridge provinces of Virginia (Fig. 1). Those of the Blue Ridge and the eastern part of the Piedmont province show the least foliation and are the best adapted for dimension stone. Of the different named and described granites, the Petersburg and Red Oak yield the best building stone. Most of the dimension stone quarries of the State are located in the eastern part of the Piedmont region, at or in the vicinity of Falls Church, Fredericksburg, Richmond, Petersburg, Kenbridge, and Burkeville.

The location and extent of the different granites are shown on the Geologic map of Virginia published by the Virginia Geological Survey in 1928. Many of the quarries described in this report are shown on the various accompanying sketch maps (Pls. 1, 4, 7, and 8, and Figs. 2 to 23, inclusive).

PIEDMONT PROVINCE

LOCATION AND EXTENT

The Piedmont province extends from the western margin of the Coastal Plain on the east to the base of the Blue Ridge on the west. Its eastern boundary is marked by a change in rocks and structure, whereas the western boundary is largely topographic. There is no essential difference in the geologic structure of adjacent parts of the Piedmont and the Blue Ridge provinces. The western part of the Piedmont in many places has more foliated rocks than the Blue Ridge, but as yet no definite geologic boundary has been drawn between the two provinces. Across northern Virginia the Piedmont province has a width of about 40 miles. This increases to a maximum of about 165 miles along the Virginia-North Carolina boundary.

TOPOGRAPHY

The Piedmont province is a dissected rolling low plateau or plain surmounted by many linear ridges aligned in a northeasterly direction. In the eastern part of the province the divides on the plain-like area have altitudes of about 300 feet, whereas at the base of the Blue Ridge they attain altitudes of about 1,000 to 1,500 feet.

East of a line passing through Haymarket, Pendleton, and Not-

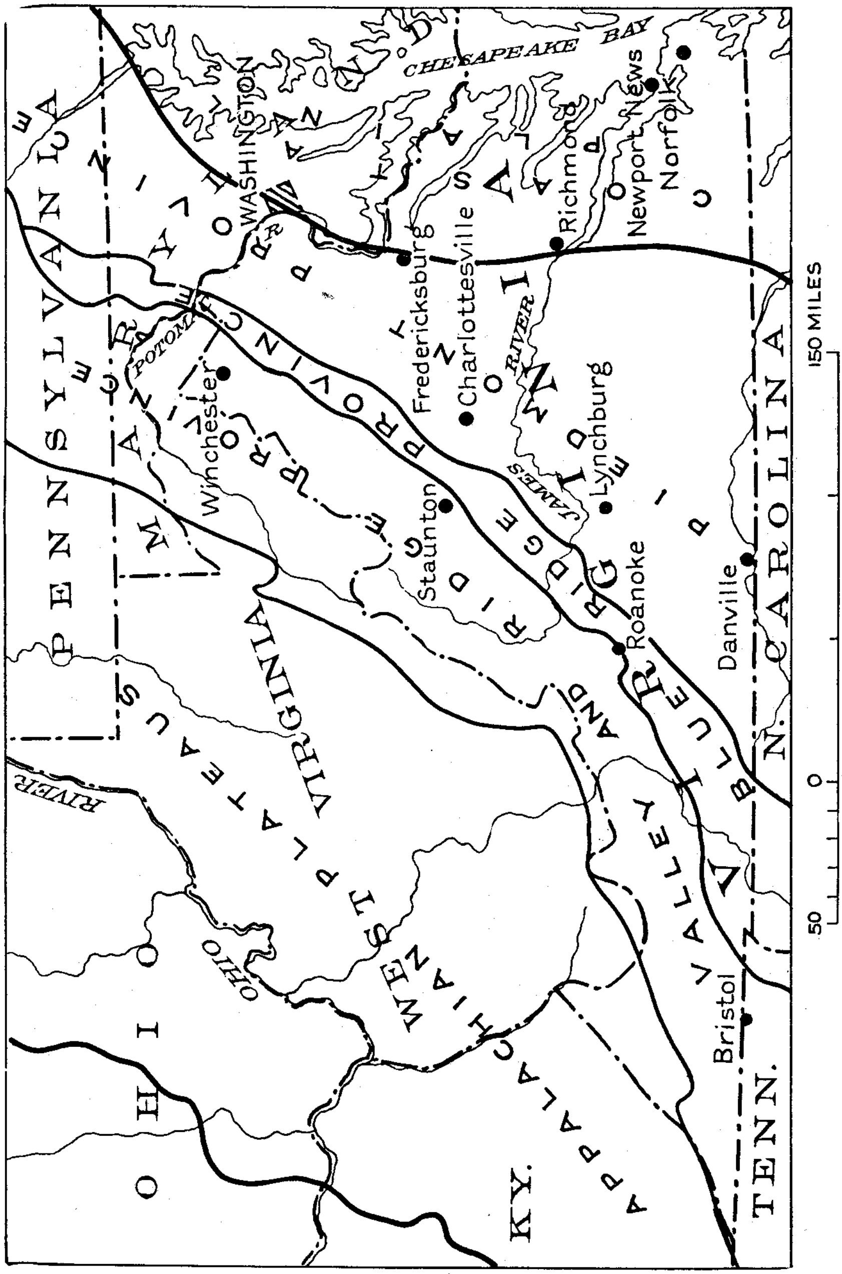


FIGURE 1.—Index map showing physiographic divisions of Virginia. The quarries described in this report are in the Piedmont and Blue Ridge provinces. (From Virginia Geological Survey Bulletin 47.)

taway, the Piedmont has almost no distinct ridges and is a gently southeastward sloping plain. The uplands of this part of the province have an average relief of about 50 feet. Along the larger streams, the relief ranges from 150 to 200 feet. West of the line indicated, long northeasterly trending ridges are common. The highest are near the Blue Ridge. The surface of this part of the province is more rugged and its dissection is quite marked. The western boundary of the Piedmont has an altitude of about 800 feet in northern Virginia and about 1,500 feet along the North Carolina boundary (Pl. 2).

DRAINAGE

Throughout most of their courses across the Piedmont province, the principal streams are swift and have many rock outcrops along their channels. During Tertiary time, the channels of the streams were nearer the level of the present uplands. Since then, the streams have lowered their channels to their present position. The process of downcutting is still in action.

GEOLOGY

The Piedmont province is underlain by granites, gneisses, schists, and other igneous and metamorphic rocks of pre-Cambrian age; folded Cambrian and Ordovician sediments; post-Ordovician granites; and Triassic sedimentary rocks and igneous intrusives. The Coastal Plain to the east is underlain by more easily eroded, mostly unconsolidated rocks,— sands, gravels, clays, and marls,—of Cretaceous, Tertiary, and Quaternary ages. Streams flowing over the boundary between the two provinces have developed rapids and falls along the Fall Zone where they plunge from the resistant granitic rocks of the Piedmont onto the weaker unconsolidated sediments of the Coastal Plain. Aside from the "fall zone," there is no other marked topographic break between the two provinces along most of their contact across Virginia.

GEOLOGIC STRUCTURE

The pre-Cambrian and Paleozoic rocks of the Piedmont province have been intensely folded and dislocated by faults. Most of the folds are overturned toward the northwest and trend in a northeasterly direction. Most of the fault surfaces dip towards the southeast. During the periods of folding and faulting the masses of rock overlying the faulted areas were pushed upward towards the northwest. All of the structures have been cut deeply by erosion, which has left outcrops of the more resistant materials standing in greater relief than those of the weaker rocks.

During Triassic time, the Piedmont surface had slight relief, and was locally warped into subsiding basins into which were deposited the Triassic sediments. The deposits in these basins were dislocated by crisscrossing faults. The movements were accompanied by the injection of basalt sills and dikes. Following this episode, erosion was resumed throughout the region and moderate crustal warping continued its rôle in modifying the land surface. To what extent erosion has been interrupted by depositional processes in post-Triassic times is unknown. The present land surface of the Piedmont province is due almost entirely to stream erosion and weathering acting upon a complex pattern of resistant and less resistant materials.

The rocks of the Piedmont region crop out in more or less parallel belts, of variable width, trending northeastward. The Geologic map of Virginia, published in 1928, shows the outcrop and structure of the different rock belts more clearly than can be explained in words. Because of the outcrop pattern, the topographic grain of the Piedmont province, that is the alignment of major hills or ridges, also shows a northeasterly trend.

MINERAL RESOURCES

Building stone has been produced from bodies of granite and greenstone locally throughout the Piedmont province. Granite has been quarried at or near Falls Church, Fredericksburg, Richmond, Petersburg, Burkeville, Kenbridge and other places. A granitic rock is quarried at Red Hill in Albemarle County, a few miles south of Charlottesville. Greenstone, a beautiful green, foliated, rock is quarried in Lynchburg. Crushed granite is produced on a large scale at Richmond, Skippers, and Boscobel, and Catoctin greenstone is a source of crushed stone near Charlottesville. The productive quarries are in rocks of either pre-Cambrian or Paleozoic age.

Diabase or trap rock of Triassic age, sometimes called "black granite," from a quarry near Buena, west of Culpeper, has been used for dimension stone. Other quarries in diabase are worked for crushed stone near Bull Run in Fairfax County, east of Leesburg in Loudoun County, and near Warrenton and Catlett in Fauquier County (Pl. 3A).

Granitic pegmatite dikes of the Piedmont region yield valuable feldspars and some mica, quartz, and kaolin. Those of Bedford and

Amelia counties lead in production. The green feldspar or Amazon stone of Amelia County is a valuable ornamental stone. An ilmenite-apatite dike on Piney River in Nelson County is an important source of titanium pigments and calcium monophosphate. At Roseland in the same county, an anorthosite body is the site of the largest rutile mine in the world. The Piedmont also produces small amounts of gold and silver. Kyanite is mined in Prince Edward County.

According to information compiled by the U. S. Bueau of Mines, stone producers in the Piedmont region of Virginia in 1941 included two granite dimension stone quarries, 13 producers of crushed stone (7 granite and 6 basalt and greenstone operations), and 2 producers of miscellaneous stone (greenstone and soapstone). The location of the larger granite and crushed stone quarries is shown in Plate 1.

BLUE RIDGE PROVINCE

LOCATION AND EXTENT

The Blue Ridge province extends southwestward across Virginia a distance of about 300 miles. In its northern part it is only 1 to 2 miles in width, but in southern Virginia it attains a width of nearly 40 miles. The Blue Ridge separates the Piedmont province on the east from the Appalachian Valley on the west.

TOPOGRAPHY

Northeast of Roanoke the Blue Ridge is essentially a narrow mountainous ridge with parallel foothills, but southwest of Roanoke it is a high triangular plateau broadening southwestward. Altitudes range from 1,200 feet at Harpers Ferry to 4,031 feet on Stony Man in Shenandoah National Park, and 5,719 feet on Mount Rogers, the highest point in the State, in the southwestern part of the plateau region. Two narrow gorges cut through the mountainous region in Virginia. They are the gorges of the James and Roanoke rivers. Each was cut by the stream which now flows through it. South of Roanoke River, no gorge cuts completely through the Blue Ridge.

In contrast with the more pronounced northeast alignment of the ridges and valleys of the Valley Ridges section on the northwest of the Valley region, a large part of the Blue Ridge presents a complex pattern of sprawling ridges and valleys radiating from one or more major crests. The Blue Ridge has a varied and complex geologic structure.

DRAINAGE

The Blue Ridge province is divided into a northern unit and a southern unit by differences in drainage. In the northern unit, the waters drain eastward and southeastward into the Atlantic Ocean. The major streams of this unit have their sources in West Virginia and in the western part of Pennsylvania. In the southern unit, the higher eastern part of the Blue Ridge plateau is a drainage divide. To the east of this divide, the waters flow down the steep eastern slopes of the mountains to the Atlantic Ocean. The plateau to the northwest of this divide drains southwestward into the Ohio River.

GEOLOGY

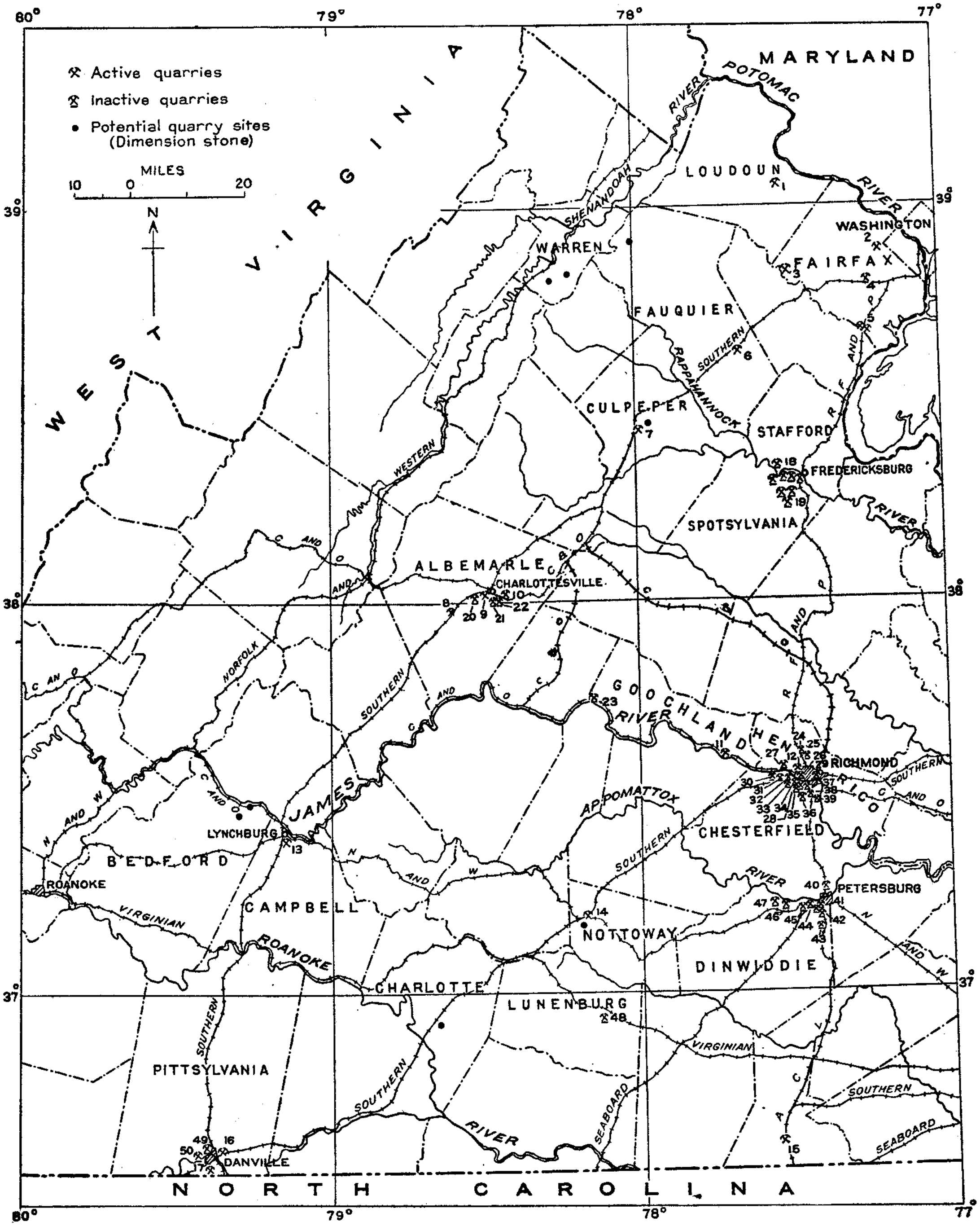
The Blue Ridge province is underlain by a complex assemblage of pre-Cambrian gneisses, schists, basaltic flows and intrusives, granites and granodiorites, and other crystalline rocks. Arkose, shale, slates, basaltic lavas, sandstones and quartzites of Cambrian age occur along the western border of the mountainous region.

The Blue Ridge is sharply separated from the Appalachian Valley to the west by differences in geologic structure. The dividing line is nearly straight. The Appalachian Valley is underlain by less resistant, sedimentary rocks—dolomites, shales, and limestones—of Cambrian and younger ages.

The Blue Ridge province is not sharply separated from the Piedmont province by differences of geologic structure. In Virginia, the eastern limit of the mountainous region locally coincides with the eastern boundary of massive pre-Cambrian granites, whereas the Piedmont lowlands to the east generally are underlain by older, more gneissic and schistose rocks.

GEOLOGIC STRUCTURE

Structurally, the Blue Ridge is an upfolded land mass, which has been considerably dislocated by a number of thrust faults. These movements took place along surfaces tilted steeply to the southeast and the rock units overlying the surfaces of slipping were thrust upward to the northwest with respect to those upon which they rested. Detailed studies of the geologic structure support this interpretation. The upbowed nature of the Blue Ridge is indicated by the steep westward descent of the pre-Cambrian mass under-



Map showing location of quarries and potential quarry sites in granite and some other crystalline rocks in Virginia. Active quarries: 1, Belmont Trap Rock; 2, Falls Church; 3, Fairfax (Bull Run); 4, Annandale; 5, Occoquan; 6, Catlett; 7, Twin Mountain; 8, Red Hill; 9, Moores Creek; 10, Shadwell; 11, Boscobel; 12, Sunnyside; 13, Virginia Greenstone Company; 14, Burkeville; 15, Trego; 16, Danville (City); 17, Virginia-Carolina; inactive quarries; 18, Taylor; 19, Hazel Run; 20, Berkeley; 21, Thomas; 22, Monticello; 23, Columbia; 24, Richmond Granite Company No. 1; 25, Richmond Granite Company No. 2; 26, McCloy; 27, Winston; 28, Philadelphia; 29, Belle Isle; 30, Chesterfield Golf Club; 31, Vietor; 32, Mackintosh and Middendorf (Old Dominion); 33, Granite Station; 34, Quarry southeast of Atlantic Coast Line trestle; 35, Donald (?); 36, Boulevard Bridge (Wray ?); 37, Forest Hill Park; 38, Middendorf; 39, McGowan; 40, Cook; 41, Burns & Campbell (Lassiter); 42, Walsh (Lassiter); 43, Asylum; 44, Dibble; 45, Granite Grove; 46, Rocky Run; 47, Booth; 48, Kenbridge; 49, Danville City No. 1; 50, Danville City No. 2. Base from U. S. Geological Survey map of Virginia.

neath the Paleozoic formations of the Appalachian Valley and by the occurrence of low-lying synclines of Cambrian and Ordovician rocks in the Piedmont province, east of the Blue Ridge.

MINERAL RESOURCES

No dimension stone of commercial grade appears to have been obtained from the Blue Ridge province, but crushed stone of good quality has been produced from granites and basalts at several wayside quarries.

Three types of granitic rocks in the Blue Ridge province are shown on the Geologic map of Virginia, published in 1928; granodiorite, Marshall granite, and Grayson granite gneiss. The granodiorite is shown as underlying most of the northern part of the Blue Ridge, as well as some of the outlying ridges to the east. The Grayson granite gneiss is shown as underlying an area in the southern part of the Blue Ridge plateau.

Other granites are known to occur locally and traverses across the granodiorite area of the Geologic map of Virginia (1928), have shown that it locally includes granite bodies, either distinct from the granodiorite or in uncertain relation to this body. In the region around Browntown, south of Front Royal in Warren County, an extensive body of graphitic granite gneiss crops out in the area mapped as granodiorite.

Red microcline granite.—Red microcline granite, nearly devoid of iron silicates, crops out in the core of an anticline exposed along Big Marys Creek, 2.7 miles south of Vesuvius in Rockbridge County. The red granite is in unconformable contact with conglomerates and shaly sandstones of Cambrian age on both flanks of the arch. Both contacts are well exposed. About half a mile north of Big Marys Creek the red granite ends and porphyritic granodiorite takes its place. The relation of the two rocks is unknown.

A similar red microcline granite cuts across the Buena Vista-Robinson Gap road, about 2 miles south of Buena Vista, at an altitude of 1,700 feet. The unconformable contact of the granite with the overlying basal conglomerate of the Cambrian series is well exposed here. This body of granite has been traced four miles southward to the head of Belle Cove Run. It is crossed by Pedlar Gap Run and Bennetts Run. Red granite also crops out in the anticline cut by James River between Balcony Falls and Snowden. Its contact with basal Cambrian conglomerates is well exposed about half a mile west of the bridge on U. S. Route 501 at Snowden. The relation of these red granite bodies to the granodiorite is unknown. This granite resembles the Air Point granite described by Jonas.[13]

Much of the red granite of Rockbridge County shows marked dynamic effects, reduction of grain size by crushing, and numerous joints. It contains no unakite, but veinlets of epidote and quartz have been observed. Although some of the granite has a pleasing color, none appears to be suitable for building stone.

Granodiorite.—Most of the granodiorite of the northern part of the Blue Ridge in Virginia is a coarse-grained, massive, dark-gray to dark greenish-gray rock in which quartz is inconspicuous and dark-colored. Most of the rock is porphyritic. In some specimens the feldspars are several inches in length, with microcline forming the large crystals. Commonly a dark-colored mineral, either biotite or hornblende, is present. Locally hypersthene is also present. The basic minerals are late comers and are closely associated with quartz in the interstices between the feldspars. Both microcline and plagioclase are common. The plagioclase ranges from albite-oligoclase to andesine. In places, the rock is gneissic or schistose. Several sections across the granodiorite area of the Vesuvius quadrangle indicate a complex assemblage, including perthitic granite, red granite, quartz monzonite, granodiorite, and quartz-hypersthene diorite. The outcrops have a northeast-southwest alignment. No contact surfaces between the various facies were found. The largest body of quartz-hypersthene diorite underlies The Priest and the Little Priest.

Some of the massive bodies of granodiorite should be considered potential dimension stone. One of the best exposures. a very massive, deep bluish-green, coarsely porphyritic rock, crops out about 2.5 miles east of Vesuvius along the Vesuvius-Montebello road.

The red granite and the granodiorite are both very satisfactory for crushed stone. The former has been used in highway construction in the James River gorge near Snowden. An outlier of granodiorite, about 7 miles northwest of Lynchburg and about 3 miles south of Holcomb Rock, has been quarried for crushed stone.

Quartz veins and other vein materials are relatively rare in the granodiorite.

Unakite.—Bodies of unakite, in places veinlike in form, are common along the western border of the granodiorite area at Fishers Gap in the Shenandoah National Park; east of Vesuvius; and, next to basal Cambrian quartzite, east of Wilkie and about 2 miles west of Montebello. Unakite is a replacement of granodiorite. It consists of red microcline, gray albite, quartz, and green epidote. It forms dikelike masses of limited extent, or irregular isolated ellipsoidal bodies of various size up to a few feet in diameter. In some road cuts it forms small blotches, rounded to roughly rectangular in form. Some of the conglomerates in the basal part of the Cambrian series next to granodiorite are locally replaced or held together by unakitic material. This type of rock was observed east of Vesuvius, also north of Big Marys Creek at an altitude of 2,500 feet, about 0.4 mile west of meridian 79° 10′.

Old Rag granite.—In the Shenandoah National Park, Furcron[9] found a coarse-grained granite with blue quartz to be common along the eastern border of the granodiorite area. He named it the Old Rag granite from an exposure east of Old Rag post office. The feldspars of this granite are orthoclase and microcline, a microperthite with rods of albite. Locally the rock is about 50 per cent microperthite. The quartz is either scattered or in crude layers. This granite resembles granodiorite but is more quartzose. It intrudes the Catoctin greenstone of the eastern part of the Blue Ridge. Furcron thinks that the Old Rag granite is a differentiate of the same magma from which the Blue Ridge granodiorite was derived.

The Old Rag granite resembles a gray to white, coarse-grained, perthitic granite with colorless to bluish quartz, extending from Alto northeastward across Rocky Mountain to Louisa Spring Branch, and thence northward across State Highway 56, between Wilkie and Mill Creek, in the Vesuvius quadrangle.

Air Point granite.—Furcron[9] also found a pink orthoclase-microcline granite with blue quartz intruded into the granodiorite and greenstones of the Park area. He called this the Air Point granite because of its similarity to a granite at Air Point on Bent Mountain in Roanoke County described by Jonas.[13] It grades into a pink granite containing epidote. The feldspars are microcline and albite. The epidote is secondary. This granite is similar to the granite on Big Marys Creek in the Vesuvius quadrangle and the granite crossed by Pedlar Gap Run, Bennetts Run, and Belle Cove Branch, south of Buena Vista, in the Buena Vista quadrangle. It also resembles the granite of the Balcony Falls anticline.

Grayson granite gneiss.—Jonas[14] believes that the Grayson granite gneiss of southern Virginia is continuous with the Blue Ridge granodiorite of northern Virginia, and that both rocks are of pre-Cambrian age. She states that the basal Cambrian formations west of Snowden on James River, west of Montebello, and on the southeast slope of Iron Mountain in Grayson County, have pebbles of the granodiorite and the Air Point granite.

Detailed studies of the structure and petrography of the Grayson granite gneiss have not yet been published. Samples taken in the area mapped under this name, along the main highway between Mouth of Wilson and Troutdale, in Grayson County, are slightly schistose and of a grayish-pink color. The feldspars of these samples are mostly microcline with minor amounts of albite-oligoclase. The dark-colored minerals amount to less than one per cent. Hornblende is more common than biotite. White mica, as a product of dynamic metamorphism, is common. Small bodies of unakite are exposed along the road, near the western border of the Grayson granite gneiss, 1½ miles northwest of Grant.

Whether any of the Grayson granite gneiss would make good dimension stone is unknown. Several exposures in cuts along State Highway 16, between Mouth of Wilson and Troutdale in Grayson County, are sufficiently massive to make excellent crushed stone.

Syenite.—Watson states[25] that in a part of Carroll County, extending northward from the northwest edge of Sylvatus, is an area of crushed and sheared hornblende syenite; also that a pink hornblende-biotite syenite, with more or less quartz, extends from Sylvatus northeastward along the Carroll County line.

INDIVIDUAL AREAS AND QUARRIES

PIEDMONT PROVINCE

FALLS CHURCH AREA

Two exposures of fresh granite are known in the vicinity of Falls Church in Fairfax County. A pink granite is quarried about half a mile west of Falls Church on the south side of the Lee Highway, U. S. Route 211. This quarry, here termed the Falls Church quarry, is referred to in earlier reports as Tripps quarry. Quartz diorite has been quarried a short distance southwest of Tripps Run, about 1½ miles south of Falls Church. The diorite outcrops are a short distance east of the main road leading south from Falls Church. The location of the quarries in the Falls Church area are shown in Figure 2.

FALLS CHURCH QUARRY

The Falls Church quarry is located at the northeast end of a low ridge which trends southwestward. The long direction of the quarry extends southeast with the quarry face. The quarry is about 30 to 40 feet high and 240 feet long.

Fairly fresh pink granite is overlain by from about 4 to 10 feet of residual clay derived from granite. The residual material is not thoroughly decomposed and contains fragments of granite. An abundance of fresh rock appears to be available at shallow depths. On the quarry face a zone of rock about 50 feet wide is in excellent condition; however, the remainder is faded in color and shows other signs of decay.

This quarry has produced both dimension stone and crushed stone. Stone from here has been used in several buildings in Falls Church, including the Falls Church School and Columbia Baptist Church, and also in St. Mary's Episcopal Church in East Falls Church. The appearance of the rock in these buildings is very pleasing. The stone has retained its pink background, spangled with glistening white mica flakes, and shows no discoloration or decay. The rock should be used more extensively.

The minerals of the Falls Church pink granite are quartz, microcline, minor amounts of albite-oligoclase, muscovite and biotite. The two micas are not evenly dispersed; muscovite is generally more common than biotite, with biotite occurring in excess locally. The mica content averages between 5 and 10 per

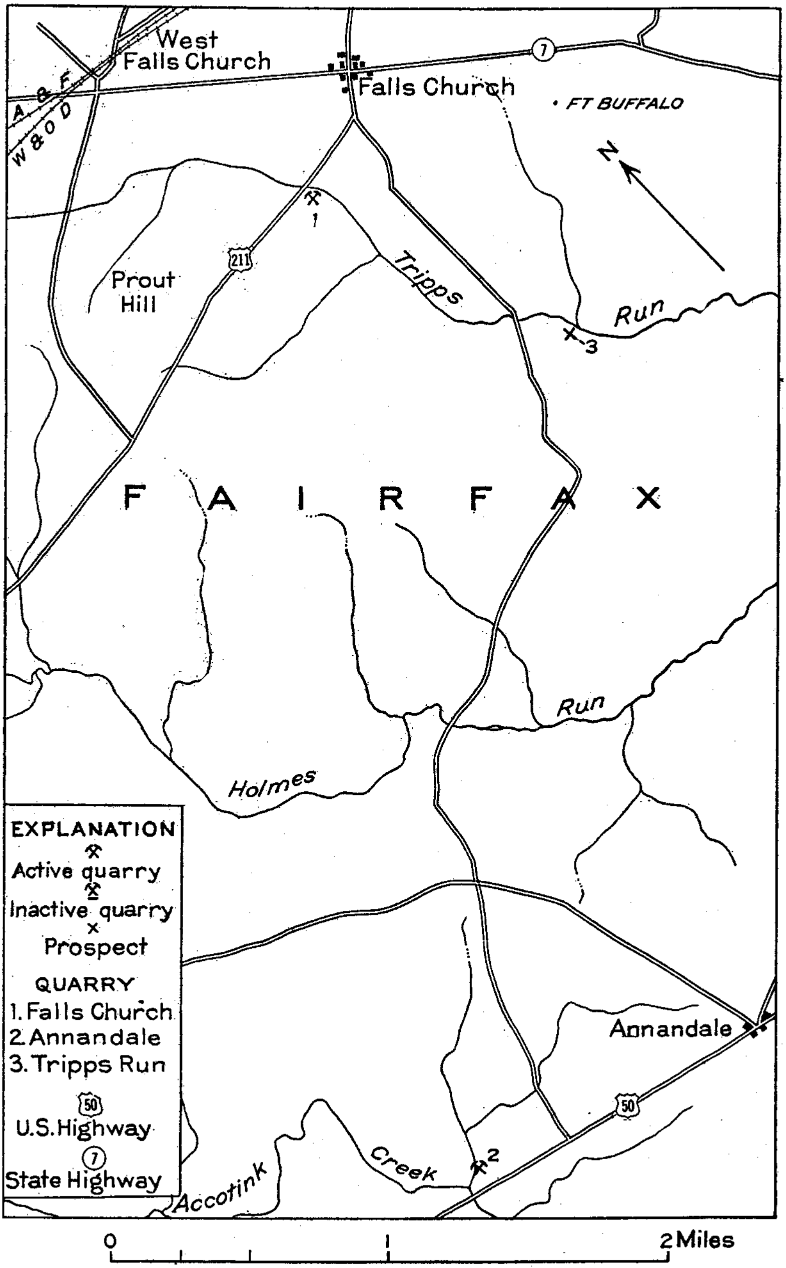


FIGURE 2.—Index map of the Falls Church area, Fairfax County, Virginia, showing location of granite quarries and prospects. 1, Falls Church quarry; 2, Annandale quarry; 3, Tripps Run prospect. Base from U. S. Geological Survey topographic map of Washington and Vicinity (1944).

cent. The quartz content is high, from 25 to 30 per cent. Some of the feldspars are cloudy and many of them contain secondary muscovite flakes aligned with the cleavage surfaces of the feldspar. Many of the mica flakes enclose minute grains of quartz and feldspar. Most of the mica is in close association with feldspar, and much of the quartz more or less completely encloses feldspar grains. Mica flakes average 0.04 inch in length and the feldspars, about 0.02 inch.

No dikes cut the rock and quartz veins are rare. The jointing in this quarry is complex and the fractures are rather closely spaced. It would be difficult to obtain large blocks from the present quarry face. The joint directions as observed are tabulated below:

Joints in the Falls Church quarry, Fairfax County, Virginia

	Strike	Dip	Remarks
1.	N.4°W.	75°W.	Spacing interval, 2 to 3 feet.
2.	N.50°E.	5°N.	Spacing irregular.
3.	N.50°E.	45°E.	Numerous.
4.	N.65°W.	75°N.	Smooth surface.
5.	N.-S.	80°W.	Numerous.
6.	N.50°E.	50°S.	
7.	N.78°E.	80°N.	
8.	N.30°W.	80°S.	
9.	N.-S.	57°E.	Smooth, polished surface.
10.	N.65°E.	60°N.	Spacing interval, 2 to 4 feet.
11.	N.85°E.	80°S.	Numerous.
12.	N.85°E.	50°S.	
13.	N.32°W.	80°S.	
14.	N.62°W.	75°N.	Smooth, polished surface.
15.	N.75°W.	5°S.	
16.	N.85°W.	80°N.	Spacing interval, 1 to 2 feet.
17.	N.60°E.	50°N.	Coated with quartz.
18.	N.72°W.	85°S.	

1 to 4, inclusive, at southeast end of quarry; 5 to 8, inclusive, about 70 feet west of southeast end of quarry; 9 to 13, inclusive, about 100 feet from northwest end of quarry; 14 to 16, inclusive, about 40 feet from northwest corner of quarry; and 17 and 18, at northwest corner of quarry.

TRIPPS RUN QUARTZ DIORITE

Outcrops of quartz diorite along Tripps Run are located on the farm of J. W. Kerns, about 1½ miles south of Falls Church (Fig. 2). They occur along the eastern slope of a group of knolls about 50 feet high which extends along the western side of Tripps Run for a quarter of a mile. No quarry has been opened, but loose fragments up to 2 feet in diameter, obtained from here, have been used in the construction of a house, and a retaining wall enclosing the garden on the Kerns farm.

Different varieties of rock crop out here. A pink color, noticeable at the north end, becomes faint farther south. One of the reddest samples contained about 30 per cent oligoclase, 35 per cent red quartz, and 35 per cent biotite with minor amounts of garnet. A sample farther south contained approximately 30 per cent quartz, 35 per cent andesine, and 35 per cent biotite, including minor amounts of quartz. Sharply defined ellipsoidal inclusions are common at the south end. One kind is a fine-grained, light-colored, granitic rock. The others are dark-colored, consisting mainly of hornblende with minor amounts of quartz, oligoclase, and pink garnet.

Pegmatite dikes up to 2 inches in width were noted in several places. They consist of sugary grained quartz with minor amounts of pink microcline and biotite. Both feldspar and mica flakes are about a quarter of an inch in length. Locally, knots of red microcline are common along the south end of the outcrops.

Joints are closely spaced. The two principal sets strike north-south and N. 80° W., and both are nearly vertical.

The outcrops of this locality indicate that the rock is too variable in color and grain pattern to be suitable for dimension stone; however, it should yield good crushed stone.

ANNANDALE QUARRY

The Annandale quarry is located on U. S. Route 50 about 2 miles west of Annandale in Fairfax County, on the west bank of a small branch of Accotink Creek (Fig. 2). The pit was started where the stream had undercut its bank and is about 300 feet north of the Little River road. The quarry faces are aligned with the two major joint surfaces of the rock. Each face is about 40 feet long and 40 feet high, which is about the maximum height possible above creek level. The overburden is residual clay, ranging from 4 to 16 feet in thickness.

When examined the quarry was being operated by the Fairfax

Granite Company of Fairfax, Virginia. The products were rough block stone and slabs. The latter averaged 24 x 15 x 4 inches in size.

The granite in this quarry is a uniform, massive, bluish-gray rock. The average content of the rock is about 25 to 30 per cent quartz, 15 per cent mica, and 60 per cent feldspar. Most of the mica is biotite. The feldspar is mainly microcline with small amounts of albite-oligoclase. The feldspar grains average between 0.05 and 0.1 inch in length. The rock has some schlieren that contain very little mica. The feldspars of the schlieren are similar to those in the main body of the rock. The schlieren weather to a cream-gray color.

The rock in the quarry is cut by joints that strike N. 50° W. and N. 30° E., and dip 80° N. and 80° W., respectively. An eastward-striking vertical joint is also present.

FAIRFAX COUNTY

FAIRFAX TRAP QUARRY

The Fairfax Quarries, Inc., operates a quarry in trap rock a short distance east of Bull Run Creek, along U. S. Route 211 between Fairfax and Warrenton (Pl. 1). The production of this quarry, which has a capacity of 75 tons per day, is for road construction and consists of crushed materials ranging from rock particles an inch in diameter to rock dust. The equipment includes a jaw crusher, rotary screens, and a storage bin.

The rock is a grayish-black, medium-grained diabase of Triassic age. It is uniform in texture, fresh, and very tough. The quarry walls are parallel to the principal joints. One set strikes N. 10° W., with spacing intervals of 1 to 2 feet. The other set strikes N. 80° E., with wide spacings. Sheets ranging from 1 to 3 feet in thickness are very distinct. The overburden, from 1 to 4 feet thick, consists of brown clay containing diabase boulders.

OCCOQUAN QUARRIES

The Smoot Sand and Gravel Corporation of Washington, D. C., has operated two granite quarries on the north side of Occoquan Creek, a short distance from the bridge on State Highway 123 at Occoquan, in Fairfax County, on land owned by Clark & Son of Occoquan (Pl. 1). The rock was used for riprap by the United States Engineers Office and was shipped from Occoquan by water. The quarries were not being worked at the time of the writer's visit.

Quarry No. 1 is located a few hundred feet west of the highway bridge. The floor of the quarry is about 75 feet above creek level and the cut extends into a bluff. The north wall is about 100 feet high and shows fresh rock to within 3 feet of the top. The main quarry face is 250 feet long and extends N. 60° E. The overburden is clay. The least weathered rock is in the middle of the north wall. The east and west walls show some decayed rock.

The rock is a porphyritic granite gneiss, consisting of pink microcline phenocrysts up to an inch in diameter, enclosed in a groundmass which is mostly quartz. Plagioclase is scarce and consists of albite-oligoclase. Biotite is the principal mica, but chlorite and muscovite are present. The micas show a distinct parallel arrangement and locally are abundant, although the average mica content is about 10 per cent. Quartz constitutes about 30 to 35 per cent of the rock by volume.

Locally due to shearing, the rock has become a chlorite-mica schist. In this facies the principal minerals are chlorite, biotite and muscovite. Near the middle of the main quarry the rock is coarsely porphyritic with microcline phenocrysts 2 inches in length. In this facies the quartz is of two kinds: bluish ellipsoidal phenocrysts about a quarter of an inch in length, and a sugary variety. The minerals present are microcline, quartz, and a small amount of albite-oligoclase. A quartz vein about two feet wide, and concordant with the schistosity, was noted. Some loose granite blocks show pegmatite dikes up to several inches in thickness. The pegmatite is associated with the schistose facies of the rock. The east wall contains a band of chlorite schist 2½ feet wide. The schistose facies strikes N. 30° E. and dips 85° or less to the west.

The principal joints follow the schistosity in strike and dip and their spacing ranges from a few inches to about 3 feet. Flat or horizontal joints, normal to the plane of schistosity, are abundant and are spaced at varying intervals. A vertical joint near the middle of the north base of the quarry, striking N. 50° W., shows very smooth walls. Another vertical joint strikes N. 15° W.

Quarry No. 2 is located directly north of the highway bridge, about 500 feet east of quarry No. 1. It is about 150 feet long parallel to the creek and 100 feet wide in the opposite direction. The rock in this quarry is more schistose and variable than that in quarry No. 1. The schistosity strikes N. 35° E., and dips steeply to the west. Both the east and west walls follow the schistosity. The north wall is about 100 feet high and hard rock extends nearly to the grass roots, but the upper 15 to 20 feet is weathered. Most of the joints follow the schistosity and are spaced at intervals ranging from a few inches to 3 feet. One set, less prominent, strikes N. 60° W. and dips 45° N. Horizontal or flat joints at right angles to the schistosity also are common.

The rock is mainly a biotite granite gneiss containing locally sheared zones and schistose bands. Quartz, in the form of elongated, bluish phenocrysts a quarter of an inch in length, is conspicuous. Locally, albite-oligoclase also forms white phenocrysts which are unlike those in the rock of quarry No. 1. Grains of calcite are common. In places the feldspars have been rolled into thin sheets 0.05 inch in length. A body of chlorite-biotite schist, 40 feet wide, is exposed in the eastern part of the quarry.

LOUDOUN COUNTY

BELMONT TRAP QUARRY

The Belmont trap quarry is located on the east side of Goose Creek, 4 miles southeast of Leesburg in Loudoun County (Pl. 1). It was first opened about 1880 and has produced both building stone and crushed stone. During recent years its product has been crushed stone for road metal and railroad ballast. The rock is diabase, an intrusion in Triassic sediments. Outcrops of the diabase extend southward to Bull Run in Fairfax County, a distance of about 15 miles. Roberts[18] has described the quarry and the geology of the area in which it is located.

The principal feldspar of the diabase is labradorite. Shannon[21] reported the following average analysis of Goose Creek diabase from this locality: Silica 51.56 per cent, alumina 13.81 per cent, ferric oxide 0.96 per cent, ferrous oxide 11.32 per cent, magnesia 7.40 per cent, lime 10.08 per cent, soda 2.08 per cent, potash 0.96 per cent, titanium oxide 1.48 per cent, phosphorus pentoxide 0.16 per cent, and manganous oxide 0.19 per cent. The U. S. Bureau of Public Roads has reported the following mineral analysis of the diabase: Essential minerals, plagioclase 48.30 per cent, augite 41.70 per cent; accessory minerals, magnetite 3.30 per cent, apatite 0.50 per cent; and secondary minerals, chlorite 40.0 per cent, kaolin 2.0 per cent, and biotite 0.2 per cent. Results of physical tests on samples of this stone, as given by Roberts, are listed in Table 27.

LOVETTSVILLE-TAYLORSTOWN TRAVERSE

The Lovettsville-Taylorstown traverse, between Lovettsville and Taylorstown in northern Loudoun County, is underlain by Catoctin greenstone and outcrops are scarce (Fig. 3). Local strips are underlain by granite gneiss which is shown as Marshall granite on the Geologic map of Virginia (1928).

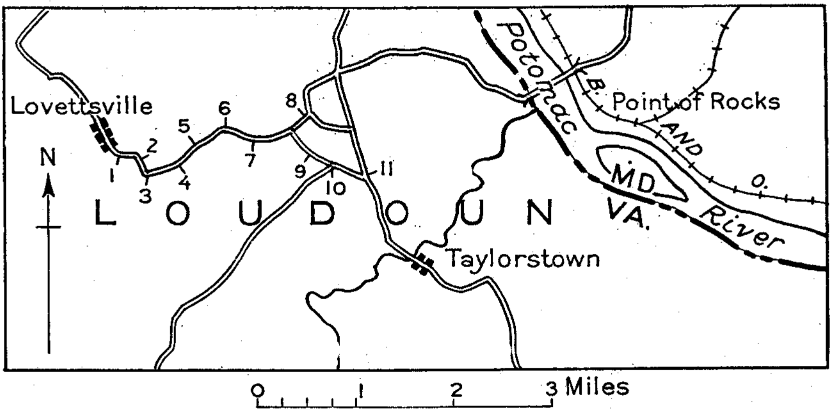


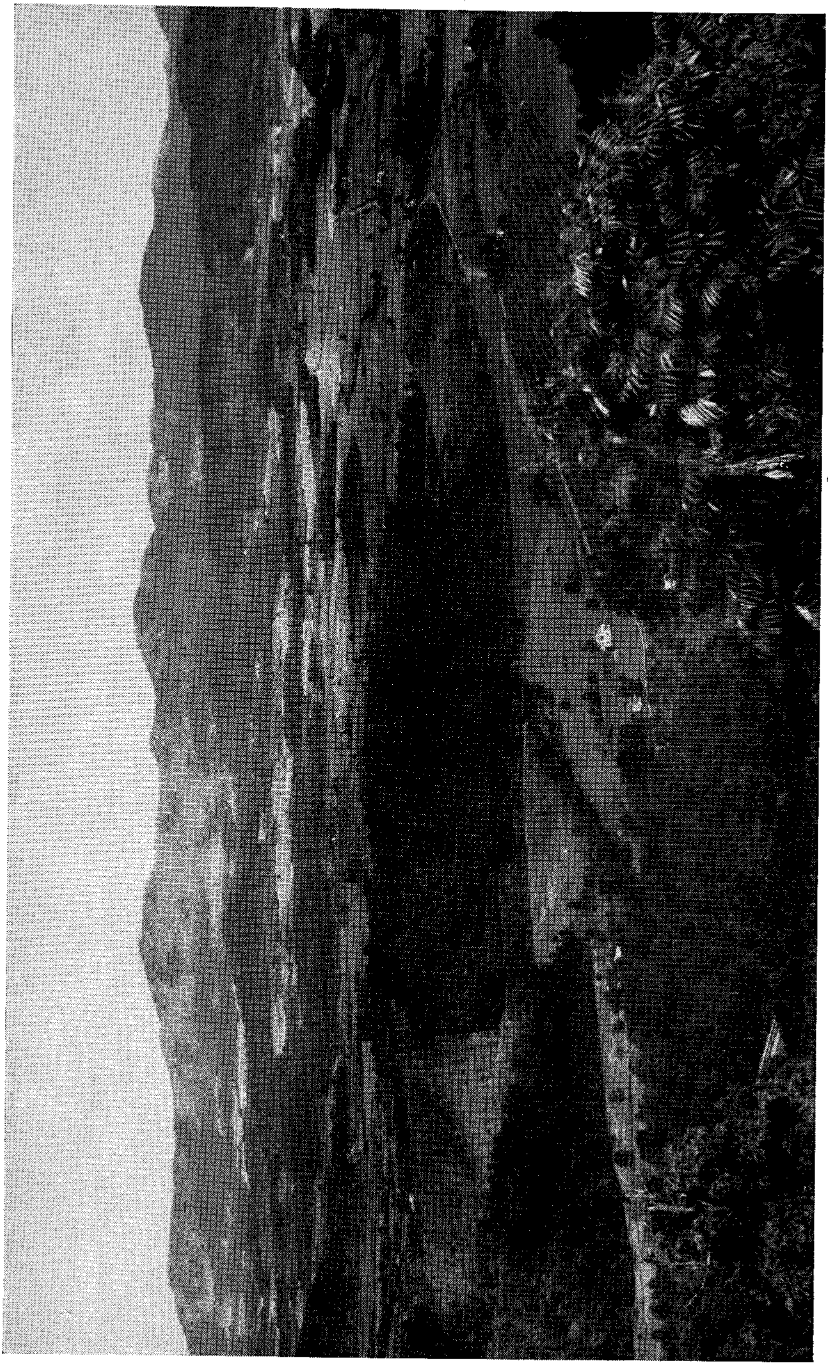
FIGURE 3.—Index map of the Lovettsville-Taylorstown traverse, Loudoun County, Virginia. 1-2, 4, 5, 7, 9, Catoctin greenstone; 3, 8, 10a, granite gneiss; 6, 10b, pegmatitic granite; 11, greenstone schist. Base from U. S. Geological Survey topographic map of the Thorofare Gap quadrangle.

The widest belt of granite gneiss, about a quarter of a mile wide, occurs about 2 miles northeast of Lovettsville and about the same distance northwest of Taylorstown. The gneiss is high in quartz. Some has more potash feldspar than soda-lime, whereas some has a considerable content of both. Narrow pegmatite dikes containing blue quartz are common. Petrographic data on the outcrops examined in this traverse are given in Table 1.

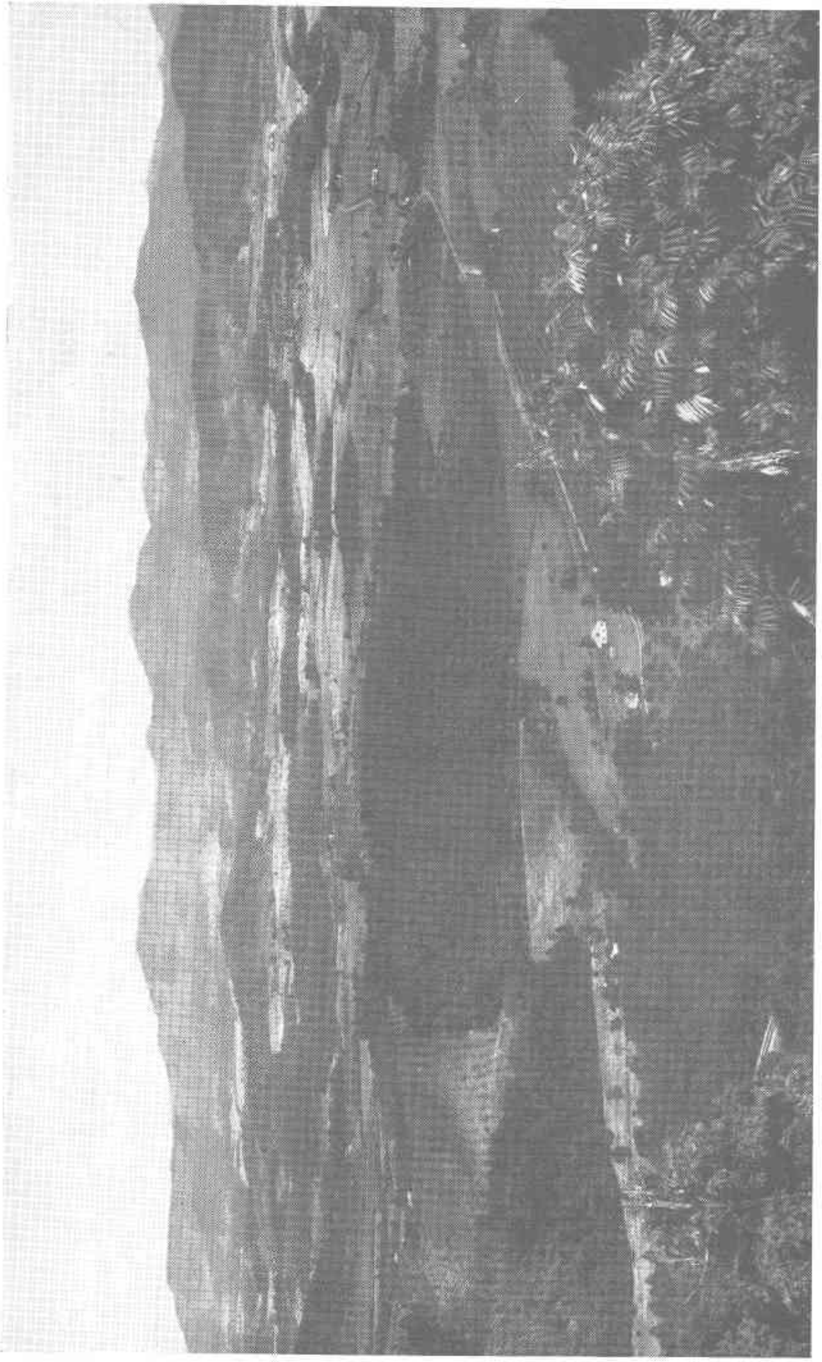
MIDDLEBURG AREA

In the vicinity of Middleburg, exposures of granite and granite gneiss were examined, along U. S. Route 50, from a tributary of Goose Creek about 1¾ miles west of town to a point about 2½ miles east of town (Fig. 4). Petrographic data on the rocks in this traverse are given in Table 2.

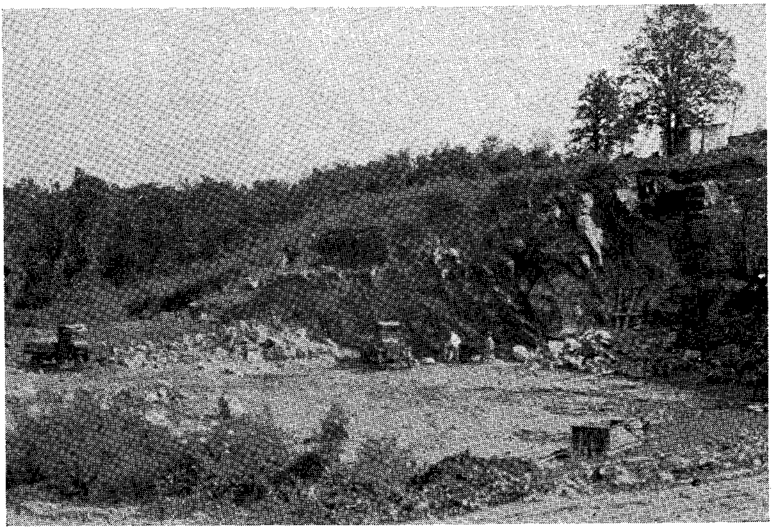
Most of the outcrops are of strongly foliated biotite granite gneiss in which microcline is the dominant feldspar. Exposures about half a



Topography of the western Piedmont province; Rockfish Valley near Afton, Nelson County, Virginia.



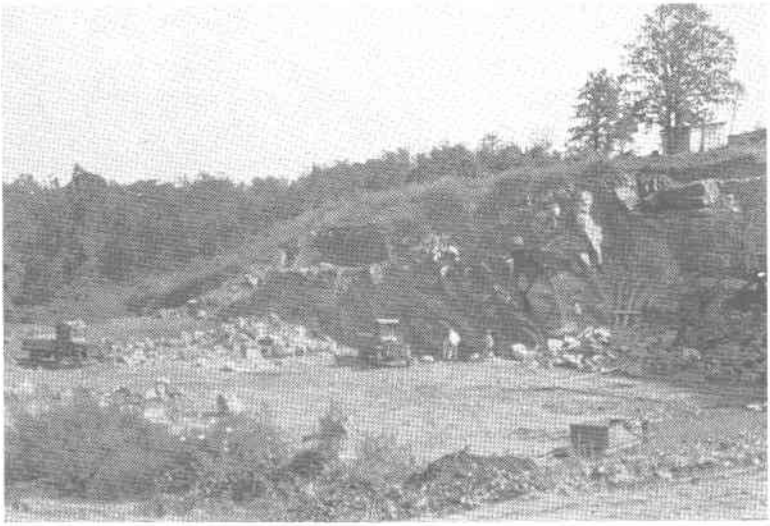
Topography of the western Piedmont province; Rockfish Valley near Afton, Nelson County, Virginia.



A.

B.

A, Quarry in Triassic diabase, near Catlett, Fauquier County, Virginia. (From Virginia Geological Survey Bulletin 54.) B, Red Hill quarry in quartz monzonite gneiss near Red Hill, Albemarle County, Virginia. Photograph courtesy Superior Stone Company.



A.

B.

A, Quarry in Triassic diabase, near Catlett, Fauquier County, Virginia. (From Virginia Geological Survey Bulletin 54.) B, Red Hill quarry in quartz monzonite gneiss near Red Hill, Albemarle County, Virginia. Photograph courtesy Superior Stone Company.

mile east of town contain angular quartz which is unevenly distributed and gives the rock the appearance of a foliated arkose. A fine-grained, faintly foliated granite is exposed in a cut about three-fourths mile west of town.

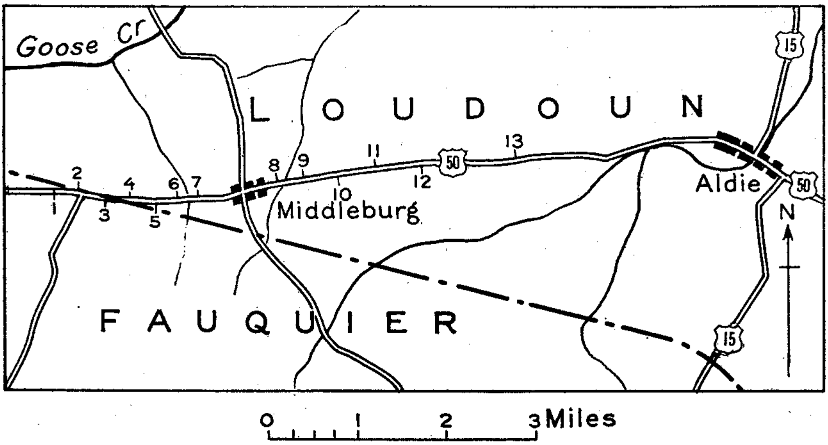


FIGURE 4.—Index map of the Middleburg area, Loudoun and Fauquier counties, Virginia. 1, 13, Catoctin greenstone; 2, muscovite schist; 3-6, foliated granite; 7, biotite schist; 8, 11, 12, biotite granite gneiss; 9-10, arkose. Base from U. S. Geological Survey topographic map of the Thorofare Gap quadrangle.

None of the rocks in the vicinity of Middleburg are suitable for dimension stone, but they would yield crushed stone. Exposures of Catoctin greenstone east and west of the area examined offer additional sources of crushed stone.

FAUQUIER COUNTY

MARKHAM-THE PLAINS TRAVERSE

Exposures of granite and other crystalline rocks were examined by the writer along State Highway 55, between Markham and The Plains, covering a traverse about fifteen miles in length (Fig. 5). Petrographic descriptions of the rocks studied along this traverse are given in Table 3.

The area between Markham and the northwestern base of Little Cobbler Mountain is underlain by a massive, gray, coarse-grained hornblende granite, similar to that forming the core of much of the northern part of the Blue Ridge in Virginia. Potash feldspar is dominant in this rock. An isolated occurrence of this same rock, having a pale-pink color, was noted about a mile northeast of the northeast end of Little Cobbler Mountain. The area between the northeastern base of Little

Cobbler Mountain and a point along the highway about 2 miles southeast of Delaplane is underlain by typical Catoctin greenstone which here consists mainly of chloritic, basaltic schists. About midway between Delaplane and Marshall, a fine-grained, foliated sericite schist, which

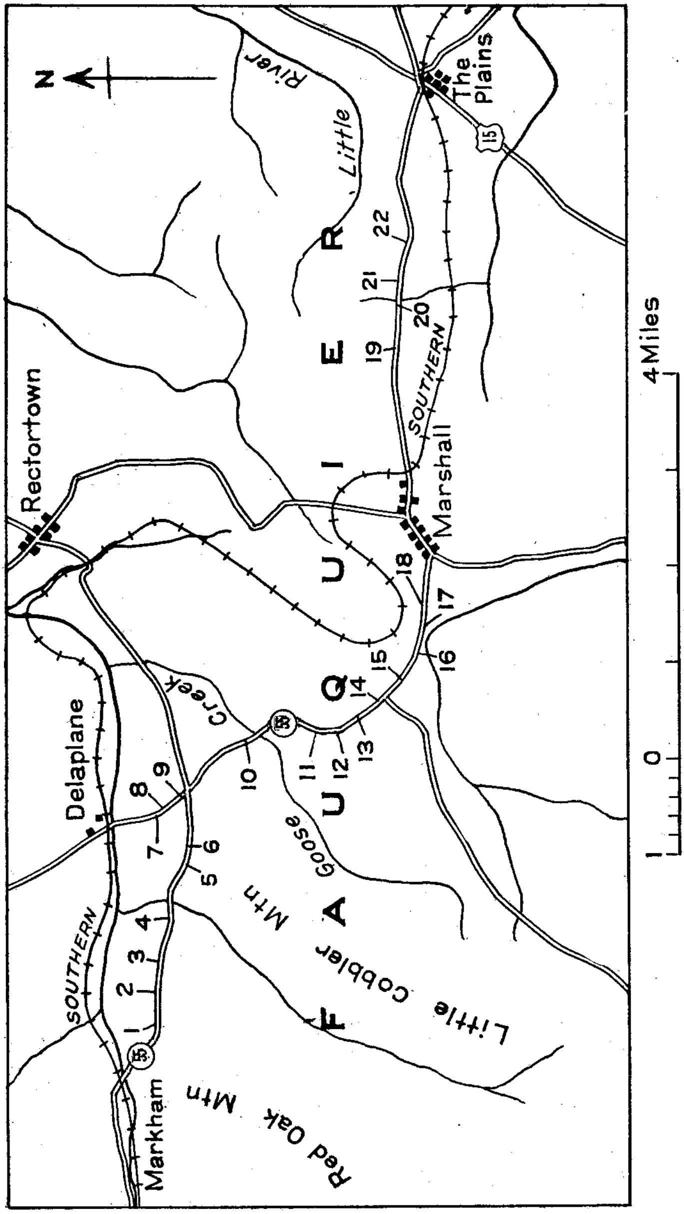


FIGURE 5.—Index map of the Markham-The Plains traverse, Fauquier County, Virginia. 1-5, 7, 9, 13, granite; 6, 8, greenstone schist; 10, 11, Catoctin greenstone; 12, 14, porphyritic felsite; 15-22, arkosic sericitic schist. Base from U. S. Geological Survey topographic map of the Thorofare Gap quadrangle.

looks like a felsite, is exposed in a northeasterly trending belt about 1¼ miles wide. Foliated phyllite is exposed from a point about a mile west of Marshall to a point about 2 miles east of that town, except at a location about 1½ miles east of town, where fragments of coarse-grained granite containing blue quartz occur in the residual soil.

Diabase or trap rock has been quarried on the north bank of Cedar Run near Catlett (Pl. 3A), and at other localities between Catlett and Calverton.

The coarse-grained granites northwest of Little Cobbler Mountain, between there and Markham, and the exposure about a mile northeast of the mountain may offer possible sources of dimension stone. These sites would afford excellent crushed stone.

RAPPAHANNOCK COUNTY

WASHINGTON-BEN VENUE TRAVERSE

The Washington-Ben Venue traverse, from Washington eastward along U. S. Route 211, through Ben Venue, Rappahannock County, about six miles in length (Fig. 6), is underlain entirely by the Marshall

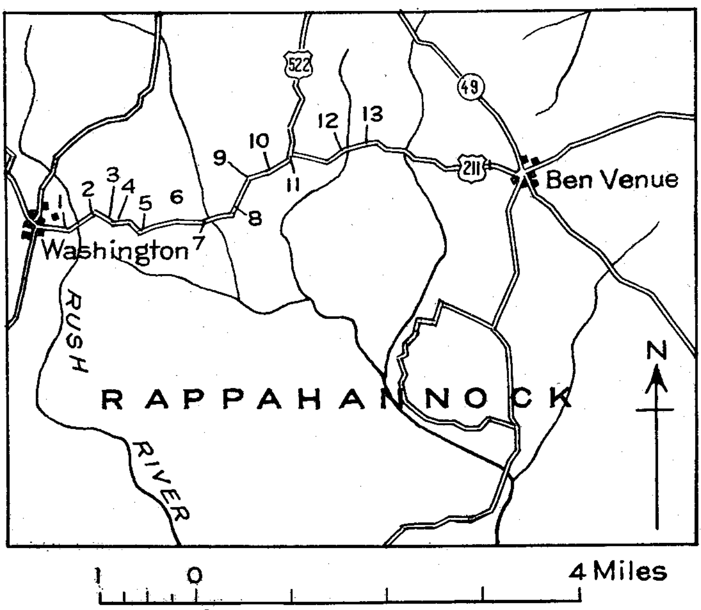


FIGURE 6.—Index map of the Washington-Ben Venue traverse, Rappahannock County, Virginia. 1, Catoctin greenstone; 2-7a, 8, granite gneiss; 7b, massive gabbro; 9-13, porphyritic granite. Base from U. S. Geological Survey topographic map of the Luray quadrangle.

granite, as shown on the Geologic map of Virginia (1928). Petrographic data on the rocks examined along this traverse are given in Table 4.

Most of the rocks in this area are granite gneisses and augen granite gneisses, nearly all of which show marked foliation. In most of the samples examined, potash feldspar is more abundant than the soda-lime variety and the quartz is either blue or violet. The bluish quartz is characteristic of pegmatitic facies of the Marshall granite. Because of their variable mineral content, state of decomposition, and foliation, none of the outcrops in this section offer sources of dimension stone, but crushed rock could be obtained from most of the larger exposures.

FREDERICKSBURG AREA

GENERAL GEOLOGY

A quartz diorite gneiss is the principal rock underlying the Piedmont province at Fredericksburg. It is well exposed in the rapids of Rappahannock River in the Fall Zone and along the near-by bluffs. Granites occur along Hazel Run about 1 mile southwest of Fredericksburg and on the south bank of the Rappahannock about 2½ miles northwest of the city. The location of the quarries in the Fredericksburg area is shown in Plate 1 and Figure 7.

The quartz diorite gneiss of the Fredericksburg area is a rather evenly banded rock. Dark-colored minerals are dominant, and light-colored bands, averaging about 0.2 inch in width, generally are not continuous. Several samples had the same mineral constituents which include hornblende, biotite, albite-oligoclase, and quartz.

An analysis of the gneiss was published by Watson[28] as follows: Silica 68.45 per cent, alumina 10.00 per cent, ferric oxide 5.71 per cent, ferrous oxide 2.59 per cent, magnesia 3.26 per cent, lime 6.20 per cent, soda 1.98 per cent, potash 1.18 per cent, and water 0.62 per cent. A recalculation of this analysis into minerals gave the following results: albite 16.64 per cent, anorthite 2.98 per cent, biotite 13.40 per cent, hornblende 35.99 per cent, and quartz 30.86 per cent.

The quartz diorite gneiss has not been quarried. It would be suitable for riprap and crushed stone. Exposures of fresh rock in bluffs about 100 feet high are located near the river and both quarrying and hauling could be done at a low cost.

TAYLOR QUARRIES

The Taylor quarries embrace five granite quarries along the south side of Rappahannock River, about 2½ miles northwest of the city on the M. F. Taylor estate, upstream from the power dam. They were worked by Cartwright and Davis about 35 years ago,

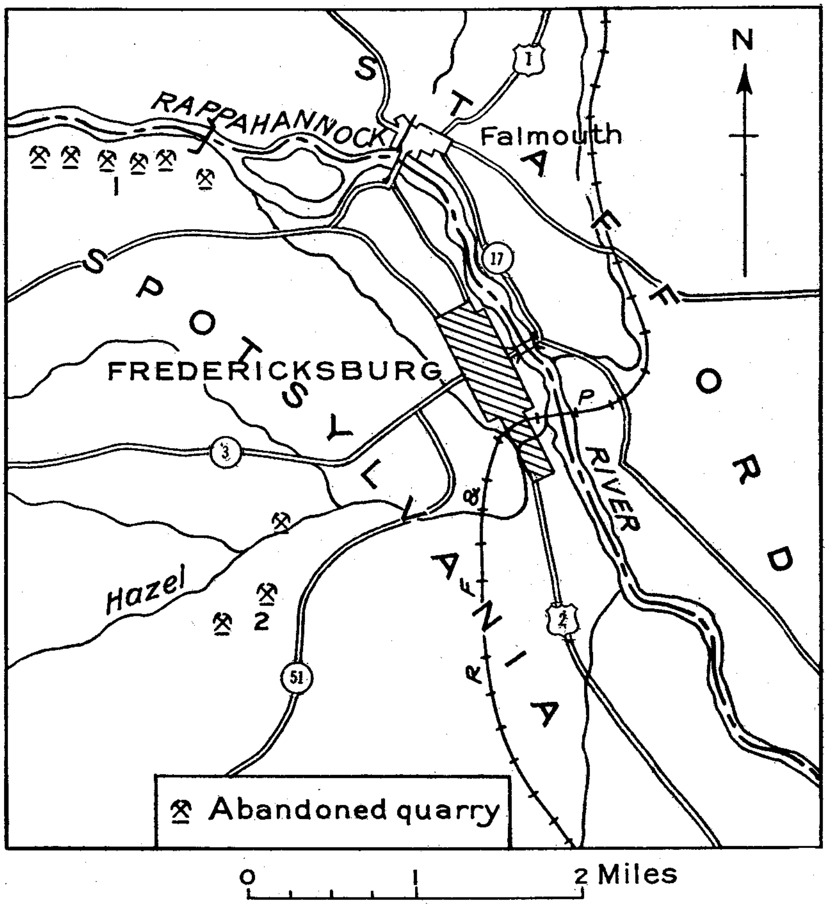


FIGURE 7.—Index map of the Fredericksburg area, Spotsylvania and Stafford counties, Virginia, showing location of granite quarries and prospects. 1, Taylor quarries; 2, Hazel Run quarries. Base from U. S. Geological Survey topographic map of the Fredericksburg quadrangle.

and the stone was used extensively for monuments. The blocks were shipped by canal boat to Fredericksburg, where they were polished for the market.

None of the granite bodies in which the quarries are located appear to be more than 200 feet in width. The granite masses are bordered by quartz diorite gneiss into which they are injected. Narrow dikes and sills of granite project into the gneiss, and fragments of gneiss form inclusions in the granite. The grain and mineral content of the granite do not appear to change along its contact with the gneiss.

The granite is dark-blue, has a fresh vitreous luster, and is massive with no gneissic or schistose structures. The average feldspar grain has a maximum length of about 0.15 inch. The dark-blue color is due to minute flakes of dark-colored mica scattered through gray-white feldspar. The minerals present include microcline, albite-oligoclase, quartz, biotite, and muscovite. Near the contacts with the quartz diorite gneiss, small amounts of epidote, in minute grains, are present. Microcline is the principal feldspar. Small pegmatite dikes from 1 to 2 inches in width are rather common. They contain orthoclase, microcline, oligoclase, biotite, muscovite, and magnetite, with orthoclase being more abundant than microcline. The plagioclase of the pegmatite has more lime than that of the granite.

Quarry No. 1 has a face 65 feet long and 100 feet high. The rock has neither pegmatitic nor gneissic inclusions. Joints are scarce, but vertical joints, striking N. 15° E. and N. 80° E., were observed.

Quarry No. 2 is about 300 feet west of quarry No. 1. The pit is 100 feet high by 150 feet square. About 20 per cent of the blocks on the dump show pegmatite dikes. Vertical joints, striking N. 15° E., and others, striking N. 80° E. and dipping 85° N., were observed. Outcrops of gneiss occur between quarries Nos. 1 and 2.

Quarry No. 3 is about 300 feet west of quarry No. 2. The pit was flooded at the time visited. Granite blocks on the refuse heap are free from flaws such as veins and inclusions. Joints noted had a strike of N. 30° E.

Quarry No. 4 is about 500 feet west of quarry No. 3 and about 0.8 mile west of the canal locks built of the local granite about 100 years ago. The pit, which has an area of 25,000 square feet, was flooded at the time of the writer's visit. Vertical joints, striking N. 35° W., N. 40° E., N. 75° W., N. 10° E., and N. 65°, were observed. One set strikes N. 22° W. and dips 85° W. The south wall of the quarry is parallel to the vertical joint, striking N. 65° W. Pegmatitic material coats a joint striking N. 85° E. and dipping

70° N. Pegmatite dikes are common and inclusions of gneiss are also abundant. The rock in the middle of the quarry face is free from flaws. The overburden is residual clay.

Quarry No. 5 is about 200 feet west of quarry No. 4, near the borderline of the property. The pit has an area of 1,500 square feet. The rock in the quarry and blocks on the dump are of good color and luster, free from the usual flaws, inclusions and pegmatite dikes. The joints noted were all vertical and trend N. 30° W., N. 75° W., and N. 15° W.

HAZEL RUN GRANITE

Outcrops of a light-gray granite are scattered along Hazel Run about 1 mile southwest of Fredericksburg, and several old pits are located along the tracks of the Richmond, Fredericksburg & Potomac Railroad (Fig. 7.). Stone from a pit north of the tracks was used in the Presbyterian Memorial Chapel in Fredericksburg, built some years ago. No stone has been removed in recent years.

The Hazel Run granite is not the same as the granite on Rappahannock River. It contains considerable mica, both light- and dark-colored varieties. Garnet is present in variable amounts. The average mineral content is about as follows: mica, with small amounts of garnet, 5 per cent; quartz 25 per cent; and feldspar 70 per cent. Microcline is the principal feldspar and albite-oligoclase is also present. The feldspar grains average about 0.2 to 0.3 inch in length.

Shear effects and some parallelism of the minerals were noticeable, especially in the micas. The schistosity strikes N. 10° to 20° E., and either dips steeply to the west or is vertical. Vertical joints, striking N. 30° W. and N. 75° W., and others, striking north-south and dipping steeply to the west, were observed. Generally they are spaced more than 5 feet apart.

Numerous pegmatite dikes, up to a few inches in width, cut through the rock. Their minerals include microcline, orthoclase, quartz, and a little biotite. No plagioclase was found.

CULPEPER AREA

TWIN MOUNTAIN TRAP QUARRY

The Twin Mountain quarry, formerly known as the Buzzard Mountain quarry and later as the Catlin quarry, is located about 1 mile east of Buena and about the same distance west of the main line of the Southern Railway, between Culpeper and Orange (Pl. 1). It was first worked about fifty years ago for stone for railroad ballast and bridge abutments. From 1919 until 1926 the main product was railroad ballast. During 1926 dimension stone was produced and, in addition to rough blocks used in retaining walls and buildings, polished base courses from this quarry were used in the construction of the Chevy Chase Bank and Shannon-Lucks Building in Washington, D. C.

The quarry is connected with the main line of the Southern Railway by a spur track. The equipment consists of a 30-ton derrick, with a mast and a 60-foot boom of wood and 12-foot bull wheels; an overhead crane; a 50-horsepower boiler; 3 drum-hoisting engines; a 350-pound steam-driven air compressor; a steam drill; two polishing machines; a sand-blasting machine; a 1,200-gpm. centrifugal pump; a 20,000-gallon water tank; and a mill house.

The rock in which the quarry is located is a hypersthene diabase stock of Triassic age. The quarry and rock have been described by Roberts[19], and an analysis of the diabase listed by him is given in Table 28. The rock is dark-gray and even textured. The minerals include labradorite, augite, minor amounts of hypersthene, magnetite, and biotite. The feldspars form laths in a groundmass of pyroxene. The augite grains are more distinct than the feldspar, the largest grains being about three-sixteenths inch in length. The rock is fresh to within a few inches of the surface. The overburden averages less than a foot in thickness, and a considerable area of bare rock exists. At the quarry the rock surface dips about 5° to the northwest.

Joints are scarce, but at the east end of the quarry one strikes north-south and another N. 65° E. Both are vertical. The rock is reported to break most easily along horizontal surfaces and on vertical planes striking N. 50° E. Results of physical tests made on samples of diabase from this quarry by the U. S. Bureau of Public Roads, are given in Table 27.

The rock of this quarry is highly recommended for dimension stone. It takes a good polish and is very durable. It is similar to the Gettysburg, Pennsylvania, granite.

SPERRYVILLE-BOSTON TRAVERSE

The Sperryville-Boston traverse extends from Sperryville, Rappahannock County, southeastward along State Highway 522-3 through Woodville and Boston to a point about midway between

Boston and Culpeper, Culpeper County, a distance of about 16 miles (Fig. 8). At Sperryville it connects with the Thornton Gap-Sperryville traverse. The Sperryville-Boston traverse is in the area un-

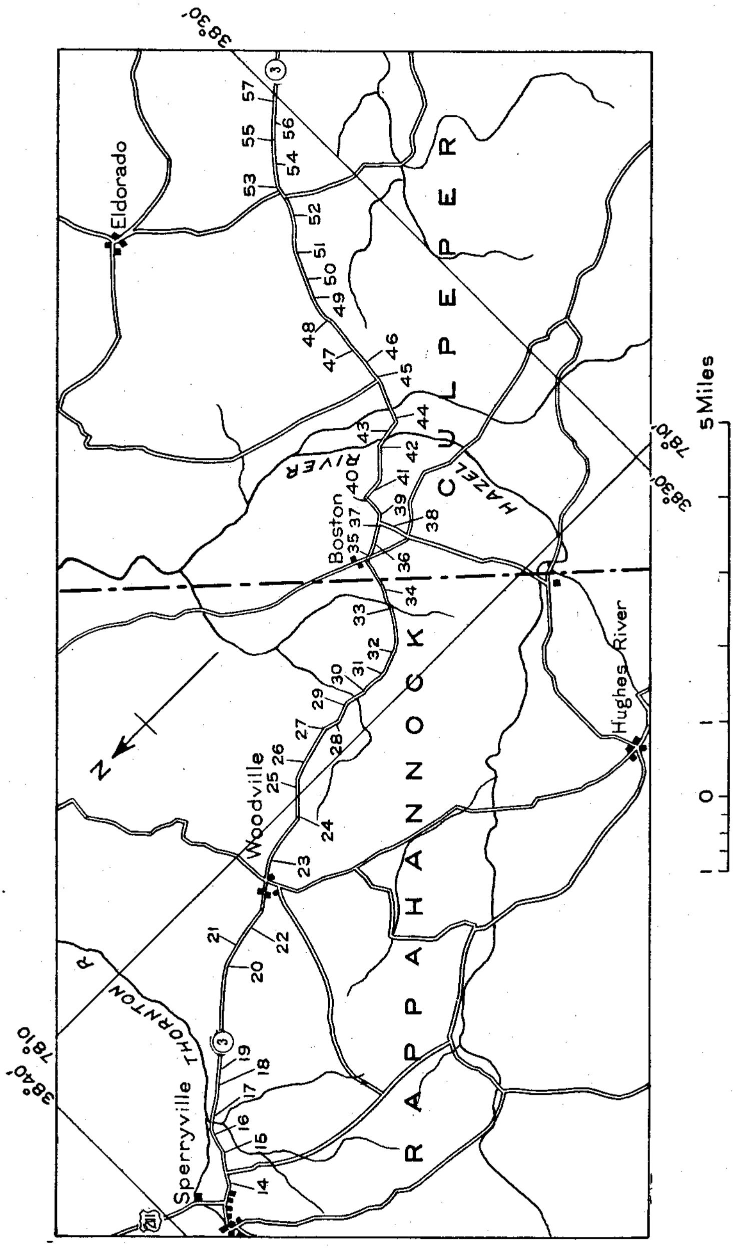


FIGURE 8.—Index map of the Sperryville-Boston traverse, Rappahannock and Culpeper counties, Virginia. 14, actinolite schist; 15, 17, quartz monzonite gneiss; 16, no sample; 18, decomposed schist; 19, 39, dacite; 20-25, biotite gneiss; 26-33, 37, 48-57, arkose; 34-36, 38, 45-46, granite; 40-44, granite gneiss; 47, quartz monzonite. Base from U. S. Geological Survey topographic map of the Luray quadrangle.

derlain by Marshall granite as shown on the Geologic map of Virginia (1928). All the rocks in this traverse have been severely folded. They range from basic schists to acid gneisses and include rocks of both igneous and sedimentary origin. Petrographic data on the rocks are given in Table 5. None of these rocks are suited for dimension stone. The State Department of Highways formerly operated a quarry for road metal in granite gneiss along Hazel River, about 2½ miles southeast of Boston.

CHARLOTTESVILLE AREA

SHADWELL QUARRY*

The Charlottesville Stone Corporation has an active quarry about 3¼ miles east of Charlottesville and about three-fourths mile west of Shadwell, just south of U. S. Route 250 (Fig. 9). The quarry is about midway between the highway and the main line of the Chesapeake and Ohio Railway, with the main operation being in the southwestern slope of a small hill east of a southward-coursing tributary to Rivanna River. Crushed stone is produced for road building, concrete, bridge foundations, and other uses. The crushing plant has a capacity of 7,000 cubic yards per month and the sizes of the products marketed range from rock dust to 3-inch particles.

The quarry is in the Catoctin greenstone of pre-Cambrian age. The rock is a massive, dense, fine-grained, greenish-gray metabasalt having a conchoidal fracture and containing chiefly chlorite and secondary amphiboles (hornblende, actinolite and tremolite). Discoid flattened bodies of chlorite, 0.5 to 1.0 inch in diameter, are common. Quartz and epidote, in irregular veinlets and small masses, occur locally. The greenstone is amygdaloidal and the amygdules commonly are filled with quartz and ringed by epidote or chlorite. Unakitic material occurs locally in small veins or dike-like bodies, from about 3 to 15 inches wide, generally along or near small fracture zones containing decomposed, schistose greenstone. Jointing is well developed. Of the joints observed one set strikes N. 70° to 80° E. and dips 76° SE., another strikes N. 18° to 20° E. and dips 16° SW., with a nearly horizontal or flat joint striking N. 40° W. The stream along which the quarry has been opened flows S. 18° to 20° E., apparently along a joint, the dip of which was not recorded. The spacing interval between joints ranges from 3 to 10

*By A. A. Pegau and W. M. McGill.

feet. The overburden, mainly clay, ranges from about 2 to 5 feet in thickness. Locally, along or above weathered zones or enlarged joints filled with decayed rock, thicknesses of 8 to 10 feet or more of soil and weathered material overlie fresh bedrock.

MOORES CREEK QUARRY*

Fox Brothers are operating a small quarry along Moores Creek, about half a mile south of Belmont Park in the southeastern part of Charlottesville. The quarry is located on the south side of the creek in the north end of a small hill, about midway between the old and new Charlottesville-Scottsville roads (Fig. 9). It is just west of the old Thomas quarry, formerly operated by the Charlottesville Stone Corporation, and about half a mile east of the old Berkeley quarry. The quarry was opened about 1936 and its main products are crushed stone for use in concrete and as road metal. Material marketed ranges from rock dust to particles 2½ inches in diameter.

The quarry is in the northeasterly trending belt of Catoctin greenstone which, as shown on the Geologic map of Virginia (1928), forms Carter and Southwestern mountains and underlies relatively narrow belts of land paralleling these mountains. The greenstone at the quarry site is a massive, dense, fine-grained, dark greenish-gray rock, similar to that in the Shadwell quarry of the Charlottesville Stone Corporation, but it contains less chlorite and minor amounts of pink microcline. Small cubes of pyrite were observed in some specimens. Small masses of quartz occur locally and narrow quartz or quartz-epidote veins are common, generally along or parallel to joints, with which they agree in strike and dip. Joints, having a spacing interval of from 1 to 3 feet, were observed striking N. 35° to 40° E. and dipping 41° SE., and striking N. 35° to 40° W. and dipping 51° NW. Other joints, with spacing intervals of 8 to 10 feet, strike N. 52° E., with a dip of 53° NW., and N. 35° W., with a dip of 78° NE. Another was recorded striking N. 60° E., with a dip of 48° NW., and a vertical joint had a strike of N. 30° W. Local enlarged portions of joints and small crevices in the upper part of the quarry face, just beneath the overburden, are filled with decomposed or schistose material. The thickness of the red clay overburden ranges from about 2 to 5 feet.

*By A. A. Pegau and W. M. McGill.

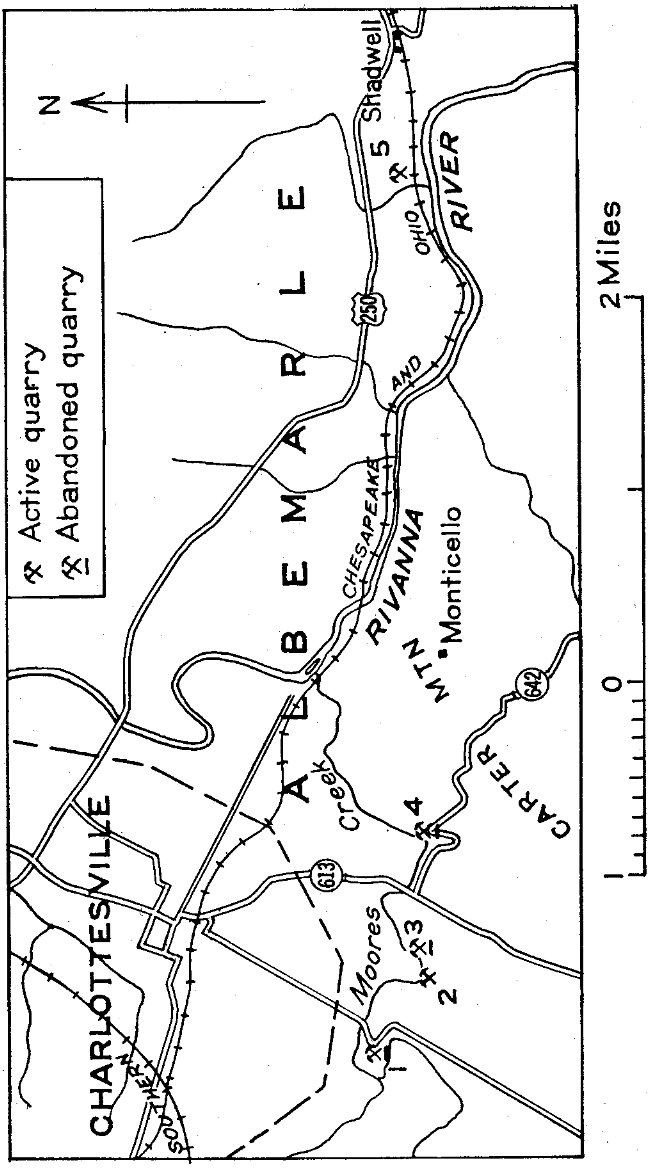


FIGURE 9.—Index map of the Charlottesville area, Albemarle County, Virginia, showing location of quarries in Catoctin greenstone. 1, Berkeley quarry; 2, Moores Creek quarry; 3, Thomas quarry; 4, Monticello quarry; 5, Shadwell quarry. Base from U. S. Geological Survey topographic map of the Charlottesville quadrangle.

MONTICELLO QUARRY*

An inactive quarry, formerly operated by Fox Brothers, is located at the northwestern base of Carter (Monticello) Mountain, on the south side of Moores Creek just outside the Charlottesville City limits (Fig. 9). The rock here is an amygdaloidal metabasalt of the Catoctin formation. The amygdules contain calcite and locally epidote. The principal joint strikes N. 35° E. and dips 70° E.

THOMAS QUARRY*

The old Thomas quarry, operated by the Charlottesville Stone Corporation from about 1930 to 1936, is located on the south side of Moores Creek just east of the quarry now being operated by Fox Brothers (Fig. 9). The quarry is in the same belt of greenstone as are the Berkeley, Monticello, Moores Creek, and Charlottesville Stone Corporation quarries, and the rock is similar to that in the Fox Brothers quarry above described. Crushed stone was obtained from this operation.

BERKELEY QUARRY*

The old Berkeley quarry, abandoned about 1931, is located on Moores Creek, just west of the old Charlottesville-Scottsville road, about half a mile south of the present city limits of Charlottesville (Fig. 9). The quarry is in the same belt of Catoctin greenstone as are the other quarries in the vicinity of Charlottesville, as shown on the Geologic map of Virginia (1928). The rock is a massive, dense, fine-grained, greenish-black metabasalt having a conchoidal fracture. The minerals include labradorite, augite, and minor amounts of chlorite. Pyrite- and chalcopyrite-bearing quartz veins about 4 inches wide, striking N. 30° E. and dipping 45° E., are common. They are slightly offset by the principal joints. The most prominent joint strikes N. 50° to 70° W. and dips 45° W. Also observed were two vertical joints, one striking N. 55° W., and the other, which locally is slaty, N. 35° E. The overburden, clay, is about 3 feet thick. Results of physical tests on samples of rock from this quarry, made by the State Department of Highways, are given in Table 27.

*By W. M. McGill.

RED HILL QUARRY*

The Superior Stone Company has a large quarry on the southeast slope of a small hill, about half a mile northeast of Red Hill in Albemarle County and about six miles southwest of Charlottesville. The quarry is on the west side of the main line of the Southern Railway, approximately opposite the southwestern end of Dudley Mountain (Pls. 1 and 4). Opened in the fall of 1940, after a detailed study of the area, the plant is under the able management of experienced crushed stone operators. Railroad ballast and crushed stone for a variety of uses, are produced. Efficient machinery and equipment, a well-planned layout, modern operating devices, safety measures, and other facilities permit of the production of large quantities of stone. The quarry and plant (Pl. 3B) were described in the April, 1941, issue of *Rock Products*[34], from which the following description is taken.

Primary drill holes 1¼ inches in diameter are sunk with Ingersoll-Rand tripod type drills and, despite unfavorable topography requiring bracing and supporting timber, well drills are used to sink 8-inch blast holes. Jackhammers are used for secondary drilling. Excavating is done by a Bucyrus-Erie steam shovel, from which stone is hauled to the primary crusher by Easton side-dump, semitrailers pulled by 95-horsepower Ford tractors. These semitrailers are dumped by an Easton pneumatic hoist. Primary crushing is done by a Traylor Bulldog jaw crusher which discharges a minus 7-inch product onto a 36-inch belt conveyor feeding a scalping screen—a large 6- by 10-foot Robins Gyrex double-deck vibrating screen. Separations from the scalping screen are fed to each of two secondary crushers and products from them go to the washing and sizing units and then to stock piles. All stone is washed. Manually operated gates and belt conveyors permit of direct loading of any one size or a mixture of several sizes of stone into railroad cars or trucks.

A large open reservoir constructed by damming a near-by surface stream affords an ample supply of water for the washing plant, which uses 600 gpm., fire protection, and other emergency needs. Fire-fighting equipment and novel "grenade type" extinguishers have been installed throughout the plant and adjacent to quarry operations.

The quarry is in an even-granular to porphyritic, medium-grained, light- to dark-gray rock, composed essentially of feldspar, quartz, and biotite. The rock may be described as a quartz monzonite gneiss and may be a facies of the Lovingston granite gneiss, briefly described under

*By A. A. Pegau and W. M. McGill.

the Afton-Shelton-Charlottesville traverse. The feldspar commonly is oligloclase, with varying but minor amounts of microcline. The quartz is gray to purple and locally occurs in small streaks and veins. Biotite is evenly distributed or segregated in blotches. Epidote, generally with pink microcline, occurs in places in small veins or dikelike masses and yields a unakitic-like rock. Joints are well developed. Of those noted, two were flat or horizontal joints and another, rather prominent, had a strike of N. 15° to 20° E. and a dip of 80° to 85° SE. Others, vertical or nearly so, were observed striking N. 22° E., N. 60° E., N. 10° to 15° W., and north.

CHARLOTTESVILLE-AFTON TRAVERSE

The Charlottesville-Afton traverse extends from Charlottesville west, along U. S. Route 250, and roughly parallel to the main line of the Chesapeake and Ohio Railway, through Ivy and Crozet to Afton, a distance of about 23 miles (Pl. 4). Petrographic data on the different rocks along the traverse are given in Table 6.

Most of the area between Charlottesville and the Blue Ridge at Afton is underlain by granite gneiss and Catoctin greenstone of pre-Cambrian age and by phyllite, mica schist, and related rocks of the Loudoun formation of Cambrian age, all striking northeastward. Nearly all of the foliated pre-Cambrian granite gneiss, shown on the Geologic map of Virginia (1928) as Lovingston granite gneiss, is quartz monzonite. The principal feldspar of the gneiss is oligoclase-andesine. Some of the foliated gneisses contain no potash feldspar, but they generally contain muscovite.

An unusual exposure of massive, coarse-grained granite, with almost no foliation, occurs on Lickinghole Creek, along the Crozet-Jarmans Gap road and near the Chesapeake and Ohio Railway, about 2½ miles west of Crozet. There are in this traverse no outcrops of massive, gray-green granodiorite such as are common in the northern part of the Blue Ridge region in Virginia.

None of the granite gneisses of the Charlottesville-Afton traverse are suitable for dimension stone and most of the outcrops are too foliated and decomposed to yield good crushed stone. The Catoctin greenstone of the belt east of Charlottesville and that of the Blue Ridge region generally yield good crushed rock.

AFTON-SHELTON-CHARLOTTESVILLE TRAVERSE

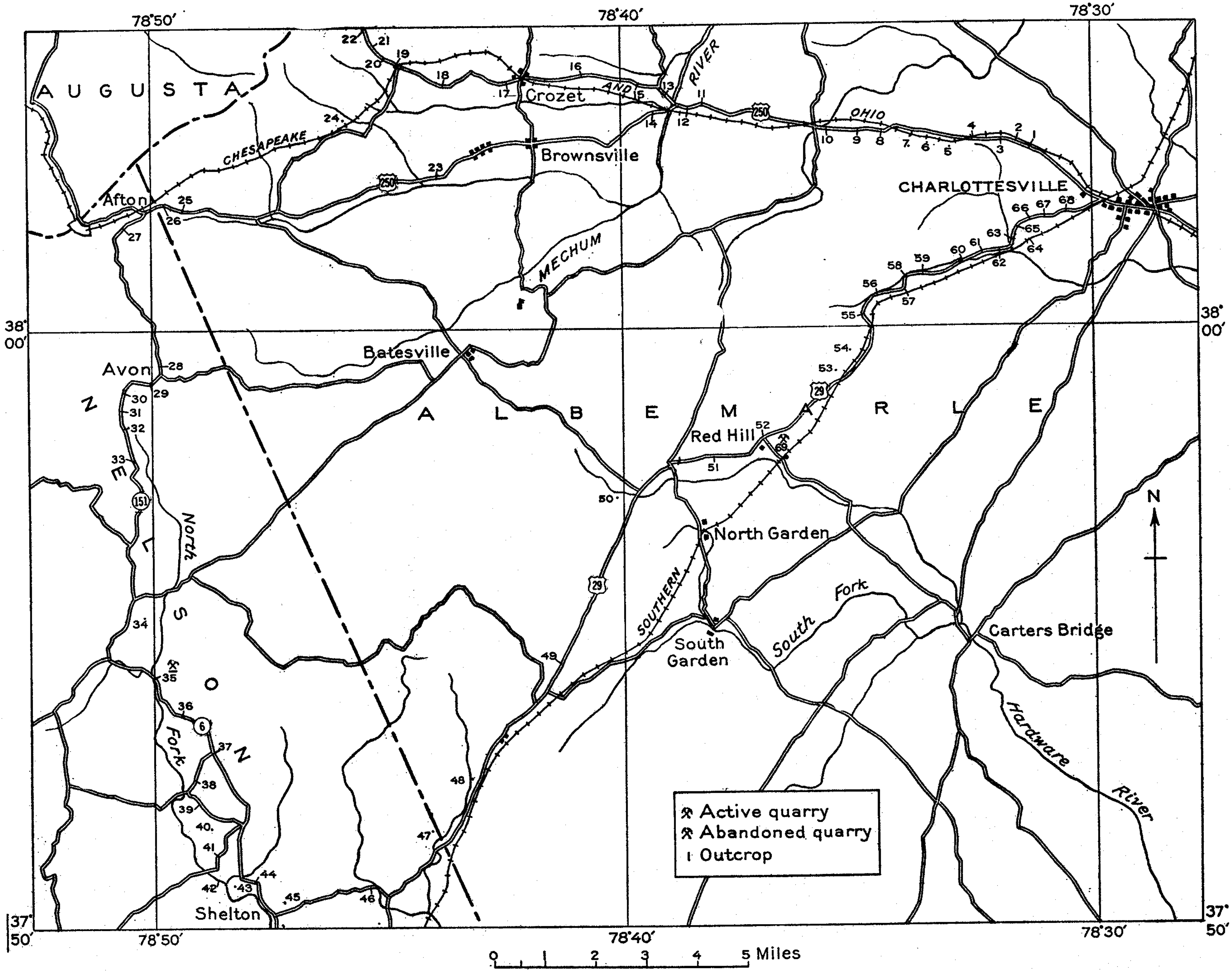
The Afton-Shelton-Charlottesville traverse embraces numerous exposures of crystalline rocks examined along State Highways 151 and 6, from Afton southward via Avon and Martins Store to Shelton, and thence northeastward along U. S. Route 29, through Covesville, North Garden and Red Hill to Charlottesville (Pl. 4). This traverse covering about 42 miles, is shown on the Geologic map of Virginia (1928) as being underlain mainly by Marshall granite and Lovingston granite gneiss. The studies by the writer did not disclose any distinctions between these two rocks in this area. Nearly all of the exposures in the area covered by the traverse are gneissic. Petrographic data on the rocks examined are given in Table 7.

The Marshall granite has been described as "pink to green granite and quartz monzonite; injected by a pegmatite with blue quartz; includes some other pre-Cambrian rocks."[24] The Lovingston granite gneiss has been designated as including augen gneiss and biotite-quartz monzonite.

If a pink to green color is distinctive of the Marshall granite, much of the traverse from Avon to Martins Store, about 8½ miles, is underlain by this unit. In this part of the traverse the granite contains primary, violet-colored quartz. Quartz monzonite occurs about half a mile south of Avon. All other exposures of granite are normal potash granites in which potash feldspar is definitely more abundant than plagioclase. The sheared foliated granites, in which biotite and muscovite are abundant as secondary minerals, generally contain no potash feldspar. Secondary biotite is abundant in most of the exposures between Martins Store and North Garden. This is a common characteristic of the Lovingston granite gneiss. Porphyritic facies, in which large ellipsoidal feldspars are embedded in a mashed and foliated groundmass, occur locally throughout the area of the traverse. A pink granite crops out on U. S. Route 29 about 3 miles north of Covesville.

An interesting exposure of a coarse-grained, granitic conglomerate along U. S. Route 29, about 1½ miles southwest of Charlottesville, may represent the basal beds of the Loudoun formation. Residual boulders of unakite occur about 3½ miles southeast of Charlottesville. The occurrence of secondary unakite in granite or granodiorite in close proximity to bodies of greenstone has been observed elsewhere.

None of the exposures in the area covered by this traverse show rock that would be desirable for dimension stone. The pattern of the rock is too variable, due to shearing and the development of secondary



Index map of the Charlottesville area, showing the Charlottesville-Afton and Afton-Shelton-Charlottesville traverses, Albemarle and Nelson counties, Virginia. 1, 25-26, 44, 49d, 51, 52a, quartz-muscovite schist; 2-4, 7-10, 15, 35, 47b, 48, 56-57, biotite gneiss; 5, 6, 13, 14, 17, 19, 28, 34, 36-39, 50, 52b, 53a, 53b, 59a, 60, 61, 64-67, granite; 11, 18, 40-43, 45, 47a, 54, granite gneiss; 12, 16, 27, 29, 69, quartz monzonite gneiss; 20-22, 24, 62, Catoctin greenstone; 23, 30-33, 49a, 49b, 49c, 68, quartz monzonite; 46, chlorite schist; 55, gabbro; 58, diorite; 59b, unakite; 63, granodiorite; 69, Red Hill quarry. Base from U. S. Geological Survey topographic maps of the Buckingham and Harrisonburg quadrangles.

foliated minerals. Nearly all the exposures in which mica is a minor constituent offer sources of good crushed stone. A small quarry on the east side of State Highway 151, on the western slope of Perry Mountain a short distance north of Martins Store, has produced crushed stone from a granite containing about 30 per cent biotite. Recently a large crushed stone quarry has been opened by the Superior Stone Company in a quartz monzonite gneiss, thought to be a facies of the Lovingston granite gneiss, about half a mile northeast of Red Hill station on the Southern Railway.

GOOCHLAND COUNTY

COLUMBIA QUARRY

The Columbia quarry, now inactive, is located just east of Columbia along the Fluvanna-Goochland County line (Pl. 1). It was described by Taber[22] under the name of the Cowherd quarry. The pit, which has a maximum depth of about 60 feet and a floor area of 20,000 square feet, is in a hillside.

The quarry is in a quartz-diorite gneiss. The gneissic structure strikes approximately N. 25° E. and dips steeply to the east. Biotite, which forms dark-colored bands about 0.04 inch wide and several inches long, constitutes about 20 per cent of the rock and quartz about 40 per cent. The feldspars are mainly albite-oligoclase and oligoclase. The general texture of the rock is quite uniform. Quartz and calcite veins, one 10 inches wide, are aligned with the gneissic structure. An analysis of this rock, published by Taber, is given in Table 28.

RICHMOND AREA

LOCATION

The Richmond granite area lies between the Triassic coal-bearing basin on the west, and the sediments of the Coastal Plain on the east. It embraces parts of Hanover, Henrico, Goochland, and Chesterfield counties and has a width ranging from about 5 to 15 miles. The granites of this area show marked similarity and are believed to be part of a large body of granite extending southward through Petersburg into North Carolina, and designated as Petersburg granite on the Geologic map of Virginia (1928). The granites and former producing quarries of this area have been described by Watson[27] and the location of most of the quarries is shown in Plate 1 and Figures 10, 11, and 12.

The Richmond area was formerly a large producer of block stone for building and paving. From it came stone for the State Capitol and U. S. Post Office in Richmond, and for the State, War, and Navy Building in Washington. A number of beautiful residences built of rough blocks of local granite can be seen in that section of Richmond north of Cary Street and west of the Atlantic Coast Line Railway. The use of stone from this area for buildings, especially residences, should be revived. Homes built of granite have beauty and durability, and can be made very comfortable by modern devices and installations such as air conditioning and rock wool insulation. The Richmond granite area supplies a large volume of crushed stone for highway, railroad, and other construction uses.

THE GRANITES

All samples of granite from the Richmond area are biotite-bearing and contain more potash feldspar, microcline as a rule, than plagioclase, as shown in Tables 8, 9, and 10. The plagioclase ranges from albite to oligoclase. Oligoclase is rare. In some samples no plagioclase was found. Quartz averages about 25 per cent of the rock.

Most of the granite is gray with a sprinkling of pink feldspar. Many grains lack crystal faces, but a sprinkling of large pink crystals with faces is common. The smaller crystals average less than 0.1 inch in diameter, whereas the larger ones are about twice that size. Locally, the gray granite is intruded by a finer grained, blue granite, exposures of which are scarce. A good contact of the two can be seen in the Forest Hill Park quarry on the south side of James River (Fig. 10).

Pegmatite dikes are present in nearly all exposures of granite. They are sheetlike bodies with nearly plane walls, commonly less than 6 inches in width. They have about the same minerals as the rock in which they are found, with gray orthoclase and pink microcline being the principal feldspars. Soda plagioclase is present in small amounts. Some of the pegmatites contain small cavities.

The granite of the Richmond area rarely shows shear zones or crushed elongated grains. It is massive and commonly has a nearly horizontal, wavy sheet structure. Joints are well developed. Most of them are vertical and strike in northeasterly and northwesterly directions, with such spacing between them that it would be hard to separate blocks more than 5 feet in length.

Outcrops of granite are common along James River and local tributary streams. Commonly the granite is fresh up to the loose surface mantle, but where weathered, as along joints, it locally has a mottled reddish tint. At most quarries the overburden, which prevailingly is loose gravel and clay, is less than 10 feet thick.

Results of physical tests and chemical analyses of samples of granite from several quarries in the Richmond area are given in Tables 27 and 28.

RICHMOND GRANITE COMPANY'S QUARRIES

The Richmond Granite Company's two quarries are located on the north side of Brook Run, a short distance northwest of Joseph Bryan Park in the northwestern part of Richmond, about 250 yards east of the Richmond, Fredericksburg & Potomac Railway (Fig. 10). They are not now in operation. In the easternmost, No. 2, quarry the rock is a gray, microcline-biotite granite, with a sprinkling of red feldspar, typical of the stone of the Richmond area. Feldspar grains average about 0.02 inch, with some partly faceted crystals having a length of about 0.2 inch. The mineral composition of the granite is given in Table 8. Vertical joints striking N. 75° W., N. 60° W., and N. 50° W., with a spacing interval of about 5 feet for the first set, were noted. Another set had a strike of N. 25° W., with a dip of 80° W. Also observed was a flat or horizontal joint having a spacing interval of about 5 feet.

The granite in the westerly, No. 1, quarry is identical with that in the quarry just described. A pegmatite dike approximately 5 inches wide follows a joint surface striking N. 25° E. Its minerals include quartz, microcline, albite, and biotite. Quartz is mostly segregated along the middle of the dike. Among the joints observed, one was vertical with a strike of N. 85° E., and another, striking N. 50° W., had a dip of 80° N. The rock in this quarry shows no weathering effects except a slight reddish coloration along joints. Blocks with edges 3 to 5 feet in length could be obtained here.

SUNNYSIDE QUARRY

The Sunnyside Granite Company's quarry is located south of Cary Street and west of the Atlantic Coast Line Railway, north of James River, in the western part of Richmond (Fig. 10). It is operated by the Sunnyside Granite Company, Inc., of Richmond. The quarry produces crushed rock only and has a capacity of 500 cubic yards per day. The pit is more than 80 feet in depth. The overburden at the quarry

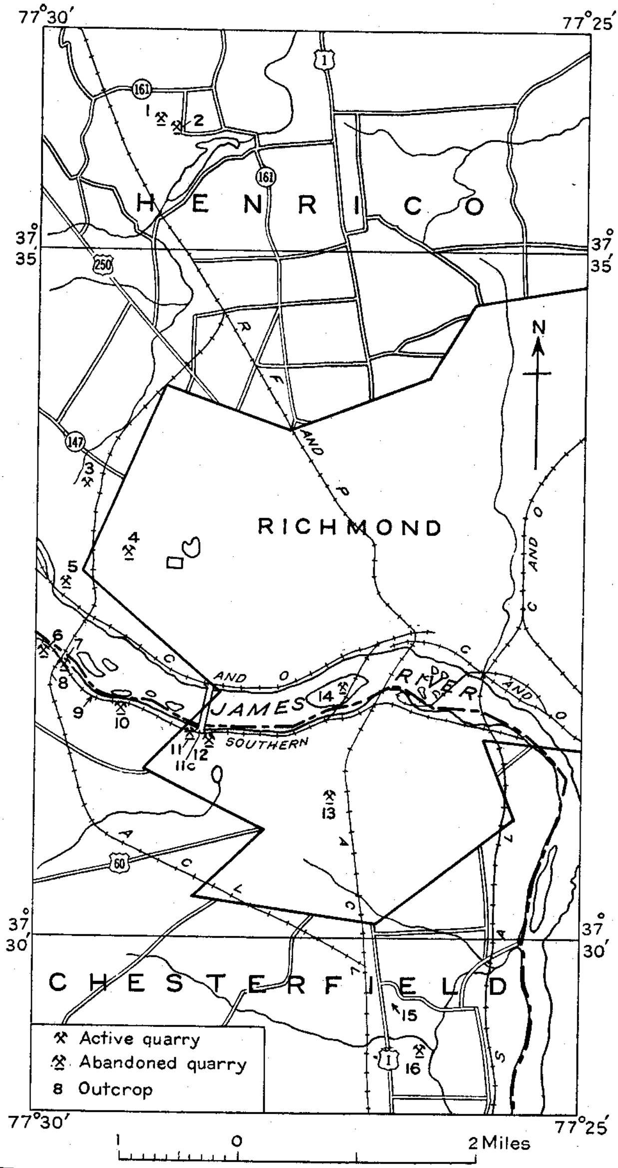


FIGURE 10.—Index map of the Richmond area, Henrico and Chesterfield counties, Virginia, showing location of granite quarries and outcrops. 1-2, Richmond Granite Company's quarries; 3, Sunnyside quarry; 4, McCloy quarry; 5, Philadelphia quarry; 6, McGranigan (?) quarry; 7, abandoned quarry; 8, 9, 11c, 15, granite outcrops; 10, Donald (?) quarry; 11, Wray (?) quarry; 12, Forest Hill Park quarry; 13, Middendorf quarry; 14, Belle Isle quarry; 16, McGowan quarry. Base from U. S. Geological Survey topographic maps of the Richmond (15′) and Bermuda Hundred quadrangles.

is about 16 feet thick, and consists of stratified gravels interlayered with clay. A white clay about 1¼ feet in thickness rests directly upon the granite. The granite is quite fresh up to its contact with the overburden. No residual clay was identified.

The granite is gray with reddish tints. The minerals of the rock are quartz, orthoclase, microcline, albite-oligoclase, biotite, and zircon. The potash feldspars are slightly more abundant than the plagioclase. The largest feldspars are 0.08 inch in length. Biotite, the only dark-colored mineral, constitutes about 10 per cent of the rock. Neither schistosity nor gneissic banding was noticed. Results of physical tests on samples of granite from the Sunnyside quarry are given in Table 27.

Coarse-grained granite dikes up to 2 inches in width are common. They contain pink microcline, quartz, and a little biotite.

Joints are abundant, striking in many directions. A horizontal parting or sheet structure is also present.

MCCLOY QUARRY

The McCloy quarry is located within the city limits of Richmond, about 500 yards west of the Richmond Reservoir and about three-fourths mile north of James River (Fig. 10). It has been idle for many years. The rock in this quarry is a microcline-biotite granite, typical of the Richmond area. The minerals of this granite are listed in Table 8. Sheet structure is well developed in the rock.

BOULEVARD BRIDGE QUARRY

The Boulevard Bridge quarry, thought to be the old Wray quarry, is located about 0.1 mile east of the south end of the Boulevard Bridge, on the south side of James River in the western part of Richmond (Fig. 10). The rock in this quarry is a medium-grained, gray, biotite granite containing pink feldspars. The principal joints are vertical or nearly so and strike N. 10° W. and N. 60° E., with a spacing interval of about 2 to 3 feet. Outcrops of the same kind of granite occur half a mile east of this quarry at the base of the river bluffs. For a petrographic description of this granite, see Table 8.

MCGOWAN QUARRY

The McGowan quarry is located near the Richmond Brick and Tile Company's plant, on the south side of Broad Rock Branch, a short distance east of U. S. Route 1 in Chesterfield County (Fig. 10). The quarry which is not now in operation, is about 12 feet deep. Petrographic data on granite from this quarry are given in Table 8.

The granite, a gray, biotite-microcline granite with a small content of albite-oligoclase, is similar to that of other quarries in the Richmond area. The largest feldspars are about 0.08 inch in length. Vertical joints, spaced at intervals of 2 to 3 feet and striking N. 25° E. and N. 50° W., cut the rock. A horizontal parting is well developed. Pyrite is common as a secondary mineral, occurring mainly along the horizontal partings. The granite contains coarse- and fine-grained dikelike bands. At one place coarse- and fine-grained dikes grade into one another. The dikes, which do not exceed 6 inches in width, have the same minerals as the granite. Part of the granite has been so much sheared as to be schistose; however, the rock as a whole is in fresh condition. The clay overburden is about 10 feet thick.

OTHER LOCAL QUARRIES

Among other abandoned quarries now within or very near the Richmond city limits, and several of which have been described by Watson[26], and Darton[8], may be mentioned the Philadelphia, McGranigan, Donald, Forest Hill Park, Middendorf, Belle Isle, and Mackintosh (McIntosh) quarries. The location of these and a few others, the original names of which are not now known, is shown in Figure 10, and briefly referred to in Table 8, which includes petrographic data on samples of granite from quarries in the Richmond area.

GRANITE STATION-LORRAINE DISTRICT

That part of the larger Richmond area, along James River, southwest of the city, is here described as the Granite Station-Lorraine district. It is underlain by the Petersburg granite as shown on the Geologic map of Virginia (1928) and there are numerous outcrops and several abandoned quarries along or near James River and the River Road (Fig. 11). Not all of the quarries were visited or examined during the investigation on which this report is based, but outcrops of granite near most of them were examined and sampled. Of the quarries not described in this report, but which have been described by other writers, are the Winston and Westham quarries. The location of these, together with other quarries and outcrops examined by the writer, is shown in Figure 11, and petrographic data on samples of granite from various quarries and outcrops are given in Table 9.

GRANITE STATION QUARRY

The Granite Station quarry is located about 300 yards east of Granite Station on the south side of the Southern Railway tracks, about a quarter of a mile southeast of the Vietor quarry (Fig. 11). It is more than 50 feet deep. Its operation has been intermittent, depending upon the demand for paving block which is its main product. Petrographic data on stone from the quarry are given in Table 9.

The granite in this quarry is similar to that of the Vietor quarry and contains quartz, microcline, albite-oligoclase, and biotite. A marked horizontal sheet structure, with a spacing interval of 2 to 3 feet, is evident. Vertical joints are scarce, but the best defined one has a strike of N. 45° E. Pegmatite dikes are rare and contain the same minerals as the enclosing rock. On one of the horizontal parting surfaces a coating of stilbite crystals about one-eighth inch in thickness was observed. Building block could be obtained from this quarry.

Only a short distance to the northeast are the overgrown pits of the old State or Capitol (Mackintosh) quarry which is said to have furnished stone for the State Capitol and the United States Post Office in Richmond.

VIETOR QUARRY

The Vietor quarry is located on the north side of the Southern Railway tracks about 300 feet east of Granite Station, on the south side of the James River in Chesterfield County (Fig. 11). It was last worked for paving blocks. Petrographic data and physical properties of stone from this quarry are given in Tables 9 and 27.

The stone of this quarry is the gray potash granite typical of the Richmond area. Biotite constitutes about 20 per cent of the rock which also contains quartz, microcline, and albite-oligoclase. The average size of the feldspar grains is about 0.08 inch, with scattered phenocrysts of microcline measuring 0.4 inch being present. Pegmatite dikes up to 6 inches in width are common. They contain quartz, microcline, and scattered flakes of biotite. Quartz occurs along the middle of the dikes. Some of the vugs in the central portion of the dikes are lined with calcite crystals. Biotite segregation lenses about 8 inches long and 2 inches wide also occur in the granite. The rock splits along two vertical surfaces, one striking N. 75° E. and the other, N. 20° W.

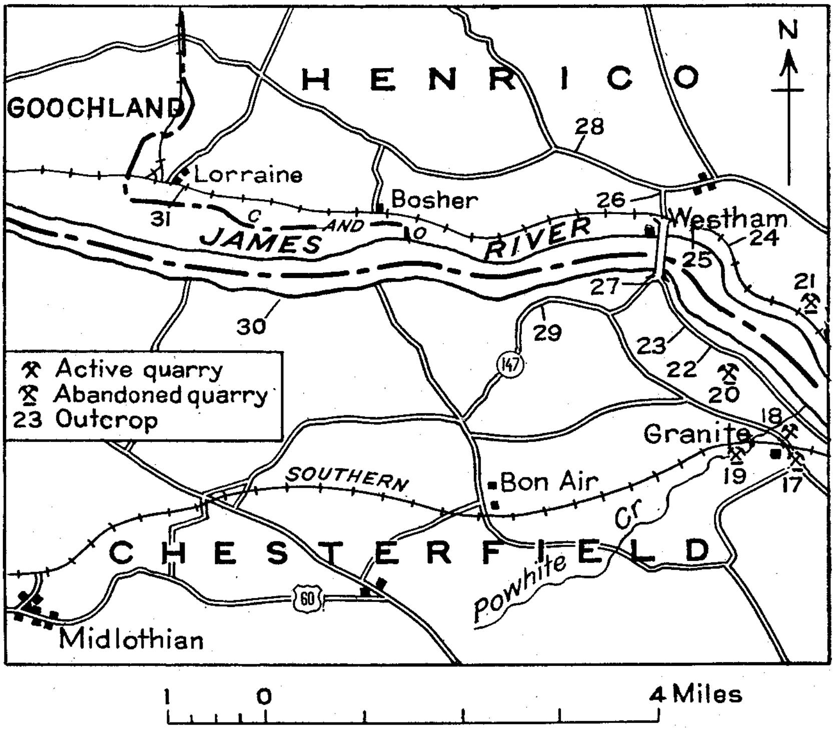


FIGURE 11.—Index map of the Granite Station-Lorraine district, Chesterfield and Henrico counties, Virginia, showing location of granite quarries and outcrops. 17, Granite Station quarry; 18, Vietor quarry; 19, Mackintosh quarry; 20, abandoned quarry south of Chesterfield Golf Club; 21, Winston quarry; 22-31, granite outcrops. Base from U. S. Geological Survey topographic map of the Goochland quadrangle.

QUARRIES SOUTHWEST OF GRANITE STATION

The Old Dominion Granite Company's (Middendorf) and the Mackintosh (McIntosh in earlier reports) quarries, extensive but long abandoned, are located about half a mile southwest of Granite Station along Powhite Creek (Fig. 11). Darton[8] described them in his report on the Richmond area. They were served by a spur line of the Southern Railway. The granite of these quarries is of the same kind as that of the Vietor and Granite Station quarries. It is a microcline granite, with minor amounts of albite-oligoclase and biotite. The rock is massive and undecomposed. The principal joints, which are vertical, strike N. 5° to 10° W. and N. 60° E., and are spaced about 5 feet apart. Sheet structure, with parting intervals of approximately 5 feet, is well defined. An unlimited amount of stone is still available and large building blocks can be obtained in this locality.

Petrographic data and chemical analyses of stone from these and other near-by quarries are given in Tables 9 and 28.

MANAKIN-MAIDENS TRAVERSE

The Manakin-Maidens traverse, about 12½ miles in length, extends along the north side of James River, between the Chesapeake & Ohio Railway and State Highway 6, from the vicinity of the Boscobel quarry on the east, to Maidens on the west. As shown on the Geologic map of Virginia (1928) this area is underlain mainly by gneiss, a gneissic facies of the Wissahickon formation, and a garnetiferous biotite granite gneiss, designated the Baltimore gneiss. The large quarry at Boscobel is the only presently active one in the area of this traverse. The location of this quarry and the various outcrops examined are shown in Figure 12, and petrographic data on samples of rock are given in Table 10.

BOSCOBEL QUARRY

The Boscobel quarry, a large granite quarry, is located at Boscobel, about 12 miles west of Richmond on the Chesapeake & Ohio

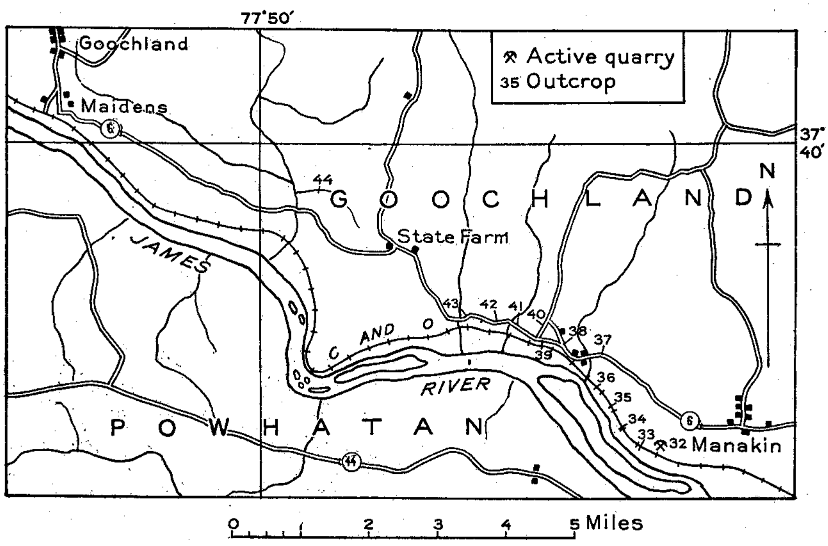


FIGURE 12.—Index map of the Manakin-Maidens traverse, Goochland County, Virginia. 32a, 32b, 32f, 32h, granite; 32c, 32i, 38, 43b, pegmatite; 32d, 32e, 32g, 33, 36a, 37, 39-41, 42a, 43a, 44, gneiss; 34-35, 36b, 42b, granite sill; 32, Boscobel quarry. Base from U. S. Geological Survey topographic map of the Goochland quadrangle.

Railway, in Goochland County (Fig. 12). The quarry, which is owned by Mr. C. S. Luck, Jr., of Richmond, produces only crushed stone and has a capacity of 750 tons per day. Most of the product is used as railroad ballast and in highway construction.

Three kinds of rock are exposed in the quarry. One is a fine-grained, pale-green rock, composed of quartz, albite-oligoclase, and small amounts of biotite. Some secondary calcite, chlorite, and pyrite are also present. This rock may be a dacite. It is intruded by sheets of pink granite which strike N. 45° E. and dip 20° E. They are composed of quartz, red microcline and albite-oligoclase. The granite sheets contain cavities about 3 inches in width which are lined with doubly terminated quartz crystals, garnet, calcite, pyrite, and a tarry substance. The pink granite, which is the second type of rock, varies in texture from medium grained to pegmatitic. This rock seems to have been injected at a shallow depth. The third kind of rock is a hybrid—a mixture of the green and pink rocks. Local foliation of the hybrid rock has developed muscovite. Intrusive relations were well shown in this quarry at the time of examination. Petrographic data and results of physical tests on the rock of this quarry are given in Tables 10 and 27.

The principal joints strike N. 70° E. and N. 45° E., with dips of 75° E. and 75° W., respectively. A fault trending N. 30° E., with a dip 80° W., cuts the south wall of the quarry. The hanging wall side appears to have been pushed upward.

PETERSBURG AREA

GENERAL STATEMENT

Granite has been produced from a number of quarries in the vicinity of Petersburg. Among these are the Cook quarry in Chesterfield County north of that city; the Lassiter, Walsh, Burns and Campbell, Petersburg Granite, Asylum and other quarries, on the western edge of the city limits; the Booth and Rocky Run quarries on or near Appomattox River, a few miles northwest; and the Butterworth quarry, along the Seaboard Air Line Railway between Dinwiddie Court House and DeWitt, all in Dinwiddie County. Several of these have been described by Watson.[29] The location of the quarries described herein is shown in Figure 13, and chemical analyses of stone from one of them are given in Table 28.

All of these quarries are in the large body of granite shown as Petersburg granite on the Geologic map of Virginia (1928). In the vicinity of Petersburg the granite belt varies in width from about 10 to 24 miles. The main body extends southward, just west of the Fall Zone, into North Carolina. The granite at the first six named quarries is similar—a grayish-pink, massive, medium-grained rock. Biotite is the principal mica. Examination of specimens under the microscope rarely gives any indication of the minerals having been mashed into elongated bodies.

COOK QUARRY

The Cook quarry, now inactive, is located about 2 miles north of Petersburg, west of U. S. Route 1 and just west of the Seaboard Air Line Railway on the south side of Oldtown Creek, in Chesterfield County. The floor of the quarry has an area of about 40,000 square feet. The granite exposed is grayish-pink. The average feldspar grain is about 0.1 inch in length. Both grain and color show a high degree of uniformity. No dikes were seen. The rock is in excellent condition to within 6 inches of the top of the quarry face. The overburden is not in excess of 4 feet.

The principal minerals which compose the rock include orthoclase, microcline, albite-oligoclase, quartz, biotite, and minor amounts of muscovite. The rock shows no indication of having been severely squeezed.

Sheet structure is evident. The sheets are from 2 to 9 feet in thickness and form a low dome. The quarry is on the south side of the dome. Vertical joints strike north-south, N. 65° E., and N. 20° to 35° W.

The rock in the Cook quarry is admirably adapted to the uses formerly made of it—for road construction, curbing blocks, and crushed stone; wall, bridge, and culvert work in rough and dressed state; and general building purposes. Stone from this quarry is said to have been shipped north to New York and west to Cincinnati.

BURNS AND CAMPBELL QUARRIES

The Burns and Campbell quarries comprise a group of three or four openings formerly known as the Lassiter, Walsh, and Petersburg Granite Company quarries, on property now owned by the Central State Hospital. They are just south of U. S. Route 1, within a quarter of a mile of the Seaboard Air Line Railway and a short distance west of Rohoic Creek, just west of the city limits of Petersburg. They have been worked extensively for monumental, building, and paving stone. The rock has very few joints, and it is reported that blocks up to 20 feet in length have been extracted

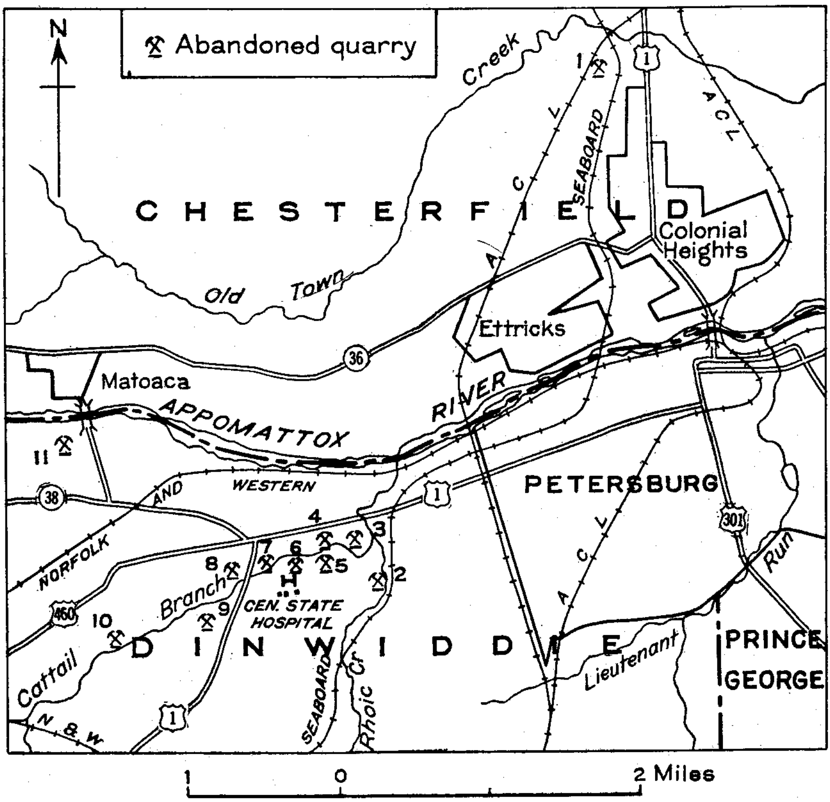
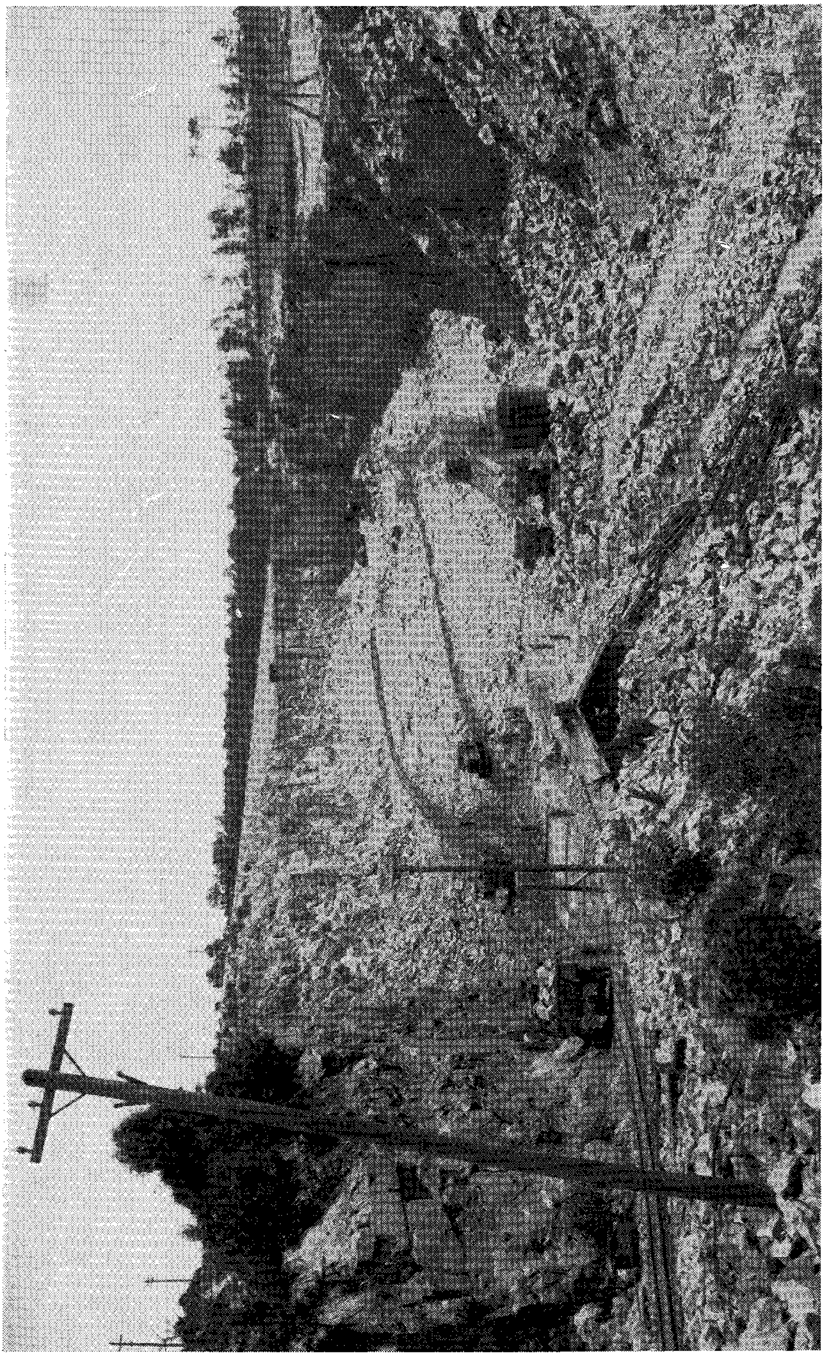
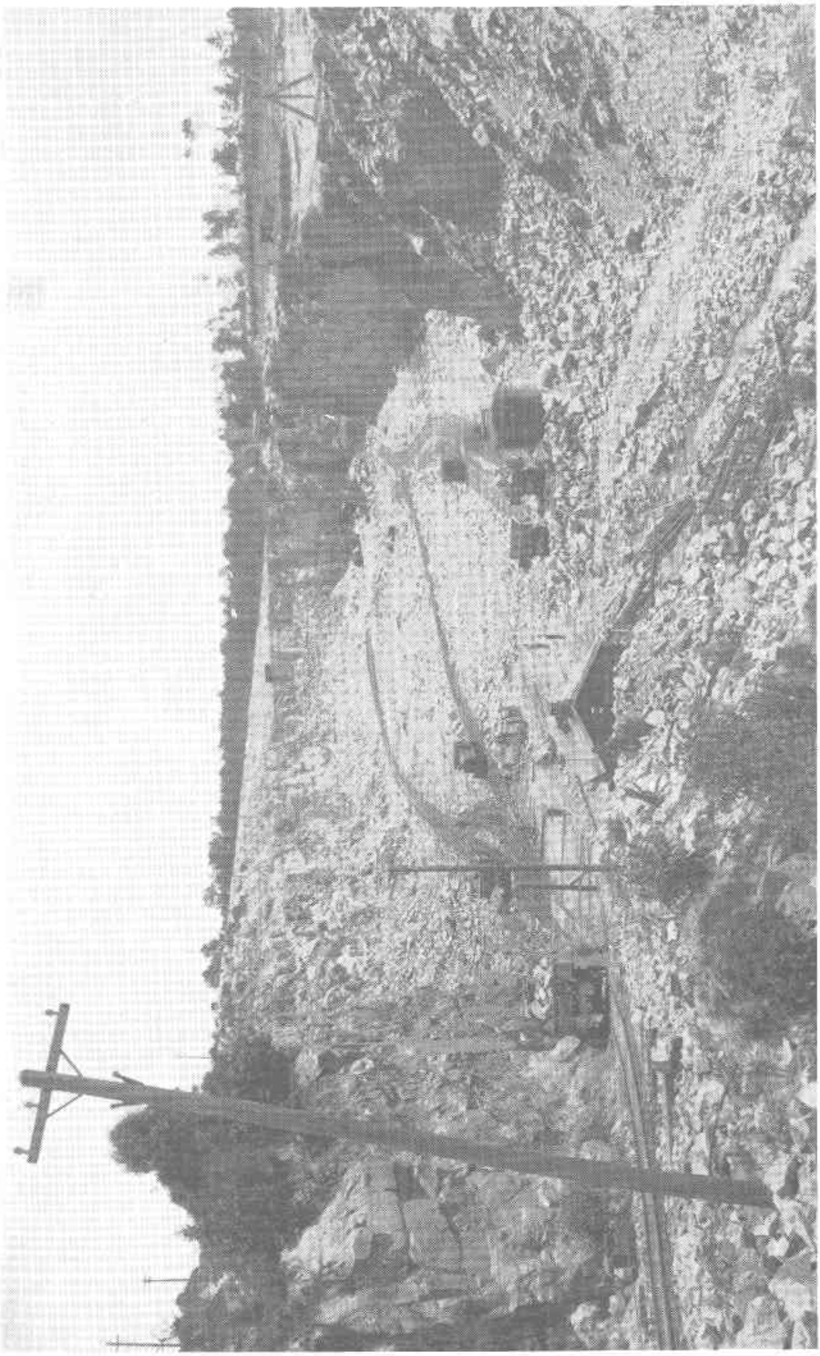


FIGURE 13.—Index map of the Petersburg area, Chesterfield and Dinwiddie counties, Virginia, showing location of abandoned granite quarries and prospects. 1, Cook quarry; 2, Sheep Pasture quarry; 3-4, Lassiter quarries; 5, Burns & Campbell quarry; 6, Asylum quarry; 7, Dibble quarry; 8, Granite Grove quarry; 9, Grey granite quarry; 10, Blue granite quarry; 11, Ferndale Park quarry. Base from U. S. Geological Survey topographic maps of the Bermuda Hundred and Petersburg quadrangles.

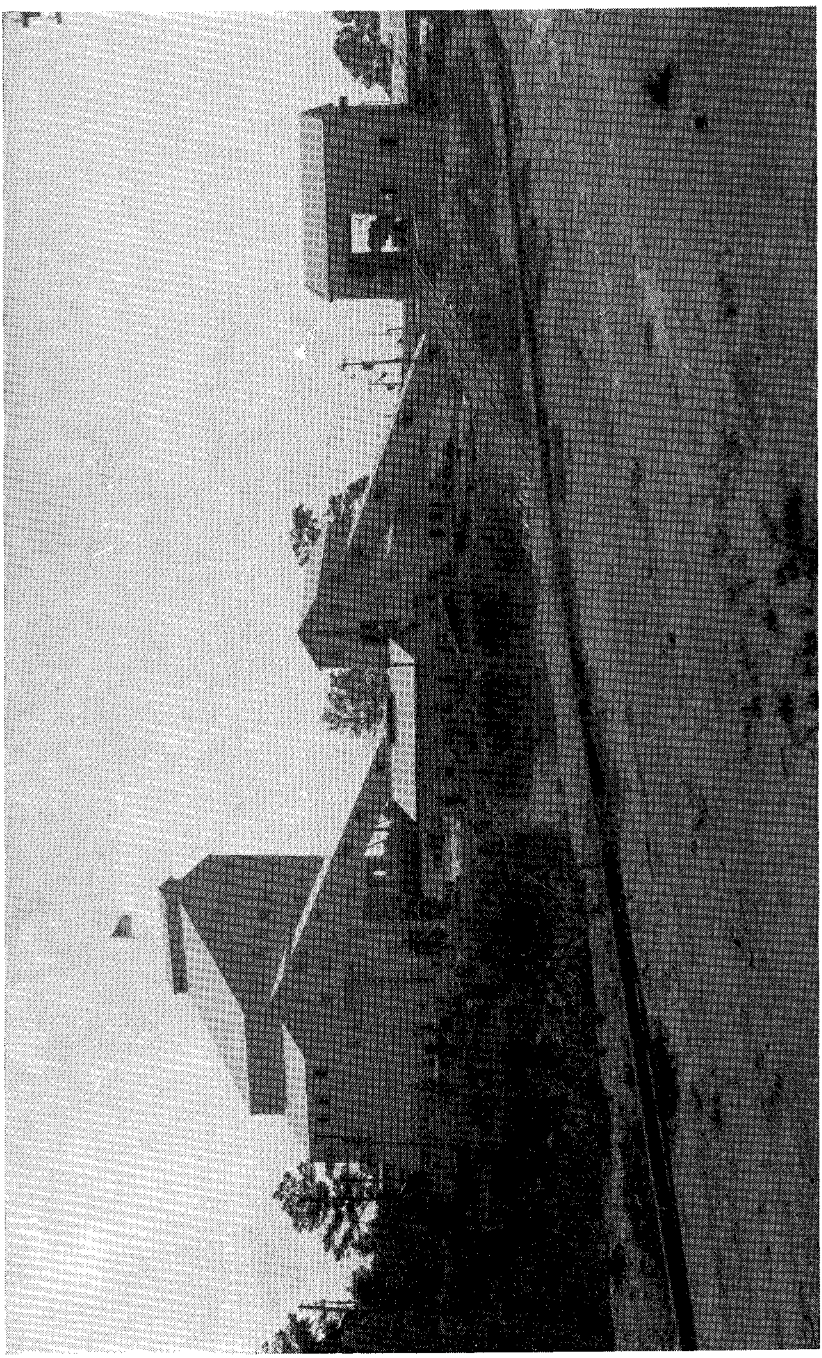
for monumental use. It is well known as a monumental stone and has the highest recommendation for durability. A tombstone of this granite erected in Petersburg more than 50 years ago shows no disintegration.



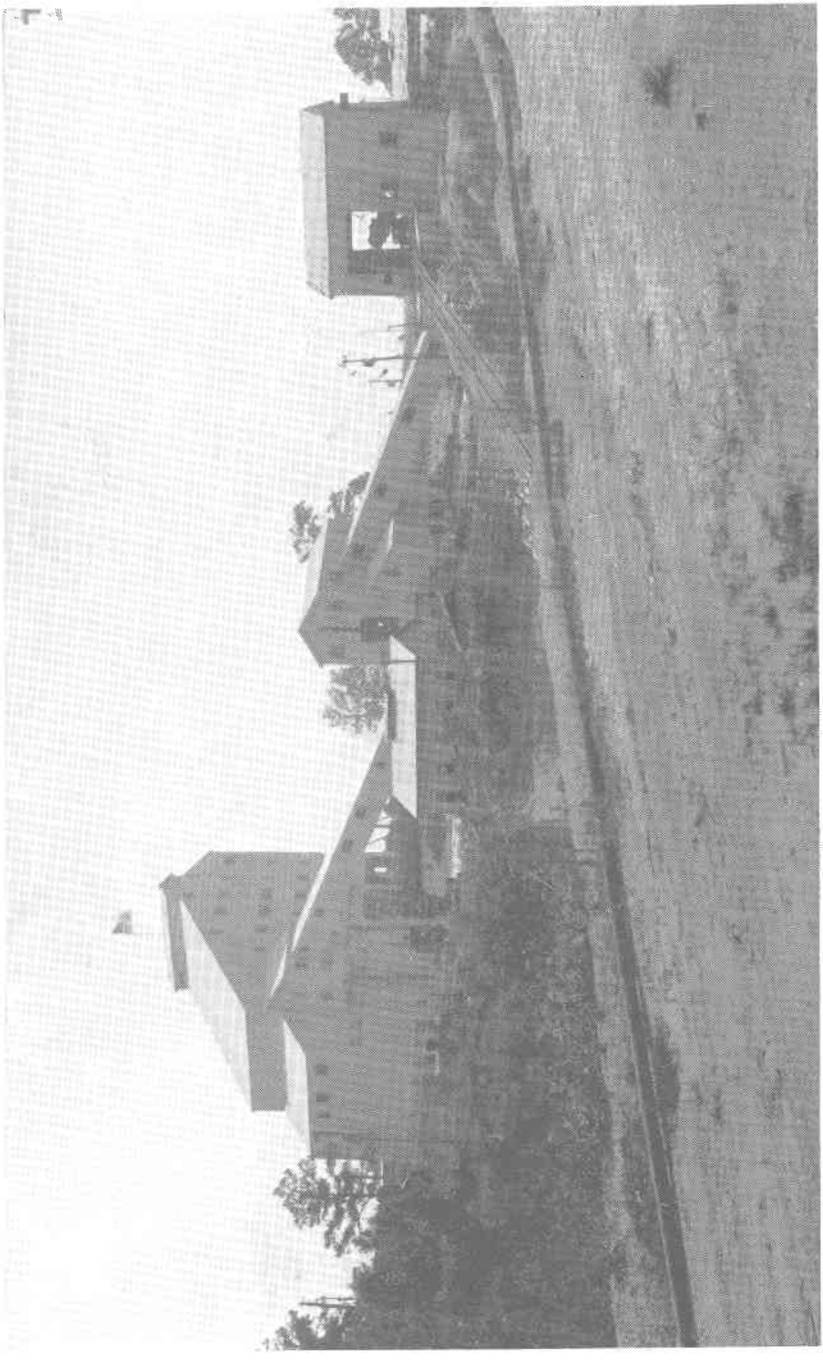
Trego granite quarry at Trego, Greensville County, Virginia. Photograph courtesy Trego Stone Corporation.



Trego granite quarry at Trego, Greensville County, Virginia. Photograph courtesy Trego Stone Corporation.



Crushing plant of Trego Stone Corporation at Trego quarry, Greensville County, Virginia. Photograph courtesy Trego Stone Corporation.



Crushing plant of Trego Stone Corporation at Trego quarry, Greensville County, Virginia. Photograph courtesy Trego Stone Corporation.

The mineral content of the rock is approximately 30 per cent quartz, 60 per cent feldspar, and 10 per cent biotite. The feldspars have the following order of abundance: orthoclase, microcline, and albite-oligoclase. The feldspars average about 0.01 inch, but scattered grains have a length of about 0.75 inch. The biotite shows a faint parallel arrangement and the borders of some of the feldspars show a little granulation.

Joints are widely spaced. Those recorded strike N. 10° W., N. 75° to 80° E., N. 15° E., and N. 65° W., all being vertical or nearly so. Pegmatite dikes from 0.5 inch to 2 inches in width occur in groups but are not abundant enough to mar the greater part of the rock. They strike N. 45° E. One group dips about 5° E., and another 30° E. The overburden, about 3 to 4 feet thick, is a transported quartz gravel with a clay matrix. The rock is fresh to within a few inches of the overburden.

CENTRAL STATE HOSPITAL QUARRIES

Of several abandoned quarries on the property of the Central State Hospital, the Asylum and Dibble, a short distance west of the Burns and Campbell (Lassiter) quarries, were operated prior to 1900 by the Petersburg Granite Company. These and the Burns and Campbell quarries above described were located immediately on or very near the former electric car line of the Petersburg Passenger and Power Company from Petersburg to Ferndale Park. The openings, reported to have been large, were made in flat exposures of granite. The stone was used mainly for building purposes in Petersburg.

The stone in the Asylum and Dibble quarries is the same, but sheet structure is not evident in the Asylum quarry. Joints observed strike N. 10° to 25° W., with dips ranging from 55° to vertical. They are widely spaced, permitting the removal of large blocks. Watson[30] described the stone as "a biotite granite of medium texture and medium-gray color. It consists, in order of abundance, of potash and soda-lime feldspars (orthoclase, variable microcline, and much oligoclase), quartz, black and white mica (biotite and muscovite), with accessary magnetite, titanite, apatite, and zircon, and secondary chlorite, epidote, and muscovite."

There is another abandoned quarry, now designated as the Sheep Pasture quarry on the property of the Central State Hospital. It is on Rohoic Creek about 2,000 feet south of U. S. Route 1 and immediately west of the Seaboard Air Line Railway.

PETERSBURG GRANITE COMPANY'S QUARRIES

There are three abandoned quarries, the Granite Grove, the Grey Granite, and the Blue Granite, along Cattail Branch, west of U. S. Route 1 and south of the Cox Road (U. S. Route 460), just west of the Central State Hospital farm, which are reported to have been operated by the Petersburg Granite Company. The most northerly of these, the Granite Grove quarry, is about 1,200 feet west of the Dibble quarry, which was operated by the same company. The Grey Granite quarry is about 1,500 feet northwest of U. S. Route 1 and about the same distance southwest of the Granite Grove quarry. The Blue Granite quarry is about 2,200 feet farther southwest along Cattail Branch and about 1,500 feet southeast of U. S. Route 460.

BOOTH QUARRY

The Booth quarry is located on Booth Branch, near Wallace Creek, on the Booth farm, north of U. S. Route 460 and the Norfolk and Western Railway and south of Appomattox River, about 3 miles east of Sutherland in Dinwiddie County. It has a floor space of about 1,500 square feet. The exposed granite is a light-pink porphyritic rock with a slight gneissic structure, striking N. 50° W., with a vertical dip. The largest feldspar crystals average 0.3 to 0.4 inch in length. Locally red granite is intruded into a grayish-blue, biotite granite gneiss. Granite veins and pegmatite dikes cut the gneiss. The clay overburden is from 2 to 3 feet thick. The principal joints observed were striking N. 50° E., with dips of 70° E. and vertical.

ROCKY RUN QUARRY

The Rocky Run quarry, now inactive, is on Rocky Run on the Dinwiddie County side of the dam across Appomattox River, about 7 miles west of Petersburg, and about 2 miles northwest of the Booth quarry. From it was quarried granite for the construction of locks and retaining walls for a canal. The rock here is a grayish-pink granite similar to that in the quarries just west of Petersburg. Locally it contains angular masses of pink pegmatite. The principal joints noted were striking N. 50° E. and N. 25° E., with dips of 75° E. and vertical. Horizontal sheets, 2 to 3 feet thick, also occur.

OTHER QUARRIES

There is an abandoned quarry in granite a short distance west of Ferndale Park, between Appomattox River and the Battersea Canal, southwest across the river from Matoaca. On the Borner Butterworth farm, about midway between Dinwiddie Court House and DeWitt, and a short distance east of U. S. Route 1 and the Seaboard Air Line Railway, is a quarry from which it is reported was obtained granite used in the new Post Office Annex (Parcels Post) Building, in Richmond.

GREENSVILLE COUNTY

TREGO QUARRY

The granite quarry of the Trego Stone Corporation is located about 2 miles west of Skippers (Trego Station), and a short distance west of Fontaine Creek in Greensville County (Pl. 1). A spur track extends from the Atlantic Coast Line Railroad at Trego to the quarry. The Trego quarry is one of the largest producers of crushed granite in Virginia (Pls. 5 and 6). The overburden is a transported clay containing seams of gravel, and having a thickness of from 15 to 20 feet. The decomposed granite averages about 7 feet in thickness and is removed with the clay overburden. Joints are very evenly spaced. Two prominent vertical joints strike N. 70° W .and N. 20° E., respectively. Another strikes N. 65° E. and dips 70° S. The principal quarry face extends in a N. 20° E. direction, along one of the main joints. Working this face yields the best results, with the least amount of secondary drilling.

The quarry is equipped with caterpillar steam shovels, 6-inch churn drills, jack hammers, and other mechanical appliances. The primary breaking in the mill is done by a 48 by 60 inch Blake jaw crusher. The product from the crusher goes on a 42-inch belt conveyor to a 20-inch Superior-McCully gyratory crusher which reduces the 8-inch pieces to 4-inch size. The product from the crusher travels on a 36-inch belt conveyor to two 60-inch sizing screens, which yield several sizes. The oversize from the screens goes to a Symons cone crusher and then back to the sizing screens. From the sizing screens, the products go to two vibrators, where they are washed and, if desired, resized, according to demand. Forty-two different sizes of crushed stone can be produced. The capacity of the mill is 350 tons per hour. The largest daily shipment has been 87 cars.

The rock in the quarry is a fine-grained, even-textured, biotite granite. The average grain size of the feldspars and quartz ranges from about 0.01 to 0.02 inch in diameter. The proportions of the major minerals are approximately as follows: feldspars 75 per cent, quartz 20 per cent, and biotite 5 per cent. Most of the feldspar is orthoclase, but minor amounts are microcline and albite.

Results of tests of physical properties of granite from the Trego quarry are given in Table 27.

LUNENBURG COUNTY

KENBRIDGE QUARRY

The Kenbridge granite quarry is about 2.1 miles south of the Virginian Railway at Kenbridge, Lunenburg County (Pl. 1). The quarry is located on the steep southern slopes of a hill above Flat Rock Creek, in the area of Red Oak granite shown on the Geologic map of Virginia (1928). The overburden is only a few feet thick and a considerable area of excellent stone has been exposed by stripping and quarrying. The quarry was last operated by the Pyramid Granite Company of Philadelphia. The rock has been used for paving, curb stone, and sewer blocks, but not for monumental stone.

The rock is a pinkish-gray, coarse-grained granite gneiss with feldspar phenocrysts about three-fourths inch in length. All the minerals show marked elongation and parallel arrangement. The quartz content is high, about 25 to 30 per cent. Both light- and dark-colored micas are present, with the dark-colored mica being more abundant. Microcline is the principal feldspar. The soda feldspar, albite-oligoclase, is rather rare. The characteristic composition of this rock has been described as that of a quartz-biotite monzonite.[16]

The gneissic structure is vertical and has a variable strike ranging from N. 5° E. to N. 30° W. It affords the surfaces of easiest splitting which are spoken of as the "run." Next to the "run," a sheet structure is utilized in removing block stone. It strikes N. 20° to 25° W. and dips 15° to 20° SW. Joints are scarce, but one strikes N. 5° W. and dips 80° S.

Most of the rock is free from flaws. An inclusion of gray granite gneiss about a foot in length and with sharply defined surfaces was observed at one place in the quarry. It is composed of albite-oligoclase, quartz, and biotite with small amounts of secondary calcite and epidote.

The granite gneiss is cut by several narrow dikes of the same composition as the enclosing rock. They too are gneissic, hence were injected before the gneiss-forming processes were active. One, about 2 inches in width, striking N. 62° E., is offset by a fault that strikes N. 40° W. and dips 70° S. Grooves on the fault surface dip 40° SE. The south wall of the fault appears to have moved upward in the direction of the grooves. Another gneissic dike about 2 inches in width strikes N. 20° W. and dips 70° S.

A small pegmatite dike 2 or 3 inches in width cuts across the gneissic rock in an east-west direction. It was injected after the deformation which developed the gneissic structure. It is exposed for a distance of about 8 feet and contains quartz, microcline, biotite, garnet and hornblende. Locally, thin lenses of quartz, a few inches in length, are embedded in the granite gneiss.

Results of physical tests made on specimens of granite from this quarry are given in Table 27.

MECKLENBURG COUNTY

VIRGINIA GREY GRANITE QUARRY*

The Virginia Grey Granite Quarries Inc., has recently opened a small quarry on the northwest slope of a small hill on the southwest side of, and about 20 feet above, Cox Creek, near State Road 637, about 6½ miles southeast of Boydton and 2½ miles north of Buggs Island in Mecklenburg County (Pl. 10A). The quarry is in a natural surface exposure which slopes northwestward above creek level, and at the time of the writers' visit the main opening was about 100 feet long, 50 feet wide, and less than 3 feet deep. The depth of overburden, mainly sandy clay, around the sides of the present opening was not more than 2 feet. The quarry is in a belt of Red Oak granite, as shown on the Geologic map of Virginia (1928).

The granite in the quarry is a massive, medium-grained, even-textured, light-gray rock, resembling the Petersburg granite. The minerals recognizable with a hand lens include white to light-pink feldspar, gray quartz, biotite, and muscovite. In the quarry the granite is relatively free of inclusions and injections, but both appear more numerous in local exposures on the hill northwest of Cox Creek. The top surface of the rock in the quarry shows a weathered pinkish layer an inch or less in depth, beneath which the stone is fresh. Joints are not particularly well developed and those

*By A. A. Pegau and W. M. McGill.

noted are widely spaced. The most prominent sets observed were striking N. 43° to 45° W., and N. 38° to 40° E., with the dip of the first being nearly vertical.

The stone appears to be well suited to the purpose for which it is now used—monumental stone. Blocks from 12 to 16 inches in thickness and from 12 to 16 feet in length, to others about 1 foot thick, 3 feet wide, and 5 feet long, are now produced (Pl. 10B). Although the quarry has not been extensively developed, it appears that there is a large reserve of good stone available here.

The Southern Aggregate Corporation has recently acquired the Penny Johnson farm, embracing nearly 200 acres, and on which the Virginia Grey Granite quarry is situated. Results of core drilling on the larger hill northwest of Cox Creek and the quarry, and several partial exposures of granite indicate a very large tonnage of stone on this property.

BURKEVILLE AREA

BURKEVILLE QUARRY

The Burkeville granite quarry is about half a mile northeast of Burkeville on the east side of a dry run, which drains to the northeast into Flat Creek. It is about equally distant from the Southern and the Norfolk and Western railway tracks. Since the surface in this locality is a gently rolling plain, the tracks easily could be extended to the quarry (Pls. 1 and 9A).

The granite of the Burkeville area is a grayish-blue, fine-grained stone with a fresh crystalline appearance. It is a good monumental and building stone.

The approximate mineral content of the granite is microcline 20 per cent, albite-oligoclase 45 per cent, quartz 20 per cent, and biotite 15 per cent. The rock is really a granodiorite, the plagioclase being more abundant than potash feldspar. The feldspar particles average about 0.15 inch in diameter and are essentially uniform in size.

The rock has a distinct rift or direction of easy splitting, which strikes N. 5° W., is vertical, and is quite independent of the joints. The head or "hard way" is also vertical and strikes about N. 85° E. It takes the best polish. Near the surface the rock shows faintly a sheet structure. At depth this structure is not in evidence and the quarrymen make the quarry floor by drilling 3 slightly inclined holes which flare from a common center, like the ribs of a fan, forming a sector of about 30 degrees. Joints are scarce and in the deeper parts of the pit are nearly absent. Of those observed two, striking N. 40° E. and N. 35° S., respectively, were vertical. Two, with dips 85° S., were striking N. 30° W. and N. 40° W., respectively, with another having a strike of N. 35° W. and a dip of 85° N.

Several small pegmatite dikes from 1 to 3 inches in width were noted. They commonly split into thin parallel sheets. The strike of two which dip steeply to the south is N. 75° W. and N. 35° E., respectively. The minerals of the pegmatite include microcline, quartz, red garnet, and dark-colored mica. No plagioclase was found, whereas in the granite, its percentage is high.

Results of physical tests made by the Testing Laboratory of the Department of Civil Engineering of the Virginia Military Institute, on specimens of granite from the Burkeville quarry, are given in Table 27.

Stone from the vicinity of Burkeville was used locally nearly 100 years ago. A house near the quarry built with this stone at that time is still standing and is said to have had a clean, fresh appearance up to about 20 years ago when it was whitewashed. A house in Petersburg is reported to have been built of stone from the Burkeville area before the War between the States. The present quarry, which is now active, was opened in 1929 by the Pyramid Granite Corporation of Philadelphia. Stone from this operation has been used in base and die monumental block, straight and curved curbstone, paving and sewer block, and building stone. Shipments have been made as far north as Quincy, Massachusetts.

GRANITES NEAR BURKEVILLE

Outcrops of granite are relatively scarce in the vicinity of Burkeville; however, a massive, medium-grained biotite granite crops out along Deep Creek, about 2⅜ miles east and seven-eighths mile north of Burkeville. Foliated muscovite-quartz monzonite crops out along Little Nottoway River southwest of Crewe, and southwest of Nottoway Court House. The feldspars in these rocks consist of microcline and albite-oligoclase, in about equal amounts. Both biotite and muscovite occur as minor constituents.

About one-fourth mile east of Saxe on the Southern Railway in Charlotte County, a pale-pink, hornblende granite gneiss was quarried for local uses about 30 years ago. The quarry is on the former Test Farm of the State Department of Agriculture. The banding of the rock is straight, varies in thickness up to half an inch, and has a strike of N. 30° E. and a dip of 45° E. Parting surfaces, spaced at intervals of 1½ to 2 feet, parallel the banding. A pale-pink microcline is the principal mineral. Albite-oligoclase is also present. Hornblende crystals, about one-fourth inch in length, constitute about 15 per cent of the rock, with quartz forming about 30 per cent. Patches of pegmatitic material are common.

Because of closely spaced partings and variations in pattern the rock is not well suited for high-grade dimension stone, but is suitable for rough block stone and for crushed rock.

LYNCHBURG AREA

VIRGINIA GREENSTONE QUARRY

The Virginia Greenstone Company's quarry is located in the southwestern part of Lynchburg, on Fort Avenue and Thurmanis Street, in the Fort Hill section of the city (Pls. 1 and 9B and Fig. 14). The quarry is in a body of greenstone thought to be intrusive into the Lynchburg gneiss. Near the quarry the body of greenstone is about 300 feet wide, and it is reported to have been traced about 1,000 feet in a northeasterly direction.

The greenstone is a chlorite-actinolite schist. The schistosity strikes N. 55° E. and is nearly vertical. The fresh rock is a uniform bright-green. The greatest depth of weathering is about 10 feet. Weathered parts of the rock are red and brown. Chlorite is the principal mineral and small needless of actinolite, barely visible with a hand lens, are next in abundance. Much of the actinolite cuts across the schistosity as though it had formed after the flakes of chlorite had been oriented under horizontal compression. A feebly magnetic black oxide of iron is also fairly common. Generally the rock is fine grained and uniform in both grain and color.

Detailed physical tests have been made, on specimens of greenstone from this quarry, by the Department of Purchase of the City of New York, by Columbia University, and by the Physical Testing Laboratory of the Department of Civil Engineering of the Virginia Military Institute. Results of these tests are given in Table 27.

Greenstone from the Lynchburg quarry has been used for building stone, for interior and exterior decorative stone, monumental stone, and for a variety of special uses. The principal product is sand-finished, cut stone prepared according to demand. A considerable part of the facade of the Allied Arts Building in Lynchburg was built of greenstone. This stone also has been used in the construction of many homes and several churches in Lynchburg (Pl. 9B). In recent years greenstone from the Lynchburg quarry has steadily gained in favor as a nonskid stone for floors and stair treads, and for spandrels.

The waste from the quarry is used in manufacturing a refractory plastic, which is now widely used in the paper pulp industry to line the furnaces of the recovery units.

GOODE-LYNCHBURG TRAVERSE

The Goode-Lynchburg traverse begins about midway between Bedford and Goode on the west and extends eastward and northeastward along U. S. Route 460, and roughly parallel to the Norfolk and Western Railway, through Forest into the western part of Lynchburg, a distance of about 20 miles (Fig. 14). Petrographic descriptions of the rocks are given in Table 11.

Outcrops of foliated granite gneiss, which is mainly quartz monzonite, occur from Little Otter River, about 5 miles west of Goode, to a point about 2 miles west of Forest. Soda-lime and potash feldspars are abundant in this rock. The soda-lime varieties range from albite to albite-oligoclase. Secondary biotite commonly is abundant, the maximum biotite content being about 30 per cent. The most foliated micaceous zones usually have no potash feldspar. Small sills and dikes of massive quartz monzonite, low in biotite, are common. The foliated monzonitic rocks are in the area shown as Lovingston granite gneiss on the Geologic map of Virginia (1928).

From a point about 22 miles northeast of Forest, northeastward into Lynchburg, the underlying rocks are highly foliated hornblende-feldspar gneiss, actinolite-chlorite schist, and diabase. This part of the traverse lies within the area shown on the same map as Lynchburg gneiss and associated basic igneous intrusions.

No exposures of stone of sufficient size and character to warrant commercial operation were found along this traverse.

LYNCHBURG-HARRIS CREEK TRAVERSE

The Lynchburg-Harris Creek traverse, about 7 miles in length, follows State Highway 130 on the north side of James River from Lynchburg to Pedlar Mills, thence northward up Harris Creek to the village of the same name (Fig. 14). It is underlain by several facies of Lynchburg gneiss, biotite schist and gneiss, and dikes of chlorite-actinolite schist, all intruded, locally at least, by a biotite granite. A

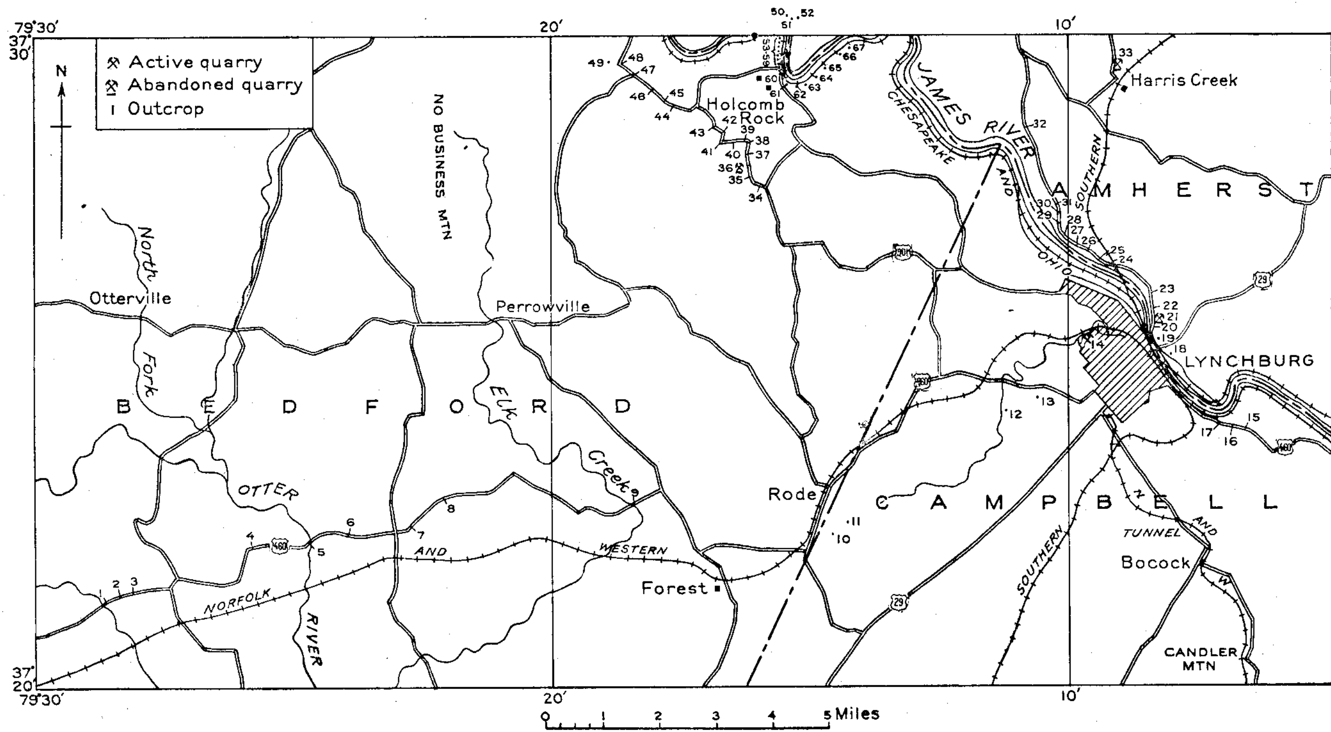


FIGURE 14.—Index map of the Lynchburg area, showing the Goode-Lynchburg, Lynchburg-Harris Creek, Lynchburg-Coleman Falls, and Holcomb Rock traverses, Amherst, Bedford, and Campbell counties, Virginia. 1-2, 8, 12, 43, 48-51, 53, 59-62, granite gneiss; 3-4, quartz monzonite gneiss; 5a, 10, 15, 16, 18, 20, 23-24, 32, biotite schist; 5b, 54, quartz monzonite; 6-7, 9, 17, 19, 21, 28, 34, 39, 56-57, 64-67, biotite gneiss; 11, diabase; 13, diorite; 14, chlorite-actinolite schist; 22, 25-27, diorite gneiss; 29, muscovite schist; 30, amphibolite dike; 31, hornblende schist; 33, 42, 44-47, 52, 58, granite; 35-38, 40-41, 55, granodiorite; 63, sericite schist; 14, Virginia Greenstone Company's quarry. Base from U. S. Geological Survey topographic maps of the Buena Vista (30′) and Lynchburg (30′) quadrangles.

hillside quarry in granite near Harris Creek, about half a mile west of the Southern Railway, has produced crushed stone for highway construction. This quarry, the back wall of which has a height of 30 feet, has a floor area of about 12,000 square feet. Petrographic data on the rocks in this quarry are given in Table 12. The granite contains orthoclase, small amounts of albite-oligoclase, quartz, and biotite. It forms knife-edge contacts with the schist. Granite sills and dikes also occur. Of the joints observed in the quarry all are vertical and strike N. 50° E., N. 40° W., and N. 80° W.

LYNCHBURG-COLEMAN FALLS TRAVERSE

The Lynchburg-Coleman Falls traverse, about 16 miles in length, begins in the northwestern part of Lynchburg and follows U. S. Route 501 northwestward along the south or southwest side of James River through Boonsboro, past Holcomb Rock to the vicinity of Coleman Falls (Fig.14). There are no exposures of fresh rock between Lynchburg and Boonsboro. At Boonsboro are exposures of biotite granite gneiss. From about 1.1 mile northwest of Boonsboro, northwestward to the northeast base of Fleming Mountain, occur exposures of massive hornblende granite similar to some of the massive granites and granodiorites of the northern part of the Blue Ridge in Virginia. At the first outcrop the rock is gneissic, but from the next exposure, about half a mile northwest of the first, nearly to Fleming Mountain, the rock is classed as hornblende granodiorite. It has a high content of oligoclase. Outcrops at the northern base of Fleming Mountain are of a foliated augen gneiss containing biotite and blue quartz. More or less foliated biotite granite in which potash feldspar is dominant is exposed between the northern base of Fleming Mountain and Coleman Falls.

A quarry which has produced crushed stone for highway construction is located on the northeastern slope of Fleming Mountain, about 2 miles northwest of Boonsboro, in dark-gray massive hornblende granodiorite, similar to that described above. The principal minerals of this rock are albite-oligoclase and oligoclase. Orthoclase is intergrown with plagioclase. There are few joints in this quarry. One set is vertical and strikes north; another strikes N. 70° E. and dips 85° S.

The massive hornblende granite and hornblende granodiorite on the southeast side of Fleming Mountain are recommended for use as dimension stone. As above stated these rocks have been used for crushed stone. Petrographic data on the rocks in the Lynchburg-Coleman Falls traverse are given in Table 13.

HOLCOMB ROCK TRAVERSE

Some of the granite gneiss along James River, northwest and southeast of Holcomb Rock, would make excellent crushed stone (Fig. 14). Nearly all the outcrops in the vicinity of Holcomb Rock are of granite gneiss with a variable content of biotite up to 30 per cent. The exposures resemble types that are common in the area of Lovingston granite gneiss shown on the Geologic map of Virginia (1928). The most foliated zones have little or no potash feldspar. In the more massive outcrops, potash feldspar is more abundant than is the soda-lime variety. Petrographic data on exposures along the Chesapeake and Ohio Railway, from a point about 1 mile west of the station at Holcomb Rock to a location about 2 miles east of the station, are given in Table 14.

VICINITY OF LYNCHBURG

In the vicinity of Lynchburg the areas underlain by Lynchburg gneiss, as shown on the Geologic map of Virginia (1928), offer the least possibilities for crushed stone (Table 11). Some stone of good quality can be obtained from the areas underlain by Lovingstone granite gneiss, and there is a possibility of obtaining building stone from the vicinity of Holcomb Rock. The area of massive granite, shown as hypersthene granodiorite on the Geologic map of Virginia (1928), offers excellent stone.

DANVILLE AREA

GENERAL GEOLOGY

The main rocks underlying the Danville area include the Wissahickon schist, a hornblende-feldspar gneiss, and a foliated granite designated the Shelton granite gneiss on the Geologic map of Virginia (1928). Of these the Shelton granite gneiss is the principal rock of the area. The quarries and outcrops examined in this area are shown in Figure 15, and petrographic data on the rocks are given in Table 15.

The strike of the foliation in and around Danville ranges from N. 80° E. to about N. 15° E. Commonly its inclination is towards the southeast at a steep angle. The dip of the foliation along Fall Creek, in the City quarry, in exposures along Dan River on the northwest side of Main Street in the center of Danville, and near the mouth of Sandy Creek along the northwestern boundary of the city, is generally to the west. Most of the joints in the rocks of this area extend in northeasterly and northwesterly directions. The principal joints usually intersect at angles of about 80°.

Wissahickon schist.—A gnessic facies of the Wissahickon schist is well exposed in the Danville City quarry. Here it is a brown rock tinged with green and composed mainly of biotite, muscovite, and chlorite. Porcelain-white quartz granules about 0.2 inch in diameter, and rather evenly distributed, constitute about 20 per cent of the rock. Feldspar, which is sericitized, is rare. A little calcite is present. Dikes, which are common in the other formations of this area, were not observed in this rock. The foliation of the schist is about the same as that of the other rocks in this area.

Hornblende-feldspar gneiss.—The hornblende-feldspar gneiss is older than the Shelton granite gneiss. The granite gneiss intrudes the hornblende-feldspar gneiss in exposures at the north end of the bridge over Dan River on U. S. Route 58 in the city, in the old City Quarry, and on the north side of the river northwest of Main Street in the northern part of the city. The best contacts between the granite gneiss and the hornblende-feldspar gneiss are in the old City Quarry. The granite gneiss forms both sills and dikes in the hornblende-feldspar gneiss. Dark-colored bands of hornblende in the granite gneiss compose about half of the rock. Light bands consist of oligoclase and small amounts of quartz. One exposure had andesine but no quartz. Secondary calcite is common in the hornblende-feldspar gneiss and is found also in many places in the granite gneiss.

Shelton granite gneiss.—The Shelton granite gneiss is nearly uniform in its mineral content. Microcline is its principal feldspar. Its soda-lime feldspar ranges from albite to albite-oligoclase. Muscovite is a persistent constituent, with biotite generally present. Pegmatite dikes, containing the same minerals as the gneiss, occur in both the Shelton granite gneiss and the hornblende-feldspar gneiss.

DANVILLE CITY QUARRY

The Danville City quarry is located on the north side of Dan River, a short distance south of U. S. Route 58, about 1,500 feet northeast of the city limits (Pl. 1 and Fig. 15). The rock here, a biotite gneiss, is shown on the Geologic map of Virginia (1928) as Wissahickon schist. It has been quarried extensively. The foliation strikes N. 45° E. and dips 20° to 25° W. Joints are scarce. They are vertical or nearly so, and strike N. 70° E. and N. 30° W. A residual clay about 15 feet thick forms the overburden.

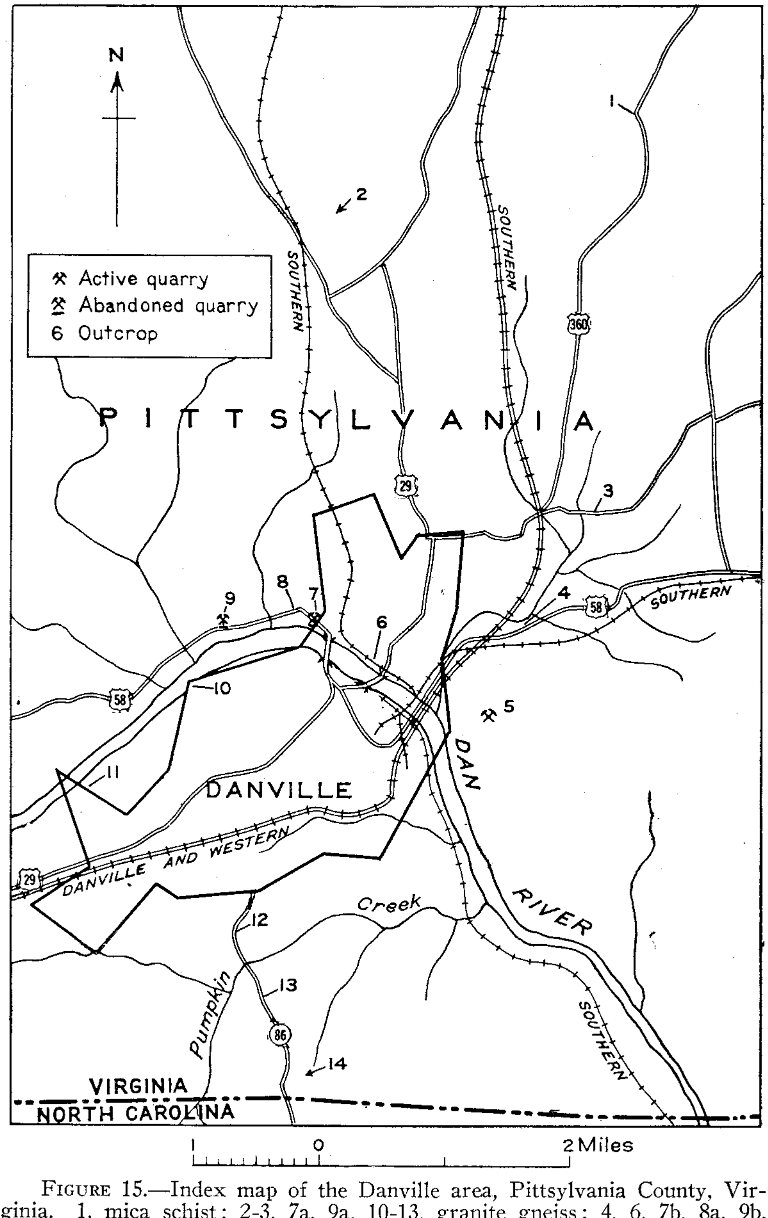


FIGURE 15.—Index map of the Danville area, Pittsylvania County, Virginia. 1, mica schist; 2-3, 7a, 9a, 10-13, granite gneiss; 4, 6, 7b, 8a, 9b, granite; 5, biotite gneiss; 8b, 9c, pegmatite dikes; 14a, chlorite-actinolite schist; 14b, massive gabbro. Base from U. S. Geological Survey topographic map of the Danville quadrangle.

OLD CITY QUARRIES

The old City quarry, which was abandoned more than 20 years ago, is located on the west side of Dan River (Pl. 1 and Fig. 15). The principal rock here is the hornblende-feldspar gneiss described above. It is injected by small dikes and sills of the Shelton granite gneiss and by small pegmatite dikes of about the same mineral content as the granite gneiss. The gneissic structure strikes east and dips 45° S. The principal joints, which are nearly vertical, strike N. 30° E. and N. 45° W. The gneiss breaks into polygonal blocks about 6 inches in length.

Another abandoned quarry, in hornblende-feldspar gneiss, originally operated by the City of Danville is a short distance from the Old City quarry above described. South of the City, near U. S. Highway 29 and near the North Carolina line, is a quarry in granite formerly operated by the Virginia-Carolina Granite Company.

MARTINSVILLE AREA

No granite masses of large extent were noted along U. S. Route 58 between Danville and Stuart (Fig. 16). Most of the outcrops near Martinsville are basic gneiss of igneous origin, mainly hornblende-andesine gneiss. Quartz-biotite plagioclase schist is also common. Several small granite dikes, higher in soda-lime than in potash feldspar, were noted. No exposures of fresh rock, suited for dimension stone, were seen in the area examined. It would be difficult to find an outcrop from which a good grade of crushed stone could be produced. Petrographic data on the rocks examined in the Martinsville area are given in Table 16.

BLUE RIDGE PROVINCE

WARREN COUNTY

BENTONVILLE-BROWNTOWN TRAVERSE

The Bentonville-Browntown traverse includes outcrops examined along the Bentonville-Browntown-Front Royal road, State Highway 522, from a high point along the road about 2 miles west of Browntown to an exposure on the same road along the western base of Dickey Hill, about 3 miles north of that town (Fig. 17). The principal rock underlying the western part of the Blue Ridge in the vicinity of Browntown is a massive hypersthene granodiorite. East of this occurs foliated biotite granite gneiss. The granite

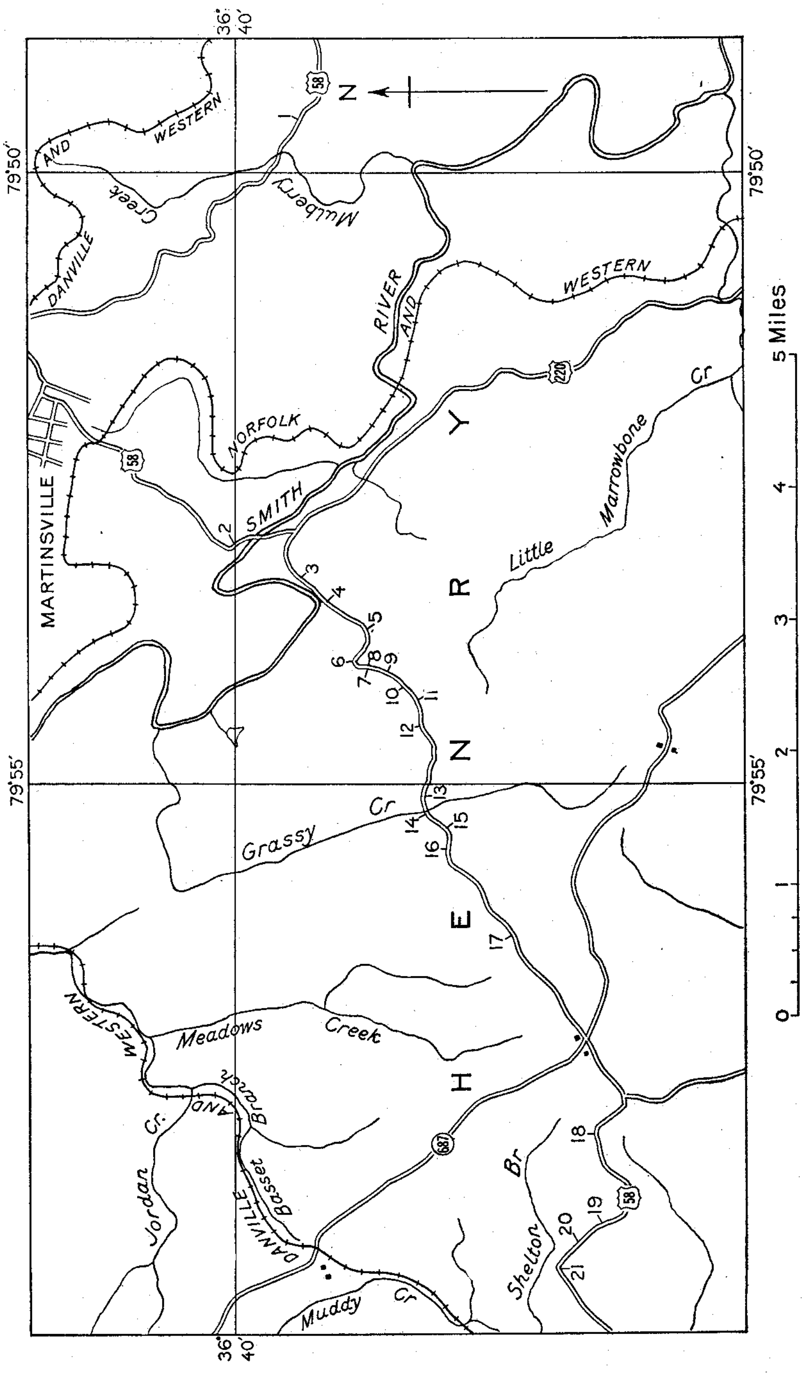


FIGURE 16.—Index map of the Martinsville area, Henry County, Virginia. 1, 6, hornblende gneiss; 2a, granite dike; 2b, 3, 4c, diorite gneiss; 4a, 4b, 4d, 14-20, diorite; 5, 11, 21, quartz diorite; 7-10, quartz-mica gneiss; 12-13, quartz-mica schist. Base from U. S. Geological Survey topographic map of the Martinsville quadrangle.

gneiss contains graphite and a considerable amount of garnet. The hypersthene granodiorite probably is younger than the foliated-granite gneiss. About 1.7 miles west of Browntown the granodiorite is cut by a gray rhyolite dike. In addition to quartz and microcline, this dike contains albite, as shown in Table 17.

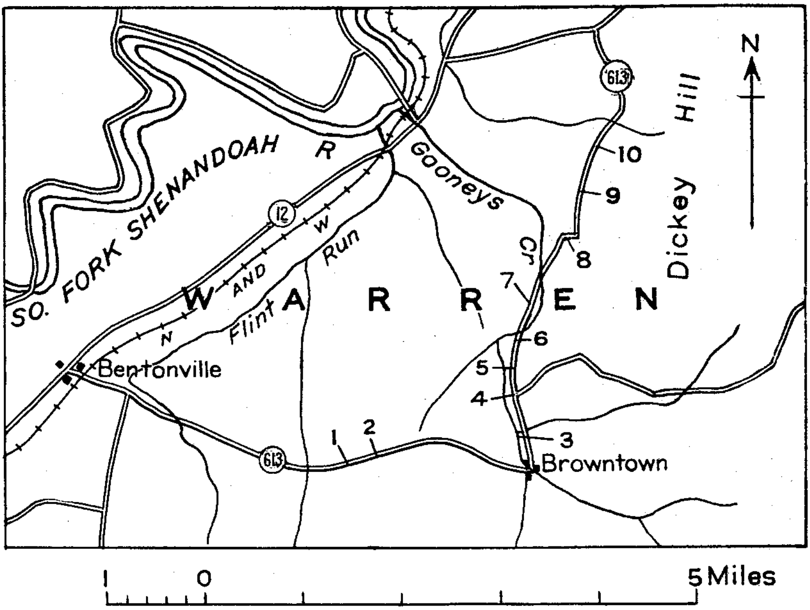


FIGURE 17.—Index map of the Bentonville-Browntown traverse, Warren County, Virginia. 1-3, 10, hypersthene granodiorite; 4-8, granite gneiss; 9, Catoctin greenstone. Base from U. S. Geological Survey topographic map of the Luray quadrangle.

RAPPAHANNOCK AND PAGE COUNTIES

THORNTON GAP-SPERRYVILLE TRAVERSE

The Thornton Gap-Sperryville (Fig. 18) traverse extends from the crest of the Blue Ridge at Thornton Gap, southeastward and eastward along U. S. Route 211 to Sperryville, a distance of about 7 miles, where it connects with the Sperryville-Boston traverse (Fig. 8). Petrographic analyses of the rocks examined in this section are given in Table 18.

The slopes of the mountain to the west of Thornton Gap have outcrops of Cambrian sandstone and amygdaloid. Exposures of coarse-grained, hypersthene granodiorite begin a few feet east of the Gap and extend down the eastern slope of the Blue Ridge, along the highway for a distance of nearly a mile. The leading feldspar of the granodiorite is oligoclase-andesine with potash feldspar being rare. The granodiorite is intruded by dikes of normal

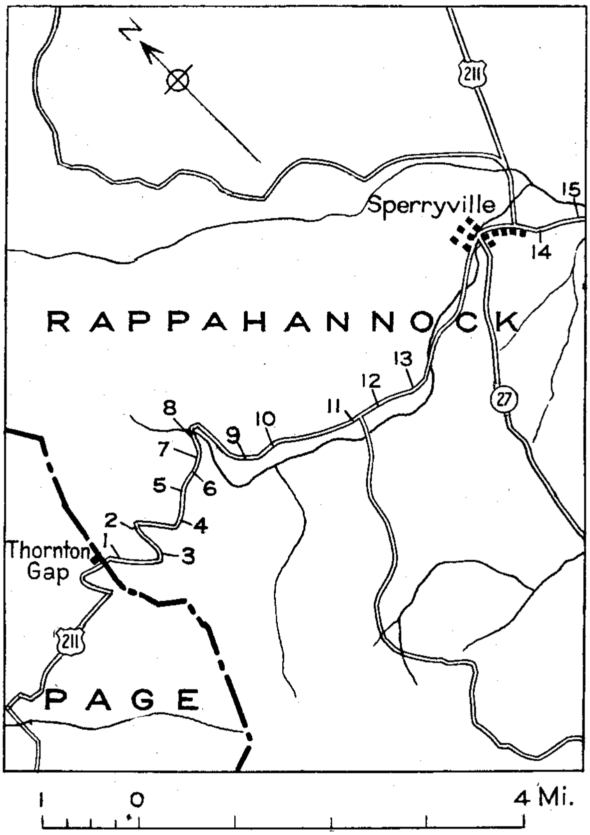


FIGURE 18.—Index map of the Thornton Gap-Sperryville traverse, Page and Rappahannock counties, Virginia. 1, 4-7, hypersthene granodiorite; 2, Catoctin greenstone; 3, granite dike; 8-13, granite gneiss; 14, actinolite schist; 15, quartz monzonite gneiss. Base from U. S. Geological Survey topographic map of the Luray quadrangle.

potash granite with a small content of biotite. Contacts between the two rocks are well exposed. Gneissic border facies, mixtures of hypersthene granodiorite and granite, were noted locally.

Farther down the slope to the east, beyond the granodiorite, the rocks are mostly coarse-grained, primary gneisses, containing almost no dark-colored silicates. At the foot of the mountain a porphyritic granite is exposed in an abandoned highway quarry. The rock here has been granulated by shear movements and is partly chloritized. The granite gneiss is cut by several basalt dikes and by a rhyolitic dike.

MADISON AND PAGE COUNTIES

MADISON-FISHERS GAP TRAVERSE

The Madison-Fishers Gap traverse extends from a quarry 1 mile north of the town of Madison, Madison County, northwestward along Robertson River and State Highway 27, through Criglersville, to a location in Page County, about a mile northwest of Fishers Gap in the Blue Ridge (Fig. 19). Petrographic data on the rocks examined in this 14-mile traverse are described in Table 19.

The highway quarry, 1 mile north of Madison, is in Lynchburg gneiss, as shown on the Geologic map of Virginia (1928). The gneiss is intruded by Marshall granite.

Beginning about 2½ miles northwest of Madison, hornblende gneiss is exposed in a belt along the northeast and north slopes of Carrs Mountain for a distance of about 1½ miles to a point about 1¾ miles southeast of Criglersville. Some outcrops are syenitic, others monzonitic. The syenitic facies has potash feldspar in excess, whereas the monzonitic facies contains about equal amounts of soda-lime and potash feldspars. From this point northwestward to a point about 3½ miles northwest of Criglersville are exposures of foliated granite gneiss of the Marshall granite type, commonly containing blue quartz. Some exposures of this rock have an arkosic appearance. The rocks are normal granites in which potash feldspar is dominant; some have biotite and muscovite.

Alternations of dark-gray granodiorite and dark-gray granite, in places containing blue quartz, crop out west of a narrow belt of Catoctin greenstone, about 4 miles northwest of Criglersville and about the same distance southeast of Fishers Gap. The granodiorite extends northwestward to another belt of greenstone along the crest of the Blue Ridge. Along or near the western margin of the granodiorite occur local bodies of unakite as epidotic replacements. The greenstone is also extensively epidotized near its contact with the granodiorite.

The Catoctin greenstone forming the crest of the Blue Ridge at Fishers Gap is bordered on the northwest by a strip of hypersthene

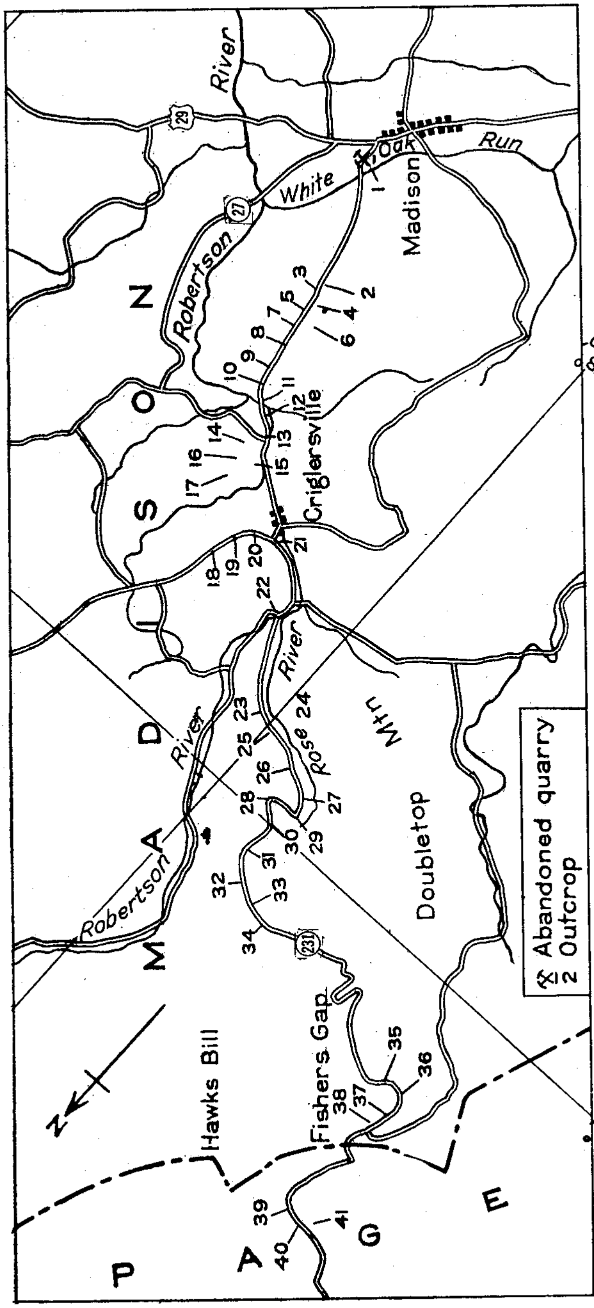


FIGURE 19.—Index map of the Madison-Fishers Gap traverse, Madison and Page counties, Virginia. 1, granite dike in granite gneiss; 2, 34, 38, Catoctin greenstone; 3, 30, 36a, 39-41, granodiorite; 4-5, 21, 27-28, quartz monzonite; 6-7, syenite; 8-9, 16-18, 24-26, 29, 31-33, 35, granite; 10-11, 22-23, quartz-biotite schist; 12-15, 19-20, gneiss; 36b, 37, unakite in granodiorite. Base from U. S. Geological Survey topographic maps of the Gordonsville and Luray quadrangles.

granodiorite that, in this locality, underlies the higher western slopes of the Blue Ridge.

In the area covered by this traverse the granitic rocks of the Blue Ridge east of its crest are mainly granites. Hornblende and biotite granodiorite are found locally; the more basic hypersthene granodiorite was noted only west of the crest of the mountain.

ROCKINGHAM AND GREENE COUNTIES

SWIFT RUN GAP-STANARDSVILLE TRAVERSE

The Swift Run Gap-Stanardsville traverse extends from Swift Run gap, on the crest of the Blue Ridge 7 miles east of Elkton, southeastward along U. S. Route 33 to Stanardsville in Greene County, a distance of about 7 miles (Fig. 20). A summary of petrographic studies of the rocks is given in Table 20.

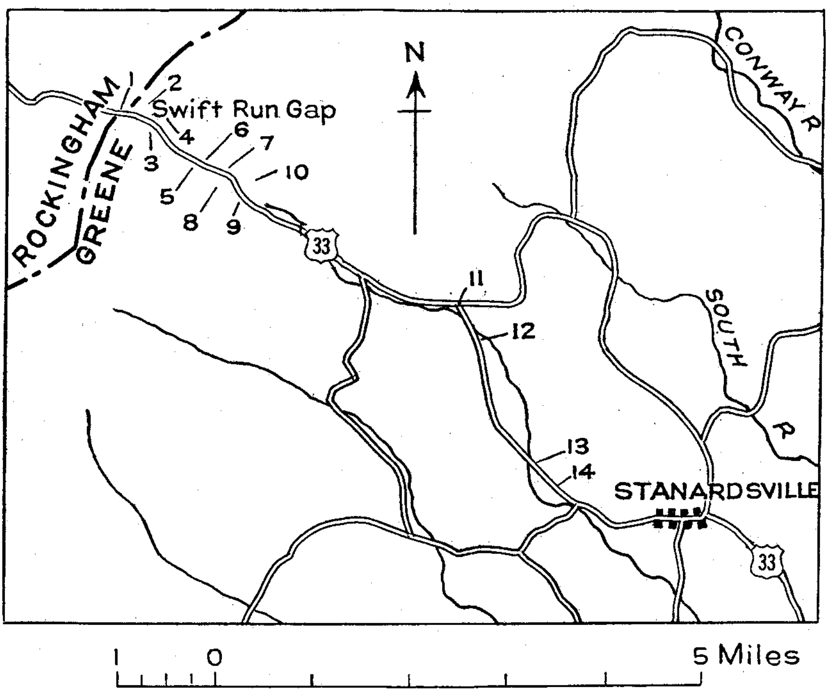


FIGURE 20.—Index map of the Swift Run Gap-Stanardsville traverse, Rockingham and Greene counties, Virginia. 1-4, 10, hypersthene granodiorite; 5-9, 11-13, granite; 14, granite gneiss. Base from U. S. Geological Survey topographic maps of the Harrisonburg (30′) and Gordonsville quadrangles.

Coarse-grained hypersthene granodiorite forms the crest of the Blue Ridge in this traverse. It is a dark-gray, generally porphyritic, rock. The largest feldspar phenocrysts are 2 to 3 inches in length. East of the granodiorite is an area of vesicular basaltic Catoctin greenstone. East of the greenstone is a belt consisting of alternations of hypersthene granodiorite and hypersthene granite. The proportions of potash and soda-lime feldspar are different in the two types of rock. In appearance, this belt of rock resembles the granodiorite which crops out west of the greenstone.

Foliated granite gneiss of a type common in the area mapped as Marshall granite lies directly east of the Blue Ridge on U. S. Route 33. Some of it looks arkosic.

ROCKBRIDGE AND NELSON COUNTIES

VESUVIUS-MONTEBELLO-MASSIES MILL TRAVERSE

The Vesuvius-Montebello-Massies Mill traverse here discussed extends from the western border of the granodiorite just east of Vesuvius, eastward and southeastward along State Highway 56 through Tye River Gap, Wilkie, Montebello, and Nash, to Massies Mill, a distance of about 18 miles (Fig. 21). Petrographic data on the rocks examined along this traverse are given in Table 21.

This area is underlain by alternations of granite, quartz monzonite, hornblende- and biotite-granodiorite, hypersthene granodiorite and quartz-hypersthene diorite, with different degrees of basicity. The unique association of the dark-colored silicates with the quartz in the last portion of the magma to crystallize has already been described as characteristic of the more basic facies of the Blue Ridge belt shown as granodiorite on the Geologic map of Virginia (1928). In the basic facies the potash feldspar is generally microcline. The plagioclase ranges from oligoclase to oligoclase-andesine, less commonly andesine. In the granitic facies the dominant feldspar is microcline with perthitic intergrowths of albite. Iron-bearing silicates are generally absent or negligible in the granitic facies. Quartz varies from colorless to violet or bluish. Red, medium-grained granites devoid of iron silicates also occur.

Hornblende granodiorite and hornblende-quartz monzonite crop out in a belt between Cambrian sediments east of Vesuvius and west of Tye River Gap. Locally the belt is interrupted by outcrops of Lower Cambrian arkosic sandstones and conglomerates associated with red shales and basalt flows. The granitic rocks range from massive to foliated.

A coarse-grained, gray granite underlies a strip extending from Tye River Gap, eastward to a fault half a mile north of Wilkie. The rocks on the south side of the fault include Lower Cambrian shales, quartzites, basalt flows, and arkoses which extend southward to a line a few feet west of the U. S. Geological Survey bench mark

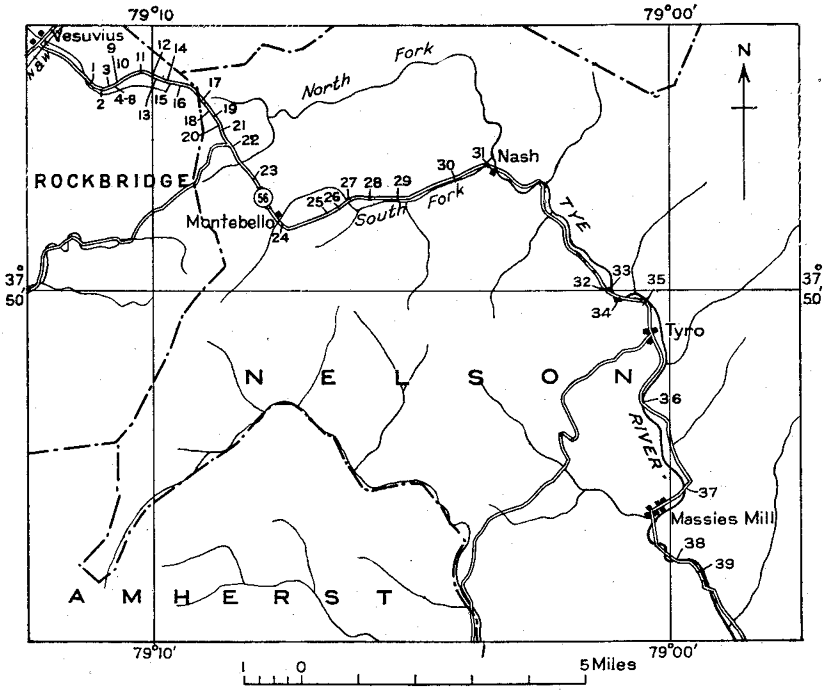


FIGURE 21.—Index map of the Vesuvius-Massies Mill traverse, Rockbridge and Nelson counties, Virginia. 1-6, 11, 18, granodiorite; 7, 10, 16-17, 22, 26-27, 30-36, quartz monzonite; 8-9, 23-25, 28-29, 38, granite; 12-15, 19-21, amygdaloidal flow; 37, biotite gneiss; 39, biotite schist. Base from U. S. Geological Survey topographic map of the Buena Vista (30′) quadrangle.

at Wilkie. A medium-grained, massive red granite lies adjacent to the fault line.

Coarse-grained, gray granite, devoid of dark-colored silicates and commonly containing violet quartz, extends from Wilkie southeastward to the mouth of Mill Creek. It is part of a belt which extends southward through Elk Pond Mountain to the gap south of Rocky Mountain, and from Alto northeastward across Rocky

Mountain to Louisa Spring Branch. Locally on the north slope of Rocky Mountain, it is a white pegmatite with coarse lenses of violet quartz. This facies resembles facies of the rutile-bearing pegmatite of the Roseland area. The feldspar of the granite is dominantly microcline with a perthitic intergrowth of albite. East of Wilkie the granite is locally replaced by unakite, a pegmatite composed of red microcline, gray albite, green epidote, and white to gray quartz.

The outcrops between the mouths of Mill Creek and Meadow Creek are basic. They include hypersthene granodiorite and hypersthene-quartz diorite.

Between Meadow Creek and Tyro, the outcrops range from granite to hypersthene granodiorite. All are coarse grained. The granites are essentially devoid of iron silicates. Granite crops out west of Nash and up North Fork of Tye River for nearly two miles. A zone of strong foliation in the granite extends northeastward just east of Nash. The outcrops west of the mouth of Campbell Creek are hypersthene granodiorite. They lie in a belt of basic rocks extending southwestward through The Priest and the Little Priest. On the crest of these mountains, the rocks are hypersthene-quartz diorite with a high content of hypersthene and a negligible amount of potash feldspar.

About three-fourths mile north of Massies Mill, along State Highway 56, the outcrops are biotite granodiorite. Here the mature nature of the Tye River valley causes a scarcity of outcrops.

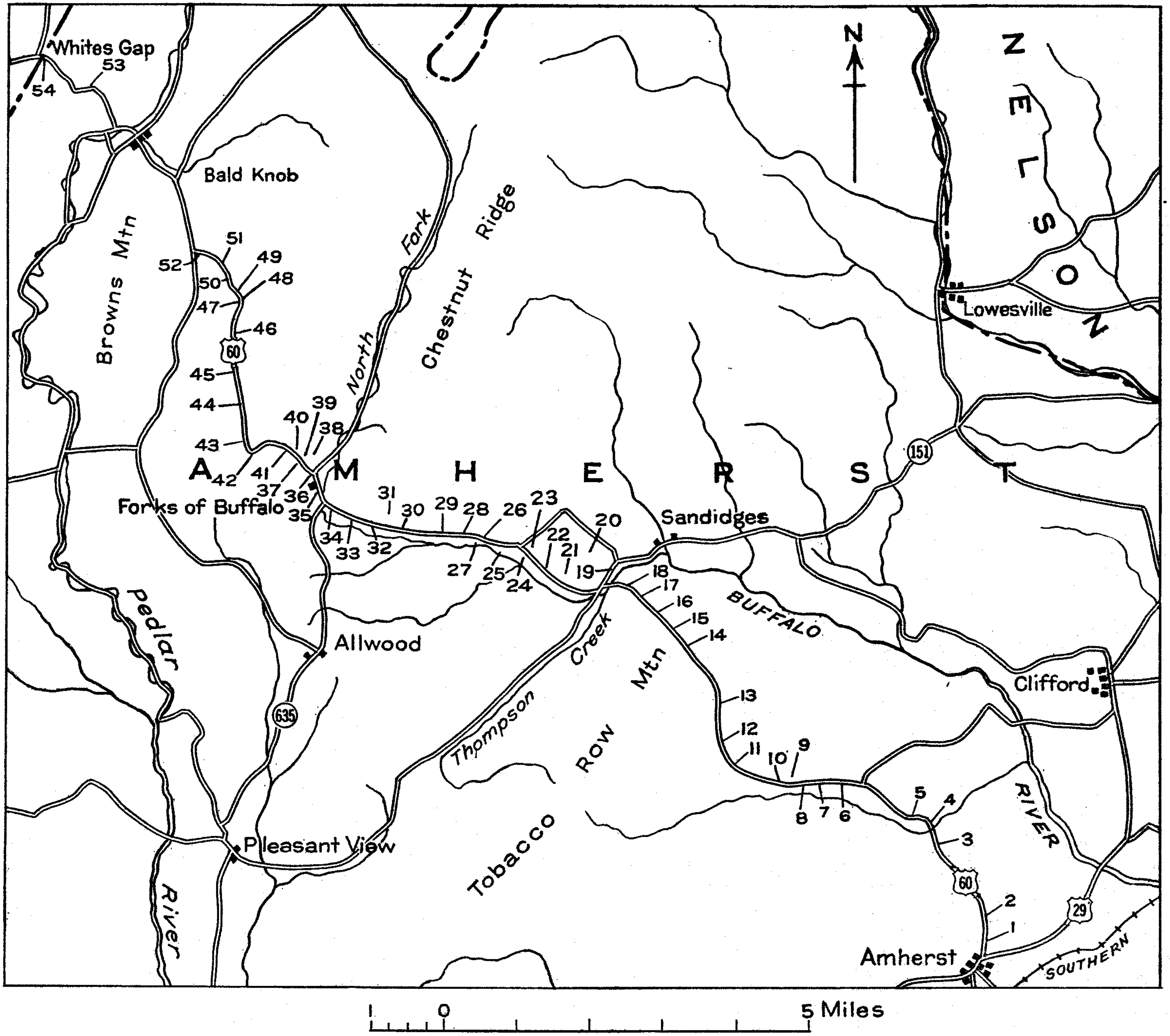
A red, medium-grained granite forms the core of an anticline on Big Marys Creek south of Vesuvius. Its relation to the other granitic rocks of the region is uncertain.

AMHERST AND ROCKBRIDGE COUNTIES

AMHERST-WHITES GAP TRAVERSE

The Amherst-Whites Gap traverse extends from Amherst in Amherst County, northwestward and northward along U. S. Route 60 and the old Jourdan road for a distance of about 20 miles, to Whites Gap athwart the Blue Ridge along the Amherst-Rockbridge County line (Pl. 7). Petrographic data on the rocks examined along this traverse are given in Table 22.

Most of the granitic intrusives of the Blue Ridge in this area are massive and show little foliation. An exception was noted a short distance east of the contact between hypersthene granodiorite



Index map of the Amherst-Whites Gap traverse, Amherst and Rockbridge counties, Virginia. 1-2, 5, augen biotite gneiss; 3-4, 13, 23-25, biotite schist; 6, 8, 53, hypersthene-quartz diorite; 7, 9-11, 16-22, 26, 28-30, 32-35, 37-39, 42, 48-51, 54, granite; 12, 45, granite gneiss; 14, 27, 40, granodiorite; 15, 41, 46, chlorite schist; 31, quartz monzonite; 36, basalt dike; 43, no sample; 44, 47, sericite schist; 52, Cambrian sandstone and shale. Base from U. S. Geological Survey topographic map of the Buena Vista (30′) quadrangle.

and Cambrian sediments, just east of Oronoco. The granitic intrusives of the Piedmont portion of this traverse are strongly foliated. Exceptions are noted in outlying ridges on the south slope of Scott Mountain, along Beaver Creek, and about 2 miles west of Sandidges. Here the exposures are massive hypersthene granodiorite, similar to that in certain sections of the Blue Ridge. In the Piedmont portion, the foliated granitic rocks are mostly granites, in which microcline is the principal feldspar. Generally the plagioclase is albite-oligoclase. The most intensely foliated granitic rocks usually have little or no microcline but contain muscovite. Rocks of this type are rare.

Only the western part of the traverse, from Pedlar River to Whites Gap, is underlain by hypersthene granodiorite. That part of the traverse between Pedlar River and Forks of Buffalo, which marks the eastern boundary of the Blue Ridge, is underlain by a granite, which has the massive, dark-gray, coarse-grained appearance of the more basic granodiorite.

The granitic rocks of the Piedmont portion of this traverse, from Amherst northwest to Forks of Buffalo, except for those noted above, are not suited for dimension stone since they are too foliated. Most of the massive granitic rocks in the Blue Ridge portion of this traverse would make excellent crushed stone.

ROCKBRIDGE AND BEDFORD COUNTIES

BALCONY FALLS-SNOWDEN-COLEMAN FALLS TRAVERSE

The Balcony Falls-Snowden-Coleman Falls traverse extends from Balcony Falls, Rockbridge County, eastward along the northeast side of James River and along U. S. Route 501 through the James River gorge to Snowden, Amherst County, thence across the river and southeastward along the southwest side of the river, via Major and Waugh to Coleman Falls, Bedford County, a distance of about 17 miles (Fig. 22). Here this traverse unites with the northwestern end of the Lynchburg-Coleman Falls traverse. Petrographic data on the rocks examined along this traverse are given in Table 23.

That part of the traverse from the first outcrop, about 200 feet east of the Rockbridge-Amherst County line in the James River gorge, to an exposure one-fourth mile northwest of Snowden, is underlain by red granite with little or no dark-colored silicates. Towards the eastern side of the granite body, the grains show crushing and grinding effects and slaty structure is developed. Several basalt dikes cut the granite. The red granite forms the core of an anticline.

A basal conglomerate, thought to be the base of the Cambrian series, overlies the granite at an exposure on the north side of the

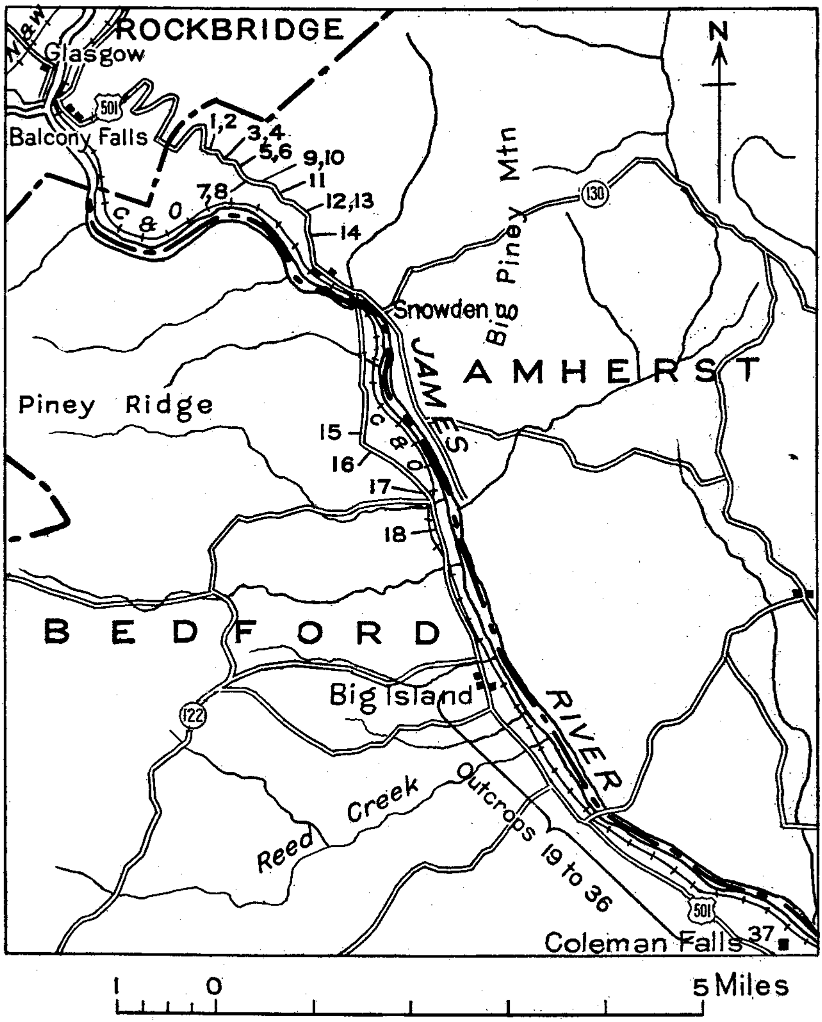


FIGURE 22.—Index map of the Balcony Falls-Snowden-Coleman Falls traverse, Rockbridge, Amherst, and Bedford counties, Virginia. 1-2, 5-8, 11, massive red granite; 3, 17, 23-28, granite gneiss; 4, pegmatite dike; 9, 14, massive gray granite; 10, 12-13, 15-16, pink granite; 18-19, foliated granite; 20-22, quartz conglomerate with biotite schist; 29, sericite schist; 30, massive pegmatite; 31-32, quartz monzonite; 33-34, 36, mica schist; 35, 37, augen gneiss. Base from U. S. Geological Survey topographic map of the Buena Vista (30′) quadrangle.

river about half a mile northwest of Snowden. Here the conglomerate contains quartz and pebbles of red granite of the same kind as the underlying granite bedrock. The conglomerate grades upward into purple and red shales. At an exposure about half a mile northwest, the basal Cambrian layers are mainly thick beds of well-cemented, gray sandstone.

The distinctive characteristics of the exposures of granite in Rockbridge County and those in the gorge of James River in Amherst County are the red color, the absence or minute content of dark-colored silicates, the dominance of potash feldspar over soda-lime, and the sparse occurrence of epidote veins without unakite. The unconformable contact between this granite and the clastic Cambrian sediments of the Blue Ridge is well exposed in 4 different places along this traverse.

Red granite similar to that of the James River gorge is exposed along Big Marys Creek about 3 miles south of Vesuvius in Rockbridge County, where it forms the core of an anticline, flanked by basal Cambrian sediments. About half a mile north of the creek, the core of the arch consists of gray-green granodiorite. The relation between the granodiorite and the red granite is uncertain. Contacts between the granodiorite and the clastic sediments are not exposed.

Another area of red granite extends from U. S. Route 60 on the western slope of the Blue Ridge, east of Buena Vista, southward to Belle Cove Valley, a few miles north of James River. This belt appears to be a part of the same body that crops out along the James River gorge. Its unconformable contact with the clastic formations of the Blue Ridge region is well exposed on the Buena Vista-Robinson Gap road, about 3 miles from Buena Vista.

Outcrops of granitic rocks southeast of the belt of Cambrian sandstone at Snowden, between there and Coleman Falls, are not the same kind of rock as the red granite in the James River gorge west of Snowden. Most of the exposures between Snowden and Coleman Falls are of more or less sheared, gray granite. Some of them contain considerable secondary mica, as does most of the Lovingston granite gneiss. About midway between Waugh and Coleman Falls the rock is an augen granite gneiss with blue quartz.

None of the granites along this traverse can be recommended for good dimension stone. They lack the freshness, uniformity of pattern, and continuity without fracture, required of the best dimension stone. Most of the outcrops would yield excellent crushed stone. Red granite was quarried for this purpose a short distance west of Snowden.

BEDFORD COUNTY

THAXTON-MONTVALE TRAVERSE

The Thaxton-Montvale traverse, in Bedford County, extends from Thaxton westward along U. S. Route 460 for a distance of about 3 miles (Pl. 8). Petrographic data on the rocks are given in Table 24.

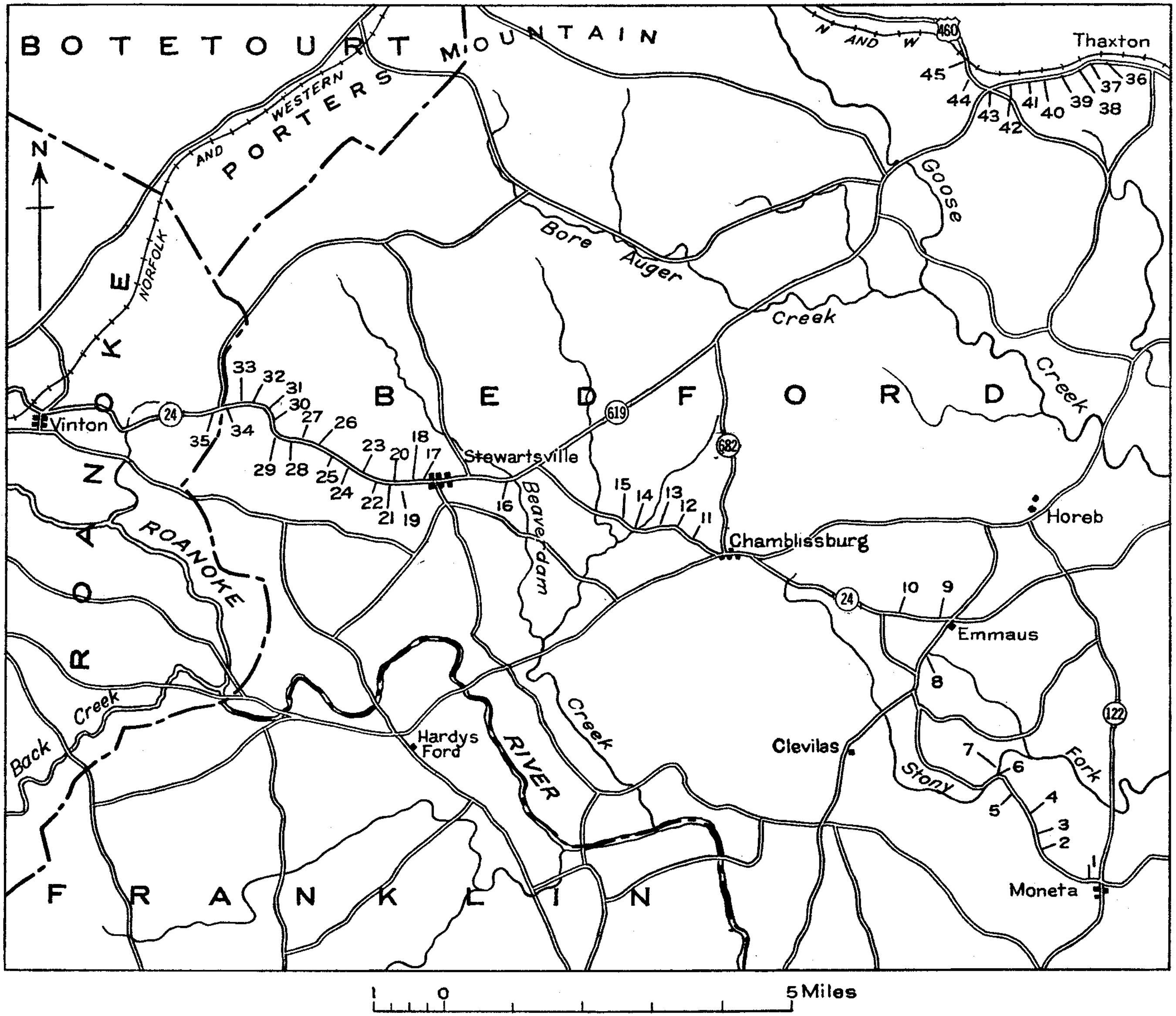
The outcrops examined along this traverse are more or less foliated, porphyritic granite gneiss containing microcline phenocrysts about an inch in length. Generally the matrix is high in biotite. A peculiarity of the phenocrysts is that, in many places, they enclose small rounded quartz grains. Similar gneisses occur northwest of Boones Mill, south of Roanoke. The feldspars of the gneiss in the Thaxton-Montvale area are dominantly microcline. Some specimens of these rocks apparently carry no plagioclase. Most of the biotite is secondary and generally does not exceed 25 per cent of the rock. No violet quartz was found in these gneisses.

BEDFORD AND ROANOKE COUNTIES

MONETA-VINTON TRAVERSE

The Moneta-Vinton traverse, here discussed, extends from an exposure in a cut along the Virginian Railway, 1 mile west of Moneta, Bedford County, westward and northwestward through Emmaus, Chamblissburg, and Stewartsville, to Vinton, Roanoke County, a distance of about 20 miles (Pl. 8). Petrographic data are given in Table 25.

Most of the exposures in this traverse comprise basic schist or biotite-granite gneiss in various stages of foliation. Augen gneiss is relatively rare; however, exposures occur between Stewartsville and Ruddell Mountain. A northeasterly extending, heretofore unmapped, belt of slate and quartzite about half a mile wide, was found along the northeastern slope of Ruddell Mountain just west of the augen gneiss. In most of the exposures examined potash feldspars are dominant, with little or no plagioclase being present. Exposures of biotite and chlorite schist, about half a mile, and a mile, northwest of Moneta, showed no potash feldspar.



Index map of the Thaxton-Montvale and Moneta-Vinton traverses, Bedford and Roanoke counties, Virginia. 1, 7, garnetiferous schist; 2-3, 8-13, 15-16, 22-26, 31, 41-42, 44a, granite gneiss; 4-5, 14, biotite schist; 6, actinolite schist; 17-21, 32-35, 37-40, 43, granite; 27-28, 44b, Cambrian (?) slate and phyllite; 29, Cambrian (?) quartzite; 30, Cambrian (?) arkose; 36, quartz monzonite; 45, decomposed volcanic rock. Base from U. S. Geological Survey topographic map of the Bedford (30′) quadrangle.

None of the granitic rocks exposed along this traverse would be suitable for dimension stone. Most of them are too foliated to be desirable for crushed stone. The Cambrian quartzites could be used for this purpose, but the cost of crushing them would be high.

ROANOKE AND FRANKLIN COUNTIES

ROANOKE-MAGGOTTY GAP-GRASSY HILL TRAVERSE

The Roanoke-Maggotty Gap-Grassy Hill traverse extends from Roanoke in Roanoke County southward along the northwest side of the Blue Ridge to Maggotty Gap, thence southeastward through the Blue Ridge via that gap to Boones Mill, and from there southward through Gogginsville to Grassy Hill, a short distance northwest of Rocky Mount in Franklin County. It has a length of about 22 miles (Fig. 23). Petrographic data on the various outcrops are given in Table 26.

The rocks along the traverse comprise four groups. The first group crops out along the west side of the Blue Ridge between Back Creek and Maggotty Gap. These rocks are porphyritic, hornblende-granite gneisses, containing purple to violet quartz. The feldspars include both albite and microcline and, in all exposures examined except two, the potash feldspar is dominant. In those soda-lime and potash feldspars are abundant.

The area between Maggotty Gap on the crest of the Blue Ridge and Boones Mill, is underlain by rocks of the second group. These rocks are augen gneisses similar to those common in areas of Lovingston granite gneiss. In these gneisses feldspar phenocrysts vary in size up to about 2 inches, and quartz grains are commonly scattered through the feldspar eyes. The foliated matrix contains considerable biotite. Potash feldspars normally exceed soda-lime feldspars; microcline is the principal feldspar.

The third group of rocks extends from Boones Mill southward to the vicinity of Gogginsville. They are more foliated than are those of the second group. They are foliated granite gneisses in association with biotite-muscovite schists. Microcline is their principal feldspar. In most samples no plagioclase was found.

The fourth group of rocks underlies that part of the traverse from Blackwater River southward to the top of Grassy Hill, a short distance northwest of Rocky Mount. They comprise mica schist, basalt, metapyroxenite, and talc schist. The metapyroxenite is high

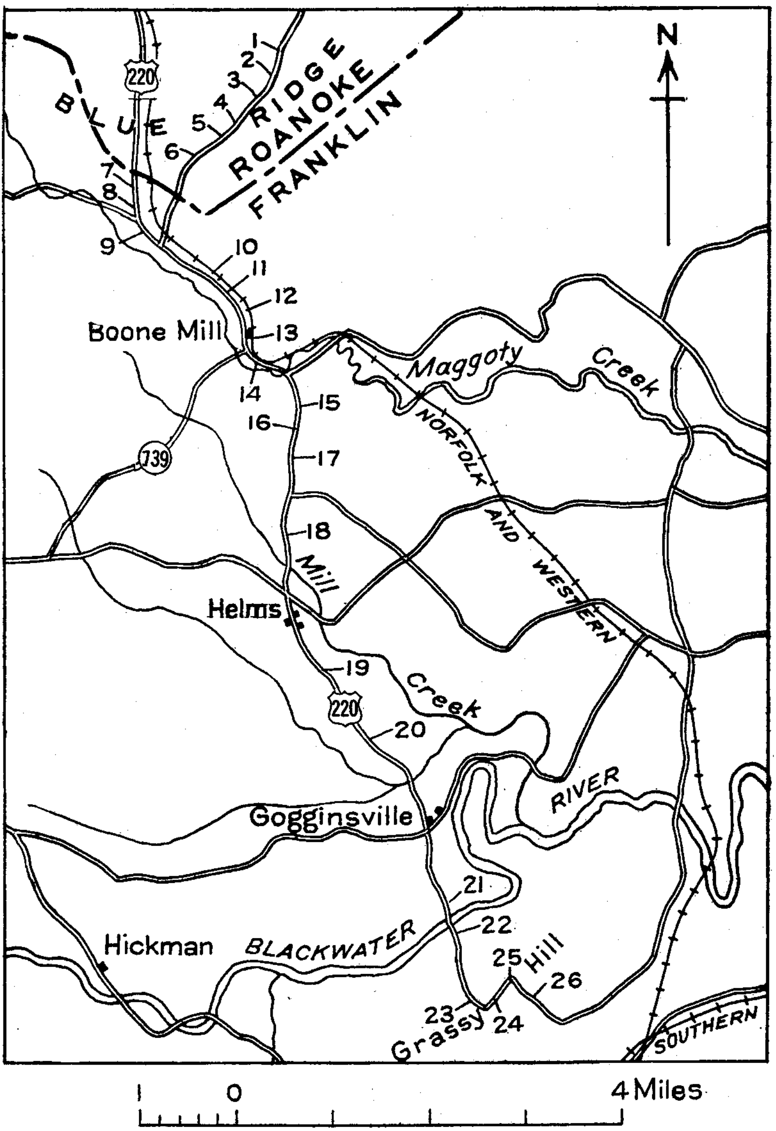


FIGURE 23.—Index map of the Roanoke-Maggotty Gap-Grassy Hill traverse, Roanoke and Franklin counties, Virginia. 1, 4-5, 11-12, quartz monzonite; 2-3, porphyritic granite; 6, 10, 13-14, 16, granite gneiss; 7-9, augen gneiss; 15, 19, 22, 25-26, mica schist; 17, 20, foliated granite; 18, 21, gneiss; 23, basalt; 24, metapyroxenite. Base from U. S. Geological Survey topographic map of the Bedford quadrangle.

in more or less amphibolized, monoclinic pyroxene; it has no feldspar.

An abundance of fresh rock for crushed stone could be obtained from the rocks of the first two groups. Most of the rocks in the third and fourth groups are too weak and decomposed to be desirable. None of the rock along the entire traverse is potential dimension stone.

GRAYSON COUNTY

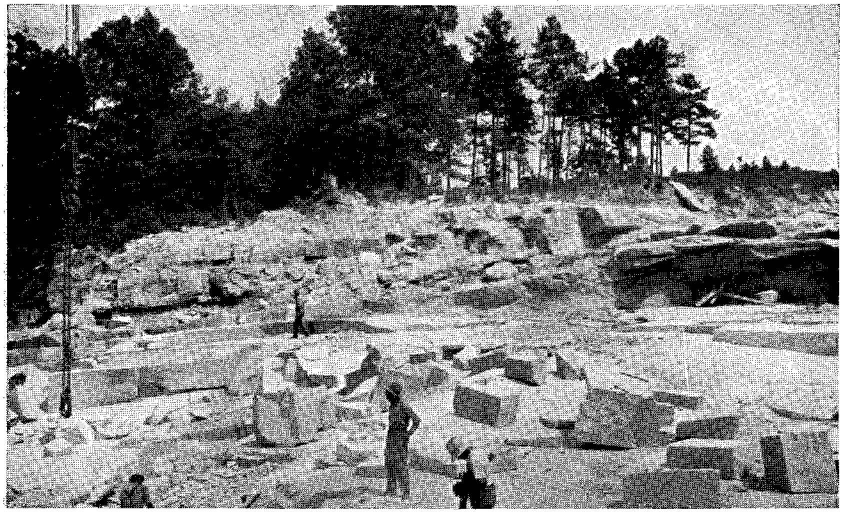
INDEPENDENCE-TROUTDALE TRAVERSE

The Independence-Troutdale traverse extends from Independence on the east, westward and northwestward along U. S. Route 58 to the crest of the Blue Ridge just beyond Troutdale, a distance of about 23 miles, all in Grayson County. That part of the traverse from Independence to a locality about 9 miles west of that town, is underlain mainly by actinolite and mica-schist with granite sills occurring locally. Most of the area from this locality westward to near the crest of the Blue Ridge is underlain by Grayson granite gneiss. Rhyolite commonly occurs along the eastern border of the granite belt, just west of the schist.

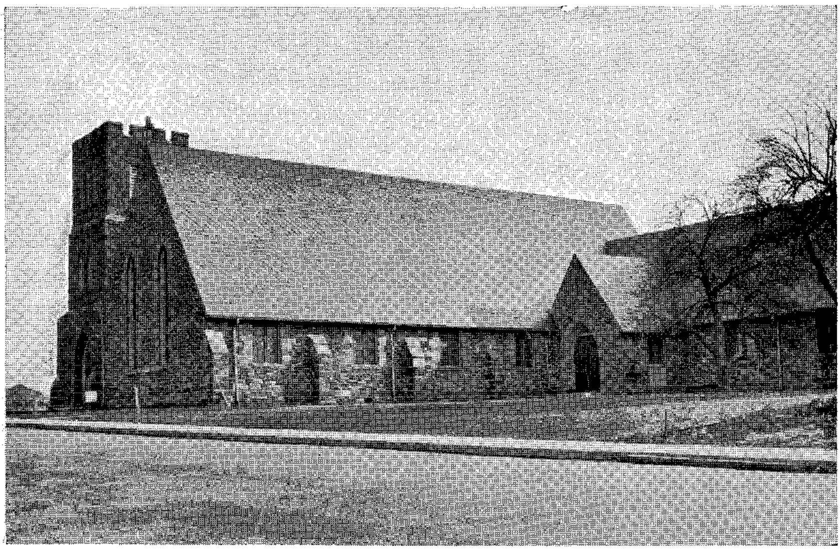
The Grayson granite gneiss in this area is a medium- to coarse-grained rock, in which microcline and orthoclase dominate. Albite-oligoclase and biotite are rare or absent; where present, albite-oligoclase is gray to pink. A massive gray granite, without biotite, crops out a short distance west of Fox, near the eastern border of the Grayson granite gneiss. It contains orthoclase and microcline, but apparently no plagioclase. A coarse-grained sheared, pegmatitic granite, one facies of the Grayson granite gneiss, crops out on the north bank of New River, about three-fourths mile west of Fox Creek dam. It contains quartz, microcline, and biotite. Northwest of Mouth of Wilson on Wilson Creek, the Grayson granite gneiss is a medium-grained, foliated rock. Its feldspar is microcline and it contains about 1 per cent biotite and hornblende combined. On the main highway 6 miles northwest of Mouth of Wilson, the Grayson granite gneiss is a sheared, gray-green porphyritic rock. It contains quartz, microcline, and very fine-grained, secondary muscovite.

From Grant northwestward to a point about one-fourth mile east of the divide between Wilson and Fox creeks, U. S. Route 58 traverses a coarse-grained, gray granite gneiss, containing quartz, microcline, small amounts of albite-oligoclase and biotite. Basalt dikes are common in the granite gneiss. Epidotization of the basalt and adjacent parts of the granite gneiss has taken place locally. From the basalt contacts the epidotization normally extends only a few inches into the gneiss. In one place a vein of unakite 1 foot wide was found in the gneiss a few feet from basalt. The unakite contains red microcline, small amounts of gray albite-oligoclase, quartz, and epidote. The feldspars are about 1 inch in length.

A few feet west of the Grayson granite gneiss on the divide between Wilson and Fox creeks northwest of Grant, on U. S. Route 58, the underlying rock is a red, sheared, porphyritic rhyolite, locally cut by basalt dikes. There is no epidotization of this rock. Outcrops of red rhyolite also occur west of the Fox Creek bridge northeast of Troutdale. About 20 per cent of the rock is matrix; quartz and microcline are the main constituents.



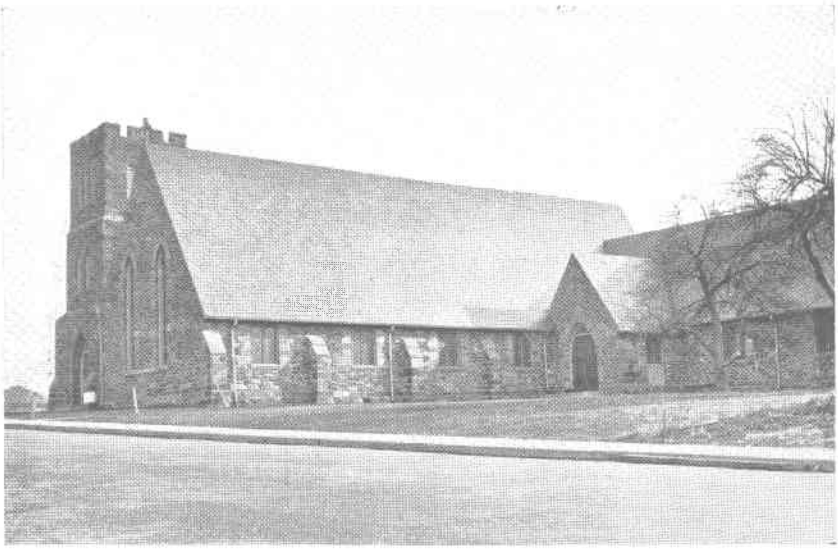
A.



B.

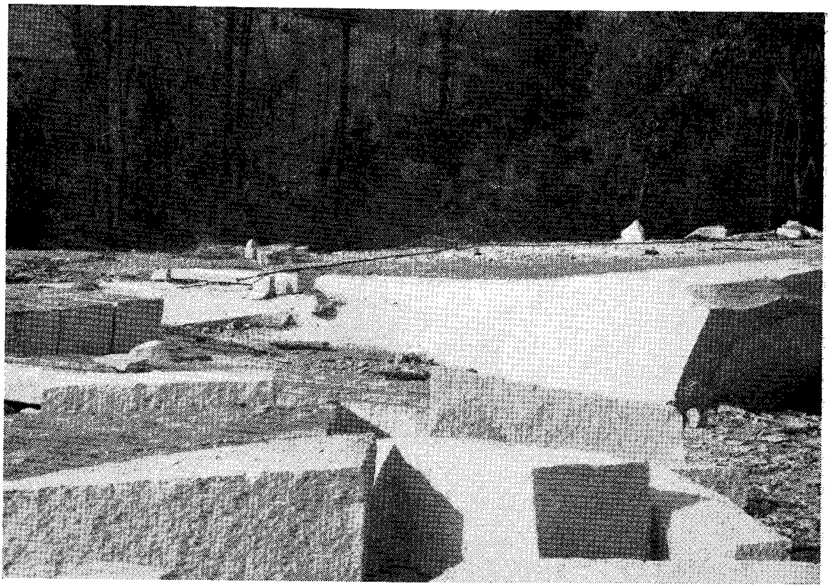
A, Burkeville granite quarry near Burkeville, Nottoway County, Virginia. Photograph by Edward Steidtmann. (From Virginia Geological Survey Bulletin 47.) B, Grace Episcopal Church in Lynchburg, Virginia, built of Virginia greenstone. Photograph by Edward Steidtmann. (From Virginia Geological Survey Bulletin 47.)

A.

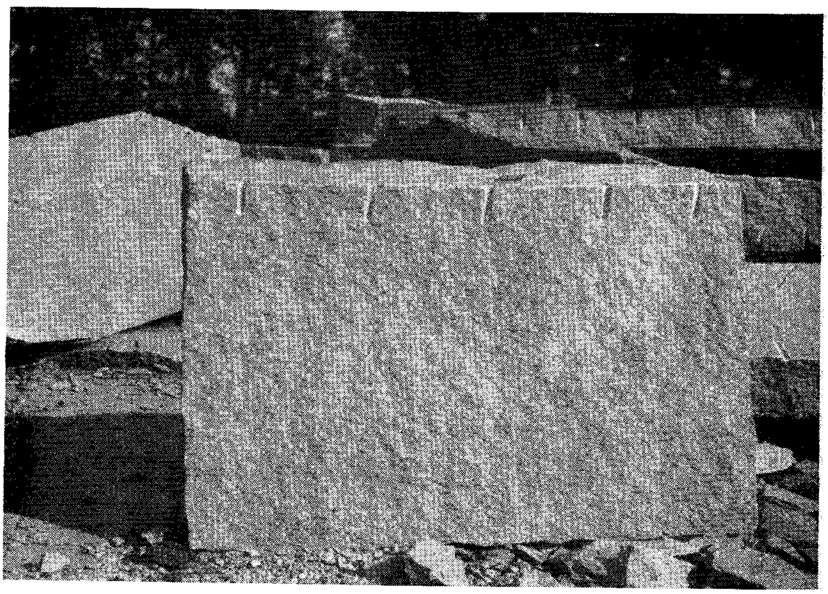


B.

A, Burkeville granite quarry near Burkeville, Nottoway County, Virginia. Photograph by Edward Steidtmann. (From Virginia Geological Survey Bulletin 47.) B, Grace Episcopal Church in Lynchburg, Virginia, built of Virginia greenstone. Photograph by Edward Steidtmann. (From Virginia Geological Survey Bulletin 47.)



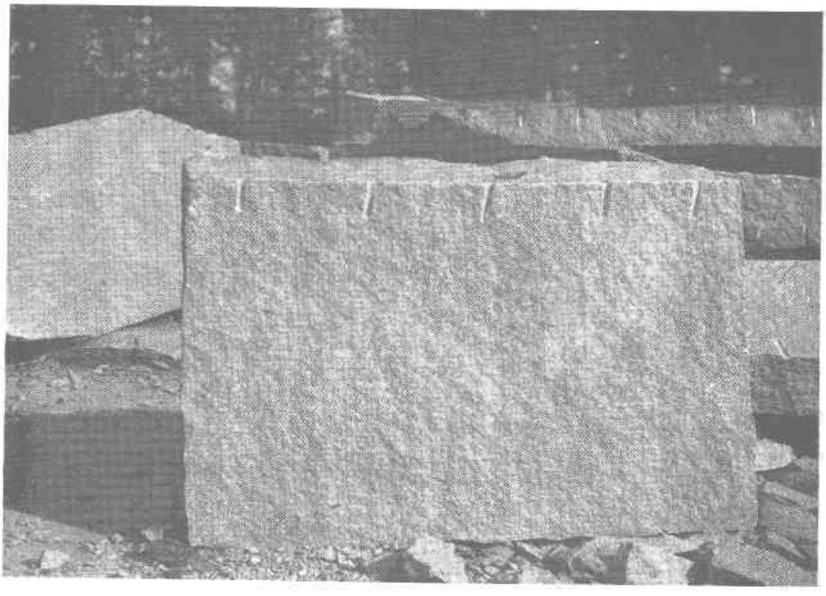
A.



B.

A, Virginia Grey Granite Quarry, about 7 miles southeast of Boydton in Mecklenburg County, Virginia. Photograph courtesy Major William Maish, C. E.
B, Block of granite, about 1½ by 3 by 5 feet, from Virginia Grey Granite Quarry. Photograph courtesy Major William Maish, C. E.

A.



B.

A, Virginia Grey Granite Quarry, about 7 miles southeast of Boydton in Mecklenburg County, Virginia. Photograph courtesy Major William Maish, C. E. B, Block of granite, about 1½ by 3 by 5 feet, from Virginia Grey Granite Quarry. Photograph courtesy Major William Maish, C. E.

SUMMARY

The production of granite and other crystalline rocks in Virginia in 1942 was valued at more than one and a half million dollars, with the larger part of the production being crushed stone. A considerable quantity of the crushed granite is obtained from small wayside quarries whose product is used in road construction, but the greater part is produced by four large quarries in the Piedmont province.

Virginia was listed as a producer of granite dimension stone prior to 1910. Building and monumental stone are still produced in the State, although in recent years the annual production has been too small to be itemized in the statistical reports of the United States Bureau of Mines. One wishes that more of our buildings, like those of the old world and of Mexico, might have been built of stone from local quarries.

Most of the dimension stone has come from the Richmond, Petersburg, and Fredericksburg areas, underlain by the Petersburg granite, and from other quarries in the Red Oak granite. Formerly about 20 large quarries were operated in the Richmond area, but only a few are now active. Large supplies of good stone, adapted to building and monumental uses, are available at or in the vicinity of several of the presently inactive quarries. The overburden ranges from 5 to 10 feet and the thickness of weathered granite directly beneath the overburden commonly is less than 2 feet. Quarrying conditions are very good.

An excellent monumental stone, of a pleasing color and considered by dealers throughout the State to be one of the most durable, was formerly quarried in the Petersburg area. Building stone of proved merit has also been produced and an unlimited supply of stone is still available in this area.

The granite of the Fredericksburg area is a durable stone of excellent color and freshness. Most of the inactive quarries in this area are favorably located for operation and reserves of stone are available.

Stone highly commended for monumental purposes and for various types of dimension stone has been produced from a grayish-blue granite in the vicinity of Burkeville. Granite similar to that near Burkeville has been quarried near Kenbridge in Lunenburg County and southeast of Saxe in Charlotte County, in areas of Red Oak granite. The rock in the vicinity of Saxe should yield rough dimension stone. A pink granite which has proved very satisfactory as a building stone has been obtained from the Falls Church area in Fairfax County. Both the color and the stone are durable. A large supply of stone is available, quarrying conditions are good and the stone should find an excellent market in the near-by Washington area. The exposures of quartz-diorite along Tripps Run, about 1½ miles south of Falls Church, offer possibilities for rough building blocks.

Building and monumental stone has been produced from a quarry in Triassic trap rock near Buena in Culpeper County. The rock is a grayish-black, distinctly grained diabase or "black granite." The stone is fresh, glassy, free from flaws and takes a good polish. The soil cover is less than one foot thick, the quarry is favorably situated for operation, large blocks can be obtained, and the supply of stone is unlimited. Other quarries in Triassic diabase, which have produced crushed stone, are located near Bull Run in Fairfax County and southeast of Leesburg in Loudoun County.

Crushed stone is also obtained from certain other crystalline rocks. A biotite gneiss is quarried in the City Quarry at Danville. Catoctin greenstone is crushed near Charlottesville in Albemarle County and locally elsewhere. Gneiss, granite gneiss, and massive quartz-bearing intrusive rocks have been quarried and crushed for local use at many places throughout the Piedmont and Blue Ridge provinces.

Among the former producing quarries in the area of the Petersburg granite, in the locality of which reserves of rock of proved dimension stone quality are available, should be mentioned the following: Richmond Granite Company No. 1, Vietor, Capital, Granite Station, McGowan, Old Dominion (Middendorf) and Mackintosh (McIntosh) quarries in the Richmond area; Taylor and Hazel Run quarries in the Fredericksburg area; and the Cook, Burns and Campbell, Butterworth, and other quarries in the Petersburg area. Of those in the area of the Red Oak granite, the Burkeville and Kenbridge quarries have reserves of stone, are especially favorably located for operation and merit consideration. The Occoquan quarries, along Occoquan Creek near U. S. Route 1, offer possibilities for building stone and riprap.

The areas of the Petersburg and Red Oak granites in the eastern part of the Piedmont province have the best exposures of fresh rock, show less fissuring, foliation and banding, and are cut by fewer dikes than any of the other bodies of granite in Virginia.

Most of the dimension stone quarries are in areas underlain by the Petersburg and Red Oak granites as shown on the Geologic map of Virginia (1928). Among other areas which offer the best possibilities for dimension stone are (1) area of hypersthene granodiorite in the northern part of the Blue Ridge province, (2) area of Old Rag granite along the east side of the Blue Ridge in the Shenandoah National Park district, (3) area of Air Point granite in the Bent Mountain district, Roanoke County, (4) area of pink microcline granite in the Vesuvius quadrangle, and (5) area of Grayson granite gneiss.

Large quantities of crushed stone are available at numerous localities throughout the Piedmont and Blue Ridge provinces. Several of the previously operated quarries in the areas of the Petersburg and Red Oak granites offer sources of good stone, as do certain others in the Falls Church area, and perhaps also in the vicinity of Occoquan, Columbia, and Danville. Reserves of stone should be available near the sites of several of the small wayside quarries referred to in the descriptions of the various traverses and shown on the traverse sketch maps.

Excellent crushed stone should be obtained (1) from the vicinity of Cobbler Mountain and between there and Markham along the Markham-The Plains traverse; (2) on the northeast slope of Fleming Mountain along the Lynchburg-Coleman Falls traverse; (3) in the vicinity of Holcomb Rock; (4) near Browntown along the Bentonville-Browntown traverse; (5) south of Vesuvius and between there and Massies Mill; and (6) in the vicinity of Snowden and locally elsewhere along the Balcony Falls-Snowden-Coleman Falls traverse.

Other sites offering possibilities for good crushed stone are to be found (1) along the Washington-Ben Venue traverse; (2) between Sperryville and Boston; (3) in the vicinity of Harris Creek along the Lynchburg-Harris Creek traverse; (4) on the Thornton Gap-Sperryville traverse; (5) between Madison and Fishers Gap; (6) along the Swift Run Gap-Stanardsville traverse; (7) from Roanoke to Boones Mill along the Roanoke-Maggotty Gap-Grassy Hill traverse; (8) in the vicinity of Danville; and (9) along the western part of the Independence-Troutdale traverse.

Bodies of greenstone in the vicinity of Middleburg and east of Charlottesville should yield good crushed stone, as should also areas of Triassic diabase, such as underlie the sites of the Belmont quarry in Loudoun County and the Buena and other small local quarries in Culpeper and Fauquier counties.

ECONOMIC FACTORS

QUARRY LOCATION

Selection of site.—The selection of the quarry site involves appraisal of costs of operation and maintenance of available markets, and studies of the inherent nature of the stone and its environment. Some of the natural factors which should receive consideration are the topographic situation, thickness and character of the overburden, drainage, climate, water supplies, and potential power. The importance of these factors is self-evident. It is also evident that some of these factors can not be appraised without prospecting and trial quarrying.

Stone requirements.—Granite used for dimension stone must be fresh. The requirements for decorative and monumental stone are especially rigid. The best commercial granites have uniform grain and color patterns, are free of blemishes such as veins, dikes, knots, stains, and blotches, which cause waste and increase production costs. Monument dealers state that blue and red granites are more salable than light-gray varieties, since inscriptions on the dark-colored stones are more legible, and these stones are also deemed more beautiful.

In quarries used for extracting dimension stone, joints and sheets or horizontal joints should be absent or widely spaced. If closely spaced they prevent the removal of desired sizes; if widely spaced, they facilitate quarrying. If possible, the quarry should be located so that the sheets dip towards the opening. When the sheeting dips towards the pit, the conditions are ideal for moving the stone. Rift and grain are generally helpful in quarrying, but some excellent quarries have neither.

Topography of site.—The hillside quarry has many advantages over an opening in a level surface, because it drains naturally and permits gravity movement of overburden, waste and quarry products. Waste piles, mills, and haulage tracks can be placed on near-by lowlands. Waste and overburden should not be dumped on lands which might be desired as future quarry sites. Generally waste from the quarry is used in fills and for crushed rock.

Overburden.—As a rule the overburden of granite in the South Atlantic states is residual clay, derived from the decay of the granite bedrock. The overburden may consist also of transported materials, such as sand, gravel, and silt, which is common in the granite areas along the eastern margin of the Piedmont region of Virginia. At most granite quarries in Virginia the overburden is less than 15 feet thick. The granite directly below the overburden generally is partially decayed. Locally the removal of the overburden and the decayed granite may be too costly to make the quarry venture profitable.

Drainage.—Drainage is generally not a major problem in granite quarrying operations. Even in pit quarries, pumping commonly is not a major item. Some quarries, although located below the level of near-by streams, have no serious water problems. In selecting a quarry site, consideration should be given to the possibility of the quarry being flooded by surface water during heavy rains and from unusually high stream waters.

OPERATING FACTORS

Profits.—A profitable granite quarry yields enough income to pay operating expenses, taxes, insurance, depreciation, amortization, a fair rate of interest on the investment, and royalties if the land is not owned by the operators. Before the operation is abandoned, the profitable quarry should yield a sufficient return to redeem equipment and other assets used during its operation. Detailed information regarding the economics of quarry operation and production may be obtained from publications of the U. S. Bureau of Mines, some of which are cited in the list of references accompanying this report. The statements that follow have been condensed from these sources.

Royalties.—Royalties on crushed stone are reported to range from 1 to 10 cents per ton. In the Atlanta, Georgia, district the royalty on block granite is 25 cents a cubic foot; on curb stone it is 2 to 5 cents a cubic foot.

Costs and prices.—Unfinished blocks of first-class granite suitable for monuments sell for an average of $3.50 to $5.00 a cubic foot. Small quantities of random building block, without cutting or carving, have been quoted at $1.40 to $2.25 a cubic foot at points of consumption. The average direct cost of block granite f. o. b., at selected quarries in Vermont, Massachusetts, and Pennsylvania, has been $2.07 a cubic foot.

According to Thoenen[23], the average direct cost of producing crushed granite, including crushing and screening, is $1.08 per ton. This is about twice the cost of producing crushed limestone.

Investment per production unit.—The actual average capital investment per annual ton of production of four crushed-stone granite operations, over a 2-year period, has been shown to be $1.20. As this cost is based on the valuation of used equipment,[3] the investment in a new plant would be greater. About 9.54 per cent of the capital outlay of 3 quarries was for land or mineral rights; the balance was for equipment. The production per annum for the larger quarries is in the order of 300,000 to 500,000 tons, but their capacity to produce is usually greater than the actual production.

TESTS OF GRANITE

DIMENSION STONE

The principal tests of dimension stone include percentage of absorption, percentage of porosity and specific gravity, crushing strength, transverse strength, tensile strength, fire resistance, frost resistance, abrasion, resistance to chemical action, chemical analysis, and microscopic analysis. These tests are not all of the same importance. Those used vary with the intended use of the stone and the conditions to which it is to be subjected.

Absorption.—The percentage of absorption test consists in determining the weight of the water absorbed by a known weight of dry rock. It is the percentage relationship between the weight of the water absorbed and the weight of the dry rock.

$$A = \frac{S-D}{D} \times 100$$

A = percentage of absorption; S = weight of saturated specimen; and D = weight of dry specimen.

Absorption is greater under vacuum and still greater under high pressure than under ordinary conditions. The percentage of absorption of a certain granite as determined by Hirschwald[11] was 0.51 per cent after rapid submersion; 0.91 per cent after slow submersion; 1.07 per cent when submerged under vacuum; and 1.25 per cent when submerged under 50 to 150 atmospheres of pressure.

Porosity and specific gravity.—The porosity is the ratio between the volume of the voids of a rock specimen and its total volume, the total volume being the volume of the voids plus the volume of the mineral matter:

$$P = \frac{V}{V + Vm} \times 100$$

P = percentage of porosity; V = volume of voids; Vm = volume of minerals.

Specific gravity is the weight of the dry specimen divided by the weight of the water displaced by the mineral matter of the specimen. This is the mineral specific gravity as distinguished from the rock or bulk specific gravity:

$$1. \quad G = \frac{D}{D - s}$$

$$2. \quad P = \frac{S - D}{(S - D) + \frac{D}{G}} \times 100$$

From 1 and 2,

$$3. \quad P = \frac{S - D}{S - s} \times 100$$

G = specific gravity; P = percentage of porosity; D = dry weight of specimen; S = saturated weight of specimen; s = weight of saturated specimen suspended in water.

Laboratory technique for obtaining the percentage of porosity and the true specific gravity has been described by Buckley.[5]

The percentage of porosity is used as an index of frost resistance. Although it is a more painstaking test, it is somewhat superior to the absorption test. The mineral specific gravity of stone seems to have no practical value as such. The weight of the saturated stone per cubic foot can be computed from the percentage of absorption and the mineral specific gravity.

Crushing strength.—The crushing strength of a rock is the pressure in pounds per square inch required to break a specimen. The sides of the specimen are unsupported in this test, in which a cylindrical core

2 inches in diameter and 2 inches high is used. The two ends of the cylinder are made smooth and parallel. The cylinder is compressed in a Universal testing machine at a rate of 0.10 inch per minute. A small spherical-bearing block is placed between the moving head of the machine and the specimen. The average of at least two tests is reported in pounds per square inch. The average crushing strength of granite is about 15,000 pounds per square inch.

The crushing strength is usually unimportant unless the rock is to bear an unusual weight. Buckley[4] showed that the weight resting on the foundation of the Washington Monument was only 314.6 pounds per square inch. The average crushing strength of granite is nearly 50 times greater.

Transverse strength.—The transverse strength of a stone is equal to the load in pounds required to break a bar one inch square resting on supports one inch apart, the load being applied in the middle. The formula expressing transverse strength follows:

$$R = \frac{3wl}{2bd^2}$$

R = modulus of rupture; w = load at center, in pounds, required to break the stone; l = distance between supports, in inches; b = width of stone, in inches; d = thickness of stone, in inches.

The transverse strength is important in the selection of stone for sills, caps, and lintels. Stone used as sills and lintels is more apt to show signs of breaking than that used for many other purposes. Fractures in stone used for sills and lintels are often due to uneven sinking of the building in which they are used. The modulus of rupture of granite usually lies between 2,500 and 3,500 pounds per square inch but may be greater or less.

Tensile strength.—The tensile strength of any rock is the load, in pounds, required to stretch a bar of stone one inch in cross section until it breaks apart. The specimen is severed in a straight pull by a machine which measures the load on a balance beam after the manner of weighing scales. Hirschwald[10] records a number of tensile strength tests on granites. He found that the tensile strength of granite averages about 1/35th of its crushing strength.

Shearing strength.—Shearing strength is the resistance of a body to forces which tend to displace it in mutually opposite directions with respect to a plane passing through the body. Hirschwald recommends that the test be made on specimens not in excess of 3 cm. in height and 5 cm. in width. The test is made by the pressure of a dull steel blade upon the rock sample which projects horizontally from the jaws of a clamp. The pressure is applied close to the edge of the clamp. The formula used for shearing strength is

$$K = \frac{S}{f}$$

S = the pressure, in pounds, required to shear off a specimen of the cross section f, in square inches.

Hirschwald found the crushing strength of granite to average about 14 times that of the shearing strength.

Fire resistance.—The fire resistance of a stone is determined by heating it to a definite temperature, and then either cooling it under normal atmospheric conditions or else quenching the hot rock with water. Granites show no marked deterioration until they are heated to temperatures above 550° C. The disruption is still more marked at about 800° C. This is below the average temperature of ordinary fires, which has been estimated to be about 850° C.

Frost resistance.—The freezing test of a rock consists in soaking a sample in water and then letting it alternately freeze and thaw about 25 or more times. The loss in weight is then determined and a search is made for signs of crumbling or the formation of minute cracks. The crushing strength before and after the freezing and thawing tests is compared. The effects of freezing and thawing are more severe if the rock has been soaked under a vacuum, the percentage of absorption being greater in this case. Hirschwald[12] found that granite soaked under atmospheric conditions and then subjected to the freezing and thawing tests showed no visible disruption. When the freezing and thawing tests were preceded by soaking under a vacuum, the micas scaled slightly.

Sulphate of soda test.—Resistance to frost action is also determined by the sulphate of soda test. The specimen of rock is soaked in sulphate of soda solution and then dried. The average of several determinations of the loss in weight is then obtained. This test is more severe than the freezing and thawing test. A coarse-grained, red granite tested in this manner by Luquer[17] showed a loss of

15.51 parts per 10,000 by weight. The same rock had lost only 1.38 parts per 10,000 in the freezing and thawing test. A fine-grained, gray granite tested by the same authority lost 5.16 parts per 10,000 by the sulphate of soda test and only 1.5 parts by the freezing test.

Abrasion.—The abrasion test is discussed under tests of crushed stone. It is of value in selecting stone for uses in which the stone is subject to scraping and rubbing, as on the treads of stairways. In some localities, stone may receive this kind of wear from wind-blown sand.

Chemical resistance.—Satisfactory tests for determining the resistance of granite to the action of warm, moist air or to industrial gases have not been devised. Brief exposures of specimens of fresh granite to moist carbon dioxide or to a mixture of oxygen and water vapor show no effects. Granite is as resistant to chemical agents as any common rock except quartzite.

Chemical analysis.—Chemical analyses of granites for commercial purposes may be advisable for detecting deleterious constituents. Numerous chemical analyses of granites are on record; however, very little of practical value can be learned from them that could not be gained by much simpler tests. Studies of thin sections under a petrographic microscope will indicate the necessary data in a more direct and less costly way. A few results determined by chemical analyses are outlined below.

A granite containing more than 75 per cent silica is above the average in hardness. A granite with 1 per cent or more water has either suffered decay or else contains an undesirably large amount of chlorite or mica. Combined carbon dioxide is not a normal constituent of granite. If present in appreciable amounts, it is indicative of decay. Sulphur is indicative of sulphides and is considered an undesirable constituent.

The percentages of oxides typical of granites generally fall within the limits indicated below: SiO_2, 65-77 per cent; Al_2O_3, 12-15 per cent; Fe_2O_3, 0.25-0.90 per cent; FeO, 0.20-2.5 per cent; MgO, 0.05-0.60 per cent; CaO, 0.15-1.25 per cent; Na_2O, 1.75-4.60 per cent; K_2O, 4.75-7.50 per cent; and H_2O (combined), 0.25-0.75 per cent.

Miscroscopic analysis.—Study of granite under a miscroscope is made to determine the mineral composition, grain size and pattern, freshness of the rock, presence of injurious minerals such as pyrite, and the presence of minute cracks which might cause rapid disintegration.

A rough estimate of the proportions of the principal minerals may be obtained by inspection of a polished surface of rock with a hand lens. The lengths of the various mineral constituents can be measured along series of parallel lines traced or laid off at regular intervals, one set intersecting the other at right angles. The total lengths of each mineral are measured along the lines. The ratio is obtained of the total lengths of each mineral to the total length of the lines along which measurements were made. It is assumed that the percentages for each kind of mineral are about the same as the ratio of their volumes to the total volume of the rock. This is the essence of the Rosiwal[15] method of mineral analysis.

The petrographic microscope permits distinction between the different kinds of feldspar which is impossible with the hand lens. Mineral volume analyses obtained by microscopic examination can be recalculated in weight analyses, and these in turn can be recalculated in chemical analyses.

The study of thin sections is best adapted to finding traces of decay, such as cloudiness in feldspars, the change of biotite and hornblende into chlorite, brown stains on pyrite or other iron-bearing minerals. Such study also discloses microscopic fractures. To show their alignment may be of help in operating the quarry. If abundant, fractures may presage the rapid decay of the rock.

CRUSHED STONE

The tests commonly made on crushed stone to determine its fitness for concrete and other purposes include mechanical analysis, apparent specific gravity and percentage of absorption, weight per cubic foot, percentage of wear, hardness, and toughness.[32]

Mechanical analysis.—Screening or mechanical analysis consists in passing a dried sample of definite weight through a series of standard sieves ranging in size from 3 inches to 0.0059 inch. Ten intermediate sizes are used. The weight of the aggregate sample varies from 1,000 to 9,000 grams. The percentage ratio of the weight of the sample left on each screen to the weight of the total sample is determined. The percentage of fines passing the smallest screen size is computed.

Specific gravity and absorption.—The apparent specific gravity of crushed aggregate is the ratio between the weight of the dry sample and the weight of the water displaced by the total volume of the sample. One way of making the test consists in drying a 1,000-gram sample to constant weight at 100° C., then cooling and re-weighing the sample. Next, the rock fragments are placed in water for 24 hours and, after surface drying, they are placed in a special cylinder previously filled with water up to an overflow spout. The weight of the overflow water is obtained, and the sample is then removed and weighed. The apparent specific gravity equals the dry weight of the sample divided by the weight of the water displaced by the saturated sample. The percentage of absorption is obtained by dividing the dry weight of the sample into the difference between the saturated and the dry weight, and multiplying the quotient by 100.

$$Ga = \frac{D}{S - s}$$

$$A = \frac{S - D}{D} \times 100$$

Ga = apparent specific gravity; D = dry weight of sample; S = saturated weight of sample; s = weight of saturated sample in water; A = percentage of absorption.

The weight per cubic foot of dry rock is equal to the apparent specific gravity multiplied by 62.37, the weight in pounds of a cubic foot of water.

Abrasion.—In the Deval abrasion test, a clean, 5-kilogram sample consisting of about fifty pieces of rock of nearly even size is placed in a hollow iron cylinder mounted diagonally on a shaft at an angle of 30°. The cylinder is revolved 10,000 times at a rate of about 30 to 33 revolutions per minute. The percentage of the total 5 kilograms which will pass through a No. 12 sieve of the American Society for Testing Materials is considered the percentage of wear.

Hardness.—The hardness test determines the resistance of the rock to frictional wear. The method used by the U. S. Department of Agriculture[31, 2] is as follows. A cylinder 25 mm. in diameter is cut, with a core drill, from the rock to be tested. Each end of the cylinder is polished to a plane surface and is held against a rotating steel disc, under a pressure of 1,250 grams, upon which sand is fed for 1,000 revolutions of the disc. The test sample is weighed before and after each treatment. The coefficient of hardness is expressed as one-third the average loss in grams, subtracted from 20. Rocks with a coefficient of hardness greater than 17 are considered hard; those from 14 to 17, medium; those under 14, soft. Due to the present scarcity of steel-tired traffic, this test is no longer as significant as formerly.

Toughness.—The toughness test determines the ability of a rock to resist fracture when subjected to blows. A cylinder of rock 24 to 25 mm. in diameter and 25 mm. in height is cut with a core drill, as in the hardness test. The ends of the cylinder are polished to plane surfaces. In the machine used, the cylinder is subjected to repeated blows of a 2-kilogram hammer which is dropped upon a steel plunger whose lower surface is spherical and rests on the test specimen. The first fall is from a height of 1 cm. The height of the fall is increased by 1 cm. after each blow. The height of the fall, in cm., when the specimen breaks, is a measure of the toughness.

REFERENCES

1. Blackwelder, Eliot, Fire as an agent in rock weathering: Jour. Geology, vol. 35, no. 2, pp. 134-140, 1927.

2. Blanchard, A. H., and Drowne, H. B., Highway engineering, 213 pp., New York, John Wiley & Sons, Inc., 1914.

3. Bowles, Oliver, Economics of crushed-stone production: U. S. Bur. Mines Econ. Paper 12, pp. 53-54, 1931.

4. Buckley, E. R., Building and ornamental stones of Wisconsin: Wisconsin Geol. and Nat. History Survey Bull. 4, p. 58, 1898.

5. ——— Idem, pp. 63-69.

6. Cederstrom, D. J., Deep wells in the Coastal Plain of Virginia: Virginia Geol. Survey Reprint Ser. no. 6, 15 pp., 1943.

7. Dale, T. N., The commercial granites of New England: U. S. Geol. Survey Bull. 738, pp. 24-27, 1923.

8. Darton, N. H., Economic geology of Richmond, Virginia and vicinity: U. S. Geol. Survey Bull. 483, 48 pp., 1911.

9. Furcron, A. S., Igneous rocks of the Shenandoah National Park area, Virginia: Jour. Geology, vol. 42, no. 4, pp. 400-410, 1934.

10. Hirschwald, J., Handbuch der bautechnischen gesteinsprüfung, p. 75, Berlin, Vorlag von Gebruder Bornträger.

11. ——— Idem, p. 118.

12. ——— Idem, p. 656.

13. Jonas, A. I., Granodiorite, its intrusion and replacement by the Air Point granite in Virginia (abstract): Geol. Soc. America Proc., 1933, p. 88, 1934.

14. —————, Hypersthene granodiorite in Virginia: Geol. Soc. America Bull., vol. 46, no. 1, pp. 47-60, 1935.

15. Johannsen, Albert, and Stephenson, E. A., On the accuracy of the Rosiwal method for the determination of the minerals in a rock: Jour. Geology, vol. 27, no. 3, pp. 212-220, 1919.

16. Laney, F. B., The geology and ore deposits of the Virgilina district of Virginia and North Carolina: Virginia Geol. Survey Bull. 14, pp. 35-36, 1917.

17. Luquer, L. McI., *cited in* Ries, H., and Watson, T. L., Engineering geology, 5th ed., p. 511, New York, John Wiley & Sons, Inc., 1936.

18. Roberts, J. K., The geology of the Virginia Triassic: Virginia Geol. Survey Bull. 29, pp. 56, 121-122, 1928.

19. ——— Idem, pp. 56, 122-125.

20. Sanford, Samuel, The underground water resources of the Coastal Plain province of Virginia: Virginia Geol. Survey Bull. 5, pp. 83-97, 1913.

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

22. Taber, Stephen, Geology of the gold belt in the James River basin, Virginia: Virginia Geol. Survey Bull. 7, pp. 64-66, 1913.

23. Thoenen, J. R., Study of quarry costs. Trap rock, sandstone, granite: U. S. Bur. Mines Inf. Circ. 6291, 24 pp., 1930.

24. Virginia Geological Survey, Geologic map of Virginia, 1928.

25. Watson, T. L., Syenite, *in* Mineral resources of Virginia: Virginia Jamestown Exposition Commission, p. 32, 1907.

26. ———, Granites of the southeast Atlantic States: U. S. Geol. Survey Bull. 426, 282 pp., 1910.

27. ——— Idem, pp. 70-114.

28. ——— Idem, p. 72.

29. ——— Idem, pp. 88-92.

30. ——— Idem, pp. 91-92.

31. Woolf, D. O., The results of physical tests of road building rock: U. S. Dept. Agr. Misc. Pub. no. 76, p. 2, 1930.

32. Anon., Tentative standard specifications for highway materials and methods of sampling and testing: Am. Assoc. Highway Officials, 294 pp., 1931.

33. ———, Science supplement: Science, new ser., vol. 83, no. 2165, p. 8, 1936.

34. ———, Crushing tough granite: Rock Products, vol. 44, no. 4, pp. 41-42, 51, April, 1941.

APPENDIX A

TABLES OF PETROGRAPHIC DATA

TABLE 1.—*Petrographic data on rocks sampled along the Lovettsville-Taylorstown traverse, Loudoun County, Virginia*

Location of sample[a]	Quartz	Microcline	Albite	Albite-oligoclase	Biotite	Dominant feldspar	CHARACTER OF ROCK
3	x	x		x	x	K	Massive granite gneiss.
6	x	x		x		K	Pegmatite dike in granite. Contains blue quartz.
8	x						Schistose facies of granite gneiss.
10a	x	x	x		x	K	Foliated granite gneiss.
10b	x	x	x			K	Pegmatite dike in granite gneiss. Contains blue quartz.

[a] See Fig. 3.

TABLE 2.—*Petrographic data on rocks sampled in the Middleburg area, Loudoun and Fauquier counties, Virginia*

Location of sample[a]	Quartz	Microcline	Biotite	Dominant feldspar	CHARACTER OF ROCK
3	x	x	x		Fine-grained granite, faintly foliated.
4	x	x	x		Same as 3.
5	x	x	x		Same as 3.
6	x	x	x		Same as 3.
8	x	x	x	K	Biotite granite gneiss; biotite, 10 to 15 per cent.
11	x	x	x	K	Granite gneiss.
12	x	x	x	K	Biotite granite gneiss. Contains pegmatite with blue quartz.

[a] See Fig. 4.

TABLE 3.—*Petrographic data on rocks sampled along the Markham-The Plains traverse, Fauquier County, Virginia*

Location of sample[a]	Quartz	Microcline	Albite	Albite-oligoclase	Biotite	Hornblende	Dominant feldspar	CHARACTER OF ROCK
1	x	x	x			?	K	Coarse-grained granite. Contains zircon and colorless quartz.
2	x	x	x			x	K	Chloritized granite.
3	x	x	x			x	K	Coarse-grained granite. Contains colorless quartz.
4	x	x	x		x		K	Granite, cut by diabase dikes.
5	x	x	x		x		K	Coarse-grained granite gneiss. Contains chlorite schlieren. Near greenstone schist.
7	x	x				x	K	Decomposed chloritic granite. Contains colorless quartz.
9	x	x		x		x	K	Coarse-grained pink granite.
13	x	x	x				K	Fine-grained pink granite.

[a] See Fig. 5.

TABLE 4.—*Petrographic data on rocks sampled along the Washington-Ben Venue traverse, Rappahannock County, Virginia*

Location of sample[a]	Quartz	Orthoclase	Microcline	Albite	Biotite	Dominant feldspar	CHARACTER OF ROCK
2	x		x	x	x	K	Granite gneiss.
3	x		x	x	x	K	Porphyritic granite gneiss. Contains violet quartz.
4	x		x		x	K	Granite gneiss.
5	x	x		x			Augen granite gneiss. Contains violet quartz.
6	x		x	x		K	Granite gneiss.
7a	x		x	x	x	K	Granite gneiss.
8	x		x	x	x	K	Granite gneiss. Contains violet quartz.
9	x		x			K	Massive coarse-grained, porphyritic granite. Contains blue quartz.
10	x		x	x		K	Similar to 9.
11	x	x		x	x	K,Na	Sheared coarse-grained granite. Contains blue quartz.
12	x	x	x	x	x	K	Sheared porphyritic granite.
13	x		x	x	x	K	Porphyritic granite.

[a] See Fig. 6.

TABLE 5.—*Petrographic data on rocks sampled along the Sperryville-Boston traverse, Rappahannock and Culpeper counties, Virginia*

Location of sample[a]	Quartz	Orthoclase	Microcline	Albite-oligoclase	Biotite	Dominant feldspar	CHARACTER OF ROCK
15	x		x	x	x	K,Na	Quartz monzonite gneiss; biotite rare.
17	x	x		x	x	K,Na	Pink quartz monzonite gneiss; biotite rare.
18	x			x		?	Decomposed schist. Contains blue quartz.
19	x	x		x		Na	White dacite.
20	x		x	x	x	K	Biotite gneiss. Contains secondary muscovite.
21	x			x	x	Na	Biotite gneiss.
22	x		x		x	K	Augen gneiss. Contains secondary muscovite and blue quartz.
23	x		x		x	K	Same as 22.
24	x	x	x		x	K	Similar to 22. Contains blue quartz.
25	x	x		x	x	K	Similar to 22, but more schistose.
34	x	x	x	x	x	K	Pink granite.
36	x	x		x		K,Na	Schistose granite; sericitic.
38	x	x		x		K	Granite.
39	x		x	x		Na	Dacite (?).
40	x		x	x	x	K	Granite gneiss.
41	x		x	x	x	K	Same as 40.
*42	x		x	x	x	K	Granite gneiss, cut by granite dikes containing blue quartz. Old roadside quarry.
43	x		x	x	x	K	Granite gneiss.
44	x		x	x	x	K	Same as 43.
45	x		x	x	x	K	White granite.
46	x		x	x		K	White granite.
47	x	x		x		K,Na	White quartz monzonite.

[a] See Fig. 8.
* Quarry.

TABLE 6.—*Petrographic data on rocks sampled along the Charlottesville-Afton traverse, Albemarle County, Virginia*

Location of sample[a]	Quartz	Orthoclase	Microcline	Albite	Albite-oligoclase	Biotite	Hornblende	Dominant feldspar	CHARACTER OF ROCK
3	x		x			x		K	Biotite gneiss.
4	x				x	x		Na	Biotite-muscovite gneiss; biotite, 50 per cent.
5	x		x		x	x		K	Schistose granite; biotite, 30 per cent.
6	x		x		x	x		K	Schistose muscovite granite, similar to 5.
7	x				x	x		Na	Foliated biotite gneiss; biotite, 40 per cent.
8	x				x	x		Na	Foliated gneiss, cut by felsite dikes.
9	x				x	x	x	Na	Biotite-hornblende gneiss; biotite, 75 per cent.
10	x				x	x	x	Na	Gneiss in schist.
11	x		x	x		x		K	Granite gneiss; biotite, 10 per cent.
12	x	x	x		x	x		K,Na	Quartz monzonite gneiss.
14	x	x	x		x	x		Na	Schistose granite; biotite, 15 per cent.
15	x				x	x		Na	Banded gneiss; biotite, 25 per cent.
16	x	x	x	x		x		K,Na	Quartz monzonite gneiss.
17	x		x			x		K	Massive granite.
18	x				x	x	x	Na	Granite gneiss; hornblende, 10 per cent.
19	x	x				x		K	Coarse-grained foliated granite.
23	x		x	x		x		K,Na	Coarse-grained, massive quartz monzonite. Contains blue quartz.
27	x	x	x		x			K,Na	Quartz monzonite gneiss; no ferromagnesian minerals.

[a] See Pl. 4.

TABLE 7.—*Petrographic data on rocks sampled along the Afton-Shelton-Charlottesville traverse, Nelson and Albemarle counties, Virginia*

Location of sample[a]	Quartz	Orthoclase	Microcline	Albite-oligoclase	Biotite	Dominant feldspar	CHARACTER OF ROCK
28	x	x		x	x	K	Granite. Contains grains of violet quartz 0.1 inch in diameter.
29	x	x		x		K	Quartz monzonite gneiss.
30	x		x	x	x	K,Na	Massive quartz monzonite, cut by diabase dikes. Contains violet quartz.
31	x		x	x	x	K,Na	Augen quartz monzonite gneiss.
32	x		x	x	x	K,Na	Massive quartz monzonite. Contains grains of quartz 0.1 inch in diameter.
33	x		x	x		K,Na	Massive quartz monzonite. Contains grains of quartz 0.1 inch in diameter.
34	x		x	x	x	K	Green sheared porphyritic granite. Contains muscovite and violet quartz.
*35	x		x	x	x	K	Biotite granite gneiss. Contains violet quartz and microcline phenocrysts 0.5 inch long; biotite, 30 per cent. Old roadside quarry.
36	x		x	x		K	Massive porphyritic granite.
37	x	x	x	x	x	K	Sheared granite. Contains feldspar phenocrysts 0.2 inch long, and apatite; biotite, 15 per cent.
38	x	?	?	x			Decomposed foliated granite. Contains feldspar phenocrysts 0.2 inch long; biotite, 15 per cent.
39	x		x		x	?	Foliated sericitic granite; biotite, 20 per cent.
40	x		x		x	K	Porphyritic granite gneiss. Contains feldspar phenocrysts 0.2 inch long.
41	x		x	x	x	K	Porphyritic granite gneiss; boitite, 10 per cent.
42	x				x		Biotite granite gneiss; biotite, 30 per cent.
43	x		x	x	x	K	Same as 42.
44	x			x	x	Na	Biotite-muscovite schist; biotite, 30 per cent.
45	x	x	x	x		K	Granite gneiss. Contains feldspar phenocrysts 0.2 inch long.
47a	x			x		Na	Pink granite gneiss. Contains epidote and muscovite.
47b	x		x	x	x	K	Augen gneiss. Contains muscovite, and feldspar phenocrysts 0.3 inch long.
49a	x		x	x	x	?	Massive, medium-grained, pink quartz monzonite. Contains small amounts of muscovite.
49b	x		x	x	x	?	Similar to 49a, but contains more muscovite.
49c	x		x	x	x	K	Pink quartz monzonite, similar to 49a, but contains more muscovite.
49d	x			x	x	Na	Muscovite-biotite schist.
50	x		x	x	x	K	Porphyritic biotite granite. Contains feldspar phenocrysts 0.5 inch long; biotite, 20 per cent.

TABLE 7.—*Petrographic data on rocks sampled along the Afton-Shelton-Charlottesville traverse, Nelson and Albemarle counties, Virginia—Continued*

Location of sample[a]	Quartz	Orthoclase	Microcline	Albite-oligoclase	Biotite	Dominant feldspar	CHARACTER OF ROCK
51	x			x	x		Biotite schist. Contains glaucophane.
52a	x			x	x	Na	Biotite schist; biotite, 20 per cent.
52b	x		x	x	x	K	Gray granite dike, cuts 52a.
53a	x			x	x	Na	Foliated white porphyritic granite.
53b	x			x	x	Na	Porphyritic granite.
54	x	x	x	x	x	K	Augen granite gneiss.
56	x	x	x			K	Augen biotite gneiss; biotite, 30 per cent.
57	x	x	x	x	x	K,Na	Foliated gneiss.
58	x			x	x	Na	Pink porphyritic diorite; biotite, 10 per cent.
59a	x	x		x	x	K	Porphyritic granite. Contains biotite. South of Catoctin greenstone.
59b	x		x			K	Unakite in granite. Red microcline partly replaced by epidote.
61	x		x	x	x	K	Granite dike in foliated biotite granite.
63	x			x	x	Na	Porphyritic granodiorite (?).
64	x		x	x	x	K	Sheared porphyritic granite.
65	x		x	x	x	K	Coarse-grained granite.
67	x		x	x	x	K	Schistose granite.
68	x	x	x	x	x	K,Na	Porphyritic quartz monzonite.
*69	x		x	x	x	K,Na	Quartz monzonite gneiss. Red Hill Quarry.

[a] See Pl. 4.
* Quarry.

TABLE 8.—*Petrographic data on rocks sampled in the Richmond area, Henrico and Chesterfield counties, Virginia*

Location of sample[a]	Quartz	Orthoclase	Microcline	Albite	Albite-oligoclase	Oligoclase	Biotite	Muscovite	Dominant feldspar	CHARACTER OF ROCK
*1a	x		x	x			x		K	Pegmatite dike in granite. Quarry No. 1, Richmond Granite Company.
*1b	x		x	x			x		K	Granite. Same as 1a.
*1c	x		x				x	x	K	Granite. Same as 1a.
*2a	x	x			x		x		K	Granite. Quarry No. 2, Richmond Granite Company.
*2b	x		x				x		K	Pegmatite dike in granite. Same as 2a.
*3	x	x	x		x		x		K	Granite. Sunnyside quarry.
*4	x	x	x				x		K	Granite. McCloy quarry.
*6	x	x			x		x		K	Gray granite. McGranigan (?) quarry, a short distance west of the south end of the Atlantic Coast Line Railroad trestle.
*7	x		x				x		K	Granite. Quarry east of south end of Atlantic Coast Line Railroad trestle.
8	x	x			x		x		K	Granite. Outcrop, about 100 feet west of south end of Atlantic Coast Line Railroad trestle.
9	x		x				x		K	Pink granite. Outcrop half a mile west of Boulevard Bridge.
*10a	x		x		x		x		?	Blue-gray granite. Donald (?) quarry, one-fourth mile west of Boulevard Bridge.
*10b	x		x				x	x	K	Pegmatite in granite. Same as 10a.
*11a	x		x		x		x		K	Granite. Wray (?) quarry, 0.1 mile east of Boulevard Bridge.
*11b	x		x			x	x		K	Same as 11a; orthoclase rare.
11c	x		x				x		K	Granite. Outcrop about half a mile east of Boulevard Bridge.
*12a	x		x	x			x		K	Gray granite. Forest Hill Park quarry, east wall.
*12b	x		x	x			x		K	Same as 12a.
*12c	x	x	x						K	Pegmatite dike. Contains gray orthoclase and pink microcline. Same as 12a.
*12d	x		x				x	x	K	Fine-grained blue granite. Same as 12a.
*12e	x		x		x				K	Coarse-grained pink granite. Same quarry, next to 12d.
*12f	x		x	x			x	x	K	Blue-gray granite. Same quarry.
*12g	x		x		x	x	x		K	Fine-grained, blue-gray granite. Same quarry, south wall.
15	x		x				x		K	Granite outcrop.

TABLE 8.—*Petrographic data on rocks sampled in the Richmond area, Henrico and Chesterfield counties, Virginia—Continued*

Location of sample[a]	Quartz	Orthoclase	Microcline	Albite	Albite-oligoclase	Oligoclase	Biotite	Muscovite	Dominant feldspar	CHARACTER OF ROCK
*16a	x		x		x		x		K	Granite. Contains considerable feldspar and albite oligoclase. McGowan quarry.
*16b	x		x		x		x		?	Biotite gneiss inclusion in granite. Contains epidote, biotite, 60 per cent. Same quarry.
*16c	x		x		x		x		K	Pegmatite in granite. Same quarry.
*16d	x		x		x		x		K	Granite. Contains secondary pyrite; albite-oligoclase rare. Same quarry.
*16e	x		x				x		K	Pegmatite. Contains scattered pyrite. Same quarry, near 16d.

[a] See Fig. 10.
* Quarry.

TABLE 9.—*Petrographic data on rocks sampled in the Granite Station-Lorraine district, southwest of Richmond, Chesterfield and Henrico counties, Virginia*

Location of sample[a]	Quartz	Orthoclase	Microcline	Albite	Albite-oligoclase	Biotite	Muscovite	Dominant feldspar	CHARACTER OF ROCK
*17	x	x	x	x	x	x		K	Granite. Granite Station quarry.
*18a	x		x		x	x		K	Granite. Vietor quarry.
*18b	x		x			x		K	Pegmatite in granite. Vietor quarry.
*19a	x	x	x		x	x	x	K	Granite. Contains feldspar phenocrysts 0.1 to 0.3 inch in diameter. Mackintosh (McIntosh) quarry, one-fourth mile southwest of Granite Station.
*19b	x		x		x	x		K	Granite, faintly foliated. Contains feldspar phenocrysts 0.04 to 0.1 inch in diameter. Old Dominion (Middendorf) quarry, one mile southwest of Granite Station.
*20	x	x	x		x	x		K	Granite. Quarry south of Chesterfield Golf Club.
22	x	x	x		x	x		K	Granite; orthoclase rare; biotite, 10 per cent..
23	x	x	x		x	x		K	Granite; biotite, 20 per cent.
24	x	x	x		x	x		K	Pink granite. Contains feldspar phenocrysts 0.1 to 0.2 inch in diameter.
25	x		x	x	x	x		K	Gray granite; orthoclase rare; biotite, 5 per cent.
26	x		x		x	x		K	Porphyritic granite. Contains pink microcline phenocrysts 0.1 inch in diameter.
27	x		x		x	x		K	Granite; biotite, 5 per cent.
28	x	x	x		x	x		K	Coarse-grained pink granite, faintly gneissic. Contains feldspar phenocrysts 0.2 inch in diameter.
29	x	x	x		x	x		K	Pink granite. Outcrops near old Westham quarries.
30	x	x	x				x	K	Pink granite; orthoclase rare. Contains feldspar phenocrysts 0.04 inch in diameter.

[a] See Fig. 11.
* Quarry.

TABLE 10.—*Petrographic data on rocks sampled along the Manakin-Maidens traverse, Goochland County, Virginia*

Location of sample[a]	Quartz	Orthoclase	Microcline	Albite	Albite-oligoclase	Oligoclase	Biotite	Muscovite	Hornblende	Dominant feldspar	CHARACTER OF ROCK
*32a	x		x				x			K	Greenish-pink, fine-grained granite. Contains pyrite and calcite. Boscobel quarry.
*32b	x		x							K	Red granite, cuts 32a. Same quarry.
*32c	x		x				x			K	Pegmatite sill about 2 feet thick. Same quarry.
*32d	x		x	x			x			K	Gneiss; northwest of pit. Same quarry.
*32e	x		x				x			K	Fine-grained granite gneiss. Same quarry, northwest wall.
*32f	x	x	x	x				x		K	Coarse-grained granite. Same quarry, south wall.
*32g	x		x					x		K	Sheared green granite gneiss. Same quarry, south wall.
*32h	x				x	x		x		Na	Fine-grained granite. Contains secondary pyrite and chlorite. Same quarry, west wall.
*32i	x		x							K	Pegmatite. Contains garnet and calcite. Same quarry, east wall.
33	x	x	x		x			x		K	Granite gneiss.
34	x	x								K	Granite sill in chlorite schist.
35	x		x	x				x		K	Gray granite sill in hornblende gneiss.
36a	x				x			x		Na	Gneiss.
36b	x	x			x					K	Granite sill in 36a.
37	x					x			x	Na	Hornblende gneiss in quartz-chlorite schist.
38	x			x	x		x			Na	Granite pegmatite in biotite gneiss.
39	x	x	x		x		x		x	K	Hornblende granite gneiss. Contains zircon.
41	x				x		x		x	Na	Biotite gneiss. Contains zircon.
42a	x				x	x	x			Na	Granite gneiss; biotite, 30 per cent.
42b	x		x		x					K	Granite sill in 42a.
43a	x				x	x	x			Na	Granite gneiss; biotite, 30 per cent.
43b	x				x		x			Na	Pegmatite, cuts 43a.
44	x	x	x		x		x	x		K	Granite gneiss.

[a] See Fig. 12.
* Quarry.

TABLE 11.—*Petrographic data on rocks sampled along the Goode-Lynchburg traverse, Bedford and Campbell counties, Virginia*

Location of sample[a]	Quartz	Orthoclase	Microcline	Albite	Albite-oligoclase	Oligoclase	Oligoclase-andesine	Biotite	Hornblende	Dominant feldspar	CHARACTER OF ROCK
1	x			x						Na	Foliated granite gneiss; biotite, 15 per cent.
2	x		x	x				x		?	Similar to 1, but less schistose. Contains apatite.
3	x		x	x				x		K,Na	Quartz monzonite gneiss. Contains zircon.
4	x		x	x						K,Na	Quartz monzonite gneiss.
5a	x		x		x			x		Na	Biotite schist; biotite, 80 per cent.
5b	x		x	x						K,Na	Fine-grained, narrow, quartz monzonite dikes and sills.
6	x		x		x			x		Na	Biotite gneiss.
7	x				x			x		Na	Foliated gneiss; biotite, 40 per cent.
8	x	x	x		x			x		K	Granite gneiss. Contains garnet.
9	x	x			x			x		K,Na	Biotite gneiss; biotite, 30 per cent.
12	x				x	x		x		Na	Granite gneiss. Contains amphibolite dikes.
13									x	Na	Diorite.
*14											Chlorite-actinolite schist. Virginia Greenstone Company's quarry.
17			x		x		x		x	K	Biotite gneiss, west of 16.

[a] See Fig. 14.
*Quarry.

TABLE 12.—*Petrographic data on rocks sampled along the Lynchburg-Harris Creek traverse, Amherst County, Virginia*

Location of sample[a]	Quartz	Orthoclase	Albite-oligoclase	Oligoclase	Biotite	Hornblende	Dominant feldspar	CHARACTER OF ROCK
*21	x			x	x	x	K	Biotite gneiss. Roadside quarry.
22			x			x		Diorite gneiss.
23	x			x	x			Biotite schist.
25			x		x			Diorite gneiss.
26			x			x		Hornblende-diorite gneiss.
27			x			x		Same as 26.
28			x	x	x			Biotite gneiss.
*33	x	x			x		K	Granite in schist. Local quarry.

[a] See Fig. 14.
* Quarry.

TABLE 13.—*Petrographic data on rocks sampled along the Lynchburg-Coleman Falls traverse, Campbell and Bedford counties, Virginia*

Location of sample[a]	Quartz	Orthoclase	Microcline	Albite	Albite-oligoclase	Oligoclase	Oligoclase-andesine	Andesine	Biotite	Hornblende	Dominant feldspar	CHARACTER OF ROCK
34	x			x					x		Na	Augen gneiss; biotite, 14 per cent.
35	x	x			x				x	x	Na	Granodiorite.
*36	x	x			x	x				x	Na	Massive granodiorite. Small quarry at base of Fleming Mountain.
37	x	x			x					x	?	Granodiorite. Contains muscovite.
38	x	x						x		x	Na	Granodiorite.
39	x		x						x		K	Biotite gneiss.
40	x	x						x		x	Na	Massive blue-gray granodiorite.
41	x	x					x	x		x	Na	Similar to 40; quartz rare.
42	x	x			x					x	K	Granite, similar to 40 in appearance; quartz abundant.
43	x	x			x				x		K	Augen granite gneiss; biotite, 5 per cent.
44	x				x				x		Na	Sheared granite.
45	x		x						x		K	Massive granite.
46	x		x						x		K	Same as 45.
47	x		x						x		K	Same as 45.
48	x	x	x								K	Granite gneiss.
49	x	x	x								K	Same as 48.

[a] See Fig. 14.
* Quarry.

TABLE 14.—*Petrographic data on rocks sampled along the Holcomb Rock traverse, Bedford County, Virginia*

Location of sample[a]	Quartz	Orthoclase	Microcline	Albite	Albite-oligoclase	Biotite	Dominant feldspar	CHARACTER OF ROCK
50	x	x			x	x	K	Granite gneiss.
51	x	x	x	x		x	K	Granite gneiss; similar to 50.
52	x		x		x	x	K	Biotite granite.
53	x		x			x	K	Granite gneiss. Contains smoky quartz.
54	x	x	x	x			K,Na	Porphyritic quartz monzonite.
55	x	x	x	x		x	Na	Granodiorite. Contains smoky quartz.
56	x	x	x	x		x	Na	Biotite gneiss; biotite, 30 per cent. Contains smoky quartz.
57	x	x	x	x		x	?	Similar to 56.
58	x		x	x			K	Massive pink granite.
60	x		x	x		x	K	Granite gneiss; biotite, 20 per cent. Contains smoky quartz.
61	x		x	x		x	K	Granite gneiss. Contains smoky quartz.
62	x		x	x		x	K	Same as 61.
63	x		x	x		x	K,Na	Sericite schist.
64	x		x			x	Na	Biotite gneiss; biotite, 30 per cent.
66	x			x		x	Na	Similar to 64.
67	x		x	x		x	K,Na	Similar to 64.

[a] See Fig. 14.

TABLE 15.—*Petrographic data on rocks sampled in the Danville area, Pittsylvania County, Virginia*

Location of sample[a]	Quartz	Microcline	Albite-oligoclase	Biotite	Dominant feldspar	CHARACTER OF ROCK
2a	x	x		x	K,Na	Biotite-oligoclase gneiss.
3	x	x			K	Muscovite granite gneiss; albite rare. Contains garnet.
4	x	x	x	x	K	Porphyritic muscovite granite. Contains garnet.
*5	x	x		x		Biotite gneiss. Facies of Wissahickon schist. City quarry.
6	x	x			K	Muscovite granite dike, cuts hornblende gneiss.
*7a	x		x		Na	Hornblende granite gneiss. Old City quarry.
*7b	x	x	x		?	Pink granite dike in 7a; muscovite rare.
8b	x	x		x	K	Muscovite pegmatite, cuts 8a.
*9b	x	x	x		K	Pink granite dike, cuts 8a. Contains secondary calcite.
*9c	x	x	x		K	Red pegmatite, cuts 9a. Contains secondary calcite.
10	x	x			K	Muscovite granite gneiss.
11	x	x			K	Same as 10.
12	x	x			K	Granite gneiss.
13	x	x			K	Similar to 12.
14b	x			x		Massive gabbro. Contains hornblende, labradorite, and magnetite; quartz rare.

[a] See Fig. 15.
* Quarry.

TABLE 16.—*Petrographic data on rocks sampled in the Martinsville area, Henry County, Virginia*

Location of sample[a]	Quartz	Orthoclase	Microcline	Albite-oligoclase	Oligoclase	Oligoclase-andesine	Andesine	Biotite	Muscovite	Hornblende	Dominant feldspar	CHARACTER OF ROCK
1	x					x				x	Na	Hornblende gneiss; hornblende, 60 per cent.
2a	x	x	x							x	K	Granite dike, cuts diorite gneiss, 2b below.
2b	x					x					Na	Diorite gneiss.
3	x			x	x			x			Na	Diorite gneiss.
4a	x						x	x			Na	Diorite dike.
4b	x			x				x		x	Na	Coarse-grained diorite dike; not gneissic.
4c	x			x	x				x		Na	Diorite gneiss dike.
4d				x				x		x	Na	Hornblende diorite dike; hornblende, 50 per cent.
5	x						x	x		x	Na	Quartz diorite; dark-colored minerals, 30 per cent.
6	x							x		x		Gneiss. Contains veins of blue quartz.
7	x						x	x			Na	Gneiss.
8	x				x			x			Na	Garnetiferous quartz gneiss; quartz, 50 per cent; biotite, 5 per cent.
9	x					x		x			Na	Similar to 8. Contains pyrite.
10	x							x	x	x		Garnetiferous gneiss.
11	x					x	x	x			Na	Quartz diorite.
12	x								x			Garnetiferous mica schist.
13	x				x			x	x		Na	Schist; feldspar rare.
14	x								x			Decomposed diorite (?).
21	x					x	x	x			Na	Massive quartz diorite.

[a] See Fig. 16.

TABLE 17.—*Petrographic data on rocks sampled along the Bentonville-Browntown traverse, Warren County, Virginia*

Location of sample[a]	Quartz	Orthoclase	Microcline	Albite	Albite-oligoclase	Oligoclase	Oligoclase-andesine	Biotite	Hornblende	Hypersthene	Dominant feldspar	CHARACTER OF ROCK
1	x		x	x						x	?	Porphyritic hypersthene granodiorite. Contains albite phenocrysts; microcline and albite abundant; hypersthene, about 1 per cent.
2	x		x		x			x		x	?	Hypersthene granodiorite; nonporphyritic. Feldspar abundant; dark-colored minerals, about 1 per cent.
3	x		x	x						x	?	Similar to 2, but gneissic.
4	x				x			x			Na	Gray garnetiferous granite gneiss; no potash feldspar; garnet, 20 per cent.
5	x	x				x		x			K	Gray granite gneiss. Contains apatite, graphite and garnet.
6	x	x				x		x			K	Similar to 5; garnet, 20 per cent; graphite, 10 per cent.
7	x	x				x		x			K	Similar to 5; biotite, 10 per cent. Contains pyrite.
8	x					x		x			Na	Similar to 5, but massive. Contains no potash feldspar.
10	x	x					x	x		x		Coarse-grained, green hypersthene granodiorite.

[a] See Fig. 17.

TABLE 18.—*Petrographic data on rocks sampled along the Thornton Gap-Sperryville traverse, Page and Rappahannock counties, Virginia*

Location of sample[a]	Quartz	Orthoclase	Microcline	Albite	Albite-oligoclase	Oligoclase	Oligoclase-andesine	Andesine	Biotite	Hornblende	Hypersthene	Dominant feldspar	CHARACTER OF ROCK
1	x	x					x			x		Na	Gray-green granodiorite; orthoclase rare; hypersthene, 10 per cent.
3	x		x						x			K	Granite dikes in hypersthene granodiorite.
4	x		x								x	K	Gray-green granodiorite, banded with coarse-grained pink granite.
5	x						x				x	Na	Hypersthene granodiorite, cut by garnetiferous rhyolite dikes; apatite abundant; quartz rare; hypersthene, 40 per cent.
6	x	x					x					Na	Granodiorite; orthoclase rare.
7	x	x					x					Na	Granodiorite, similar to 6.
8	x		x			x					x	K	Primary granite gneiss; dark-colored bands alternating with bands of quartz.
9	x		x			x					x	K	Primary granite gneiss, cut by basalt dikes; microcline abundant in dark-colored bands; oligoclase rare; hypersthene, 1 to 5 per cent.
10	x		x									K	Primary gneiss; no dark-colored minerals.
11	x		x		x							K	Coarse-grained gneiss. Contains crystals of feldspar 0.5 inch long and rhyolite dikes 12 inches wide.
12	x		x	x								K	Primary granite gneiss.
*13	x		x		x				x	x		K	Porphyritic granite gneiss. Contains phenocrysts of microcline 3 inches long; dark-colored minerals slightly chloritized. Abandoned road quarry.

[a] See Fig. 18.
* Quarry.

TABLE 19.—*Petrographic data on rocks sampled along the Madison-Fishers Gap traverse, Madison and Page counties, Virginia*

Location of sample[a]	Quartz	Orthoclase	Microcline	Albite	Albite-oligoclase	Oligoclase	Biotite	Hornblende	Hypersthene	Dominant feldspar	CHARACTER OF ROCK
*1	x		x				x				Thin granite dikes in granite gneiss and actinolite schist. Highway quarry.
3	x		x			x		x			Coarse-grained chloritic granodiorite; hornblende abundant.
4			x		x			x		?	Quartz monzonite. Contains hornblende.
5			x		x			x		?	Same as 4.
6			x		x			x		K	Coarse-grained syenite; microcline abundant; albite-oligoclase rare.
7			x		x			x		K	Same as 6, alternating with dikes of quartz monzonite.
11	x		x				x			K	Quartz-biotite schist.
12	x		x	x			x			K	Augen gneiss. Contains blue and colorless quartz.
13	x		x	x			x			K	Similar to 12.
14	x		x	x						K	Similar to 12, but arkosic.
15	x		x	x			x			K	Similar to 12.
17	x	x					x			K	Fine-grained granite; biotite rare.
18	x		x	x			x			K	Schistose granite.
19	x		x	x			x			K	Granite gneiss. Contains blue quartz.
20	x		x	x			x			K	Similar to 19; quartz enclosed by feldspar.
21	x		x	x			x			?	Quartz monzonite. Contains violet quartz.
22	x	x		x			x				Quartz-biotite schist; biotite, 80 per cent.
23	x			x			x				Schist schlieren in granite.
24	x		x	x			x			K	Granite, with blue quartz; biotite rare.
25	x		x	x			x			K	Granite, with lenses of blue quartz 0.5 inch long.
26	x		x	x			x			K	Similar to 25.
27	x		x			x	x			?	Quartz monzonite, cut by massive basalt dike 30 feet wide.
28	x		x			x	x			?	Quartz monzonite.
29	x		x				x			K	Biotite granite, faintly foliated.
30	x	x	x			x	x	x		?	Hornblende granodiorite.
31	x		x		x		x	x		K	Porphyritic granite; feldspar crystals 0.2 inch in diameter.
32	x	x	x	x			x			K	Fragments of coarse-grained, sheared granite. Contain amethyst quartz and apatite.
33	x		x				x			K	Coarse-grained granite. Contains apatite and colorless quartz; feldspar phenocrysts 0.5 inch long.
35	x		x	x			x	x		K	Granite, similar to 33. Contains colorless quartz.
36a	x		x	x						Na	Granodiorite.
36b	x		x		x					?	Unakite in granodiorite. Contains red microcline, gray albite-oligoclase, zircon, and epidotized feldspar.

TABLE 19.—*Petrographic data on rocks sampled along the Madison-Fishers Gap traverse, Madison and Page counties, Virginia—Continued*

Location of sample[a]	Quartz	Orthoclase	Microcline	Albite	Albite-oligoclase	Oligoclase	Biotite	Hornblende	Hypersthene	Dominant feldspar	CHARACTER OF ROCK
37	x		x		x						Decomposed material, with fragments of granodiorite and unakite, similar to 36a.
39	x		x	x			x		x	?	Gray-green, porphyritic hypersthene granodiorite. Contains colorless quartz, and phenocrysts of feldspar 0.2 inch long.
40	x		x	x			x		x	?	Same as 39.
41	x	x	x		x		x		x	?	Similar to 39, but orthoclase rare. Contains apatite and crystals of feldspar 0.1 inch long.

[a] See Fig. 19.
* Quarry.

TABLE 20.—*Petrographic data on rocks sampled along the Swift Run Gap-Stanardsville traverse, Rockingham and Greene counties, Virginia*

Location of sample[a]	Quartz	Orthoclase	Microcline	Albite-oligoclase	Oligoclase	Oligoclase-andesine	Biotite	Hornblende	Hypersthene	Dominant feldspar	CHARACTER OF ROCK
1	x	x				x	x		x	Na	Coarse-grained, gray-green hypersthene granodiorite; feldspar phenocrysts 3 inches long.
2	x	x				x	x		x	Na	Similar to 1.
3	x	x				x	x		x	Na	Similar to 1.
4	x	x				x	x		x	Na	Similar to 1; vesicular greenstone to the east.
5	x	x								K	Coarse-grained, gray granite; dark-colored minerals chloritized.
8	x	x								K	Similar to 5.
9	x	x			x				x	K	Hypersthene granite; hypersthene abundant.
10	x	x				x			x	?	Coarse-grained, hypersthene granodiorite; hypersthene, 1 per cent.
11	x	x		x				x	x	K	Partly sheared, dark-gray porphyritic hypersthene granite; hornblende abundant.
12	x	x		x				x	x	K	Same as 11.
13	x	x		x				x	x	K	Same as 11.
14	x		x				x			K	Granite gneiss; locally arkosic in appearance.

[a] See Fig. 20.

TABLE 21.—*Petrographic data on rocks sampled along the Vesuvius-Montebello-Massies Mill traverse, Rockbridge and Nelson counties, Virginia*

Location of sample[a]	Quartz	Orthoclase	Microcline	Albite-oligoclase	Oligoclase	Oligoclase-andesine	Andesine	Biotite	Hornblende	Dominant feldspar	CHARACTER OF ROCK
1	x		x	x							Granodiorite containing unakite in ellipsoidal masses and sheets 1 foot thick. Red microcline crystals 4 inches long; albite-oligoclase is gray and is more epidotized than is microcline.
2	x	x	x		x			x	x	?	Coarse-grained, gray-green granodiorite.
3	x	x	x	x				x	x	?	Gray-green, porphyritic granodiorite; albite-oligoclase phenocrysts.
4	x	x			x			x	x	Na	Dark-green, porphyritic granodiorite; oligoclase phenocrysts 3 to 4 inches long.
5	x	x			x			x	x	Na	Coarse-grained, dark-green granodiorite; unakite dike 2 inches wide. Contains apatite.
6	x	x	x		x	x			x	Na	Porphyritic granodiorite, with oligoclase-andesine phenocrysts 4 inches long. Contains irregular bodies of unakite 2 to 3 feet wide, with red orthoclase, gray albite-oligoclase, quartz, and epidote.
7	x	x		x						?	Gray-green, porphyritic quartz monzonite; no ferromagnesian minerals.
8	x	x		x					x	K	Porphyritic granite; orthoclase phenocrysts intergrown with albite.
9	x	x			x				x	K	Coarse-grained granite.
10	x	x		x					x	?	Epidotized quartz monzonite; red albite-oligoclase phenocrysts bordered by epidote.
11	x			x					x	?	Granodiorite.
16	x	x					x		x	?	Green quartz monzonite, with irregular bodies of unakite several feet wide composed of pink orthoclase, epidote, and quartz.
17	x	x					x		x	?	Similar to 16.
18	x	?		x					x		Decomposed granodiorite (?).
22	x	x		x						?	Gray-green, epidotized quartz monzonite.
23	x		x							K	Coarse-grained granite; red microcline phenocrysts 1 to 2 inches long; some chloritized ferromagnesian minerals.
24	x		x							K	Same as 23.
25	x		x							K	Same as 23.
26	x	x		x					x	?	Gray-green quartz monzonite; feldspar phenocrysts 1 inch long.
27	x	x		x					x	?	Gray-green quartz monzonite.
28	x	x		x					?	K	Dark-gray granite. Contains chlorite and hornblende.
29	x	x	x	x					x	K	Coarse-grained, dark-gray granite.
30	x	x		x	x				x	?	Quartz monzonite; oligoclase rare.
31	x	x		x	x				x	?	Similar to 30.

TABLE 21.—*Petrographic data on rocks sampled along the Vesuvius-Montebello-Massies Mill traverse, Rockbridge and Nelson counties, Virginia—Continued*

Location of sample[a]	Quartz	Orthoclase	Microcline	Albite-oligoclase	Oligoclase	Oligoclase-andesine	Andesine	Biotite	Hornblende	Dominant feldspar	CHARACTER OF ROCK
32	x	x		x						?	Fine-grained, gray-green, quartz monzonite.
33	x	x		x						?	Gray-green quartz monzonite.
34	x	x		x	x				x	?	Similar to 30, but slightly foliated.
35	x	x		x	x				x	?	Coarse-grained, gray-green, quartz monzonite.
37	x		x					x			Biotite augen gneiss.
38	x		x								Coarse-grained granite. Contains amethyst quartz.

[a] See Fig. 21.

TABLE 22.—*Petrographic data on rocks sampled along the Amherst-Whites Gap traverse, Amherst and Rockbridge counties, Virginia*

Location of sample[a]	Quartz	Orthoclase	Microcline	Albite-oligoclase	Biotite	Dominant feldspar	CHARACTER OF ROCK
1	x		x	x	x	K	Augen gneiss; biotite, 30 per cent. Contains apatite.
2	x		x	x	x	K	Similar to 1; biotite, 25 per cent.
3	x			x	x	Na	Biotite schist; biotite, 35 per cent. Contains apatite.
4	x			x	x	Na	Similar to 3.
5	x		x		x	K	Augen gneiss.
6	x		x			K	Hypersthene-quartz diorite; nonporphyritic.
7	x		x		x	K	Coarse-grained oligoclase granite.
8	x		x			Na	Hypersthene-quartz diorite. Contains apatite.
9	x		x	x	x	?	Schistose granite; biotite, 25 per cent.
10	x		x	x	x	?	Similar to 9.
11	x		x			K	Gray massive (granite ?) dikes.
13	x			x	x	Na	Biotite schist; biotite, 50 per cent.
14	x		x			Na	Massive, fine-grained, hypersthene granodiorite. Contains oligoclase-andesine.
16	x			x		Na	Foliated, fine-grained granite.
22	x		x		x	K	Massive, fine-grained sericitized granite.
26	x	x		x	x	K	Foliated, coarse-grained granite, cut by 2-foot dike of basalt.
27	x			x		Na	Gray-green hypersthene granodiorite.
28	x	x		x	x	K	Massive granite.
29	x		x		x	K	Foliated granite.
30	x	x		x	x	K	Strongly foliated biotite granite.
31	x	x		x	x	?	Sheared porphyritic quartz monzonite. Contains biotite.
32	x	x	x		x	K	Massive granite.
33	x		x	x	x	K	Massive, coarse-grained granite.
34	x		x	x	x	K	Similar to 33.
35	x		x	x	x	K	Porphyritic hornblende granite; microcline phenocrysts 1.5 inches long; biotite rare.
37	x		x	x		K	Massive hornblende granite.
38	x		x	x	x	K	Schistose biotite granite.
39a	x		x	x		K	Schistose porphyritic granite; feldspar phenocrysts 1 inch long.
39b	x		x	x		K	Massive, white granite dikes; no mafic minerals.
40	x		x	x	x	Na	Schistose sericitized granodiorite.
42	x		x	x		K	Massive, white granite sills, similar to 39b.
44	x		x	x		K	Banded sericite schist; feldspar phenocrysts 0.4 inch long.
45	x		x			K	Banded granite gneiss.
47	x		x			K	Sericite schist.
48	x		x				Massive, fine-grained, decomposed granite; no mafic minerals.
49	x		x	x		K	Sheared chloritic granite.
50	x		x	x		K	Massive granite.

TABLE 22.—*Petrographic data on rocks sampled along the Amherst-Whites Gap traverse, Amherst and Rockbridge counties, Virginia—Continued*

Location of sample[a]	Quartz	Orthoclase	Microcline	Albite-oligoclase	Biotite	Dominant feldspar	CHARACTER OF ROCK
51	x		x			K	Chloritic granite; feldspar phenocrysts 0.5 inch long.
53	x		x			Na	Hypersthene-quartz diorite with a gneissic structure; oligoclase abundant; hypersthene, 5 per cent.
54	x		x		x	K	Red granite.

[a] See Pl. 7.

TABLE 23.—*Petrographic data on rocks sampled along the Balcony Falls-Coleman Falls traverse, Rockbridge, Amherst, and Bedford counties, Virginia*

Location of sample[a]	Quartz	Orthoclase	Microcline	Albite-oligoclase	Biotite	Dominant feldspar	CHARACTER OF ROCK
1	x		x	x		K	Massive red granite; no dark-colored silicates.
2	x	x	x	x		K	Massive, coarse-grained red granite; orthoclase abundant. Contains epidote.
3	x		x	x		K	Granite gneiss; no dark-colored silicates.
4	x		x	x		K	Red pegmatite dike 20 feet wide; walls undefined; chloritized amphibole.
5	x		x	x		K	Similar to 1; epidotized.
6	x		x	x		K	Fine-grained red granite.
7	x	x		x		K	Similar to 6.
8	x	x	x			K	Similar to 7.
9	x		x	x		K	Massive, dark-gray, chloritic granite.
10	x	x	x	?		K	Fine-grained pink granite.
11	x	x	x	x		K	Fine-grained, red gneissic granite.
12	x	x	x	x		?	Similar to 10, cut by basalt dikes.
13	x	x	x	x		K	Fine-grained pink granite.
14	x	x	x	x		K	Massive, coarse-grained, gray-green granite. Contains specularite and red hematite in fractures.
15	x	x		x		K	Fine-grained pink granite, similar to 10.
16	x	x	x			K	Pink gneissic granite, cut by basalt dikes.
17	x		x			K	Granite gneiss.
18	x		x	x		K	Foliated granite; no dark-colored silicates.
19	x		x			K,Na	Foliated granite.
23				x	x	Na	Granite gneiss.
27	x		x			K	Granite gneiss.
28	x		x	x	x	K	Hornblende granite gneiss.
29	x				x		Oligoclase-sericite schist.
30	x		x				Massive pegmatite.
31	x		x	x	x	?	Foliated quartz monzonite; secondary biotite.
32	x		x		x	?	Quartz monzonite.
35	x		x	x		K	Augen gneiss. Contains blue quartz.
36	x			x			Biotite schist.
37	x		x	x		K	Augen gneiss; biotite abundant.

[a] See Fig. 22.

TABLE 24.—*Petrographic data on rocks sampled along the Thaxton-Montvale traverse, Bedford County, Virginia*

Location of sample[a]	Quartz	Orthoclase	Microcline	Albite	Albite-oligoclase	Oligoclase	Biotite	Dominant feldspar	CHARACTER OF ROCK
36	x		x		x		x	K,Na	Sheared porphyritic quartz monzonite.
37	x		x				x	K	Porphyritic granite.
38	x		x					K	Sheared fine-grained granite.
39	x		x					K	Massive granite; no dark-colored minerals.
40	x		x				x	K	Coarse-grained pink granite.
41	x		x	x			x	K	Fine-grained, porphyritic, hornblende granite gneiss.
42a	x		x	x			x	K	Porphyritic hornblende granite gneiss.
42b	x	x	x				x	K	Same as 42a.
43	x		x					K	Coarse-grained pink granite.
44a	x		x			x	x	K	Granite gneiss.

[a] See Pl. 8.

TABLE 25.—*Petrographic data on rocks sampled along the Moneta-Vinton traverse, Bedford and Roanoke counties, Virginia*

Location of sample[a]	Quartz	Orthoclase	Microcline	Albite	Albite-oligoclase	Oligoclase	Biotite	Dominant feldspar	CHARACTER OF ROCK
1	x				x	x	x	Na	Garnetiferous biotite schist; biotite, 30 per cent. Near hornblende gneiss.
2	x						x	Na	Granite gneiss; biotite, 30 per cent. Contains oligoclase-andesine.
3	x		x	x				?	Granite gneiss.
7	x		x				x	K	Garnetiferous schist.
8	x		x				x	K	Granite gneiss; biotite, 25 per cent.
9	x		x		x		x	Na	Granite gneiss; biotite, 5 per cent.
10	x		x				x	K	Granite gneiss; biotite, 15 per cent. Contains quartz lenses.
11	x		x				x	K	Granite gneiss; biotite, 1 per cent. Contains quartz lenses.
12	x		x				x	K	Similar to 11; coarse-grained.
13	x		x				x	K	Granite gneiss, similar to 11.
15	x		x				x	K	Augen granite gneiss.
16	x		x					K	Fine-grained granite gneiss.
17	x		x					K	Massive, fine-grained granite.
18	x		x	x				K	Similar to 17.
19	x		x	x				K	Similar to 17.
20	x		x				x	K	Similar to 17.
21	x		x				x	K	Similar to 17.
22	x		x	x			x	K	Porphyritic granite gneiss.
23	x		x				x	K	Foliated granite gneiss; sericitic.
24	x		x				x	K	Coarse-grained, porphyritic granite gneiss. Contains violet quartz.
25	x	x	x	x			x	K	Coarse-grained, porphyritic granite gneiss.
26	x	x					x	K	Fine-grained, porphyritic granite gneiss.
31	x	x					x	K	Granite gneiss; biotite, 15 per cent.
32	x		x				x	K	Blue-gray granite.
34	x		x				x	K	Fine-grained green granite.
35	x		x				x	K	Massive, coarse-grained granite.

[a] See Pl. 8.

TABLE 26.—*Petrographic data on rocks sampled along the Roanoke-Maggotty Gap-Grassy Hill traverse, Roanoke and Franklin counties, Virginia*

Location of sample[a]	Quartz	Orthoclase	Microcline	Albite	Biotite	Hornblende	Dominant feldspar	CHARACTER OF ROCK
1	x		x	x	x	x	K,Na	Foliated quartz monzonite; biotite, 10 per cent.
2	x	x		x	x		K	Sheared, porphyritic, granite gneiss. Contains violet quartz.
3	x	x	x		x	x	K	Massive porphyritic granite.
4	x		x	x	x	x	K,Na	Massive quartz monzonite. Contains purple quartz.
5	x	x	x	x	x	x	K,Na	Same as 4.
6	x		x	x	x	x	K	Sheared granite gneiss.
10	x		x		x		K	Porphyritic, sericitic, granite gneiss.
11	x		x	x	x		K,Na	Porphyritic, quartz monzonite gneiss; albite phenocrysts.
12	x		x	x	x		K,Na	Similar to 11; albite phenocrysts 1.5 inches long.
13	x		x	x	x		K	Foliated, porphyritic, granite gneiss.
14	x		x		x		K	Granite gneiss; biotite, 1 per cent.
16	x		x	x	x		K	Foliated granite gneiss; biotite, 50 per cent.
17	x		x	x	x		K	Foliated muscovite granite.
18	x		x		x		K	Foliated granite gneiss.
20	x		x		x		K	Foliated granite; biotite, 5 per cent.
21	x				x		Na	Gneiss. Contains oligoclase-andesine.

[a] See Fig. 23.

APPENDIX B

TABLES SHOWING PHYSICAL PROPERTIES OF GRANITES AND OTHER CRYSTALLINE ROCKS OF VIRGINIA

TABLE 27.—*Physical tests of granites and other crystalline rocks of Virginia*[a]

Sample	Specific gravity	Absorption (per cent)	Toughness	Loss (per cent), Deval abrasion test	Crushing strength (pounds per square inch)	ROCK AND SOURCE OF SAMPLE
1	2.65	.20	9.0	3.40		Granite. Sunnyside quarry, Sunnyside Granite Company, Inc., Richmond.
2	2.64	.20	8.5	4.00		Granite. Same quarry and location as 1.
3	2.63	.50		6.20	16,225	Granite. Vietor quarry, near Granite Station, southwest of Richmond.
4			23.0	2.30	29,104	Granite. Trego quarry, Trego Stone Corporation, Skippers, Greensville County.
5	2.66	.10	16.6	1.60		Granite. Same quarry as 4. Grade "A" stone.
6	2.69	.10	19.5	2.60		Granite. Same quarry as 4.
7	2.60	.80		8.60	17,180	Granite. Burns & Campbell quarry, Petersburg.
8	2.64	1.00		5.00	11,400	Granite gneiss. Kenbridge quarry, Kenbridge.
9	2.62	.95*	7.0	5.00		Granite gneiss. Same quarry as 8.
10	2.68	1.00		6.10	21,950	Granite. Burkeville quarry, Burkeville.
11	2.64	.36*	9.0	2.50	32,310	Muscovite granite. Falls Church quarry, Falls Church.
12	2.69	.30*	13.0	2.10	29,910	Biotite granite. About 2 miles west of Annandale, Fairfax County.
13	2.67	.42*	8.0	3.30	20,210	Granite. Near Occoquan, Prince William County.
14	2.70	.34*	9.0	3.40	17,870	Granite. Same locality as 13.
15	2.72	.30	12.0	3.00		Granite gneiss. Quarry of Beasley and Crowder, 1 mile south of Galax, Grayson County.
16	2.65	1.50		4.60	22,050	Diabase. Twin Mountain (Catlin) quarry, near Buena, Culpeper County.
17		.17*	12.0	3.20	37,550	Diabase. Same quarry as 16.
18	2.76	1.40		14.00	9,350	Greenstone. Quarry of Virginia Greenstone Company, Inc., Lynchburg.
19	2.91				8,010	Greenstone. Same quarry as 18.
20			16.3	2.60		Greenstone. Berkeley quarry, Charlottesville.

[a] See Pl. 1 for location of quarries. * In pounds per cubic foot.

Samples 1, 2, 5, 6, 15, and 20, tested by State Department of Highways, Richmond, Va.; 3, 7, 8, 10, 16, and 18, tested by Department of Civil Engineering, Virginia Military Institute, Lexington, Va.; 4, tested by Froehling and Robertson, Inc., Analytical Chemists, Richmond, Va.; 9, 11-14, and 17, tested by U. S. Office of Public Roads, Washington, D. C.; 19, tested by Columbia University Testing Laboratories, Columbia University, New York, N. Y.

TABLE 28.—*Chemical analyses of*

	1	2	3	4	5	6	7	8
SiO_2	72.27	71.19	70.83	69.44	69.29	71.51	69.48	68.45
Al_2O_3	14.30	14.01	12.70	15.46	14.07	13.82	13.95	10.00
Fe_2O_3	1.16	1.66	2.67	1.31	2.59	1.76	2.82	5.71
FeO	0.97	1.29	1.36	1.43	2.03	1.20	1.70	2.59
MgO	0.70	0.44	0.53	1.01	1.32	0.80	1.10	3.26
CaO	1.56	2.04	1.88	2.11	2.76	1.79	2.81	6.20
Na_2O	3.46	3.56	3.49	3.97	2.89	3.64	3.65	1.98
K_2O	5.00	4.45	4.83	4.25	2.87	4.63	3.45	1.18
H_2O (−110°C.)	0.04	0.04	0.07	0.07	0.06	0.17	0.04	0.18
H_2O (+110°C.)	0.25	0.33	0.34	0.29	0.37	0.31	0.50	0.62
TiO_2	0.31	0.35	0.41	0.48	0.50	0.33	0.47	0.20
MnO	trace	0.02	0.03	0.03	0.08	0.03	0.03	0.05
MnO_2	......	......	......	......	......	......	......	......
CO_2	0.21	trace	trace	trace	trace	trace	trace	trace
P_2O_5	0.02	0.34	0.33	0.22	0.26	0.30	0.49	0.25
	100.25	99.72	99.47	100.07	99.09	100.29	100.49	100.67

1. Medium-textured and medium-gray biotite granite. Westham granite quarries, 4.5 miles west of Richmond, Chesterfield County.
2. Fine-grained, dark blue-gray biotite granite. McGowan, Netherwood, and Donald quarries, Chesterfield County, and Mitchell and Copeland quarry, Henrico County, near Richmond.
3. Medium coarse-textured and medium-gray biotite granite. Netherwood, State (Old Dominion), Granite Development Company, Krimm and Middendorf quarries, Chesterfield County, near Richmond.
4. Medium-textured and medium-gray, biotite granite. McIntosh quarry, Chesterfield County, 5 miles west of Richmond.
5. Medium coarse-textured, gray biotite granite gneiss. Middendorf (Belt Line Railway) quarry, near South Richmond [Manchester], Chesterfield County.
6. Medium-textured and medium-gray, biotite granite. Lassiter and Petersburg Granite Company's quarries, Petersburg, Dinwiddie County.
7. Fine-grained, dark blue-gray biotite granite. Cartwright and Davis quarries, near Fredericksburg, Spotsylvania County.
8. Medium coarse-textured, gray biotite granite gneiss. Cartwright and Davis quarries, near Fredericksburg, Spotsylvania County.
9. Amelia-Goochland quartz monzonite gneiss. Near the Patterson mine, Amelia County.
10. Amelia-Goochland quartz monzonite gneiss. In a stream bed northeast of Goochland Court House, Goochland County.
11. Biotite gneiss facies of the Moneta gneiss. Moneta, Bedford County.
12. Leatherwood granite. Ridgeway area, Henry County.
13. Biotite-quartz monzonite gneiss. Arrington-Roseland road, 1 mile north of Colleen, Nelson County.
14. Biotite-quartz monzonite gneiss. County road, 0.75 mile north of Lovingston, Nelson County.
15. Quartz-diorite gneiss. Columbia [Cowherd] quarry, Columbia, Fluvanna County.
16. Unakite. Milam Gap, Page and Madison counties.
17. Syenite. Milam Gap, Madison County.
18. Hypersthene diabase. Culpeper Granite Company's quarry, 0.75 mile east of Buena, on Buzzard [Twin] Mountain, Culpeper County [Twin Mountain Trap quarry].
19. Average diabase. Goose Creek, 4 miles southeast of Leesburg, Loudoun County.

granites and other crystalline rocks of Virginia

9	10	11	12	13	14	15	16	17	18	19
60.78	66.86	76.83	75.02	63.40	66.46	72.43	58.32	60.52	51.74	51.56
18.58	17.76	11.86	14.02	15.94	14.92	13.93	15.77	16.99	21.30	13.81
1.06	1.58	0.26	1.04	2.01	1.87	0.90	6.56	0.60	1.83	0.96
4.32	2.18	2.38	1.37	3.91	3.08	2.45	0.89	6.53	7.44	11.32
2.13	1.12	0.71	0.52	1.33	1.11	0.58	0.09	1.59	3.18	7.40
4.15	3.89	1.58	3.93	3.75	3.10	3.38	11.68	4.58	12.39	10.08
2.93	3.38	2.65	2.81	3.53	2.63	3.20	0.32	2.83	1.22	2.08
3.71	1.88	3.35	0.91	3.30	4.74	2.14	4.01	3.91	0.30	0.96
......	......	......	......	0.06	0.06	0.11	......	......	0.07	......
0.75	0.45	0.74	0.10	0.76	0.80	0.54	1.73	0.88	0.18	......
1.26	0.68	0.66	0.08	1.33	0.83	0.21	......	......	0.67	1.48
......	......	......	0.06	0.05	0.07	0.02	0.13	0.25	0.14	0.19
0.08	0.02	0.03	......	......	......	......	......	......	......	......
......	......	......	0.15	trace	trace	0.09	......	......	trace	......
0.29	0.19	......	......	0.55	0.29	0.04	0.48	0.74	0.06	0.16
100.04	99.99	101.05	100.01	99.92	99.96	100.02	99.98	99.42	100.52	100.00

1-8, Watson, T. L., Annual report on the mineral production of Virginia, 1908: Virginia Geol. Survey Bull. 1A, pp. 81-82, 1909, William M. Thornton, Jr., Analyst; 9-12, Pegau, A. A., Pegmatite deposits of Virginia: Virginia Geol. Survey Bull. 33, pp. 21, 24, 30, 1932, Penniman and Browne, Analysts; 13 and 14, Watson, T. L., and Taber, Stephen, Geology of the titanium and apatite deposits of Virginia: Virginia Geol. Survey Bull. 3A, p. 63, 1913, William M. Thornton, Jr., Analyst; 15, Taber, Stephen, Geology of the gold belt in the James River basin, Virginia: Virginia Geol. Survey Bull. 7, p. 65, 1913, Roger C. Wells, Analyst; 16 and 17, Watson, T. L., Mineral resources of Virginia, Lynchburg, Va., Virginia Jamestown Exposition Commission, pp. 31, 33, 1907, W. C. Phalen, Analyst; 18 and 19, Roberts, J. K., The geology of the Virginia Triassic: Virginia Geol. Survey Bull. 29, p. 56, 1928, S. D. Gooch, and E. V. Shannon, Analysts.

INDEX