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GRANITES OF THE SOUTHEASTERN ATLANTIC STATES

BY

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GRANITES OF THE SOUTHEASTERN ATLANTIC STATES.

By Thomas Leonard Watson.

INTRODUCTION.

Economically, granite is the most important rock in the crystalline region of the Atlantic States south of Susquehanna River. Areally, it is one of the dominant rock types the distribution of which is shown on the map (fig. 1). Commercially, it is produced in this region in Georgia, Maryland, North Carolina, Virginia, and South Carolina, the five States being named in the order of their production. No production is reported from Alabama and Tennessee. The statistics on pages 270, 271 of this report indicate the annual value of the granite industry in these States to be about $3,500,000, or about 20 per cent of the granite output of the entire country.

In Bulletins 313 and 354, published in 1907 and 1908 by the United States Geological Survey, the granites of Maine and of Massachusetts, New Hampshire, and Rhode Island were described by T. Nelson Dale from both the scientific and the economic standpoint. The present work similarly describes the granites in the Atlantic States south of Pennsylvania, including Maryland, Virginia, North Carolina, Tennessee, South Carolina, Georgia, and Alabama. Chapter I contains a scientific discussion of granite adapted to the general reader, with special reference to the granites of the region described; in later chapters the occurrences are considered by States, the matter relating to each State being subdivided into a scientific part treating of the granite in that particular State and an economic part describing individual granite areas and quarries.

The field work on which this report is based was done in 1898, 1899, and 1903 for the state geological surveys of Georgia and North Carolina and in parts of the years 1905 to 1908, inclusive, for the United States Geological Survey. During this time the writer visited the granite quarries in each State described. The petrographic work included the study of more than 600 thin sections of typical rocks.

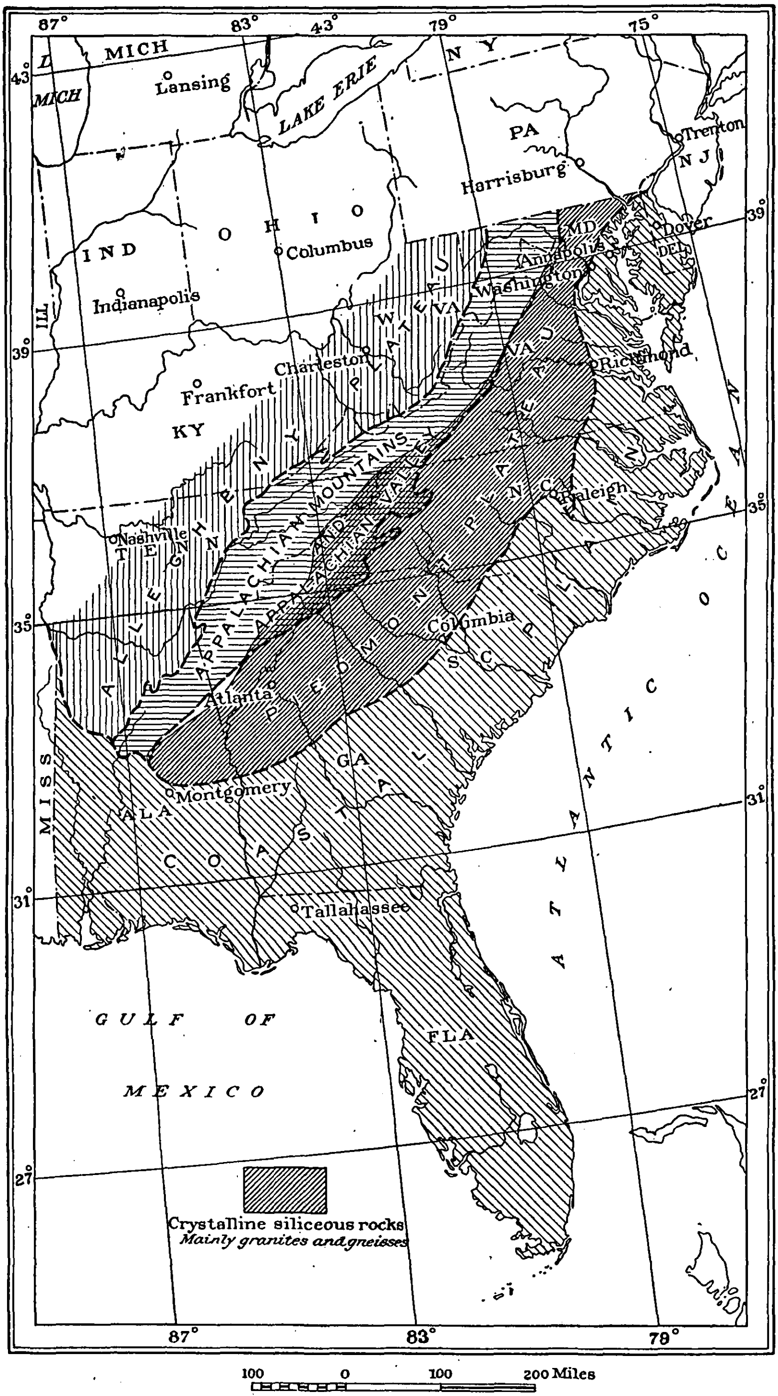

FIGURE 1.—Map showing distribution of granite in crystalline region of South Atlantic States.

The writer is indebted to the published reports on granite by the state geological surveys of Georgia, North Carolina, Maryland, and South Carolina, which he has used freely in the preparation of those parts of the report treating of the granite of these States. Much helpful information has been derived from Bulletins 313 and 354 of the United States Geological Survey on the granites of Maine, Massachusetts, New Hampshire, and Rhode Island, by T. Nelson Dale, and from the works of Merrill, Geikie, and Buckley.

To Professors Clark and Mathews, of the Maryland Geological Survey, the writer is indebted for the loan of thin sections of the Maryland granites in the geologic collections of Johns Hopkins University, and of Plate IV, *A*; to Dr. Joseph Hyde Pratt, state geologist of North Carolina, for the loan of Plate XX; to Dr. George P. Merrill, of the United States National Museum, for the loan of Plates XV and XVIII; to the Mount Airy Granite Corporation for the loan of Plate XIX; and to Mr. R. E. McClenahan, of Port Deposit, Md., for Plate VI, *A*. Miss A. T. Coons, of the United States Geological Survey, has contributed the statistical tables of granite production.

The word "granites" in this report is restricted to the quartz-bearing plutonic rocks, and includes both the massive and the schistose forms of even-granular and porphyritic textures. The only exceptions are in North Carolina, the augite syenite, leopardite (quartz porphyry), and orbicular gabbro-diorite occurring in that State being briefly described. The so-called "black granites" are not discussed.

CHAPTER I.

GRANITE IN GENERAL.

SCIENTIFIC DISCUSSION.

DEFINITION.

Granite is the family name applied to a large and common group of entirely crystalline igneous rocks, consisting essentially of quartz and potash feldspar (orthoclase or microcline, or both); more or less plagioclase feldspar—albite (soda feldspar) or oligoclase (soda-lime feldspar), usually the latter, or both—is generally present. Besides these minerals, which make up the mass of the rock, there is as a rule a small amount of either white mica (muscovite) or black mica (biotite), or both, locally hornblende, and here and there pyroxene. Each of these is evident to the eye without the aid of a lens.

Normally, granite is a massive rock without foliation or banding. When it takes on a foliated or banded structure, subsequent to its crystallization, it is no longer a true granite, but a granite gneiss.

MINERAL COMPOSITION.

The light-colored minerals, feldspar and quartz, are the essential minerals in granite and make up the mass of the rock. Of these, feldspar is the more conspicuous and generally the more abundant. It is readily distinguished by having two cleavages inclined at an angle of 90° or nearly 90°, the cleaved surfaces being smooth and brilliantly reflecting. The mineral is usually white, gray, or pinkish, but is sometimes green. Two kinds of feldspar are generally present, the more abundant of which is usually potash feldspar, a silicate of alumina and potash. This may be either orthoclase or microcline, or both, distinguished only by means of the microscope. The other feldspar (plagioclase)—albite (soda feldspar) or oligoclase (soda-lime feldspar), or both, but usually oligoclase—can generally be distinguished from the potash feldspar by the fine parallel lines on its basal surface. The potash and soda-lime feldspars are readily distinguishable from each other under the microscope. The granites which form the subject of this bulletin are generally characterized by nearly equal proportions of potash and soda-lime feldspars and are, technically, quartz monzonites.

Quartz is the next most abundant mineral and is readily distinguished by its glassy luster, uneven fracture, and brittleness. It is colorless, gray, or dark smoky, less commonly bluish or opalescent.

Mica, the third most abundant mineral in granites, may be present in two forms—white (muscovite or potash mica) and black (biotite or iron-magnesia mica). One or both of these minerals may be present in granite, and they are alike in cleaving along one direction into thin elastic folia, a property by which they are easily distinguished from the other constituents. They are distinguished from each other by their color. With only a few exceptions the granites described in this bulletin are mica granites. Biotite is much the commoner of the two micas, and granite containing biotite but no muscovite is sometimes called granitite.

Hornblende, a constituent of many granites, is much less common than mica in the granites here described. It may be as dark in color as the black mica (biotite), but it is readily distinguishable from biotite by the fact that it does not cleave into thin elastic scales, but possesses two cleavages inclined at an angle of approximately 124°. Augite and hornblende, when present in a granite, resemble each other so closely that they can at times be distinguished only by means of the microscope.

Besides these more important minerals which usually determine the character of the granite, others are present in microscopic proportions and are usually called minor accessory minerals. Of these, minerals like zircon, apatite, magnetite, ilmenite, titanite, pyrite, garnet, allanite, rutile, tourmaline, and fluorite are regarded as original. Others, such as chlorite, epidote, kaolin, sericite, and calcite, are the result of chemical changes in the feldspars or the dark ferromagnesian minerals, or both, and are therefore secondary. In a few instances calcite has been regarded as an original mineral in granite.[a] With the exception of fluorite, all the accessory minerals enumerated have been found in the granites described in this bulletin.

Of the minor accessory minerals named, pyrite (iron disulphide) and calcite (calcium carbonate), when present in an exposed surface of granite, are harmful, the pyrite producing discoloration on oxidation and the calcite when dissolved causing weakness in the stone.

The relative proportions of the minerals in granite differ within rather wide limits for granites from different localities. The percentages of feldspar and quartz are large, while that of the bisilicate minerals (micas, hornblende, and augite) is small. This variation in the percentages of the minerals is shown in the table below, which gives the mineral percentages of well-known granites.

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[a] Bull. U. S. Geol. Survey No. 313, 1907, p. 17, references cited.

Percentages of minerals in various granites.

Constituents.	1.	2.	3.	4.	5.	6.	7.	8.	9.
Feldspar {Orthoclase	43	28	28.85	28.2	[a] 55.4	[a] 58.9	12.26	8.91	[b] 53.33
Feldspar {Plagioclase	[c] 9	[d] 7	22.45	32.5	15.1	1.3	29.95	34.86	2.55
Quartz	44	59	44.65	35.5	26.0	28.5	33.82	42.28	33.41
Mica	[e] 4	6	4.05	[f] 3.3	3.3	10.3	17.83	10.41	10.71

[a] Reported as microcline chiefly, subordinate orthoclase.
[b] Reported entirely as microcline.
[c] Albite.
[d] Plagioclase.
[e] Biotite.
[f] Biotite, 1.3; hornblende, 2.0.

1. Red granite from Egypt.
2. Porphyritic granite from the Vosges. Prestwich, Jos., Geology: Chemical, physical, and stratigraphical, vol. 1, 1886, p. 42.
3. Biotite granite from Hardwood Island quarry, Maine. Dale, T. N., Bull. U. S. Geol. Survey No. 313, 1907, p. 173.
4. Hornblende granite from Rockport, Cape Ann, Massachusetts. Washington, H. S., Jour. Geology, vol. 6, 1898, p. 794.
5. Acidic granite from south end of Millstone Hill, Barre, Vt. Rept. State Geologist for 1901-2, 1902, p. 56.
6. Granite (medium stock) from eastern slope of Millstone Hill, Barre, Vt. Rept. State Geologist, 1901-2, 1902, p. 56.
7. Hornblende-biotite granite (quartz monzonite) from Cecil County, Md. Maryland Geol. Survey, 1902, p. 120.
8. Biotite granite (quartz monzonite) from Port Deposit, Cecil County, Md. Maryland Geol. Survey, 1902, p. 119.
9. Biotite granite from Platte Canyon, Jefferson County, Colo., Bull. U. S. Geol. Survey No. 150, 1898, p. 173.

The figures above indicate, as is usual, much variation in the relative proportions of the feldspar and the quartz, and to a greater extent in the potash feldspars (orthoclase and microcline) and the soda-lime feldspars (plagioclase). A careful examination, however, of the chemical analyses of the granites described in this bulletin discloses a smaller range in the relative amounts of the potash and soda-lime feldspars than is usual for normal granites from widely separated areas.

CHEMICAL COMPOSITION.

The chemical composition of granite, though conditioned by mineral composition, is now regarded to be of less economic importance than the latter. The chemical analysis corroborates the microscopic analysis. The analyses of granite here given will suffice to show the general range in composition.

Four analyses of granites from Scotland, Ireland, Italy, and Sweden give the following:

Analyses of European granites.[a]

Silica (SiO_2)	70.60–74.82
Alumina (Al_2O_3)	14.86–16.40
Ferric oxide (Fe_2O_3)	.10– 1.63
Ferrous oxide (FeO)	.36– 1.64
Manganese oxide (MnO)	.00– .48
Magnesia (MgO)	.23– 1.00
Lime (CaO)	.89– 2.47
Soda (Na_2O)	3.51– 6.12
Potash (K_2O)	3.55– 5.10

[a] Geikie, Archibald, Textbook of Geology, 4th ed., 1903, vol. 1, p. 207.

Ten analyses made in the laboratory of the United States Geological Survey of granites from Arizona (1), California (4), Colorado (4), and Michigan (1), show the following ranges:

Analyses of ten United States granites.[a]

Silica (SiO_2)	66.28–77.68
Alumina (Al_2O_3)	11.63–16.38
Ferric oxide (Fe_2O_3)	.00– 2.73
Ferrous oxide (FeO)	.09– 1.88
Magnesia (MgO)	.04– 1.63
Lime (CaO)	.12– 3.75
Soda (Na_2O)	2.85– 5.16
Potash (K_2O)	1.87– 6.50
Titanium dioxide (TiO_2)	Trace– .54
Phosphoric oxide (P_2O_5)	Trace– .30

Analyses of granites from Maryland, South Carolina, and Georgia show the following ranges for the individual States:

Analyses of Maryland, South Carolina, and Georgia granites.

Constituents.	Maryland.[a]	South Carolina.[b]	Georgia.[c]
Silica (SiO_2)	62.91–74.87	62.34–73.26	63.27–72.56
Alumina (Al_2O_3)	12.89–19.13	13.72–17.22	14.81–19.93
Ferric oxide (Fe_2O_3)	Trace– 2.07	.70– 1.85	.94– 2.85
Ferrous oxide (FeO)	.51– 3.23	1.24– 2.49	
Magnesia (MgO)	.16– 2.19	.22– 1.30	.20– 1.30
Lime (CaO)	.48– 4.89	1.28– 3.28	1.19– 3.27
Soda (Na_2O)	1.95– 3.94	.55– 5.39	4.14– 5.88
Potash (K_2O)	1.48– 5.36	2.85– 6.89	3.29– 5.85

[a] Eight analyses. W. F. Hillebrand, analyst.
[b] Thirteen analyses. Earle Sloan, analyst. Bull. South Carolina Geol. Survey, ser. 4, No. 2, 1908, pp. 177-223.
[c] Twenty-one analyses. Bull. Geol. Survey Georgia No. 9-A, 1902, pp. 241-242.

TEXTURE.

Texturally, granites are holocrystalline granular rocks. The crystalline granules (minerals) are in close contact and usually interknit. Granites, therefore, possess a minimum of pore space and a maximum degree of strength. Some granites are even grained; others contain prominently developed feldspars, with or without crystal outlines, embedded in a finer even-grained groundmass—that is, they are porphyritic in texture. The prominent or distinct crystals of feldspar are known as phenocrysts.

Difference in the magnitude of the minerals (granularity)[b] of even granites gives rise to a variety of texture. Three grades of texture may thus be distinguished—(1) coarse, in which the feldspars generally measure over 1 cm., or two-fifths inch; (2) medium, in

[a] Bull U. S. Geol. Survey No. 228, 1904, p. 197, analysis D; p. 231, analysis A; p. 232, analysis A; p. 240, analysis E; p. 241, analysis F; p. 185, analysis B; p. 161, analyses A, C, F; p. 78, analysis A.
[b] Cross, Iddings, Pirsson, and Washington, The texture of igneous rocks; Jour. Geology, vol. 14, 1906, pp. 694 et seq.

which they measure under 1 cm. (two-fifths inch) and over 0.5 cm. (one-fifth inch); and (3) fine, in which they measure under 0.5 cm. (one-fifth inch).[a] In some coarse-grained granites the feldspars measure one or more inches and in some fine-grained ones as low as one-fiftieth inch.

Under the microscope the arrangement of the minerals in granite shows that these have observed the following order in crystallizing out: (1) Minor accessory minerals (magnetite, apatite, zircon, titanite, pyrite, and ilmenite); (2) characterizing accessory minerals (hornblende, biotite, and muscovite); and (3) the essential minerals (feldspars and quartz). Examination of any medium or coarse-grained granite will show the quartz filling the spaces between the feldspars. Some of the earlier-formed minerals are, as a rule, partly or entirely inclosed by the later-formed ones (feldspars and quartz). In many granites the feldspars and quartz are intergrown, indicating overlapping in part of the periods of crystallization of these minerals.

PHYSICAL PROPERTIES.

Among the more important physical properties of granite are color, weight, strength, hardness, and porosity. These are briefly discussed in the order here named.

COLOR.

The usual color of granites is some shade of gray, though pink or red varieties are not uncommon. Color depends chiefly on the relative abundance of the dark ferromagnesian mineral or minerals (biotite or hornblende, or both) and the character of the feldspars. Those granites containing a large proportion of biotite or hornblende are of darker gray color than those containing but little. The pink and red colors are due to the presence of pink and red feldspars.

The Appalachian granites described in this bulletin are, with few exceptions, of some shade of gray varying from nearly white (Stone Mountain, Ga., granite), through medium gray (Richmond, Va., granites in part, and the Guilford, Woodstock, and Port Deposit, Md., granites), to dark blue-gray (Richmond and Fredericksburg, Va., granites in part; Winnsboro and Heath Springs, S. C., granites in part; and Oglesby, Ga., granite). A part of the granite of Dunns Mountain, near Salisbury, N. C., is of a pronounced beautiful pink color.

WEIGHT.

The specific gravity of a rock is the ratio of its density to that of an equal volume of distilled water at 4° C. (39.2° F.). The specific gravity of granite ranges from 2.593 to 2.731, with an average of

[a] Dale, T. N., The granites of Maine: Bull. U. S. Geol. Survey No. 313, 1907, p. 20.

2.663. The weight of granite, expressed in pounds per cubic foot, is obtained by multiplying the specific gravity by 62.5, the weight in pounds of a cubic foot of distilled water at 4° C. (39.2° F.).

STRENGTH.

Hundreds of tests to determine the compressive strength of granite have been made. It will suffice here to direct attention only to the usual range in the ultimate compressive strength of granite, which is from 18,000 to 34,000 pounds per square inch. The range in ultimate compressive strength of the Wisconsin granites is, according to Buckley,[a] from about 15,000 to 43,973 pounds per square inch. For the compressive strength of the granites described in this bulletin, see pages 49–50, 149, 183, 213, 221, 252, 253.

HARDNESS.

By the hardness of a building stone is meant its resistance to wear. The principal factors which determine hardness are (1) aggregation of the constituent grains or the firmness with which they adhere, thereby diminishing proportionately the pore space; (2) actual hardness of the individual mineral grains; (3) size and relative abundance of the component minerals; and (4) mineral composition. Tests for hardness show that granites differ greatly. As stated by Dale,[b] "this difference is due not merely to differences in the percentage of quartz, but also to variations in the character of the feldspars."

POROSITY.

Fresh granite contains less than 1 per cent of water and is capable of absorbing a small fraction of a per cent more. According to Ansted[c] granite usually contains about 0.8 per cent of water and is capable of absorbing about 0.2 per cent more; a cubic yard of granite usually contains, therefore, 3.5 gallons of water. The pore space in 14 Wisconsin granites, as determined by Buckley,[d] ranges from 0.019 to 0.62 per cent, and the ratio of absorption of the same granites ranges from 0.04 to 0.50 per cent. According to Merrill[e] certain Maryland granites absorb from 0.196 to 0.258 per cent of water after drying twenty-four hours at 212° F. and then being immersed for twenty-four hours. The writer[f] found that the ratio of absorption of 12 Georgia granites ranged from 0.037 to 0.093 per cent.

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[a] Buckley, E. B., On the building and ornamental stones of Wisconsin: Bull. Wisconsin Geol. and Nat. Hist. Survey No. 4, 1898, pp. 361, 390.

[b] Dale, T. N., The granites of Maine: Bull. U. S. Geol. Survey No. 313, 1907, p. 22.

[c] Quoted by Hull, Edward, A treatise on building and ornamental stones of Great Britain and foreign countries, 1872, p. 30.

[d] Op. cit., p. 400.

[e] Merrill, G. P., Stones for building and decoration, 3d ed., p. 435.

[f] Watson, T. L., Granites and gneisses of Georgia: Bull. Geol. Survey Georgia No. 9-A, 1902, p. 351.

VARIETIES OF GRANITE.

Granites are usually classified, mineralogically, on the basis of the prevailing accessory mineral or minerals—mica (biotite or muscovite), hornblende, and augite. Thus a granite containing muscovite (white mica) is termed a muscovite granite; one containing biotite (black mica) a biotite granite (granitite); one containing both a muscovite-biotite granite; one containing hornblende a hornblende granite; one containing hornblende and biotite a hornblende-biotite granite, etc. The name unakite is given to a granite with pink feldspars and rich in epidote that occurs in the Unaka Mountains of eastern Tennessee and western North Carolina and is known in two localities in the Blue Ridge of Virginia.

The varieties of granite occurring in the region covered by this bulletin are chiefly biotite, muscovite, and muscovite-biotite granites, and hence are referred to as mica granites. The biotite granites greatly predominate.

A general classificatory scheme of the granites occurring within this region is not given here; those of each State, however, are classified in the respective chapters.

STRUCTURE.

Under the term structure are included all divisional planes that traverse granite, whether of microscopic or macroscopic proportions, such as rift and grain, joints, faults, etc.

RIFT AND GRAIN.

The rift and grain in granite are structures of considerable economic importance, for they lessen the cost of quarrying, when well developed, by facilitating the operations of the workmen. They are obscure microscopic foliations, inclined at an angle of about 90° to each other, along which the rock splits more easily than in other directions. The rock splits easier in the direction of rift than of grain. These structures may not be visible to the ordinary observer, but are easily detected by an experienced stonecutter.

In the study of the hornblende-biotite granite of Cape Ann, Mass., Tarr [a] found that rift consisted of minute fractures and faults crossing the feldspar and quartz alike, although some go around the quartz grains rather than through them. Whittle [b] details similar observations for the granite quarried at Redstone, N. H., and remarks that notwithstanding the pronounced rift and grain of this granite it stood a compression test of 22,370 pounds to the square inch and was not appreciably weakened by the microscopic fractures. Dale [c] later corroborated Whittle's observation on this granite.

[a] Tarr, R. S., The phenomena of rifting in granite: Am. Jour. Sci., 3d ser., vol. 41, 1891, pp. 267-272.
[b] Whittle, C. L., Rifting and grain in granite: Eng. and Min. Jour., vol. 70, 1900, p. 161.
[c] Dale, T. N., The granites of Maine: Bull U. S. Geol. Survey No. 313, 1907, p. 27.

Rift and grain data were collected by Dale[a] at 53 quarries of Maine granites; at 29 of these the rift was vertical, and at 24 it was horizontal and the grain was vertical. According to Dale the courses of the rift and grain are distributed as follows:

Courses of rift in Maine granites.

	Number of quarries.
N. 10° W.–N. 10° E	6
N. 22°–50° W	5
N. 30°–77° E	3
N. 60°–70° W	9
East-west to N. 85° E. and N. 80° W	6

Courses of grain in Maine granites.

	Number of quarries.
North-south	2
N. 20°–25° W	2
N. 45°–75° E	4
N. 45°–72° W	6
East-west to N. 80° E	10

From these observations Dale says: "It appears, therefore, that when rift or grain is vertical the east-west and west-northwest to northwest courses are the most common, and next the north and east-northeast to northeast courses."[b]

The rift and grain are not always pronounced in the granites of the southeastern Atlantic States, but, as a rule, they are sufficiently developed to facilitate quarrying operations. In some places they are but poorly defined, but nowhere, so far as the writer is aware, are they entirely absent.

From the numerous tests it seems that rift, in some cases at least, influences the crushing strength of the granite. That is to say, the ultimate strength of granite is greater when pressure is applied at right angles to the rift than when applied parallel to it.[c]

JOINTS.

OCCURRENCE.

Joints in rocks of commercial grade are of considerable economic importance, for their character and abundance largely determine the size of blocks that may be quarried. Where not too closely spaced and not discolored by sap they greatly benefit the quarries; but where too abundant and closely spaced and where they intersect at sharp and obtuse angles, they are decidedly harmful, as the extraction of dimension stone is rendered impossible.

[a] Dale, T. N., The granites of Maine: Bull. U. S. Geol. Survey No. 313, 1907, pp. 28, 29.

[b] Idem, p. 29.

[c] See results of tests of materials by J. W. Reilly, as quoted by Dale, T. N., The granites of Maine: Bull. U. S. Geol. Survey No. 313, 1907, p. 29.

Two systems of joints, a vertical set and a horizontal set, and, in many places, a third, diagonal system intersect the granites treated in this bulletin. These may be widely spaced or closely spaced. Usually the spacing is sufficiently wide to admit of dimension stone being quarried. Motion in the granite masses since the formation of the joints is evident from the polished and striated surfaces of the joints.

VERTICAL JOINTS.

Considerable variation is shown in the development of the vertical joints. In most places they are conspicuously developed; in others, especially in the granite domes of Georgia (Stone Mountain and similar domes in the Lithonia area) and North Carolina, they are much less abundant. Visible jointing is not apparent in the Mount Airy, N. C., quarries.

Observations in the quarries of the southeastern Atlantic States show two principal sets of vertical joints, lying in the northeast and the northwest quadrants; in many quarries there is also minor jointing in two other directions, east-west and north-south. In some localities the joints are irregular with respect to continuity, strike, and dip. Joints indicating a considerable degree of curvature are noted in a few localities and are described in some detail in the chapters on the individual States.

HORIZONTAL JOINTS.

Joints dividing the granite into "sheets" are usually strongly developed in the granites of the Southern States. Such joints are usually parallel to the granite surface. In flat-surface exposures they approach a horizontal position; in gently arched exposures they have approximately the same degree of curvature as that of the granite surface; and in the steep domes they are correspondingly steep, observing parallelism with the doming surface.

Horizontal joints are usually more conspicuous at and near the surface, and become less prominent below. They apparently disappear in most quarries that are opened to any considerable depth. Ordinarily the joint planes separate the rock into thinner sheets at or near the surface and into thicker sheets at greater depth. The thickness of the sheets shows considerable variation, ranging from several inches to 6 feet or more.

There is a great diversity of opinion among geologists as to the cause of these joints, some regarding them as one of the effects of external temperature changes (solar heat), and some believing them to be due chiefly to compressive or torsional strain.[a]

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[a] See a recent review of the literature on "sheeting" by Dale in Bull. U. S. Geol. Survey No. 313, 1907, pp. 30-38.

Joint structure, vertical and horizontal, in the granites of the Southern States is shown in Plates II, X, and XI.

SLICKENSIDES.

In most of the granite quarries where the joint structure is at all well developed the joints show smooth, more or less polished and striated surfaces, indicating considerable movement in the granite masses since the formation of the joints. A very thin coating or veneer of a reddish and yellow to greenish-yellow mineral substance is developed on many of the joint surfaces. This is an alteration product, derived from certain original minerals of the fresh granite and resulting from the rubbing together of the two sides along the plane.

ROCK VARIATIONS.

Under the term "rock variations" are grouped those variations from typical granite that are due to injection, infiltration, inclusion, segregation, etc.[a]

DIKES.

The dikes in the southern granites are divisible on a chemical basis into two groups—(1) dikes of acidic composition, including very fine grained, nearly mica-free granite (aplite), and very coarse grained granite (pegmatite); and (2) dikes of basic composition, including diabase and amphibolite.

ACIDIC DIKES.

Granite-aplite.—Granite-aplite differs from normal granite in its greater fineness of grain, in containing very little or no mica, and in its very light, nearly white color. Dikes of it are only occasionally seen in the granites of the Southern States. They have been noted by the writer in the Richmond, Va., granite area;[b] the Raleigh, N. C., granite area;[c] the Columbia and Lexington granite areas and the Anderson quarry in Fairfield County, S. C., and the Stone Mountain, Ga., granite area,[d] and are plainly of an intrusive nature. They occur both as separate dikes in the granite and associated with the pegmatite dikes as banded aplite-pegmatite dikes. They are usually less than 6 inches thick, and in color they are very light, except those of the Columbia, S. C., area which are decidedly reddish brown. They are very fine grained in texture, the mineral particles not being distinguishable, as a rule, with the unaided eye. For a detailed description of the individual occurrences see pages 85, 120, 178–179.

[a] Dale, T. N., op. cit., p. 42.
[b] Bull. Geol. Soc. America, vol. 17, 1906, p. 530.
[c] Bull. North Carolina Geol. Survey No. 2, 1906, pp. 33, 180. Jour. Geology, vol. 12, 1904, pp. 403-404.
[d] Jour. Geology, vol. 10, 1902, pp. 186-190. Bull. Georgia Geol. Survey No. 9-A, 1904, pp. 275-276.

Pegmatite.—Pegmatites are present, usually, in great numbers in the granites of the Southern States, and some of them attain considerable size. (See Pl. III.) They are abundant in some quarries and entirely absent in others. Only here and there are they so numerous as to interfere seriously with quarrying operations, the most noteworthy example being at the city quarries of biotite granite at Raleigh, N. C., where hardly a block of any size can be quarried that is entirely free from pegmatite dikes; this is illustrated in the state building in Raleigh, which is constructed of this stone.

The pegmatites are granitic in their mineralogy, consisting of very coarse crystallizations of feldspar and quartz with less mica (muscovite or biotite, rarely both). As a rule, these minerals are not uniformly distributed through all parts of the dikes, but are scattered very irregularly, first one and then the other predominating. The pegmatites associated directly with the granites in the quarries are as a rule remarkably free from unusual or rare minerals. Garnet is commonly present, and in the dark-blue granite quarries of Fredericksburg, Va., massive granular magnetite is associated with the garnet. In the pegmatites of the granite quarries at Stone Mountain, Ga., both tourmaline and garnet occur. Black tourmaline is observed in some of the pegmatites of the Johnson quarry near Pacolet, S. C.

Many of the larger pegmatite dikes penetrating the crystalline rocks of the southern region contain unusual minerals. This is especially true of parts of the crystalline area in Virginia and the Carolinas.[a]

The potash feldspars, orthoclase and microcline, are the dominant feldspar species in the pegmatites, though an acidic plagioclase is usually present. The commonest colors are white and reddish pink, with pronounced green in some of the Virginia dikes. Twinning on the Carlsbad law is common and good cleavage development is a marked characteristic. The quartz is usually of the light and the dark smoky varieties, which contrast sharply with the feldspar. Of the micas, both muscovite and biotite occur in places associated in the same dike, but usually separated, with biotite probably more common than muscovite. The biotite is usually present in large, stout, platy forms, at some places irregularly distributed between the feldspar and quartz, at others distributed along a central axis in the dike. The micas are of the usual kinds and are in no way noteworthy.

As a rule, the pegmatites are more irregular in width than the aplites, though here and there they extend for considerable distances

[a] Watson, T. L., Mineral resources of Virginia, 1907, pp. 276-285, references cited. Kunz, G. F., Bull. North Carolina Geol. Survey No. 12, 1907, pp. 25-28. Graton, L. C., and Lindgren, Waldemar, Bull. U. S. Geol. Survey No. 293, 1906, pp. 20-22, 35-40, 42-43, 53-54, 57. Keith, A., Cranberry folio (No. 90), 1903; Mount Mitchell folio (No. 124), 1905; Pisgah folio (No. 147), 1907, Geol. Atlas U. S., U. S. Geol. Survey.

with remarkable regularity. Some dikes are very extensive, are apparently deep seated, and are of aqueo-igneous origin. Others are small, are surrounded entirely by the granite, and probably denote true veins of segregation. Locally they conform to the joint courses, and in some of the gneisses they are insinuated in the planes of the schistosity, but at many places they apparently do not conform to any definite or fixed direction but cut the granite at random and at all angles.

The pegmatites in some localities are of different periods of formation. In the Richmond (Va.) granite area[a] there are three granites (including the granite gneiss), representing as many periods of intrusion, each of which was accompanied by the formation of pegmatites. The structural relations of the pegmatites to the granites in the Richmond area are shown in figures 4, 5, and 7.

Faulting has been observed in the pegmatites at the Donald quarry (fig. 8) in the Richmond area; in the large granite exposures on the Adams place near Clover, in York County, S. C., and at the following quarries in North Carolina: The Raleigh City quarry; the Carrigan quarry, 3 miles northeast of Mooresville, Iredell County; and the Walker quarry, 1½ miles southeast of Ridge Summit station, Guilford County. The displacement amounts to only a few inches, and in each locality the faulting occurs at the point of intersection of one pegmatite by another.

Granite.—The granite dikes differ from those of aplite and pegmatite in being formed of fine or medium grained granite, and they correspond in composition and otherwise to the normal granite. They vary in width from a few inches to 40 feet as an extreme, near Camak, Ga.; usually they vary from 4 to 12 inches. They are dark gray in color and fine to medium grained in texture, and are composed of potash (orthoclase and microcline) and soda-lime (oligoclase) feldspars, quartz, and biotite as the essential minerals, together with the usual microscopic accessory minerals.

Granite dikes are typically developed in some of the granite quarries of Maryland, Virginia, North Carolina, and Georgia. The more important localities are the following: Maryland, Weber's quarry at Ellicott City, and the railroad cut at Dorsey Run; Virginia, Davis and Cartright quarries, near Fredericksburg; North Carolina, Greystone quarries in Vance County, and Mount Mourne in Iredell County; Georgia, Sparta quarries in Hancock County, near Camak, and at Holders Mill in Warren County, and the Odessa quarry in Meriwether County.

[a] Watson, T. L., Lithological characters of the Virginia granites: Bull. Geol. Soc. America, vol. 17, 1906, pp. 536-539.

A chemical analysis of specimens collected from a 40-foot dike of fine-grained dark-gray granite cutting porphyritic granite gneiss near Camak, Warren County, Ga., yielded the following results:

Analysis of granite dike near Camak, Ga.

[T. L. Watson, analyst.]

Silica (SiO_2)	68.76
Alumina (Al_2O_3)	16.80
Iron oxide (Fe_2O_3)	.99
Lime (CaO)	2.72
Magnesia (MgO)	1.00
Soda (Na_2O)	4.82
Potash (K_2O)	3.70
Ignition	.29

A chemical analysis of selected specimens from different parts of light-colored granite dikes penetrating massive granite and gneiss in the railroad cut at Dorsey Run station, Howard County, Md., gave the following results.[a]

Analysis of granite dikes at Dorsey Run, Md.

[W. F. Hillebrand, analyst.]

Silica (SiO_2)	70.45
Alumina (Al_2O_3)	15.98
Ferric oxide (Fe_2O_3)	.75
Ferrous oxide (FeO)	1.84
Magnesia (MgO)	.77
Lime (CaO)	2.60
Soda (Na_2O)	3.83
Potash (K_2O)	3.59
Water (H_2O)	.43
Lithia (Li_2O)	Trace.
	100.26

BASIC DIKES.

Dikes of basic igneous rocks, principally diabase or its altered form, penetrate the granite in many localities, especially in North Carolina and to a smaller extent in South Carolina and Georgia. In several of the North Carolina granite quarries as many as half a dozen dikes were observed in a single quarry. The dikes are rarely 50 feet across and usually are less than 4 feet.

Lithologically two types are indicated. The principal type is usually an unaltered massive rock, thin sections of which display the mineralogy and texture of diabase. The pyroxene in this type may be considerably altered in some of the dikes, and in hand specimens the rock has a pronounced greenish color, from the amount of chlorite present. The other and less abundant type is more or less completely thinly schistose, is largely composed of hornblende with some

[a] Keyes, C. R., Fifteenth Ann. Rept. U. S. Geol. Survey, 1895, pp. 722, 723.

feldspar and quartz, and may contain much pyrite; it is, therefore, a typical amphibolite.

The structural relations of the dikes to each other and to the inclosing granites clearly indicate at least two different periods of formation. In some places both the inclosing granite and the dike are schistose in structure, indicating intrusion of the dike material into the granite prior to the period of dynamic disturbance that induced schistosity in the two rocks. These dikes are regarded as pre-Newark in age. In many localities, however, the dike rock is entirely massive and the granite schistose in structure, indicating that the dike material was intruded into the granite after the period of dynamic disturbance. A few of these dikes have been traced from the granites into the Triassic sandstones along the eastern border of the Piedmont region, and are therefore of Mesozoic age.

In the North Carolina quarries conditions are more favorable for studying the relations of the basic dikes to joint structure than in the granite areas of the other Southern States. Of 71 dikes measured in the North Carolina quarries, 37 lie in the northwest quadrant and 22 in the northeast, 13 have a north-south course and 2 an east-west one. Likewise, measurements of 136 joints show that 44 lie in the northwest quadrant and 57 in the northeast, and that the remainder have north-south and east-west courses. Furthermore, in nearly every quarry exposing basic dikes the strike of the dikes and that of one set of joints were coincident, probably indicating that for the North Carolina areas the jointing has exercised some influence on the direction of the dikes.[a]

QUARTZ VEINS.

Quartz veins of large dimensions are numerous over the crystalline region of the Southern States, but they are rather exceptional in the granite quarries of that region. In a number of the North Carolina quarries and in the Port Deposit quarries, Maryland, quartz veins of small dimensions have been observed. These commonly occur in those quarries in North Carolina where pegmatite dikes are abundant. The quartz veins are more or less closely associated with the pegmatites, and do not exceed a few inches in width. The quartz composing the veins is of the usual clear vitreous variety.

In the Columbia quarries of Fluvanna and Goochland counties, Va., quartz veins up to 2 feet wide are abundant. They are very irregular in thickness and inclose thin seams of chlorite (from biotite) along central and contact positions.

[a] Watson, T. L., and Laney, F. B., with the collaboration of Merrill, G. P., The building and ornamental stones of North Carolina: Bull. North Carolina Geol. Survey No. 2, 1906, pp. 184–187.

BASIC SEGREGATIONS (KNOTS).

In many of the quarries the granite contains dark-gray or black basic segregations (knots) of fine-grained texture, formed from the cooling magma. The segregations are finer grained and of darker color than the granite in which they occur. Thin sections show the same essential minerals as in the granite but in different proportions, the dark ferromagnesian minerals, biotite and hornblende, or both, in large excess, with less quartz and feldspar. Some segregations are so fine grained and so very dark in color that it requires very close naked-eye examination to detect other minerals than the ferromagnesian silicates. In outline the knots are usually circular or elliptical, much-elongated masses, ranging in diameter from less than an inch to several feet.

The distribution of the segregations in the granite is subject to considerable variation, but is always irregular and without definite order or orientation. From some quarries they are entirely absent, in others they are developed only locally, and in others still they are so abundant as to disfigure the rock and exclude it from use for the higher grades of work. The segregations appear to be most abundantly developed in the hornblende-biotite granites, especially those of the Falls Church area in Virginia and the Mecklenburg County areas in North Carolina, where many of them are large.

The following table shows the percentage of silica in and the specific gravity of basic segregations in granite.[a]

Silica percentage and specific gravity of knots.

Locality.	Silica.		Specific gravity.	
	Granite.	Segregation.	Granite.	Segregation.
Port Deposit, Maryland	73.70	62.20	2.69	2.83
Peterhead, Scotland	73.70	64.39	2.69	2.73
Shap Fell, Westmoreland	69.78	56.95	2.69	2.77
Gready, Cornwall	69.64	65.01	2.72	2.73
Barr-Andlan, Alsace	68.97	57.89	2.68	2.78

[a] Bascom, F., Maryland Geol. Survey, Cecil County, Md., 1902, p. 112.

INCLUSIONS.

Inclusions are irregular fragments of country rock of all sizes and shapes that have been torn off and incorporated in the granite during its intrusion. They not uncommonly closely resemble the basic segregations (knots) described above, but can usually be distinguished from them by their different microscopic structure. Inclusions of this kind occur here and there in the granites of the Southern States, but are especially well marked in the granites of the Woodstock and Sykesville districts, Maryland.[a] At Woodstock the inclusions are chiefly irregular blocks of gneiss, 6 to 8 or even 10 feet in size. Their

[a] Keyes, C. R., Origin and relations of central Maryland granites: Fifteenth Ann. Rept. U. S. Geol. Survey, 1895, pp. 723-724, 726-729.

outlines are sharply defined against the granite which contains them. In the Sykesville district the inclusions comprise fragments of all sizes and shapes, of limestone, soapstone, pyroxenite, vein quartz, and hornblende and biotite gneisses.[a]

In the Richmond-Fredericksburg area, Virginia, the dark-blue gray granite in some of the quarries contains inclusions of the massive light-gray granite and of the gneiss. The foliation of the gneiss inclusions incorporated in the granite at the McGowan quarry is entirely preserved (Pl. XII, *B*).

In the Carolinas and Georgia granite areas inclusions have been noted but are less numerous and, with several exceptions, are not so pronounced in character as in the Maryland and Virginia areas.

MINERALS ON JOINT FACES.

The surfaces of the joint planes in the granites of the region discussed in this bulletin are at many places coated with minerals which occur but sparsely or not at all in the granite. Generally the coat consists of the barest film or veneer of a yellow, yellowish-green, or reddish mineral substance, which, as a rule, is probably damourite, in some places epidote, or a mixture of the two, being a dynamic alteration product resulting from movement in the granite mass. At the old state (Middendorf) quarries, near Granite station, Virginia, the joint faces are coated here and there with radiating tufts or clusters of stilbite, a hydrous silicate of alumina, lime, and soda. Joints in some of the North Carolina quarries are coated with pyrite, which has probably resulted from infiltrations along the joint courses.

At Stone Mountain, Ga., the minerals uranophane[b] (CaO, $2UO_3$, $2SiO_2+6H_2O$) and hyalite ($SiO_2 . nH_2O$, opal) occur as incrustations, coating the faces of many of the joints that cut the light-gray biotite-bearing muscovite granite. The uranophane is of yellow color and the coating of it does not exceed one-eighth to one-sixteenth inch in thickness, and is usually less. It is tipped or coated with clear, colorless, and transparent droplike globules of hyalite. The two minerals are so intimately associated that it is almost impossible to effect a complete separation of them.

A chemical analysis of the uranophane by Packard gave:

Analysis of uranophane from Stone Mountain, Ga.

SiO_2	18.55
$U(UO_4)_2$	47.18
$(UO_2)_2$, Fe_2O_3, P_2O_5	4.95
Al_2O_3	6.33
CaO	6.64
MgO	1.98
H_2O (ignition)	13.28
	98.91

[a] Keyes, C. R., Origin and relations of central Maryland granites: Fifteenth Ann. Rept. U. S. Geol. Survey, 1895, pp. 726–729.

[b] Watson, T. L., On the occurrence of uranophane in Georgia: Am. Jour. Sci., 4th ser., vol. 13, 1902, pp. 464–466.

In Maryland G. H. Williams[a] reported the following minerals on the surfaces of the joints that intersect the gneiss in the large quarries on Jones Falls and Gwynns Falls, at the northern and western limits of the city of Baltimore: Haydenite (chabazite), laumontite, harmotome (or phillipsite?), stilbite, beaumontite (heulandite), siderite, pyrite, barite, halloysite, epidote, garnet, and tourmaline.

WEATHERING.

When exposed for a sufficient length of time to the atmosphere all rocks undergo decay, the siliceous crystalline rocks like granite being converted superficially into a loose, incoherent mixture of ferruginous sand and clay. As a result of this process of degeneration, or weathering as it is commonly called, the rocks of the Southern States are very generally covered with a mantle of variable thickness of residual materials. Frequently the loose, decayed rock mantle must be removed before quarrying can be commenced. (See Pl. V, *B*.)

Notwithstanding this widespread decay of the rocks over the southern region, exposures of the granite are numerous, presenting a variety of form. They appear chiefly as flat-surfaced masses of variable extent, as large and small bowlders either lying on the surface or partly buried in the residual material (Pls. XVI, *B;* XVII, *A;* XXIII, *A*, *B*), as dome-shaped masses of large and small dimensions having steep or gentle slopes (Pls. XIV, *B;* XVII, *B;* XXV, *A*, *B;* XXVII, *A*), and as low or high ledges along stream courses (Pls. X, XI).

Much has been written recently on the decay (weathering) of granite, but it will suffice here to give only some of the more important references to the literature:

JULIEN, ALEXIS A. The durability of building stones in New York City: Tenth Census, vol. 10, 1884, pp. 370, 371; A study of the New York obelisk as a decayed bowlder, Annals New York Acad. Sci., vol. 8, 1893, pp. 93–166.

KEYES, C. R. The origin and relations of central Maryland granites: Fifteenth Ann. Rept. U. S. Geol. Survey, 1895, p. 725; Surface disintegration of granitic masses: Proc. Iowa Acad. Sci., vol. 1, pt. 3, 1893, pp. 22–24; Secular decay of granitic rocks, Proc. Iowa Acad. Sci., vol. 2, 1895, pp. 27–31.

MERRILL, GEORGE P. Stones for building and decoration, 3d ed., New York, 1903, pp. 418–446; The physical, chemical, and economic properties of building stone: Maryland Geol. Survey, vol. 2, 1898, pp. 92–94; A treatise on rocks, rock weathering, and soils, 2d ed., New York, 1906, pp. 185–195, 231–232; Disintegration of the granitic rocks of the District of Columbia: Bull. Geol. Soc. America, vol. 6, 1895, pp. 321–332.

WATSON, THOMAS L. A preliminary report on a part of the granites and gneisses of Georgia: Bull. Georgia Geol. Survey No. 9–A, 1902, pp. 298–348; Weathering of the granitic rocks of Georgia: Bull. Geol. Soc. America, vol. 12, 1901, pp. 93–108.

The views shown in Plates V, *A*, *B*, and XVII, *A*, indicate the mode of weathering usually characteristic of granites, particularly where

[a] Notes on the minerals occurring in the neighborhood of Baltimore, 1887, 17 pages. (Quoted by Mathews, E. B., op. cit., p. 164.)

traversed by joints. Joints are easy lines for the percolation of surface waters, which move downward along the vertical joints and laterally along the horizontal joints, producing disintegration and decomposition of the granite, extending inward from the joint surfaces. The incipient stage of granite weathering may be observed in any exposed granite ledge by the whiteness and opacity of the feldspars, the rock having undergone kaolinization from hydration. The amount of water increases rapidly as decomposition advances.

In the more advanced stages of weathering, solution and oxidation, promoted through atmospheric waters, become dominant factors in the process. As a result of these changes, disintegration and decomposition, the granite is finally reduced to sand and clay, more or less discolored by iron oxides set free through decomposition of iron-bearing minerals, such as biotite, hornblende, etc.

The weathering of siliceous crystalline rocks like granite involves the following chemical changes: A loss in silica, a greater proportional loss in lime, magnesia, and the alkalies (soda and potash), and a proportional increase in the amounts of alumina and sometimes of iron oxide.[a] In extreme cases the total loss may be nearly 75 per cent of the entire rock mass,[b] though it rarely amounts to more than 60 per cent. Careful study of District of Columbia granites by Merrill and of Georgia granites by the writer shows the total losses produced by chemical decay (decomposition), calculated from chemical analyses of the fresh and corresponding decayed rock, to be as follows:

Total percentage losses accompanying the decay of granites.

DISTRICT OF COLUMBIA.[c]	
Foliated gray micaceous granite	13.79
GEORGIA.[d]	
Light-gray biotite granite, Swift & Wilson quarry, Elberton	7.92
Blue-gray biotite granite, Lexington Blue Granite quarry, Lexington	14.56
Porphyritic biotite granite, Heggie Rock, Columbia County	15.84
Biotite granite gneiss, Crossley quarry, Lithonia	26.69
Porphyritic biotite granite gneiss, Brinkley Place, Camak	34.04
Porphyritic biotite granite, McCollum quarry, Coweta County	35.07
Biotite granite, Cole quarry, Newnan	38.45
Biotite granite, Coggins quarry, Oglesby	44.72
Biotite granite, Greenville Granite Company's quarry, Greenville	71.84

[a] Merrill, G. P., A treatise on rocks, rock weathering, and soils, 2d ed., New York, 1906, p. 220.

[b] Watson, T. L., A preliminary report on a part of the granites and gneisses of Georgia: Bull. Geol. Survey Georgia No. 9-A, 1902, pp. 312-317.

[c] Merrill, G. P., Bull. Geol. Soc. America, vol. 6, 1895, pp. 321-332.

[d] Watson, T. L., Bull. Geol. Survey Georgia No. 9-A, 1902, p. 333.

It should be remarked that decay was not equally advanced, chemically, in these granites. However, in each one the decayed product represented loose material. Those granites showing the smallest percentage loss listed in the table crumbled largely through physical changes (disintegration). The most advanced stage in chemical decay (decomposition) is represented in the granite from the Greenville Granite Company's quarry, Greenville, Ga.

An interesting form of weathering very frequently observed in the southern granites is illustrated in Plate V, *A*, *B*, which shows granite bowlders consisting peripherally of concentric shells, which break off one after another in passing from the surface toward the center. This form of weathering has resulted from the more rapid decay on the edges and corners than on the flat sides of the jointed granite blocks, the blocks being gradually rounded and formed into bowlder-like masses of varying size.

DISTRIBUTION OF THE GRANITIC ROCKS.

Reference to the map (fig. 1) will show that the region discussed includes the southern half of the northern Appalachians and all of the southern Appalachians. The boundary between the northern and southern Appalachians [a] is a line drawn from the most easterly point of Kentucky southeastward across Virginia and North Carolina to Cape Fear, on the Atlantic. The two divisions show decided differences in the forms of relief and in the drainage.

The region is divided into three well-defined physiographic provinces, which are intimately related to its geologic structure. These are, named in order from southeast to northwest, (*a*) the Coastal Plain; (*b*) the Piedmont Plateau; and (*c*) the Appalachian Mountains. The three provinces observe a general parallelism with each other and with the present coast line, trending northeast and southwest.

COASTAL PLAIN.

The easternmost of the provinces, known as the Coastal Plain, comprises the area between the Atlantic Ocean and a line passing in a general southwesterly direction from a point near New York City to Columbus, Ga., through or near Trenton, Philadelphia, Baltimore, Washington, Richmond, Petersburg, Raleigh, Columbia, Augusta, Macon, and Columbus. There is a general widening of the Coastal Plain region to the southwest from about 100 miles in northern Maryland to 200 miles or more in Georgia. It is characterized as a low, flat-lying area, whose elevation gradually increases from sea level at the coastal border to 400 or 500 feet at its western edge. It is com-

[a] Hayes, C. W., Physiography of the United States; The southern Appalachians: Nat. Geog. Mon., No. 10, New York, 1896, p. 305.

posed of loose and partly consolidated sediments, chiefly sands, clays, and marls, which preserve a gentle seaward dip.

No granites are found within the Coastal Plain except in small areas of a few inliers of the Piedmont crystalline rocks, which are exposed mainly along the stream courses near its western margin by stripping off the veneer of loose sediments. The inliers are composed, either partly or wholly, of granite, and quarries are opened in a few of these areas in Maryland, Virginia, the Carolinas, and Georgia.

PIEDMONT PLATEAU.

The middle province, known as the Piedmont Plateau, is named from its position along the eastern foot of the Appalachian ranges. It is bordered by the Coastal Plain on the east and extends to and along the southeastern base of the Appalachian Mountains. It averages about 50 miles in width in Maryland but broadens toward the southwest until it reaches a maximum of approximately 125 miles in North Carolina; it narrows through South Carolina and Georgia, and finally passes beneath the Paleozoic and Coastal Plain sediments in central Alabama. (See fig. 2.)

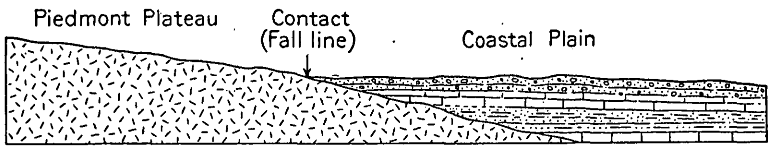

FIGURE 2.—Generalized section showing relations of the Coastal Plain formations to the Piedmont Plateau crystalline rocks.

The surface of the Piedmont Plateau shows a gentle eastward slope from an altitude of 1,000 to 1,200 feet at the western edge to one of 400 to 500 feet along the eastern margin. Geologically the region is formed of a complex of highly metamorphosed sedimentary and igneous rocks of Paleozoic and pre-Paleozoic age, largely concealed beneath a cover of residual material due to decay. Because of the thick mantle of loose residual material exposures of the fresh rock are less numerous than they are farther north.

The Piedmont Plateau differs markedly from the Coastal Plain in the nature and origin of its surface features and in the age, kinds, and structure of its rocks. Its surface is not a smooth plain but is broadly undulating or rolling, and the streams cross it in rather deep and narrow channels. Less reduced areas of the harder rocks, rising several hundred feet above the upland surface of the plateau, are not uncommon over the region. Toward the eastern margin the hills rise but little above the plateau surface but as the western margin is approached they rise higher and higher above the general surface until, in North Carolina, a few of them reach elevations of several thousand feet. Through the Carolinas and a part of Georgia the western limit of the plateau is irregular and is marked by the change from the general sloping surface to the steep slopes of the Blue Ridge and its outliers. Farther south in Georgia and Alabama its western limit is less well defined, owing to the fact that the surface of the mountain belt has been worn down nearly to that of the plateau. The transition from the rocks of the plateau along its northwest margin to the metamorphosed strata of the mountain province is less distinctly marked and not so abrupt as the change from the Coastal Plain sediments.

The rocks of the Piedmont Plateau are wholly crystalline and are derived in part from original sediments and in part from original igneous masses. They include chiefly crystalline gneisses and schists associated with crystalline limestones, quartzites, and phyllites, intruded by granitic and gabbroitic rocks and more basic rocks (peridotites and pyroxenites). The gabbroitic rocks include a wide range of types, many of which are admirably suited for structural purposes and have been or are being quarried in places for building and ornamental stone. The abundance, variety, and general excellence of the granites make them the most important for use in commercial work. The entire production of granite from the southeastern Atlantic States is from the Piedmont province.

Over parts of the Piedmont region in Maryland, Virginia, and North Carolina Newark (Triassic) sediments, including sandstones, conglomerates, and shales, have been deposited. These sediments are broken by faults and are penetrated by large and small dikes of diabase, which are quarried in places, the product being known to the trade as "black granite."

As a rule, the original features of the rocks composing the Piedmont Plateau have been largely changed by profound metamorphism since the formation of the rocks. The principal changes have been recrystallization and textural modification. The most marked textural change has been the development of pronounced foliation or schistosity in most of the rock types. The foliation or schistosity of the rocks is in general coincident with the trend of the province, northeast and southwest, but varies in dip. It is present in both the sedimentary and the igneous rocks. In the former the foliation is so strongly developed that it largely obscures the original bedding planes, and frequently renders their determination impossible. In the igneous rocks foliation is in places so pronounced as entirely to obscure the original appearance of the rock; in other places all gradations between the unaltered massive rock and the foliated types may be traced.

The streams crossing the Piedmont Plateau have rapid currents as far as its eastern border, but even the largest rivers are not navigable. Several of the easternmost areas, however, in Maryland

and Virginia more especially, lie adjacent to tide water, where shipment by water is possible over the larger navigable streams which cross the Coastal Plain region. But, notwithstanding the favorable location of these areas, practically all the quarried material in the Piedmont region is shipped by rail, largely because of the excellent transportation facilities afforded by the numerous lines of railway which traverse nearly all parts of the region.

Granites are extensively worked at the following localities in the Piedmont Plateau south of Pennsylvania: At Port Deposit, Guilford, and Woodstock, in Maryland; near Fredericksburg, Richmond, and Petersburg, in Virginia; near Mount Airy, Salisbury, and Greystone, in North Carolina; near Beverly, Columbia, Heath Springs, Lexington, and Winnsboro, in South Carolina; at Stone Mountain, Lithonia, Oglesby, and Sparta, in Georgia; and in numerous minor areas. Plates I, VII, XIII, XXI, and XXIV show the location, by States, of the granite quarries from Pennsylvania to Alabama.

APPALACHIAN MOUNTAINS.

The Appalachian Mountains[a] region is bordered by the Piedmont Plateau on the southeast, and extends northwestward to the eastern limits of the greater Appalachian Valley, comprising a mountainous belt of variable width. It extends southwestward from the high land of South Mountain in Pennsylvania, through Maryland, Virginia, and western North Carolina, and terminates in northern Georgia and eastern Alabama. Throughout their extent the eastern members of this belt are generally known as the Blue Ridge. Maximum heights of 6,600 and 6,700 feet are reached in western North Carolina, and there is a gradual lowering toward Alabama and Virginia. The mountain belt widens to its greatest width of about 70 miles in western North Carolina. Its southeastern edge is marked by the southeastern front of the Blue Ridge, and the northwestern edge by the somewhat higher Unaka Range. It merges into the Blue Ridge toward the Virginia line, and terminates southwestward in northern Georgia. Between the two ranges the area is occupied by numerous groups of irregular mountain masses which rise to elevations of 4,000 to 6,700 feet. The mountains are rugged and deeply dissected.

Roanoke River and the major streams north of it, like the James, Potomac, and Susquehanna, rise west of the Blue Ridge and flow southeastward across it into the Atlantic Ocean. New River, which gathers its waters in the Blue Ridge region of northwestern North

[a] Hayes, C. W., Physiography of the United States: The southern Appalachians, 1896, pp. 305-336.
Willis, Bailey, Physiography of the United States: The northern Appalachians, 1896, pp. 169-202.
Powell, J. W., Physiography of the United States: Physiographic regions of the United States, 1896, pp. 65-100.
Keith, Arthur, The Appalachian mountains and valleys: Science, n. ser., vol. 25, 1907, pp. 865-867.

Carolina, follows a northwestward course across the greater valley and the plateau into the Ohio. From Roanoke River southwestward the crest of the Blue Ridge marks the divide between the Atlantic and the Gulf drainage. The southeastern slopes of the Blue Ridge are usually steep, in contrast with the more gentle northwestern slopes.

Igneous rocks, comprising acidic and basic volcanic rocks and granites of pre-Cambrian (Algonkian) age, make up a considerable part of the mountain belt (Blue Ridge) in Maryland and Virginia.[a] The granites are closely associated with and cut the volcanic rocks, forming long, narrow belts, which vary in width up to 6 miles. The granites vary in texture and composition and, as a rule, are greatly changed by metamorphism, many of them resembling schists.

Keith's studies [b] of the region farther southwest, in the western Carolina portion of the belt, disclose the fact that the main mass of the mountains is composed of gneisses, through which have been injected igneous rocks of various descriptions, mainly granites. According to Keith, these rocks are, for the most part, Archean, but include some also of Algonkian age. The granites, which are very abundant over the Carolina portion of the mountain belt, vary in texture and color and show marked evidences of metamorphic changes. They are described in some detail on pages 153-161.

Over many parts of the mountain belt, but more especially over the western Carolina portion, granites of excellent quality are to be found. These, however, have nowhere been developed, except that here and there a quarry has been opened to supply a very local trade. The remoteness of many of them from lines of transportation, the ruggedness of the region in general, and the practical lack of demand for stone of this kind within the belt have been the principal factors against development.

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[a] Keith, Arthur, Geology of the Catoctin belt: Fourteenth Ann. Rept. U. S. Geol. Survey, 1894, pp. 285-395.

[b] Keith, Arthur, Cranberry folio (No. 90), 1903; Asheville folio (No. 116), 1904; Mount Mitchell folio (No. 124), 1905; Nantahala folio (No. 143), 1907; Pisgah folio (No. 147), 1907: Geol. Atlas U. S., U. S. Geol. Survey.

CHAPTER II.

THE GRANITES OF MARYLAND.

THE MARYLAND PIEDMONT REGION.

The Maryland portion of the Piedmont province embraces a small trapezoidal area which is bounded by the fall line on the east, Catoctin Mountain on the west, Potomac River on the south, and the southern boundary of Pennsylvania on the north.[a] According to Abbe, its topography embraces features of three different classes—the broad, rolling upland surface, the valleys carved in the upland, and the residual masses which rise above the upland. It is divided near its central portion by an area of high land known as Parrs Ridge into an eastern and western district, each of which has its own peculiar characters. It has an approximate total area of 2,500 square miles, including Cecil, Harford, Baltimore, Howard, and Montgomery, and parts of Frederick and Carroll counties. Parrs Ridge forms the divide between the streams flowing eastward across the Piedmont into Chesapeake Bay direct, and those which flow westward to the Monocacy and thence to the bay.

It is in the eastern division of the Piedmont that the granites are found. The drainage of this district flows to the east and southeast. Susquehanna and Potomac rivers, which drain directly into Chesapeake Bay, traverse it on its northern and southern boundaries. Among the larger intermediate streams which head on Parrs Ridge are Patuxent, Patapsco, and Gunpowder rivers. These streams are not navigable beyond the western limits of the fall line, and material quarried in that region must be shipped either by rail, canal, or wagon routes.

To the east of Parrs Ridge the rocks consist of highly metamorphosed sediments and a complex of intruded igneous masses which have been more or less metamorphosed, rendered schistose, or laminated. The highly metamorphosed sediments[b] comprise the following formations, which, according to the Maryland Geological Survey, range in age from Archean to Ordovician: The Baltimore gneiss, the Cockeysville marble, the Wissahickon mica gneiss, the Octoraro schist, the Cardiff quartzite, and the Peachbottom slate. The igneous rocks comprise extensive areas of gabbros, granites, and other plutonic types. The gabbros were intruded earlier than the

[a] Abbe, Cleveland, jr., A general report on the physiography of Maryland, Maryland Weather Service, 1899, p. 117.

[b] Maryland Geol. Survey, vol. 6, 1906, pp. 105-113.

granites, but the exact period of intrusion of the igneous masses is still somewhat uncertain. In addition to these, small dikes of acidic volcanic rocks (metarhyolite) occur along the lower Susquehanna in the vicinity of Frenchtown and Havre de Grace, and a series of Mesozoic diabase dikes can be traced with interruptions across the entire eastern part of the Piedmont district.[a]

The western division of the Maryland Piedmont extends from Parrs Ridge to Catoctin Mountain. On its east side the rocks are scarcely distinguishable from those of the eastern division, but in the western part the rocks are much less metamorphosed. Semicrystalline sediments, chiefly limestone and sandstone of Cambro-Ordovician and Mesozoic age, and igneous rocks, chiefly Archean basic and acidic volcanic rocks and Mesozoic diabase, compose the rocks of this division.[b]

The rocks east of Parrs Ridge are more crystalline and the folding is a little more pronounced than in the western division of the Piedmont. The older rocks have suffered extreme metamorphism which has produced in them a marked lamination or schistosity, accompanied by recrystallization. Schistose structures, having a general northeast-southwest trend and variable dip, are developed in both the sedimentary and the igneous rocks.

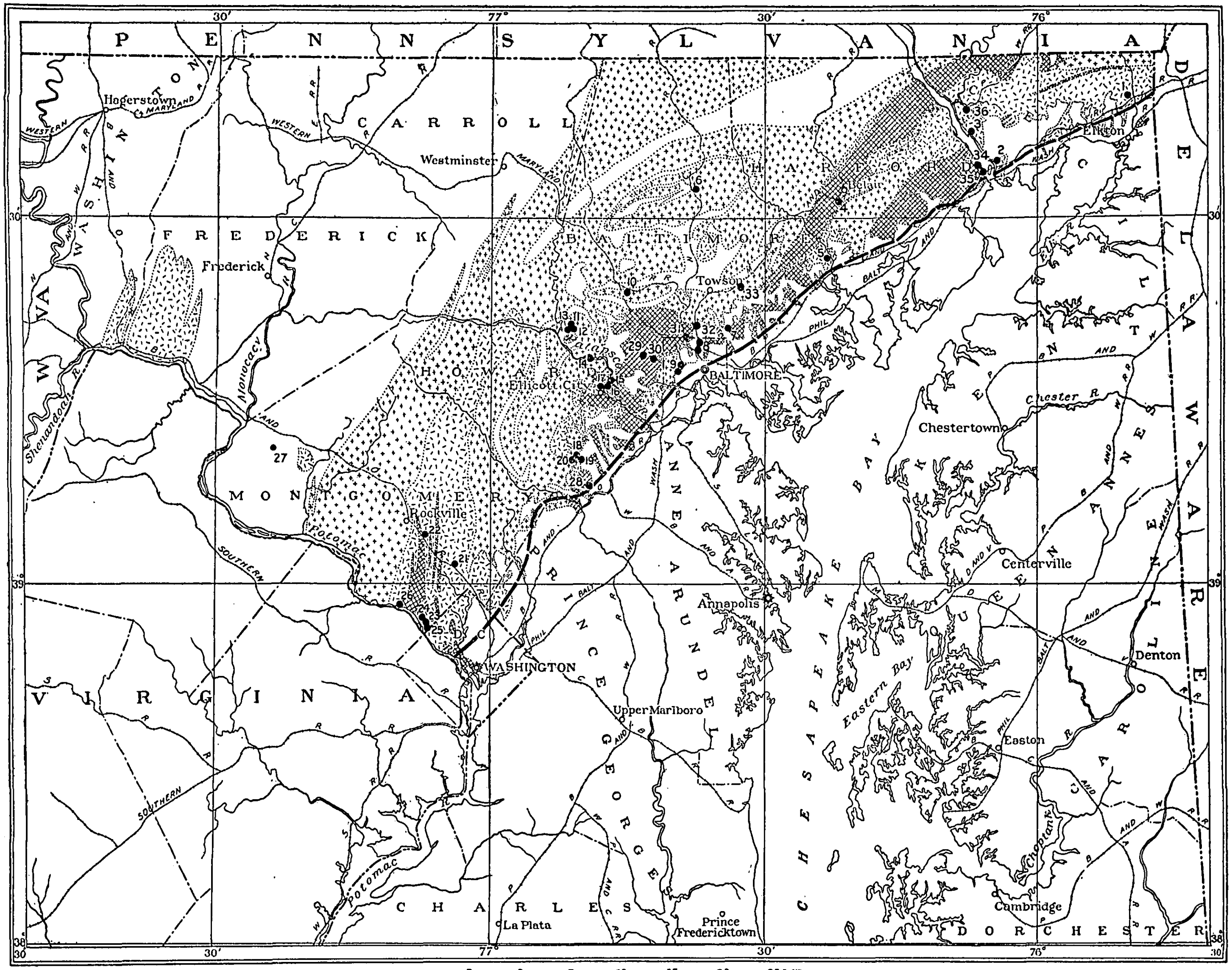
DISTRIBUTION OF THE GRANITES.

The granites and gneisses of Maryland are limited to the Piedmont Plateau province (see Pl. I); and within this region the quarrying industry is confined to a triangular area between the Coastal Plain on the east and Parrs Ridge on the west, including the whole or parts of Cecil, Harford, Baltimore, Howard, and Montgomery counties. The granites occupy several distinct areas in the eastern division of the Piedmont Plateau. The largest of these areas extends from Sykesville southward to Washington and across the Potomac into Virginia. The most important, economically, is the lenticular area that extends southward from Rising Sun through Port Deposit and along the southwest side of Susquehanna River. Of the fifteen areas where granite is prominently developed, there are at least five which include quarries of considerable economic importance.[c] These are, named from north to south, (1) Port Deposit, (2) Frenchtown, (3) Ellicott City, (4) Woodstock, and (5) Guilford. Besides these there are several minor areas in which quarries have been worked from time to time to supply the local demand for stone. The most important of the smaller areas is that of Dorseys Run, on the Baltimore and Ohio Railroad between Ellicott City and Woodstock.

[a] Maryland Geol. Survey, vol. 6, 1906, pp. 113-118.

[b] Idem, pp. 118-123.

[c] Mathews, E. B., An account of the character and distribution of Maryland building stones, together with a history of the quarrying industry: Maryland Geol. Survey, vol. 2, 1898, p. 138.



LEGEND

Granite quarries (numbers refer to lists)

Granite

Diorite and gabbro

Schists

Fall line

QUARRIES

1 Baldwin
2 Frenchtown (Perryville Granite Co., Luken & Yerkes)
3 Port Deposit (McClenahan Granite Co.)
4 Amoss
5 Franklinville (Cotton Duck Factory Co.)
6 Phœnix (J. Baker)
7 Rapsburg
8 Jones Falls (Gatch, Atkinson, Schwind, Peddicord)
9 Gwynns Falls (Schwind, Peddicord, Leonard)
10 Stevenson (Shoemaker)
11 Fox Rock
12 Guilford and Waltersville Granite Co. (Woodstock)
13 Fearing & Atherton
14 Dorsey Run
15 Werner Bros.
16 Gaither
17 Patapsco Quarry Co.
18 Maryland Granite Co.
19 Guilford and Waltersville Granite Co. (Guilford)
20 Guilford Granite and Stone Co.
21 Garrett Park (Riggs)
22 Rockville
23-25 Potomac River Quarries
26 Cabin John (Gilbert)
27 Dickerson (Standard Lime and Stone Co.)
28 Savage, B. F. Pope Stone Co., W. T. Manning
29 Franklin Road (Langley Quarry Co., Maryland Quarry Co., T. R. Martin & Sons)
30 Windsor Hills (Campbell), Dickeyville (Hook & Ford Contracting Co.)
31 Woodberry (Hook & Ford Contracting Co.)
32 Govanstown
33 Lockraven (Conway Co.)
34 Standard Lime and Stone Co.
35 Baltimore and Ohio Railroad
36 Rowlandsville (Thomas S. Gerry, Armstrong & McDowell)

MAP OF MARYLAND, SHOWING DISTRIBUTION OF GRANITE QUARRIES AND OF GRANITE AND GNEISS AREAS.

Based on maps of Maryland Geological Survey, vol 2, 1898; vol. 6, 1906.

The others are Sykesville, Garrett Park and Brookville, Franklinville, Benson, Baldwin station in Cecil County, Texas, and Relay.

Quarries of gneisses of granitic composition have been operated for many years near and in the city of Baltimore, grouped about two centers—Jones Falls and Gwynns Falls, on the north and west sides of the city, respectively.

SCIENTIFIC DISCUSSION.

VARIETIES OF THE GRANITE.[a]

On the basis of mineral composition the Maryland granites are divisible into the following leading types: (1) Biotite granite or granitite, under which most of the granites of the State may be grouped, including Port Deposit, Frenchtown, Woodstock, Dorseys Run, Texas, Ellicott City, and Ilchester among the most important areas. In addition to biotite, the granites of some of the Port Deposit localities, of Woodstock, Dorseys Run, Ellicott City, and Ilchester contains considerable epidote and allanite, and may be designated as allanite-epidote granitite; (2) muscovite-biotite granite, of which the Guilford area is the only typical representative; and (3) hornblende-biotite granite, represented by the granites occurring northeast of Washington, near Garrett Park, and near Rowlandsville, in Cecil County.

Structurally there are three rather well-marked types of the Maryland granites—(1) even-granular (massive) granites; (2) porphyritic granites; and (3) banded or schistose granites (granite gneisses). To these should be added the two subvarieties graphic granite and pegmatite. Quarries are worked in some of the larger pegmatites for feldspar.

MINERAL COMPOSITION.

Conforming with other well-known granites, the Maryland rocks are made up of a mixture of quartz and feldspar with biotite usually as the third essential mineral. Orthoclase, abundant plagioclase (oligoclase), and microcline in variable amount compose the feldspathic constituent. Biotite is an important constituent in all the granites of the State. In some of the areas it is associated with hornblende; in others with muscovite, epidote, and allanite. In the granites near Garrett Park and Rowlandsville hornblende forms an important constituent and is about equal in amount to biotite. At Guilford muscovite occurs with biotite as an important mineral. Besides these there occur magnetite, apatite, zircon, titanite, and locally some other minerals.

[a] Williams, G. H., Petrography and structure of the Piedmont in Maryland: Bull. Geol. Soc. America, vol. 2, 1891, p. 321; The general relations of the granitic rocks in the middle Atlantic Piedmont Plateau: Fifteenth Ann. Rept. U. S. Geol. Survey, 1895, pp. 657–684.

Keyes, C. R., The origin and relations of the central Maryland granites: Fifteenth Ann. Rept. U. S. Geol. Survey, 1895, pp. 714–718.

Examination of the table of analyses of the Maryland granites given below discloses the fact that in about half of them soda is equal to or greater than potash, indicating the prevailingly large quantity of plagioclase (soda-lime feldspar) present in these rocks. Again, one of the most striking features of the Maryland granites is the prevalence of microcline, which has developed in part from orthoclase by pressure metamorphism.

The granites of some of the Port Deposit localities, of Woodstock, Dorseys Run, Ellicott City, and Ilchester,[a] contain a considerable quantity of epidote and allanite as important characteristic constituents, and for this reason they were grouped by Keyes[b] as allanite-epidote granites.

CHEMICAL COMPOSITION.

Variation in the chemical composition of the granites and gneisses of Maryland and the District of Columbia is indicated in the analyses of these rocks, which follow:

Analyses of Maryland and District of Columbia granites and gneisses.

[Analysis 1, by William Bromwell; analyses 2-12, by W. F. Hillebrand; analysis 13, by G. P. Merrill.]

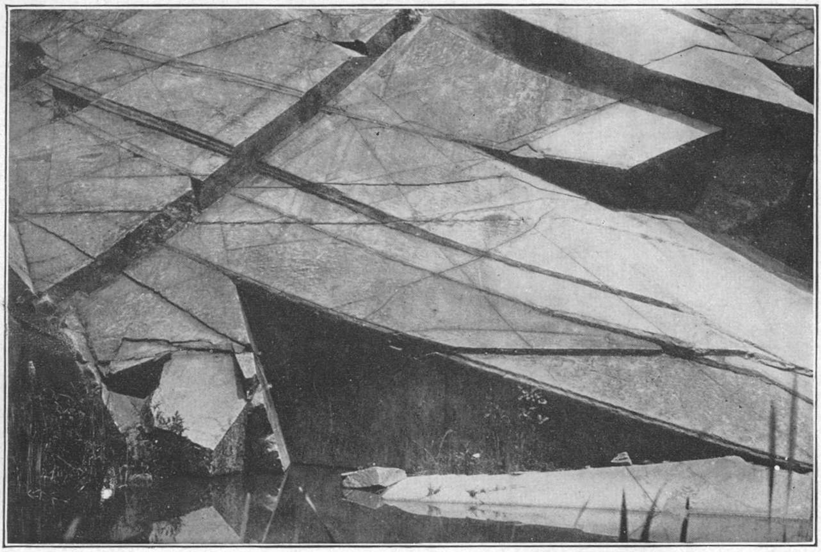
Constituents.	1.[a]	2.	3.	4.	5.	6.	7.	8.[b]	9.[c]	10.[c]	11.[c]	12.[c]	13.[d]
SiO_2	73.69	74.87	72.57	71.79	71.45	70.45	69.33	66.68	62.91	67.22	63.43	78.28	69.33
Al_2O_3	12.89	14.27	15.11	15.00	14.36	15.98	14.33	14.93	19.13	15.34	16.69	9.96	14.33
Fe_2O_3	1.02	Tr.	1.02	.77	2.07	.75	.....	1.58	.98	2.78	3.36	1.85	.....
FeO	2.58	.51	.59	1.12	2.78	1.84	3.60	3.23	3.20	3.41	3.87	1.78	3.60
MgO	.50	.16	.30	.51	1.17	.77	2.44	2.19	1.69	1.65	2.33	.95	2.44
CaO	3.74	.48	1.65	2.50	1.58	2.60	3.21	4.89	4.28	1.36	.80	1.68	3.21
Na_2O	2.81	3.06	3.92	3.09	1.95	3.83	2.70	2.65	3.94	2.00	2.38	2.73	2.70
K_2O	1.48	5.36	4.33	4.75	3.28	3.59	2.67	2.05	3.38	3.26	3.22	1.35	2.67
H_2O- at 110° C. } H_2O+ at 110° C. }	1.06	.66 / .26	.47	.64	1.30	.45	1.22	1.09 / .16	.63	.29 / 1.68	.23 / 2.67	.12 / .83	1.22
TiO_2	.....	.05	.....	.....	.....	.....	.....	.50	.....	.84	.91	.70	Not det.
P_2O_5	.....	.21	.....	.....	.....	.....	.10	.10	.....	.14	.11	.11	.....
MnO	.....	Tr.	.....	.....	.....	.....	.....	.10	.....	.13	.09	.08	.....
BaO	.....	.....	.....	.....	.....	.....	.....	.08	.....	.04	.03	.02	.....
SrO	.....	.....	.....	.....	.....	.....	.....	Tr.	.....	Tr.	Tr.	Tr.	Tr.
Li_2O	.....	Tr.	Tr.	Tr.	Tr.	Tr.	Tr.	Tr.	Tr.	Tr.	Tr.	Tr.	Tr.
	99.77	99.89	99.96	100.17	99.94	100.26	99.26	100.23	100.14	100.14	100.12	100.44	99.60

[a] Mathews, E. B., Maryland Geol. Survey, vol. 2, 1898, p. 142. (See Grimsley, G. P., Jour. Cincinnati Soc. Nat. Hist., vol. 17, 1894.)
[b] Bascom, F., Geology of the crystalline rocks of Cecil County: Cecil County Rept., Maryland Geol. Survey, 1902, p. 120.
[c] Williams, G. H., The general relations of the granitic rocks in the middle Atlantic Piedmont Plateau: Fifteenth Ann. Rept. U. S. Geol. Survey (1895), pp. 670, 672.
[d] Merrill, G. P., A treatise on rocks, rock weathering, and soils, New York, 1906, p. 186.

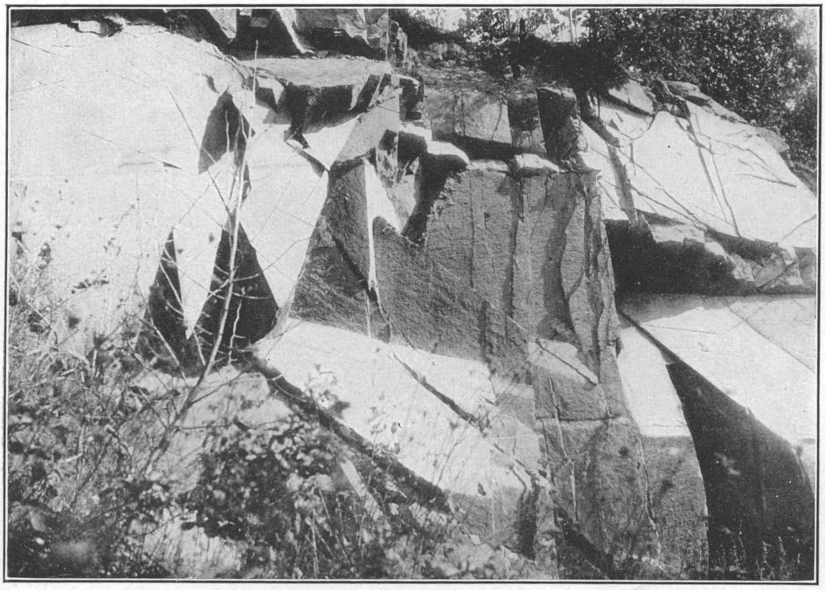
1. Biotite granite (quartz monzonite), Port Deposit, Cecil County, Md.
2. White granite, Brookville, Montgomery County, Md.
3. Muscovite-biotite granite, Guilford, Howard County, Md.
4. Biotite granite, Woodstock, Baltimore County, Md.
5. Biotite granite, Sykesville, Carroll County, Md.
6. Biotite granite dike, Dorseys Run cut, Howard County, Md.
7. Biotite granite gneiss, Broad Branch quarry, District of Columbia.
8. Hornblende-biotite granite, Rowlandsville, Cecil County, Md.
9. Biotite granite, Dorseys Run cut, Howard County, Md.
10. Gneiss from Potomac Stone Company's quarry, 1 mile below the Chain Bridge, District of Columbia.
11. Chloritic gneiss from Emery's store, northwest of Cabin John Bridge, Montgomery County, Md.
12. Gneiss from second lock at Great Falls, Montgomery County, Md.
13. Foliated biotite granite from the District of Columbia.

[a] Hobbs, W. H., Johns Hopkins Univ. Circ., vol. 7, No. 65, 1888, p. 70; Am. Jour. Sci., 3d ser., vol. 38, 1889, p. 223; Tschermaks Min. pet. Mitt., vol. 11, 1890, p. 1.

[b] Keyes, C. R., The origin and relations of central Maryland granites: Fifteenth Ann. Rept. U. S. Geol. Survey, 18 5, p. 717.



A.



B.

QUARRIES NEAR GLEN ECHO, MD.

A. Joints and faults. *B.* Intersecting joints.

The high soda content in the Maryland granites in general has been commented on above. In many of the analyses soda equals or exceeds potash, indicating in these the predominance of plagioclase (soda-lime feldspar) over orthoclase (potassic feldspar), which places the granites with the quartz-monzonite type.

Analysis 12 in the table does not correspond to any known igneous type, but is in close agreement with certain siliceous sediments; as Williams [a] remarks, "so far as the chemical evidence can be relied upon, we may safely regard the rock as of sedimentary origin." The other gneisses represented by analyses in the table are of igneous origin.

STRUCTURAL FEATURES.

JOINTS.

Jointing, both vertical and horizontal, is prominently developed in the Maryland granites (see Pl. II, *A*, *B*), and a third set of diagonal joints is distinct in many of the quarries. The courses of many of the principal vertical joints are N. 30°–35° E., N. 40°–45° E., and N. 55°–60° E.; N. 10° W., N. 40°–45° W., and N. 60°–70° W.; north-south, and east-west. The joints of the dominant system extend approximately northeast and northwest, east-northeast and west-northwest. The spacing of the joints varies considerably, ranging from less than 1 foot to more than 20 feet, but is usually from 6 to 15 feet.

The horizontal joints, prominent in all the larger quarries, separate the granite into sheetlike masses, which usually have their strongest development near the surface, but in some quarries extend to the entire depth of working. Nowhere is this better shown among the Maryland granites than in the old Guilford and Waltersville Granite Company's quarry in the Woodstock area (Pls. IV, *B*; VI, *B*). The sheets may vary from a few inches in thickness at or near the surface to 2 to 10 feet at some distance below the surface. In the quarries on the Baltimore County side of Patapsco River, at Ellicott City, sheeting extends to the depth of working, more than 90 feet, and the sheets range in thickness from 2 to 4 feet. In the quarries of the Woodstock area the sheets are from 2 to 6 feet thick, and in the quarries of the Guilford area from 3 to 10 feet thick. Approximately the same range in thickness is shown in the Port Deposit quarries, one of which has been worked to the extreme depth of 230 feet.

Some movement in the granite masses is indicated in the slickenside joint surfaces of the larger quarries. Slickensides are especially noticed on some of the joint surfaces in the quarries at Port Deposit, Frenchtown, Ellicott City, and Guilford.

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[a] Williams, G. H., op. cit., p. 670.

SCHISTOSITY.

The Maryland granites, and indeed the granites of the Southern States generally, strongly contrast in the amount of foliation secondarily induced in them by pressure metamorphism. The granites of Ellicott City, Woodstock, and Guilford show little or no pressure effects, but are massive. Those near Sykesville, Texas, and Rowlandsville, and the Murdoch Mill area west of Washington are slightly foliated, but not sufficiently so to disguise their essential features. In the Port Deposit region and in the Broad Branch area west of Washington secondary foliation has resulted in a complete rearrangement of the constituents,[a] and the rocks are more properly designated granite gneisses.

In the Piney Run type, which occupies a considerable area south of Laurel and on Potomac River, extreme foliation has obliterated most of the original granite features. Concerning this type Williams says:[b] "It is only because of the abundance of indistinct masses resembling inclusions which are scattered through it that we assume for this rock an igneous origin."

DIKES.

GRANITE.

In some of the granite areas true granite dikes penetrate the rocks into which the granite was intruded and are to be regarded as apophyses. These are described by Keyes[c] as being especially well developed and exposed in the railroad cut at Dorsey Run, where dikes of very light colored, fine-grained granite penetrate gneiss and, as shown in the analyses below, are more acidic than the main massive granite and also finer grained in texture. The more acidic, finer-grained granite dikes also penetrate the more massive granite as well as the gneiss.[d]

Analyses of granite from dikes at Dorsey Run, Md.

Constituents.	1.	2.
Silica (SiO_2)	62.91	70.45
Alumina (Al_2O_3)	19.13	15.98
Ferric oxide (Fe_2O_3)	.98	.75
Ferrous oxide (FeO)	3.20	1.84
Magnesia (MgO)	1.69	.77
Lime (CaO)	4.28	2.60
Soda (Na_2O)	3.94	3.83
Potash (K_2O)	3.38	3.59
Water (H_2O)	.63	.45
Lithia (Li_2O)	Trace.	Trace.
	100.14	100.26

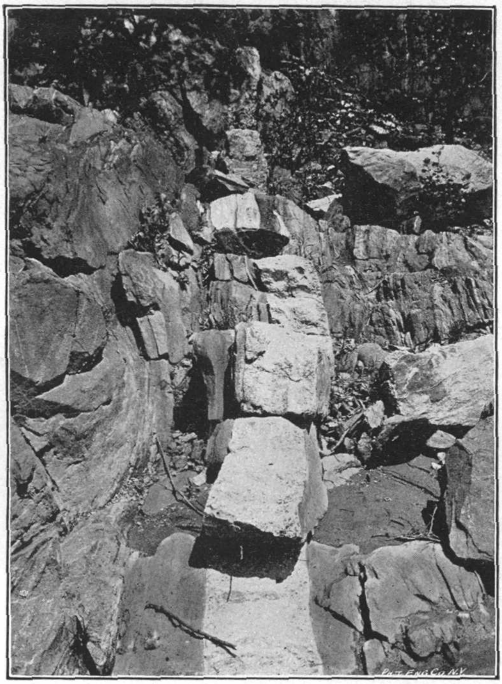
1. Typical granite from selected average specimens of the large granite mass; W. F. Hillebrand, analyst; Fifteenth Ann. Rept. U. S. Geol. Survey, 1895, p. 722.
2. Selected specimens from the light-colored granite dikes; W. F. Hillebrand, analyst; idem, p. 722.

[a] Williams, G. H., op. cit., p. 669.

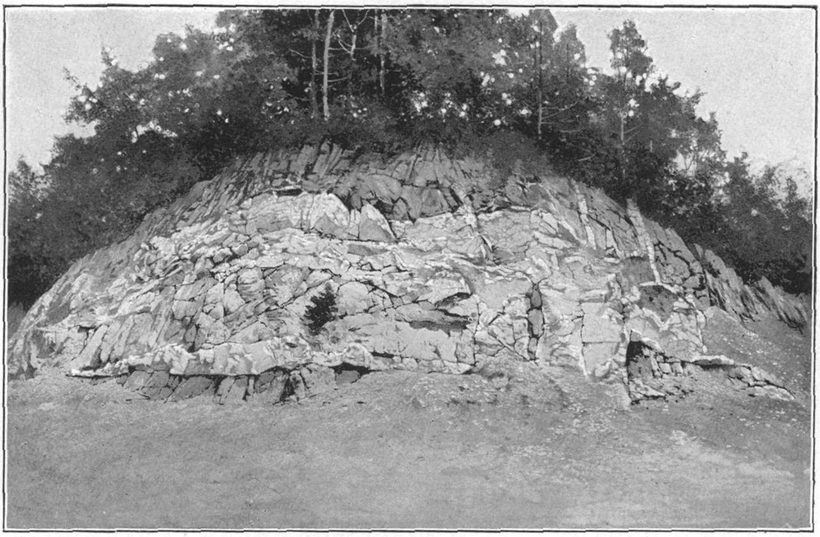
[b] Idem, p. 669.

[c] Keyes, C. R., Fifteenth Ann. Rept. U. S. Geol. Survey, 1895, pp. 722-723.

[d] Fifteenth Ann. Rept. U. S. Geol. Survey, 1895, pl. xxxvii, fig. 3, p. 694.



A.



B.

PEGMATITE DIKES, MARYLAND.

A. Ilchester station. *B.* Orange Grove.

Granite dikes of dark-gray color and fine-grained texture, not exceeding 6 feet in width and striking N. 60° E., penetrate the porphyritic granite of Weber's quarry at Ellicott City. At Port Deposit, in the rear of Mr. McClenahan's residence, the granite is penetrated by a dike of foliated dark basic rock, 7 feet wide and nearly vertical. A second dike of similar character is exposed in the granite cliffs along the path leading from the town to Tome Institute.

PEGMATITE.[a]

Pegmatites and quartz veins are largely developed in the Maryland Piedmont region, where they traverse indiscriminately all the formations of both sedimentary and igneous rocks. The pegmatites differ from the quartz veins mineralogically in the addition of an alkali feldspar and muscovite or biotite. They are essentially very coarse crystallizations of quartz and feldspar aggregates, with more or less mica. In width they vary from a few inches up to several hundred feet (Pl. III, *A*, *B*), and can be traced for considerable distances on the surface. They may either break through or cut across the schistosity of the inclosing gneisses.

Some of the pegmatites have probably had an origin similar to that of the widely distributed quartz veins; others, usually of smaller dimensions and wholly inclosed by the granite mass, have probably been formed by a process of segregation; while still others seem to show equally strong evidence of an intrusive origin. As a rule the rock composing the dikes of an intrusive character is a muscovite granite, essentially similar to the granite which it intrudes, except that it is more acidic. The minerals composing dikes of this class are quartz, orthoclase, microcline, albite, muscovite, and a few small crystals of red garnet. Williams[b] has shown that these dikes of pegmatite agree closely in composition with the large masses of granite, and are quite independent of the character of the rocks which surround them. The Maryland pegmatites, according to Williams, belong to the youngest periods of the granitic intrusion and show little or no effect of dynamic metamorphism.

The Maryland pegmatites are not especially rich in unusual minerals. They have become of economic importance within recent years for their feldspar and quartz (flint) content, especially the feldspar, and have been worked in Baltimore, Howard, Harford, and Cecil counties. The principal producing area is in the vicinity of Woodstock, Howard County, and in the adjacent portion of Baltimore County. As is indicated in the analyses below, the feldspar of these dikes belongs partly to the potassic and partly to the sodic varieties.[c]

[a] For a detailed description of the Maryland pegmatites and their origin, see Williams, G. H., General relations of the granitic rocks in the middle Atlantic Piedmont Plateau: Fifteenth Ann. Rept. U. S. Geol. Survey, 1895, pp. 657–684.

[b] Idem, p. 683.

[c] Mineral Resources U. S. for 1906, U. S. Geol. Survey, 1907, pp. 1257, 1269. Maryland Geol. Survey, Cecil County, 1902, pp. 96, 97, 101–103, 217, 218.

Analyses of feldspar from Maryland pegmatites.

Constituents.	1.	2.	3.
Silica (SiO_2)	65.96	68.60	64.62
Alumina (Al_2O_3)	19.53	19.10	20.57
Ferric oxide (Fe_2O_3)	.24	.14	Trace.
Magnesia (MgO)	None.	.28	2.36
Lime (CaO)	.18	Trace.	.14
Soda (Na_2O)	1.13	2.09	10.27
Potash (K_2O)	12.92	9.03	1.94
	99.96	99.24	99.90

1. Potash feldspar from quarry of Guilford and Waltersville Granite Company, Woodstock, Howard County, Md. Partial analyses of other specimens from the same quarry made at the Maryland agricultural experiment station show 13.2 per cent potash with 1.8 per cent soda, and 13.5 per cent potash with 1.6 per cent soda. (Quoted by E. S. Bastin, Mineral Resources U. S. for 1906, U. S. Geol. Survey, 1907, p. 1259.)
2. Potash-soda feldspar; quarry of Walter F. Patterson, jr., Henryton, Carroll County, Md. Analysis by Pittsburg Testing Laboratory (Limited). (Quoted by E. S. Bastin, op. cit., p. 1257.)
3. Soda feldspar, variety albite, from quarry of Sparavetta Mining Company, Chester County, Pa., near Sylmar, Md. (Quoted by E. S. Bastin, op. cit., p. 1257.)

QUARTZ VEINS.

Like the pegmatite dikes, quartz veins are numerous over parts of the eastern division of the Maryland Piedmont, and the two are as a rule closely associated. Many of the veins assume large dimensions, and they traverse the formations indiscriminately. Though in many places concealed by soil covering, their abundance is indicated locally by the innumerable quartz fragments strewn over the surface.

Quartz veins have been observed actually penetrating the granite in quarries of two Maryland localities, Frenchtown and Port Deposit, Cecil County. They are, however, by no means numerous, and they do not exceed 12 inches in width, the average probably being only 1 or 2 inches. They are apparently more abundant, in the same granite, in the high and steep cliffs along the north side of Susquehanna River at and just below the town of Port Deposit. The course of the quartz veins in the Frenchtown quarries is N. 60° E.

INCLUSIONS.

Inclusions of foreign rocks, including sedimentary and eruptive kinds, incorporated in the granites at Sykesville, Woodstock, Dorseys Run, and Garrett Park, were described in some detail by Keyes.[a] They comprise irregular fragments and blocks of all sizes and shapes identical with the neighboring rocks. For the most part they display characteristic border zones of complete alteration with essentially unaltered interiors.

The inclusions were found in greatest abundance in the granite at Sykesville. Among the various foreign rock fragments noted by Keyes in this granite were limestone, soapstone, pyroxenite, vein quartz, and hornblende and biotite gneisses. The granite at Wood-

[a] Fifteenth Ann. Rept. U. S. Geol. Survey, 1895, pp. 722, 723, 724, 726–729, 732.

stock shows similar phenomena equally well. The incorporated fragments are mostly gneiss; many of them are puckered and wrinkled and some measure 10 feet. Inclusions of gneiss usually exhibit only a very narrow marginal metamorphosed zone. In the small openings made in the Garrett Park outcrops, a few miles northeast of Washington, numerous irregular blocks of dark gneiss are in places incorporated in the granite. Similar fragments and blocks derived from a near-by gneiss are shown in the granite at Dorseys Run.

A chemical analysis, made by W. F. Hillebrand, of the United States Geological Survey, of a large assortment of inclusions in the granite on Dorseys Run, is given by Keyes:[a]

Analysis of inclusions in granite from Dorseys Run.

Silica (Si_2O)	57.33
Alumina (Al_2O_3)	15.31
Ferric oxide (Fe_2O_3)	3.39
Ferrous oxide (FeO)	8.19
Magnesia (MgO)	4.36
Lime (CaO)	3.95
Soda (Na_2O)	1.22
Potash (K_2O)	4.57
Water (H_2O)	1.80
Lithia (Li_2O)	Trace.
	100.12

In his description of the granitoid rocks which emerge from beneath the Coastal Plain south of Laurel and extend across the Potomac into Virginia, Williams says:[b]

These rocks, though typical gneisses in their structure, are filled with what seem to be inclusions of foreign rock, especially of vein quartz and irregular fragments of similar though older gneisses. They may best be studied along the Potomac, between Washington and the Chain Bridge, where they are extensively exposed in the great quarries. They are also typically shown near the north end of Analostan Island, at the Falls of the Patuxent west of Laurel, and along Sligo Branch, Piney Run, and the lower portions of Rock Creek, near Washington. They may also be seen to advantage where Fourmile and Holmes runs have cut deeply into the Coastal Plain deposits in Fairfax County, south of Washington.

BASIC SEGREGATIONS (KNOTS).

Segregations of the ferromagnesian minerals do not seem to be so abundant in the Maryland granites as in some of the granites in others of the Southern States. A small quarry opening made near Garrett Park on the south side of Rock Creek, near the Rockville road, is in a light-colored granite poor in ferromagnesian minerals. Keyes[c] reports numerous basic secretions of lenticular shape and various sizes in the granite. Occasional dark segregations (knots), few of

[a] Keyes, C. R., op. cit., pp. 722, 723.
[b] Williams, G. H., op. cit., p. 665.
[c] Op. cit., p. 730.

them exceeding 12 inches in size, were observed by the writer in the granite quarries opened at Port Deposit, Frenchtown, Ellicott City, Woodstock, and Guilford. They were most abundant in the quarries opened along Patapsco River on the Baltimore County side, opposite Ellicott City. In these quarries many of the knots are drawn out parallel to the schistosity of the granite and measure as much as 2 feet in length.

The percentage of silica in and the specific gravity of the basic segregations (knots) in the granite at Port Deposit are compared with those of other well-known granites on page 30.

PHYSICAL TESTS.

ABSORPTION TESTS.

Figures obtained by Merrill[a] showing the relative amount of water absorbed by some of the well-known granites and gneisses of Maryland are given in the following table:

Absorption tests of Maryland granites and gneisses.

Kind of stone.	Weight after drying 24 hours at 212° F.	Weight after immersion 24 hours in water.	Gain in weight.	Absorption.
	Grams.	*Grams.*	*Grams.*	*Per cent.*
Granite, Port Deposit	351.33	352.22	0.89	0.253
Do	341.34	342.00	.66	.196
Granite, Woodstock	340.43	341.31	.88	.258
Do	340.45	341.24	.79	.232
Gneiss, Baltimore	354.37	355.07	.70	.197
Do	323.36	326.97	3.61	1.116

A second set of experiments was conducted by E. B. Mathews[b] on blocks of the same size (2-inch cubes) as those of the first set.

Absorption tests of Maryland granite and gneiss.

Kind of stone.	Weight, air dry.	Weight after immersion one hour.	Weight after immersion one day.	Weight after immersion one week.	Gain in weight.	Absorption.
	Grams.	*Grams.*	*Grams.*	*Grams.*	*Grams.*	*Per cent.*
Granite, Woodstock	345.00	345.50	345.50	345.55	0.05	None.
Gneiss, Baltimore	350.70	350.65	350.70	350.67	....	None.

The tests show that practically no water is absorbed by the specimens. Merrill states that the weather during the experimenting was warm (85° to 95° F.), and the humidity was approximately 70 per cent.

[a] Merrill, G. P., The physical, chemical, and economic properties of building stones: Maryland Geol. Survey, vol. 2, pt. 2a, 1898, p. 94.

[b] Quoted by Merrill, G. P., loc. cit., p. 94.

MISCELLANEOUS TESTS.

Tests to ascertain resistance to freezing were made on 1-inch cubes of granite from Port Deposit, Cecil County, and from Great Falls, on Potomac River, Montgomery County, Md., with the following results.[a]

Freezing tests of Maryland granites.

Locality.	Specific gravity.	Loss, in grains.
Port Deposit	2.609	5.05
Great Falls	....	.35

Merrill states that the inch cubes were immersed for half an hour in a boiling solution of sulphate of soda and then hung up to dry, this performance being repeated daily throughout the four weeks of the experiment. The result is assumed to be analogous to that of freezing.

Strength and other physical tests of granite from Port Deposit were made by Gillmore[b] with the following results:

Miscellaneous tests of granites from Port Deposit, Md.

Position.	Cracked.	Strength of specimen.	Strength per square inch.	Specific gravity.	Weight of 1 cubic foot.	Ratio of absorption.	Remarks.
	Pounds.	*Pounds.*	*Pounds.*		*Pounds.*		
On bed	....	79,000	19,750	2.720	170	0	Coarse, strongly dashed with black.
On edge	33,000	52,400	13,100	2.720	170	0	Do.
On bed	....	66,000	16,000	2.720	170	0	Do.
Do	....	60,000	15,000	2.720	170	0	Burst suddenly.

Concerning the following tests, Mathews[c] states that the specimens were 2-inch cubes carefully prepared and subjected to tests under the most uniform conditions:

Strength, absorption, and freezing tests of Maryland granites.

Simple crushing.		Absorption gain.	Freezing loss.	Crushing after freezing.	
Crack.	Break.			Crack.	Break.
Pounds.	*Pounds.*	*Per cent.*	*Per cent.*	*Pounds.*	*Pounds.*
....	67,100	0.253	0.00[illegible]	83,000	86,000
....	79,200	.193	.011	78,100	90,800
....	86,200	....	....	....	....
....	101,540	....	....	....	....

a Merrill, G. P., op. cit., p. 105.

b Gillmore, Reports on the compressive strength, specific gravity, and ratio of absorption of the building stones in the United States: Rept. Chief of Engineers for 1875, appendix 2, p. 847; republished 8, 37 pp., Van Nostrand, New York, 1876. (Quoted by Mathews, E. B., Maryland Geol. Survey, vol. 2, 1898, p. 144.)

c Mathews, E. B., Maryland Geol. Survey, vol. 2, 1898, p. 145.

Tests made by Messrs. Booth, Garrett, and Blair, of Philadelphia, on a 2-inch cube of the granite from Port Deposit gave the crushing strength as 84,730 pounds, which is equivalent to 21,180 pounds per square inch.[a]

Mathews[b] reports the following tests on specimens from the Waltersville quarries at Woodstock:

Strength, absorption, and freezing tests on granite from Woodstock.

Simple crushing.		Absorption gain.	Freezing loss.	Crushing after freezing.	
Crack.	Break.			Crack.	Break.
Pounds.	*Pounds.*	*Per cent.*	*Per cent.*	*Pounds.*	*Pounds.*
79,700	85,700	0.258	0.011	79,400	102,200
79,200	83,420	.232	.029	86,800	90,300

Mathews[c] gives the following results of tests made on the gneiss from the extensive quarries on Jones Falls, at the northern limits of the city of Baltimore:

Strength, absorption, and freezing tests on gneiss from Jones Falls.

Kind of stone.	Crushing.		Absorption gain.	Freezing loss.	Crushing after freezing.	
	Crack.	Break.			Crack.	Break.
	Pounds.	*Pounds.*	*Per cent.*	*Per cent.*	*Pounds.*	*Pounds.*
Quartzose layers ("blue stone")	66,700	70,140	0.197	0.028	80,118	118,000
	85,940	96,300				
Feldspathic layer ("biotite granite")	....	94,200	1.116	.052	63,060	84,220
	78,600	103,500	....	....	....	....

INDIVIDUAL QUARRY AREAS.

GENERAL STATEMENT.

The granitic rocks of Maryland are discussed below by areas under (*a*) granites and (*b*) gneisses.

Under granites are included the even-granular granites and their porphyritic facies and the massive and foliated varieties of both. Porphyritic granites are of very minor extent and are merely local facies of the larger even-granular masses. They are represented in the Ellicott City, Relay, and Texas areas. Of the massive, even-granular granites, the Guilford and Woodstock areas are the most typical. In most of the other areas a foliated or gneissic structure, resulting from pressure metamorphism, is more or less developed in the granite masses. Granite gneisses, or foliated granites, the most

[a] Eighteenth Ann. Rept. U. S. Geol. Survey, pt. 5, 1897, p. 964.
[b] Mathews, E. B., op. cit., p. 156.
[c] Idem, p. 164.

typical representatives of which are those of Port Deposit and Frenchtown, are also included under granites.

Under gneisses are included the highly crystalline, banded rocks of granitic composition of alternating hornblendic and micaceous types, belonging chiefly to the Baltimore gneiss. They are typically represented at the western and northern limits of the city of Baltimore about two principal centers, Gwynns Falls and Jones Falls.

GRANITES.

ELLICOTT CITY AREA.

GENERAL STATEMENT.

As indicated on the map (Pl. I), the Ellicott City granite area comprises an irregular L-shaped mass, which has an extreme length of about 5 miles in an east-west direction and a width varying from one-half mile to 2 miles. On the north, west, and south the granite mass is bordered by a large gabbro area, and on the east by gneiss. Much of the area is overlain by the Coastal Plain gravels and clays of Lafayette and Potomac ages. All the streams in the area have cut through this thin covering of recent sediments into the underlying older crystalline rocks, allowing the ready determination of the boundaries of the granite, gabbro, and gneiss. The best exposures of the granite occur along the gorge of Patapsco River at Ellicott City, where quarries have been opened.

The quarries are located on both sides of Patapsco River in Baltimore and Howard counties, about 9 miles west of Baltimore, and the granite in which they occur extends as far east as Ilchester on the east side of the river, but only as far as Grays siding on the west side. On the east or Baltimore County side of the river the granite has a decided foliated or gneissic structure, but on the west or Ellicott City side, in Howard County, the granite is massive and of porphyritic texture. The date of opening of the quarries is unknown, but was probably some time in the latter part of the eighteenth century. The foliated granite from the quarries opened opposite Ellicott City, on the Baltimore County side, was used in building the Cathedral in Baltimore, in 1806 to 1812 and 1815 to 1821. This was doubtless one of the most important stone structures in the United States at the time of its construction.

DESCRIPTIONS OF QUARRIES.

BALTIMORE COUNTY.

Several quarries opened in the steep and moderately high granite cliffs along the east side of Patapsco River have been operated nearly opposite Ellicott City. The largest of these, known as the *Gaither quarry,* comprises two large openings that adjoin each other and have been worked back from the river into the granite cliffs, with an elevation from the base to the top of about 75 feet. (See Pl. IV, *A*.)

The rock is a biotite granite of medium dark blue-gray color and medium grain. Its structure is decidedly foliated or schistose, though much less pronouncedly so than that of the granite gneiss at Port Deposit and Frenchtown; and its original granite characters are still apparent. Hand specimens of the granite show abundant fine granules of yellow epidote closely associated with the biotite. Irregular grains of brownish allanite are also apparent in the hand specimens. Because of its richness in epidote and allanite Keyes classified this granite and some of the granites from the Port Deposit, Woodstock, Dorseys Run, and Ilchester localities as allanite-epidote-bearing granites.

The granite consists of soda-lime feldspar (oligoclase), potash feldspars (orthoclase and microcline), quartz, and biotite, together with accessory zircon, apatite, hornblende, allanite, epidote, and secondary chlorite and epidote. Intergrowths of the feldspar and quartz in more or less rounded grains are of common occurrence. The feldspar is partly cloudy and opaque from alteration, and the larger individuals inclose small rounded grains of feldspar and quartz. Allanite and epidote occur as parallel growths. Partial granulation of the quartz and feldspar into fine mosaics from pressure metamorphism is pronounced.

The structure of the granite both in the quarry and in the hand specimens is schistose or foliated. Vertical joints strike N. 40° E. and N. 60° to 70° W. Many joints of the N. 40° E. course observe southeast (70°) and northwest dips. Some joints of the N. 60° to 70° W. course show curved faces. Horizontal joints, separating the granite into sheetlike masses of varying thickness, are well developed to the entire depth of the quarry opening—about 75 feet. The vertical joints are spaced at intervals of 2 inches to 6 feet, and the horizontal joints give sheets from 2 to 4 feet thick at the bottom of the quarry. Slickensides developed on the surfaces of some of the vertical joints indicate movement in the granite mass.

There are at this locality numerous pegmatite dikes ranging from a fraction of an inch to more than 12 inches thick, with an average thickness of less than 6 inches. These cut the granite indiscriminately, but most of them apparently conform to a N. 30° W. course. They contain biotite as the principal mica, with a flesh-colored feldspar and quartz as the chief constituents. Dark-colored segregations (knots), chiefly of biotite with some feldspar and quartz, much elongated or elliptical in shape, are abundant. These range up to more than 2 feet in length and usually show pronounced foliation parallel to that of the inclosing granite.

A. GAITHER'S GRANITE QUARRY, ELLICOTT CITY, MD.

B. GUILFORD AND WALTERSVILLE GRANITE COMPANY'S QUARRY NEAR WOODSTOCK, MD.

The granite is decayed from the surface downward to a depth that is more than 20 feet in some places, but is usually much less.

The quarries on the Baltimore side of Patapsco River, in the Ellicott City area, were idle when examined in 1908 and had not been worked for some time.

HOWARD COUNTY.

The *Weber quarry*, opened in moderately high cliffs along the Baltimore and Ohio Railroad on the opposite side of Patapsco River from the Gaither quarry, is the principal quarry in the Ellicott City area in Howard County. The opportunity for shipment is excellent, as the quarry is so close to the Baltimore and Ohio Railroad that cars are readily loaded by turning the derrick boom.

The granite is a porphyritic biotite granite of dark-gray color and medium grain and is massive. Its mineral composition is essentially the same as that of the granite of the Gaither quarry already described. The minerals are soda-lime feldspar (oligoclase), potash feldspar (microcline and orthoclase), quartz, very little muscovite, and accessory zircon, apatite, and allanite. Secondary minerals are chlorite and epidote. Intergrowths of feldspar and quartz are numerous. Many of the larger feldspar individuals inclose small, rounded grains of feldspar and quartz.

The feldspar phenocrysts are distributed without orientation through the granite groundmass. They show both crystal (idiomorphic) and noncrystal (allotriomorphic) boundaries, are in places twinned on the Carlsbad law, are of a pronounced red color, and contain abundant inclosures of biotite. The idiomorphic phenocrysts are usually flat-tabular in outline and are as much as 1½ to 2 inches long.[a]

Jointing is prominent and irregular and necessitates the working of the irregular masses into the desired shape by hand after quarrying. There are at least four sets of vertical joints; the principal set strikes N. 60° E. Slickensides characterize many of the joint surfaces. Horizontal joints are emphasized in the granite mass in the upper portion of the quarry. Dark basic segregations (knots) occur, but are not abundant.

A dike of even-granular biotite granite, 6 feet thick, of dark blue-gray color and fine grain, penetrates the porphyritic granite in a N. 60° E. course. A thin section of the dike granite showed soda-lime feldspar (oligoclase), potash feldspar (orthoclase and microcline), quartz, and biotite, together with accessory apatite and zircon and secondary chlorite and epidote. Intergrowths of feldspar and quartz are abundant.

The Weber quarry was the only quarry operating in the Ellicott City area at the time of examination in 1908.

[a] See Maryland Geol. Survey, vol. 2, 1898, Pl. XI, for reproduction of a polished surface of a block of porphyritic granite from the Weber quarry.

GUILFORD AREA.

GENERAL STATEMENT.

The Guilford granite area, located in Howard County, a few miles southwest of the Ellicott City area, is of large size and irregular outline, as shown on the map (Pl. I). It is bordered on the north and west by the Baltimore gneiss and on the east by the gabbro. It is also covered in part by the gravels and clays of the Coastal Plain.

The granite from this area differs from that of the other areas in the State in containing both light mica (muscovite) and dark mica (biotite). Muscovite occurs as a subordinate constituent in some of the other Maryland granites, but not so abundantly nor characteristically as in the granite of this area.

The granite of the Guilford area varies from a coarse-grained granite of red color at the Guilford Granite and Stone Company's quarry through a medium-grained reddish-gray granite at the Penny quarry to a fine-grained medium-gray granite at the Maryland Granite Company's quarry. This last-named type is the one most extensively quarried, because it possesses durable qualities that give it a wide range of uses.

The quarries are located on Little Patuxent River about 5 miles northwest of Annapolis Junction and about 2 miles from the nearest railroad point—Savage Factory. They were opened about 1834 and were worked almost continuously until the outbreak of the civil war in 1860. Very little work was done from 1860 to 1893, but in 1893 the quarrying industry was revived and has continued to the present time.

DESCRIPTIONS OF QUARRIES.

Four quarries, located close together on Little Patuxent River, have been opened. These are, in order of importance, the Maryland Granite Company's quarry, Guilford and Waltersville Company's quarry, Penny quarry, and Guilford Granite and Stone Company's quarry.

The *Maryland Granite Company's quarry* is on the east side of Little Patuxent River 2 miles north of Savage Factory and about 5 miles northwest of Annapolis Junction. It is the principal quarry in the Guilford area and was the only one operating at the time of examination in 1908.

The rock is a muscovite-biotite granite of medium-gray color and of even, fine grain, with biotite uniformly disseminated and in excess of muscovite. It consists of potash feldspar (orthoclase and microcline), soda-lime feldspar (oligoclase), quartz, biotite, and muscovite, together with accessory zircon and apatite and secondary chlorite, epidote, muscovite, and kaolinite. Intergrowths of feldspar and quartz are numerous. The larger feldspar grains show inclosures of feldspar and quartz. The stone takes a fine polish, the durability of which is favored by the smallness of the biotite scales.[a] A chemical analysis of this granite is given in column 3 of the table on page 42. The percentages of soda and potash show that the rock contains nearly equal amounts of the potash and soda-lime feldspars.

The quarry measures about 500 by 300 feet and has a depth of about 100 feet. The average depth of stripping is about 10 feet. The sheets, 3 to 10 feet thick, are approximately horizontal and tapering lenticular. Vertical joints strike north-south and east-west, recurring at wide intervals. Many of the joint surfaces are slickensided, indicating movement in the granite mass. There are a few dark basic segregations (knots), the largest observed not exceeding 6 inches long by 3 inches wide. No pegmatite dikes were noted.

The product is used chiefly for monuments, though much of it is used for general building purposes in the dressed and rough states, largely in the rough. Much of the coarse waste is worked into paving blocks. Very little of the stone is used for curbing and no crushed stone is produced.

The principal markets are in Maryland and Pennsylvania. Shipments have been made as far west as St. Louis and Chicago, north to New York, and South to Atlanta.

The *Guilford and Waltersville Granite Company's quarry* is on the east side of Little Patuxent River a short distance from the Maryland Granite Company's quarry. Work had been suspended sometime prior to the writer's examination in 1908.

The rock is a muscovite-biotite granite of medium-gray color and of even, fine grain, with biotite uniformly disseminated and in excess of muscovite. This granite appears to be identical in composition, color, and texture with that of the Maryland Granite Company's quarry, and is equally well adapted to the same uses.

The *Penny quarry* is on the north side of Little Patuxent River about 300 feet northeast of the Maryland Granite Company's quarry. The quarry was nearly filled with water at the time of the writer's examination in 1908, but during its activity it was operated by the Maryland Granite Company.

The quarry is a small one, less than 100 feet square and less than 50 feet deep. The granite is a biotite-muscovite granite of medium pinkish-gray color and medium-coarse grain. Its feldspar contrasts strongly in color with that of the Maryland Granite Company's granite in having a pronounced pinkish cast. The rock is also of coarser texture and differs in composition, muscovite being in excess of biotite. It consists of potash feldspar (orthoclase and

[a] See Maryland Geol. Survey, vol. 2, 1898, Pl. XVI, for reproduction of a polished surface of a block of this granite.

microcline), soda-lime feldspar (oligoclase), quartz, muscovite, and biotite, together with accessory apatite, and zircon and secondary chlorite. Microcline and orthoclase are present in nearly equal proportion; the latter is intergrown with a second feldspar as microperthite. The feldspar shows very general alteration. The larger feldspar individuals inclose rounded grains of other feldspar and quartz. Intergrowths of feldspar and quartz are observed.

Vertical joints strike north-south and east-west. Many of their surfaces show slickensides. Segregations (knots) and pegmatite dikes were not observed in the granite.

The *Guilford Granite and Stone Company's quarry* is on the opposite (west) side of Little Patuxent River from the Maryland Granite Company's quarry. It comprises three small openings, the largest one of which is about 75 by 60 feet and 50 feet deep. The object of the company was to produce crushed stone, and a large crusher was erected and operated near the quarry. Operations were suspended about four months prior to the writer's examination in March, 1908.

The rock is a biotite-bearing muscovite granite of pronounced reddish color and coarse grain. The feldspar which imparts the red color to the granite contrasts strongly with the dark glassy quartz. The granite of this quarry is similar in composition to that of the three other quarries in the Guilford area described above, except that muscovite is the principal mica and is greatly in excess of the biotite. The rock consists of potash feldspar (orthoclase and microcline), soda-lime feldspar (oligoclase), quartz, muscovite, and very little biotite, together with accessory apatite and zircon. Potash feldspar is in excess of soda-lime feldspar, and both are considerably altered. Orthoclase is intergrown with a second feldspar as microperthite. Intergrowths of feldspar and quartz occur.

The granite differs from the other granites quarried in the Guilford area in being coarser grained and of a more pronounced red color and in having a larger preponderance of muscovite over biotite.

Closely spaced vertical joints are prominently developed. There are several sets, intersecting at approximately right angles and recurring at such short intervals as to render the quarrying of dimension stone very doubtful.

WOODSTOCK AREA.

GENERAL STATEMENT:

The Woodstock granite area is located in the extreme southwest corner of Baltimore County, about 2 miles north of Woodstock, on the Baltimore and Ohio Railroad, in the Patapsco River valley. The area lies about 25 miles a little north of west of Baltimore. As indicated on the map (Pl. I), the granite forms an isolated oval-shaped area scarcely 2 miles in extent from northeast to southwest and 1 mile from northwest to southeast. Although small, this area is economically one of the most important in Maryland.

The granite is entirely surrounded by the Baltimore gneiss, of pre-Cambrian age, into which it is intruded. No dikes or apophyses of the granite have been observed penetrating the surrounding gneiss, but that the gneiss is older than the granite is shown by the large number of inclusions of the gneiss incorporated in the granite. These are described in some detail on pages 46–47.

The systems of horizontal and vertical joints are prominently developed in these quarries, especially in the Guilford and Waltersville (Pls. IV, *B*, and VI, *B*) and the Weller quarries.

A chemical analysis of the granite from Woodstock is given in column 4 of the table on page 42. A noteworthy item in this analysis is the large percentage of soda, which indicates the presence of much soda-lime feldspar.

The granite bowlders first attracted attention to this area and operations were begun about 1832–33. The principal demand at first was that by the Baltimore and Ohio Railroad for stone for bridge and culvert work. One of the most important of the early contracts for the granite from Woodstock was that for the Baltimore custom-house about 1873–74.

DESCRIPTIONS OF QUARRIES:

Several extensive quarries have been operated in the Woodstock area. These are the Guilford and Waltersville Granite Company's quarry, the Fox Rock quarry, the Weller quarry, and the Atherton quarry. The first two are the most important and extensive and, together with the Atherton, which had only recently been opened, were operating at the time of the writer's examination in March, 1908. The village of Granite is located within the quarry area. A railroad spur 2 miles long connects the quarry of the Guilford and Waltersville Granite Company with the main line of the Baltimore and Ohio Railroad at Putney & Riddle's bridge, about 1 mile east of Woodstock.

The *Guilford and Waltersville Granite Company's quarry* is the largest quarry in the area. The opening is roughly circular in outline, measuring about 500 by 600 feet, and is worked to an average depth of about 12 feet. (See Pl. IV, *B*.)

The rock is a biotite granite of medium-gray color and medium grain. Because of slightly increased biotite the granite is a fraction darker in color than the gray granite at Guilford and is of slightly coarser texture.[a] The granite consists of potash feldspar (orthoclase and microcline), soda-lime feldspar (oligoclase), quartz, and biotite, together with accessory zircon, apatite, and allanite and secondary

[a] See Maryland Geol. Survey, vol. 2, 1898, pl. XIII, for a reproduction of a polished surface of a block of the granite from this quarry.

chlorite, epidote, and muscovite. Orthoclase is partly intergrown with a second feldspar as microperthite. A part of the feldspar shows considerable alteration in some of the thin sections. Intergrowths of feldspar and quartz are abundant. The quartz shows strain shadows and is in places fractured from pressure metamorphism.

The sheets measure from 1½ to 6 feet in thickness and are approximately horizontal (Pl. VI, *B*). There are two principal sets of vertical joints, striking about northeast-southwest and northwest-southeast, and several minor sets having different courses. Many of the joint faces are curved irregularly. They are spaced at sufficiently wide intervals to permit the quarrying of blocks of almost any size. The rock contains some thin pegmatite dikes. A very few dark segregations (knots), of biotite chiefly, the largest rarely exceeding 12 inches in length, were observed.

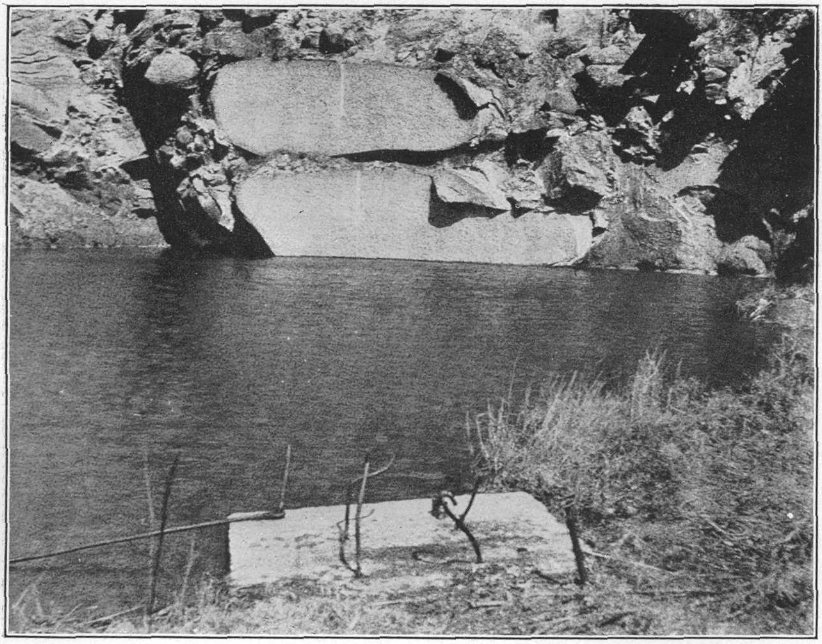
Physical tests made on specimens of this granite to determine absorption, compressive strength, and freezing loss, the results of which are given on pages 48, 50, show it to be a most durable stone. A chemical analysis is given on page 42 (No. 4).

The product is used chiefly for general building purposes, in both the rough and the dressed states. Other uses are for monuments, paving blocks, some curbing, and crushed stone (mostly for concreting). It is shipped to Maryland, Pennsylvania, New York, Delaware, Washington, D. C., and occasionally to Virginia and Ohio.

The *Fox Rock quarry* is the oldest one in the area and has been worked to an extreme depth of 96 feet. The rock is a biotite granite of medium-gray color and medium grain. It is entirely similar in color, texture, and composition to that of the Guilford and Waltersville quarry described above. It consists of potash feldspar (orthoclase and microcline), soda-lime feldspar (oligoclase), quartz, biotite, and scant muscovite, together with accessory zircon, apatite, and allanite and secondary chlorite, muscovite, and epidote. The feldspars are partly intergrown in microperthitic structure, and some of them are cloudy and opaque from alteration. Intergrowths of feldspar and quartz are shown.

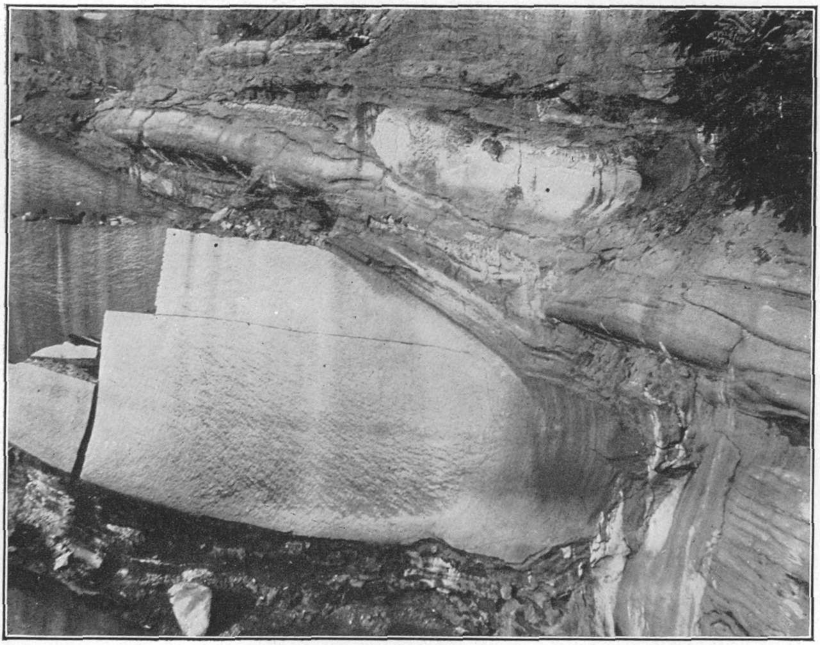
Vertical joints strike N. 55° E., N. 10° W., and N. 50° W., spaced at intervals of 8 inches to 4 feet and more. There are a few pegmatite dikes of small thickness. Occasional dark segregations (knots), of biotite chiefly, occur in the granite. The thickness of the decay at the surface ranges up to more than 15 feet in places.

The principal uses made of the product are for general building and monumental work and for street curbing and paving blocks. No crushed stone is produced. The product is shipped to Pennsylvania and West Virginia and to various points in Maryland. Occasionally it has been shipped as far west as Indiana and as far north as New York.



A. WELLER QUARRY, NEAR WOODSTOCK, MD.

Showing elongated concentric shells of granite.



B. LONG GRANITE COMPANY'S QUARRY, NEAR OGLESBY, GA.

Showing concentric weathering.

WEATHERING OF GRANITE.

The *Weller quarry* is adjacent to the Guilford and Waltersville quarry on the west. It was the only quarry in the area not operating at the time of examination, in March, 1908. It had apparently been idle for some time, as the opening, which is a large one, probably 300 feet long by 100 feet wide and 70 feet deep, was nearly filled with water, and very little could be seen of the actual quarry conditions. (See Pl. V.)

The rock is a biotite granite of the same color, texture, and composition as that at the Guilford and Waltersville and the Fox Rock quarries, already described. The effects of weathering along vertical and horizontal systems of joints are probably the most characteristic to be found within the State. Keyes [a] has described it as follows:

> The quarry ledge has the appearance of a great wall of cyclopean masonry, layer upon layer of huge blocks, rising one upon another with the regularity and precision of human workmanship. The separate blocks are more or less oblong in shape, and often measure 15 to 20 feet in length and from 2 to 8 feet in height. They are all more or less rounded, the spaces between the different bowlders being filled with incoherent granitic sand, derived from the decomposed edges and the sides of the blocks. It is quite evident that the granitic mass was originally everywhere jointed, and that atmospheric decay took place much faster on the edges and corners than on the flat sides of the great fragments, thus quickly rounding and forming them into bowlders like those found throughout drift areas. The sandy matrix is usually from 5 to 10 inches in thickness. The interior of the bowlders is perfectly fresh, and affords the best of rock for building purposes. As decomposition progresses the amount of interstratified sand greatly increases, and the blocks become proportionately smaller.

The *Atherton quarry* is a short distance west of the Guilford and Waltersville quarry. It was opened about eighteen months prior to the writer's examination in March, 1908, in bowlder exposures of the granite.

The rock is a biotite granite and is entirely similar in color, texture, and composition to that of the other quarries in the Woodstock area, already described. It is likewise equally suited for the various uses made of the granite from the Guilford and Waltersville quarry (p. 58).

PORT DEPOSIT AREA.

Probably the Maryland granite which is best known outside of the State is that quarried in Cecil County, near the northern limits of the town of Port Deposit, on the northeast side of Susquehanna River. The value of this granite was early recognized, and it was quarried for foundation stone for the oldest colonial dwellings. Though it was worked in a small way for many years, the quarrying industry may be said to date from the years 1816 and 1817, when stone was quarried for the bridge built across Susquehanna River.

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[a] Fifteenth Ann. Rept. U. S. Geol. Survey, 1895, p. 725.

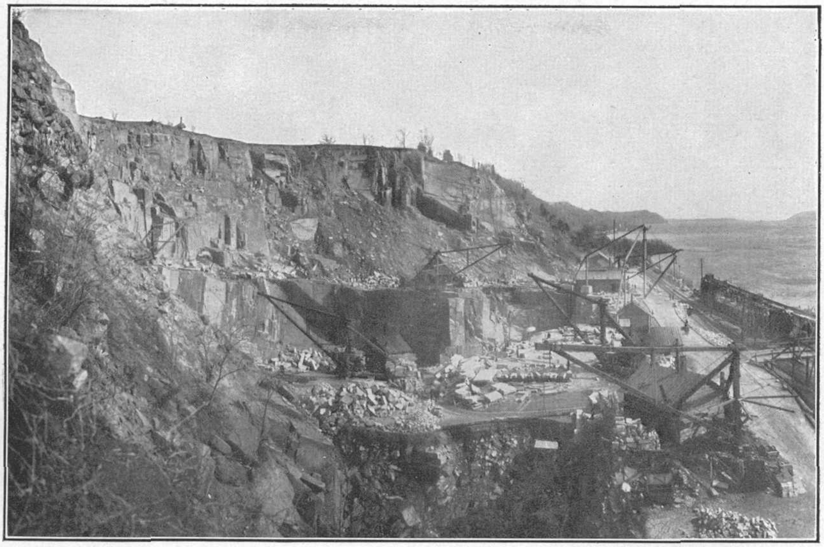
The only quarries operated in this area are those of the McClenahan Granite Company, 1 mile northwest of Port Deposit, immediately on the northeast side of the Susquehanna. (See Pl. VI, *A*.) The quarries are opened in the nearly vertical granite wall (cliff) which extends for some distance along the northeast side of the river, and measures about 200 feet from the base to the top. A number of very extensive openings have been worked in the wall along the river front within a distance of 3,000 feet. The natural advantages for quarrying and shipping at this point would, indeed, be difficult to excel. The average depth of the quarry is 200 feet, with an extreme depth of 230 feet, and in one exposure it is opened to a depth of 15 feet below the river level. The depth of stripping on the surface varies from 1 to 25 feet.

The rock is a biotite granite gneiss (foliated granite) of light bluish-gray color and medium grain. Its schistose, or foliated structure, is pronounced and is highly characteristic.[a] The principal minerals are soda-lime feldspar (oligoclase), potash feldspar (orthoclase and microcline), quartz, and biotite, with accessory apatite, zircon, titanite, allanite, garnet, tourmaline, and magnetite. The secondary minerals are muscovite, hornblende, epidote, chlorite, and occasionally calcite. The quartz and feldspar occupy well-defined areas, which show crushing and recrystallization into a mosaic, as a result of the dynamic forces, which have modified the original granite. The feldspars show less perfect granulation than the quartz. Acidic plagioclase, the extinction angles of which place it between Ab_3An_1 and Ab_2An_1, so that it corresponds to oligoclase, is the dominant feldspar. The microcline has been derived, probably, in part at least, from orthoclase by pressure. The shreds of biotite are orientated and lie in approximately parallel lines, thus producing the gneissoid structure of the granite gneiss. The lines of mica shreds are not straight and continuous, but are arranged in more or less disconnected and overlapping bands.

A chemical analysis of the granite gneiss from Port Deposit is given on page 42. The analysis indicates that soda is in excess of potash, thus confirming the apparent predominance of plagioclase over orthoclase and placing the granite with the quartz monzonite type.

The course of the foliated or gneissoid structure is N. 35° E. Vertical joints strike N. 35° E., N. 60° E., N. 70° W., and north-south. Zones of close jointing occur at intervals in the direction of the N. 70° W. set, and to a less extent in the N. 35° E. set. The N. 35° E. joints show a dip of as much as 58° N., 35° W. The spacing between joints varies from a fraction of an inch up to 15 feet, and is in general sufficiently great to allow the extraction of dimension stone.

[a] For description see Maryland Geol. Survey, vol. 2, 1898, pp. 138–147; Pls. VIII, IX.



A. McCLENAHAN GRANITE COMPANY'S QUARRY, PORT DEPOSIT, MD.

B. GUILFORD AND WALTERSVILLE GRANITE COMPANY'S QUARRY, GUILFORD, MD.

Movement in the granite mass is indicated in slickensided surfaces of many of the joint planes. Pegmatite dikes were not observed, but a few narrow veins of quartz up to 6 and 12 inches wide penetrate the granite gneiss in the quarries and are more abundant in the steep, high cliffs of granite in and below the town of Port Deposit. A few dark segregations (knots) of small and large size occur.

Tests (see p. 49) of the crushing strength (over 20,000 pounds per square inch), the absorption capacity (0.19 to 0.25 per cent), and the freezing loss establish the durability of the granite gneiss under most circumstances. This is further confirmed by a study of its mineralogical and chemical composition and of the stone itself under natural conditions in the quarries.

The product of the quarries is shipped as far west as Chicago and Cincinnati and as far north as New England; but the principal market is in Pennsylvania. No shipments have been made south of Norfolk, Va. The quarries are favorably located for shipment by water and rail routes.

The principal use made of the product is for general building purposes, in both the rough and the dressed states. It is largely used for bridge and ashlar work and, as crushed stone, for various purposes, such as for ballast, macadam, and concrete, in chemical filtering, and in fertilizers.

FRENCHTOWN AREA.

Near Frenchtown, about 4 miles southeast of Port Deposit, in Cecil County, is another body of granite gneiss similarly situated. The rock is of the same general character as that quarried at Port Deposit. One quarry has been opened at the east end of the suspension bridge of the Baltimore and Ohio Railroad over the Susquehanna, on the northeast side of the river. It is reported to have been opened during the construction of the railroad bridge, but quarrying did not assume importance until 1894. The cold-storage warehouse and an extension of the Baldwin Locomotive Works in Philadelphia were built from the Frenchtown rock.

The rock is a biotite granite gneiss (foliated granite) of gray color and medium grain. It is probably a shade darker in color than the granite at Port Deposit because of the prevailingly darker color of the biotite. Its microscopical characteristics are the same as those of the granite gneiss at Port Deposit (p. 60). The chief minerals are soda-lime feldspar (oligoclase), potash feldspar (orthoclase and microcline), quartz, and biotite, with accessory apatite, zircon, and allanite. The secondary minerals are chlorite, epidote, muscovite, garnet, and kaolinite. Granulation of the quartz and feldspar into fine mosaics and orientation of the biotite along parallel lines, producing gneissoid or foliated structure, are the most characteristic dynamic modifications of the original granite. The foliated or schistose structure of the granite gneiss is not so strongly developed as in the Port Deposit rock, but the two are closely similar in color, texture, and composition.

In 1908 the dimensions of the opening were approximately 300 by 75 feet by 30 feet deep. Two prominent sets of vertical joints are developed at approximately right angles to each other, striking N. 60° E. and N. 40° W., with a wide range in dip. The surfaces of some of the joints are smooth and polished and are coated with a thin veneer of dark-greenish to yellowish micaceous material, resulting from motion in the granite mass. Horizontal joints, separating the rock into sheetlike masses of varying thickness, are most pronounced in the upper portions of the quarry. Decay is shown prominently along the vertical and horizontal joints near the surface, in the gaping of the joints and in the hydration and oxidation of the rock minerals. Scattered quartz veins striking N. 60° E. and varying in width from a fraction of an inch to 6 inches penetrate the granite gneiss. There occur, also, a few dark segregations (knots) of small dimensions.

At the time of examination in 1908 most of the product was worked into blocks for paving. It is capable, however, of a wide range of uses. Its principal markets are reported to be in Pennsylvania and Maryland. The transportation facilities are very good, and are similar to those at Port Deposit.

Other masses of similar granite gneiss (foliated granite), less favorably located for commercial purposes, occur on either side of Susquehanna River in the vicinity of Port Deposit.

MINOR GRANITE AREAS.

In addition to the five principal areas already described, there are a number of minor granite areas in the State which have been worked from time to time to supply the local demands. Of these minor areas the most important are Dorsey Run, on the Baltimore and Ohio Railroad between Ellicott City and Woodstock; Sykesville, on the Baltimore and Ohio Railroad west of Woodstock; Garrett Park and Brookville, a few miles northwest of Washington; Franklinville, on Little Gunpowder River, 3 miles north of Bradshaw; Benson, in Harford County; Baldwin station, in Cecil County; Texas, about 12 miles north of Baltimore; and Relay, 9 miles southwest of Baltimore. No quarries have been opened in the Texas and Relay areas.

DORSEY RUN AREA.

The Dorsey Run area comprises a small oval-shaped granite mass located on Patapsco River a few miles northwest of Ellicott City. It is surrounded on all sides by dark-colored Baltimore gneiss. The relations of the granite to the gneiss are well shown in a cut of the

Baltimore and Ohio Railroad 400 feet in length and 40 to 50 feet in height.[a]

The rock is a biotite granite of dark color and is massive, even grained, and homogeneous in texture. Allanite and epidote are abundant accessory constituents, and the granite is classed by Keyes as an allanite-epidote granite which differs but little from the other allanite-epidote granites of the region. Biotite is much altered to chlorite. Orthoclase, abundant plagioclase (oligoclase), and variable microcline compose the feldspathic constituent. Much of the quartz is crushed and fractured, and the feldspar is peripherally granulated from pressure metamorphism. Chemical analyses of the granite and of the lighter-colored, more acidic granite dikes, regarded as probable apophyses from the main mass, are given on page 42.

According to Mathews the granite was first used on the Baltimore and Ohio Railroad to protect it against the encroachment of Patapsco River. Several small quarries have been opened since, but had not been operated for some time prior to the writer's visit in 1908.

SYKESVILLE AREA.

The Sykesville granite area is one of the largest in the State. Except in the vicinity of Washington and for a short distance northward on the east side, the granite is entirely surrounded by the Wissahickon mica gneiss, of probable pre-Cambrian age. According to the recent map of the Maryland Geological Survey and as shown on the map accompanying this report (Pl. I), the granite is prolonged southward into Virginia.

The rock is a biotite granite of gray color and fine grain. Its principal minerals are orthoclase and plagioclase (oligoclase), quartz, and biotite. The biotite is considerably altered to chlorite and the feldspars to scales of colorless mica and kaolin. Large plates of muscovite are aboundant in some sections. Muscovite is partly secondary. A few garnets occur in several of the thin sections. Pressure effects are pronounced in the granulation of the feldspar and quartz, more especially the quartz, and as a rule the granite is more or less foliated.

A quarry opened in 1888 for paving blocks, a few hundred rods below the railway station, showed a large number of inclusions of irregular fragments of foreign rocks of all sizes and shapes incorportated in the granite. Keyes says:[b] "Among the fragments noted may be mentioned those which were originally limestone, soapstone, pyroxenite, vein quartz, hornblendic, and biotitic gneisses."

At present no quarries are in operation in the Sykesville granite area.

[a] See Fifteenth Ann. Rpt. U. S. Geol. Survey, 1895, Pl. XXXVII, fig. 3, for a diagrammatic section of this cut.

[b] Fifteenth Ann. Rept. U. S. Geol. Survey, 1895, p. 726.

GARRETT PARK-BROOKVILLE AREA.

Extending westward along Potomac River and northward from Washington, in Montgomery County, Md., and the northwestern portion of the District of Columbia, are extensive areas of granitic rocks. According to Williams and Keyes the rock types have been largely derived from original granites by dynamic metamorphism and over most of the district are now more properly called granite gneisses. Extreme foliation has obliterated most of the granitic features, but the abundance of indistinct masses, which resemble inclusions, scattered through the granite gneiss in places, led Williams to assume for the rock an igneous origin. Within this large district are included the Cabin John Bridge, Murdoch Mill, Broad Branch, Garrett Park, Rock Creek, Brookville, Sligo Branch, and Piney Run localities referred to by Williams and Keyes.[a]

The principal rock type is a foliated biotite granite or granite gneiss, containing hornblende as an important constituent in some localities. The feldspar constituent comprises usually the potash varieties (orthoclase and some microcline) and the soda-lime variety (oligoclase). The biotite-bearing granite ranges from fine to medium grained in texture, and from light to dark gray in color. The typical hornblende granite is exposed for some distance along the Rockville road about 2 miles north of Garrett Park. It is of dark color and contains about equal amounts of hornblende and biotite. Analyses of the biotite type of gneiss along Potomac River, in Montgomery County, Md., are shown in columns 11 and 12 of the table on page 42, and of the foliated granite in the District of Columbia in column 13 of the same table.

The gradation of the different facies of the granitic rocks of this area into each other is stated by Williams as follows:[b]

> In the large granite area extending from Tridelphia southward to Brookville, in Montgomery County, the rock grades from a dark basic granite resembling a diorite to one which is very light colored and acid. In the Murdoch Mill granite area, west of Washington, gradual passages into a diorite facies are frequent, while the same thing takes place, with the development of still more basic varieties, in the granite area which extends southward from Falls Church, in Fairfax County, Va. The most striking example of gradual passage from one igneous type into another is, however, to be found in the wide belt which crosses the Potomac River at Cabin John Bridge. This originates near the southern portion of the Frederick sheet, above Bethesda Park, as a normal gabbro similar to that occurring near Baltimore; and as it passes southward it gradually becomes more acid, developing hornblende in the place of pyroxene, and thus merging into a diorite. Still farther south the diorite becomes biotitic, its feldspar more acid, while a little quartz commences to show itself. After the passage of the river the rock becomes a hornblende granite and, without any break in the continuity of the mass, is developed along Pimmit Run as a typical granite.

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[a] Fifteenth Ann. Rept. U. S. Geol. Survey, 1893-94 (1895), pp. 665, 669, 670-671, 729-730.
[b] Idem, p. 671.

The recently published map [a] of the Maryland Geological Survey differentiates the rock types in this region as follows: A large granite heel extending westward and northward from Washington to Sykesville, in Carroll County, Md., west of Baltimore; diorite and gabbro areas, chiefly diorite, within the granite, extending northward from the Potomac and only a short distance northwest of Washington; and a small area of Baltimore gneiss in contact with the granite on the east side and a short distance north of Washington. From the southern border of the Baltimore gneiss to Potomac River the eastern limits of the granite are concealed beneath the Coastal Plain formations, and the entire granite mass is surrounded by the Wissahickon mica gneiss on the west and north sides and for most of the distance on the east side.

A number of quarries have been operated within the area. The first was opened at Brookville about the beginning of the last century and was operated in a small way at intervals up to 1881. A second quarry was opened at Brookville in 1850. Several small quarries, opened in the granite exposures along Rock Creek at Garrett Park, have been worked at intervals to supply the local demand. Perhaps the most extensive quarry in Montgomery County was opened in 1850 near Cabin John in a schistose granite of dark-gray color. The total production of stone from this quarry was very large, the product being used principally for general building purposes, foundations, and road metal.

FRANKLINVILLE AREA.

The Franklinville granite area is located partly in the counties of Baltimore and Harford, northeast of the city of Baltimore, and is traversed in a southeastward course by Little Gunpowder River. It is partly covered by Coastal Plain sediments, and is in contact with gabbro on the south and west sides and with Baltimore gneiss on the north side. The rock is a foliated biotite granite resembling that quarried at Port Deposit, although somewhat darker and more foliated.

A quarry opened at Franklinville, on the Little Gunpowder, 3 miles north of Bradshaw, has supplied local demands. Mathews states that large curbing blocks might be obtained easily, as blocks 11 by 2 by 1 foot have been quarried.

BENSON AND BALDWIN STATION.

Mathews reports that a little granite is quarried in the town of Benson, Harford County, and near Baldwin station, Cecil County. The operations have been greatest at the latter locality, where the quarry was first opened in 1842 in a schistose granite. The writer did not visit either of these two localities.

[a] Maryland Geol. Survey, vol. 6, 1906.

TEXAS AREA.

The Texas area, situated about 12 miles north of Baltimore, comprises an oval-shaped granite mass between 4 and 5 square miles in extent. It is surrounded chiefly by the Cockeysville marble, except at the northwest corner, where it is in contact with the Wissahickon mica gneiss. A second thin band of the gneiss extends for some distance along the margin on the east side between the granite and the marble.

The main body of the rock is a biotite granite with a distinct porphyritic facies along the western margin. It is composed of the essential minerals feldspar (including orthoclase with about equal amounts of oligoclase and microcline), quartz, and biotite. Biotite is much altered to chlorite and epidote and the feldspars to a light-colored mica. Zircon and apatite are the principal microscopic accessory minerals. Pressure effects are pronounced in the quartz and feldspar, and the rock presents, both in thin sections and in hand specimens, a distinct gneissoid appearance. The porphyritic portions of the mass along the western margin may be designated an augen gneiss.

No quarries have been opened in the Texas granite area.

RELAY AREA.

A small area of granite lies on Patapsco River in the vicinity of Relay, 9 miles southwest of Baltimore. The rock is a biotite granite of dark-gray color, rather coarse grained, more or less porphyritic in texture, and somewhat foliated from pressure metamorphism. Biotite, here and there intergrown with shreds of muscovite and considerably altered to chlorite, is orientated along parallel directions. The quartz is much crushed and fractured and the feldspar exhibits pronounced peripheral granulation. Orthoclase and some plagioclase (oligoclase) make up the feldspar content. The feldspar phenocrysts usually exhibit crystal boundaries. This granite resembles, microscopically, that quarried at Ellicott City, a short distance up the river.

GNEISSES.

INTRODUCTORY STATEMENT.

The Baltimore gneiss, mapped by the Maryland Geological Survey as extending along the eastern slope of the Piedmont in several well-defined areas between Susquehanna and Potomac rivers, is the oldest formation in the State and is of Archean age. It is described by the Maryland Survey as follows:[a]

> The easternmost of these Baltimore gneiss occurrences is within the area of Cecli County, east of the Susquehanna River, and extends from this point southwestward, widening to an area of 5 miles or more in breadth where it is overlain by Coastal Plain

[a] Clark, W. B., and Mathews, E. B., Maryland Geol. Survey, vol. 6, 1906, pp. 106, 107.

deposits in Harford County. This formation is limited on either side by igneous rocks. A northern outlier a mile or less in width extending for several miles southwestward from the Susquehanna River probably represents a detached portion of this larger mass lying a little to the south.

The second area of Baltimore gneiss is found in an anticlinal dome, 15 miles long and 5 miles broad, lying on either side of the Northern Central Railroad 10 miles south of the Mason and Dixon line and 20 miles north of Baltimore. Three smaller areas occur in the vicinity of Baltimore. Two of these are portions of anticlinal domes which are either completely inclosed by overlying sediments or cut off by faults and igneous rocks, while the third, underlying the northwestern part of Baltimore City, is entirely surrounded by gabbro and other igneous masses and is overlain in great measure by the Coastal Plain deposits.

The rocks in each of these areas consist of highly crystalline gneisses composed of quartz, feldspar, and mica, with accessory minerals, which are so distributed as to produce well-marked, gray-banded gneisses, the individual bands of which vary from a fraction of an inch to several feet, the average thickness, however, being quite slight. Some of these bands are highly quartzose, resembling a micaceous quartzite; others are rich in biotite or hornblende, producing dark schists, which in a hand specimen are indistinguishable from metamorphosed igneous masses. Within the areas of Baltimore gneiss are also numerous small bodies of metamorphosed granites and more basic igneous rocks, which have been intruded into the gneiss and subsequently metamorphosed until they are practically indistinguishable from it.

Extensive quarries have been opened in the Baltimore gneiss and worked for very many years on the north and west sides of the city of Baltimore, grouped about two centers, Jones Falls and Gwynns Falls.

JONES FALLS QUARRIES.

The quarries on Jones Falls, at the northern limits of the city of Baltimore, were opened probably before the beginning of the last century. A published record in 1811 states that the gneiss was quarried on both sides of Jones Falls.[a] The first quarries opened, situated probably on the right bank of the stream, were worked until about 1830. The quarries opened on the left bank are reported to have been continuously operated from the date of opening until the present time. The principal quarries in operation at the time of examination in 1908 were the Atkinson, Curley-Schwind, and Peddicord.

The rock is a banded gneiss of variable color, texture, and composition. The bands range in thickness from 2 or 3 inches to 5 or 6 feet, and are usually rather uniform for considerable distances. They dip to the northwest at an angle of about 45°, but flatter and steeper dips are not uncommon. The variation in color is from very light gray to blue-black, being dependent on the amount of biotite or hornblende present. Probably a blue-gray is commonest, and this has given rise locally to the term "blue stone" among the quarrymen and in the trade. In texture the rock ranges from fine to medium grained. In many of the beds the component grains are of approximately the same size, producing a rock of uniform texture.

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[a] Mathews, E. B., op. cit., p. 162.

The gneiss is highly variable in composition, ranging from essentially a hornblende gneiss on the one hand to a biotite gneiss on the other. Both biotite and hornblende, more especially the former, are subject to wide variation in amount. In the mica-bearing gneiss, which is probably the most abundant facies, the rock may be composed almost entirely of quartz, with very little mica and feldspar, or it may be made up of quartz, feldspar, and mica (biotite) in nearly the proportions of a very acidic granite. In the hornblende-bearing facies of the gneiss the very dark, blue-black bands are composed largely of hornblende with very little feldspar or quartz. Among the secondary minerals occurring in the gneiss are epidote and garnet, less commonly fibrolite, cyanite, and staurolite. Many thin sections of the light-colored bands show the constituent grains to be somewhat rounded and not interlocked as in igneous rocks, suggesting that the gneiss is probably of sedimentary origin, and it is so regarded by the geologists of the Maryland Geological Survey.

In some quarries the rock is thoroughly decayed in places to a depth of 25 feet and more. Usually two sets of vertical joints are developed at approximately right angles to each other. Their courses are N. 30° E. and N. 40° W. The surfaces of some of the joints are slickensided, indicating movement. These quarries are well known for the large number of minerals that coat the surfaces of some of the joints (p. 32). Pegmatite dikes ranging from an inch to several feet across cut the gneiss in places. For figures of tests to determine crushing strength, absorption, and freezing loss, see pages 48, 50.

The product of these quarries is used principally in the city of Baltimore for paving and curbing, chiefly the latter, and in the form of crushed stone.

GWYNNS FALLS QUARRIES.

The quarries along Gwynns Falls, near the western limits of the city of Baltimore, were not opened for about fifty years after those along Jones Falls. Systematic work dates from about 1850 and has continued to the present time. The principal quarries in the area are the John G. Schwind quarry, on Edmondson avenue, and the Leonard quarry, a little farther west on Gwynns Falls. In addition to these two, there are a number of smaller quarries in the immediate vicinity. The rock is essentially the same in all and is closely similar to that quarried along Jones Falls. Quarrying operations extend from the dam south of Edmondson Avenue Bridge for a distance of a mile or more southward, along the west side of Gwynns Falls.

The rock is an irregular gneiss showing variations of color, texture, and composition similar to those of the gneiss quarried along Jones Falls. The general strike of the beds is N. 45° E., and the average dip is 30° NW. Much steeper dips are observed in places, resulting from irregularity of the folding. The average thickness of the beds ranges from 1 to 4 feet. In composition the rock ranges from a hornblende gneiss to a biotite gneiss, with wide variation shown in the amount of hornblende and biotite, especially the latter. The lighter-colored layers are composed essentially of quartz, much or little feldspar, and very little biotite, closely resembling a light-colored, very fine-grained granite. Some bands are more feldspathic and micaceous than others and likewise vary in the degree of lamination. The lighter beds furnish the most desirable grade of stone.

Two principal sets of vertical joints, nearly at right angles to each other, strike N. 55° E. and N. 50° W.; minor jointing is developed in other directions. The joints are spaced at intervals ranging from a few inches to several feet, but are not so close as to prevent the quarrying of dimension stone. Numerous minerals, such as laumontite, stilbite, etc., listed on page 32, are distributed along the faces of some of the joints.

Pegmatite dikes of very large dimensions intersect the gneiss in places. The principal mica in the pegmatites is the light-colored potash variety, muscovite. Abundant large and small red garnets occur in the pegmatite shown in the figure. (See Pl. III.)

Like the material already described as characteristic of the Jones Falls quarries, the product from these quarries has a wide range of uses. Some of it is reported to have been furnished for many well-known buildings in Baltimore. Part is used for foundations; much of it is worked into paving blocks; and the quarry waste is utilized in the form of crushed stone for various purposes.

OTHER GNEISS QUARRIES.

Besides the large quarries on Jones Falls and Gwynns Falls, described above, there are smaller scattered quarries in the vicinity of Baltimore which have been worked to supply a local demand. The principal ones are opened along Herring Run, near Hall Spring; at Ivy; and along the upper course of Gwynns Falls, near McDonogh. Mathews reports that the material from these quarries is similar to that obtained from those on Jones Falls and Gwynns Falls, and is used locally for paving blocks, sills, steps, and curbing. The principal use made of the product, however, is for road metal in the construction of the highways radiating from Baltimore.

CHAPTER III.

THE GRANITES OF VIRGINIA.

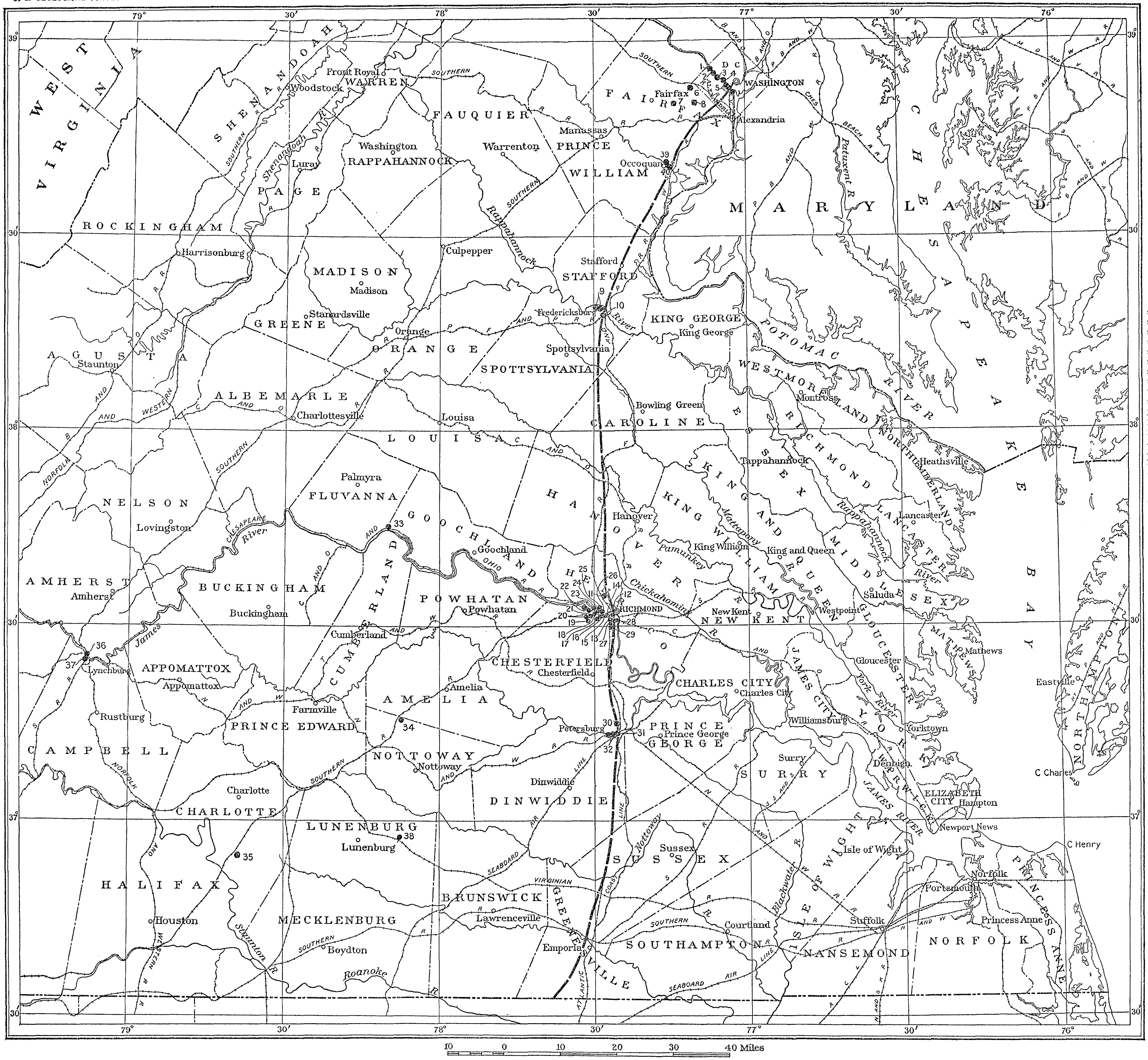
THE VIRGINIA PIEDMONT REGION.

The Piedmont province in Virginia, a part of the eastern crystalline area which extends southwestward from New York to north-central Alabama, stretches eastward from the Blue Ridge to the western margin of the Coastal Plain and widens southward. Lack of systematic study of the Virginia Piedmont region forbids more than a most general statement of its geology. The rocks occupying the region are the oldest in the State, and, except in the Triassic areas, they are all crystalline. Rogers mapped the crystalline rocks of the region as Archean, but more recent studies reveal the fact that a part of them are as late as Ordovician in age. The rocks comprise sedimentary and igneous masses so greatly altered through metamorphism that many of them bear but slight resemblance to the original rocks. They constitute a complex of schists, gneisses, and granites, with local areas or belts of slates, quartzites, and limestones. This complex is further intersected by intrusions of basic eruptive rocks belonging, so far as they have been studied, to the diabasic, dioritic, and gabbroic types. To the east of Danville, in the extreme southern part of the region, is an extensive area of altered andesite and acidic porphyries, and their associated pyroclastic rocks (tuffs), which extends into North Carolina and is regarded as pre-Cambrian in age.

Over the eastern, northern, central, and southern parts of the Piedmont are areas of Triassic shale, sandstone, and conglomerate. The northern and eastern areas of these rocks are extensive.

DISTRIBUTION OF THE GRANITES.

In Virginia the granites are limited to the crystalline area described above and comprise both massive and schistose types. The schistose granites (gneisses) are widely distributed throughout the Virginia crystalline area, forming one of the dominant rock types. Only a small part of this area has yet furnished first-grade quarry material, for over most of the area the granites have been rendered schistose from metamorphic action and are not desirable for use in the higher grades



LEGEND

Granite quarries (numbers refer to list)

Fall line

QUARRIES

1–5 Potomac River
6 Trip
7 Hoffman & Miller
8 Annandale (?)
9 Cartwright & Davis
10 Hazel Run
11 Richmond Granite Co.
12 Old Dominion Iron and Nail Works (Belle Island)
13 Netherwood
14 Wray
15 Donald
16 McGranigan
17 Granite Development Co.
18 Old Dominion (Middendorf)
19 McIntosh
20 Krimm
21 Old Dominion Granite Co.
22 Westham
23 Smith
24 Winston & Co.
25 McCloy
26 Philadelphia
27 Middendorf
28 Tidewater Quarry Co.
29 McGowan
30 Cook
31 Lassiter
32 Petersburg Granite Co.
33 Cowherd
34 Wingo
35 State test farm
36, 37 Lynchburg
38 Kenbridge
39 Occoquan
40 Occoquan Stone and Lumber Co.

MAP OF VIRGINIA, SHOWING DISTRIBUTION OF GRANITE QUARRIES.

of work. There are, however, many localities capable of furnishing granite of superior quality for general building and monumental purposes. The principal areas which have produced and are now producing granite of superior quality are distributed in a north-south direction along the eastern margin of the crystalline region. They include the Petersburg area, the Richmond area, and the Fredericksburg area. The granite from quarries in these areas has an established reputation and has been shipped more or less to all the States and the principal cities south of New England. In addition to these there are several minor areas capable of yielding granite suitable for general building purposes, but in none of them has the stone more than a strictly local use, and it has not been placed on the market. The location of the principal granite quarries in the State is shown on the map (Pl. VII).

SCIENTIFIC DISCUSSION.

MINERAL COMPOSITION.

Conforming with well-known granites elsewhere, the Virginia rocks are mixtures of feldspar and quartz, with biotite as a third essential component in the most important areas. Muscovite in subordinate amount usually accompanies the biotite in all the granite areas of the State, and it becomes a principal constituent in the granite of the Hazel Run area, west of Fredericksburg. Hornblende is an important constituent in only a part of the granites of the Falls Church area, southwest of Washington, and it is almost unknown in the granites of the other areas. It is essentially absent from the economically most important granites of the State.

In the unique variety of granite known as unakite, occurring in the Blue Ridge near Luray, in Page and Madison counties, and near Troutdale, in Grayson County, epidote is a principal constituent and the ferromagnesian silicates are nearly or entirely absent. The epidote is entirely a secondary mineral.

The feldspathic constituent of Virginia granites is composed of plagioclase (oligoclase), orthoclase, and microcline in variable amount. In some places microcline may equal or even exceed orthoclase in amount. One of the most striking features in the mineralogical composition of these rocks is their richness in plagioclase (oligoclase), and to a less extent in microcline. Both oligoclase and microcline, however, are subject to variation, and in a few thin sections examined their poverty was a noticeable feature. It seems probable that a part of the microcline in the Virginia rocks has developed in part from orthoclase by pressure metamorphism.

Besides the above-named minerals the granites contain apatite, zircon, titanite, magnetite, and some other minerals.

CHEMICAL COMPOSITION.

The chemical composition of the Virginia granites in the Richmond, Petersburg, and Fredericksburg areas is shown in the table of analyses below:

Chemical analyses of Virginia granites.[a]

[Wm. M. Thornton, jr., analyst.]

Constituents.	1.	2.	3.	4.	5.	6.	7.	8.
Silica (SiO_2)	72.27	71.51	71.19	70.83	69.48	69.44	69.29	68.45
Alumina (Al_2O_3)	14.30	13.82	14.01	12.70	13.95	15.46	14.07	10.00
Ferric oxide (Fe_2O_3)	1.16	1.76	1.66	2.67	2.82	1.31	2.59	5.71
Ferrous oxide (FeO)	.97	1.20	1.29	1.36	1.70	1.43	2.03	2.59
Magnesia (MgO)	.70	.80	.44	.53	1.10	1.01	1.32	3.26
Lime (CaO)	1.56	1.79	2.04	1.88	2.81	2.11	2.76	6.20
Soda (Na_2O)	3.46	3.64	3.56	3.49	3.65	3.97	2.89	1.98
Potash (K_2O)	5.00	4.63	4.45	4.83	3.45	4.25	2.87	1.18
Water (H_2O)− at 110° C	.04	.17	.04	.07	.04	.07	.06	.18
Water (H_2O)+ at 110° C	.25	.31	.33	.34	.50	.29	.37	.62
Titanium oxide (TiO_2)	.31	.33	.35	.41	.47	.48	.50	.20
Manganese oxide (MnO)	Tr.	.03	.02	.03	.03	.03	.08	.05
Carbon dioxide (CO_2)	.21	Tr.	Tr.	Tr.	Tr.	Tr.	Tr.	Tr.
Phosphoric acid (P_2O_5)	.02	.30	.34	.33	.49	.22	.26	.25
	100.25	100.29	99.72	99.47	100.49	100.07	99.09	100.67

[a] Watson, T. L., Bull. Virginia Geol. Survey No. 1-A, 1909, p. 81.

1. Medium-textured medium-gray biotite granite. Westham granite quarries, 4.5 miles west of Richmond, Chesterfield County.
2. Medium-textured medium-gray biotite granite. Lassiter and Petersburg Granite Company's quarries, Petersburg, Dinwiddie County.
3. Fine-grained dark blue-gray biotite granite. McGowan, Netherwood, and Donald quarries, Chesterfield County, and Mitchell & Copeland quarry, Henrico County, near Richmond.
4. Medium-coarse medium-gray biotite granite. Netherwood, State (Old Dominion), Granite Development Company, Krimm, and Middendorf quarries, Chesterfield County, near Richmond.
5. Fine-grained dark blue-gray biotite granite. Cartwright & Davis quarries, near Fredericksburg, Spottsylvania County.
6. Medium-textured medium-gray biotite granite. McIntosh quarry, Chesterfield County, 5 miles west of Richmond.
7. Medium-coarse gray biotite granite gneiss. Middendorf (Belt Line Railway) quarry, near Manchester, Chesterfield County.
8. Medium-coarse gray biotite granite gneiss. Cartwright & Davis quarries, near Fredericksburg, Spottsylvania County.

The high percentage of soda in the Virginia granites has been commented on above. Soda molecularly exceeds potash in every analysis, indicating the predominance of soda-lime feldspar over potassic feldspar, a fact which places the Virginia granites with the quartz monzonites.

KINDS OF GRANITE.

Like the granites of the southeastern Atlantic States in general, the granites of Virginia vary in structure from massive to schistose, and in texture from even granular to porphyritic. On this basis three types of rocks are distinguished: (1) Massive even-granular granites, (2) porphyritic granites, and (3) schistose granites or granite gneisses. The granite gneisses were derived from the massive granites, from which they differ principally in the pronounced schistose structure secondarily induced by dynamic metamorphism.

On the basis of mineral composition the Virginia granites are divisible into the following leading types: (1) Biotite granite, which usually carries a little muscovite in addition to the biotite, and under which a majority of the granites of the State may be grouped, including the Richmond and Petersburg areas and most of the Fredericksburg area; (2) muscovite granite, of which the Hazel Run area, 1 mile west of Fredericksburg, is the only typical representative yet known; (3) hornblende-biotite granite, represented by a part of the granites occurring southwest of Washington in the Falls Church area, Fairfax County, and near Saxe, Charlotte County; and (4) epidote granite (unakite), of which there are only two known localities, one in the Blue Ridge at Milams Gap, near Luray, in Page and Madison counties, and the other near Troutdale, in Grayson County.

In addition to these types pegmatites, coarse crystallizations of quartz and feldspar with subordinate mica, in dikelike form, abundantly penetrate the finer granites and associated crystalline rocks over much of the Piedmont region. Aplite is represented only in the granite of the Richmond area, and here principally on the western border of the Richmond basin, near Midlothian.

NATURE OF THE GRANITE OUTCROPS.

Rock decay is somewhat profound over all parts of the Piedmont region, and the rocks are generally concealed beneath a variable thickness of the loose residual material. Exposures of the moderately fresh granite, however, are by no means uncommon, and because of their favorable location and topographic relations they usually afford desirable quarry sites. These exposures lie usually along the major stream courses in the form of both high and low steep slopes bounding the streams, and on the surface they are usually of a bowldery character. This is particularly true in the stream beds, where the exposures are almost invariably made up of large and small bowlders. Outcrops of this character are strikingly developed along James, Appomattox, and Rappahannock rivers in the vicinity of Richmond, Petersburg, and Fredericksburg. In these areas the quarries have been largely opened in the steep slopes immediately facing the rivers.

On the smaller streams the exposures are low and more in the form of true ledges, which may or may not be of bowldery character. The exposures on the interstream areas are in the nature of low, flat-surfaced masses, and the extent of the exposed granite varies greatly in the outcrop. Prominent granite domes, such as Stone Mountain in Georgia and North Carolina, do not occur in the Virginia region.

EVEN-GRANULAR GRANITES.

The even-granular granites are economically the most important in Virginia. Five types are distinguished: (1) The medium-gray biotite granite of the Richmond-Petersburg area, (2) the dark blue-gray biotite granite of the Richmond-Fredericksburg area, (3) the light-gray muscovite granite of the Fredericksburg area, (4) the dark-gray hornblende-biotite granite of the Falls Church area, and (5) the yellowish-green and pink epidote granite known as unakite. The differentiation of these five types is based on certain differences which are best brought out under the individual descriptions.

MEDIUM-GRAY BIOTITE GRANITE OF THE RICHMOND-PETERSBURG AREA.

The medium-gray granite has been quarried for many years in the vicinity of Richmond and Petersburg. (For description of individual quarries, see pp. 88–106.) It extends over parts of three counties—Dinwiddie, Chesterfield, and Henrico. It is a biotite granite, in many places containing a little muscovite, and the mineral grains (anhedra) range in size from 1 to 5 millimeters. Variation in the size of the anhedra within the limits given is a noticeable feature of this type of granite in the quarries around Richmond and Petersburg. Its principal minerals are quartz, orthoclase, microcline, plagioclase near oligoclase, biotite, a little muscovite, titanite, magnetite, apatite, zircon, and rutile. The secondary minerals are chlorite, epidote, a light-colored mica, and kaolin. An important feature in the mineral composition of this granite is its large content of plagioclase, which either equals or is greater than the potash feldspar. It occurs in large, stout laths, and is always characterized by polysynthetic twinning striæ in basal sections. Extinction angles measured against the twinning striæ usually indicate a plagioclase near oligoclase. Microcline is variable in amount, and may either equal or exceed orthoclase. Twinning on the Carlsbad law is generally visible among the feldspars, both in thin sections and in hand specimens of the rock. Microperthitic intergrowths of the feldspars are seen in most of the thin sections studied. Many of the larger feldspars contain microscopic inclusions of other minerals (micropoikilitic), the inclosures consisting of quartz and other feldspars.

Rutile needles are abundant in some of the quartz. Granophyric intergrowths (mutual penetrations) of the quartz and feldspars are very abundant in the thin sections studied, indicating overlap in the period of formation of these minerals. The quartz intergrowth is not restricted to any single species of feldspar, but seems to be of about equal development in the orthoclase, microcline, and plagioclase species.

Biotite is the third essential constituent; it is deep brown and strongly pleochroic. It is distributed through the rock in single long and stout shreds and as small aggregates. This constituent is subject to some variation both in size of shred and in amount; the rock becoming, according to quantity of biotite, either lighter or darker in color. Under the microscope numerous inclusions of the older minerals are seen in the biotite, among the most important of which are zircon, apatite, and magnetite. In most of the thin sections a little primary muscovite is intimately associated with the biotite, here and there as a parallel growth; in places the two micas penetrate each other, always preserving sharp and clear-cut boundaries. Much chlorite occurs as an alteration product of the biotite. Epidote, though not abundant, is usually present in many of the sections, always as an alteration product from the interaction of the biotite and feldspars, and is associated with the biotite.

Titanite is present to a minor extent in many of the sections, mostly as irregular grains and aggregates, but in part as rhombic crystals. The tint varies from nearly colorless to reddish brown, with noticeable pleochroism in the deeper hues.

Pressure-metamorphic effects are clearly defined in all the thin sections of granite of this type. They are more strongly marked in the granite from the Petersburg portion of the area than in that from Richmond. Under the microscope the pressure effects are shown in an optical disturbance of the quartzes and feldspars, more marked in the former, in the form of a wavy or undulous extinction; in a fracturing of the quartz and feldspar, which is rather strongly developed in some of the plagioclase individuals of thin sections from the Petersburg area; and lastly in peripheral shattering or granulation of the larger quartz and feldspar individuals in the granite from the Petersburg area. Also, in several sections, biotite shreds were noticed broken across, and in still other cases the folia were markedly curved or bent.

At the Netherwood quarry, several miles west of Richmond, this granite is typically shown and in some of the largest quarried blocks dressed up during the summer of 1905 a distinct schistosity was discernible. As a rule, however, the rock from this quarry and from the Richmond area in general belonging to this type appears entirely massive. In the Petersburg part of the area the dynamic effects are the most pronounced, both in the thin sections and in the hand specimens, and a tendency toward a rough parallel arrangement of the minerals—schistosity—is shown on close examination of the rock in nearly every opening.

The State, War, and Navy Building in the city of Washington was constructed from granite of this type obtained near Richmond; and the stone, which has been extensively quarried in the vicinity of Richmond and Petersburg, is used in most of the territory south of New England for building purposes.

DARK BLUE-GRAY BIOTITE GRANITE OF THE RICHMOND-FREDERICKSBURG AREA.

The dark blue-gray granite does not differ essentially in mineral composition from the light-gray rock just described, although the two bear no resemblance to each other in hand specimens. The dark blue-gray rock is much more finely crystalline, the anhedra averaging less than 0.5 millimeter in size. The biotite is uniformly distributed through the granite in minute irregular shreds which impart the pronounced dark-blue color to the rock. Like the light-gray type this is a biotite granite containing a very little muscovite associated with the biotite. Plagioclase and microcline, in quantity and occurrence, are similar in both the dark-blue and the light-gray granites.

Microscopically the two types are unlike in the degree of pressure effects indicated. The dark blue-gray granite is entirely massive, and the only effects of pressure metamorphism discernible in the thin sections are those of undulous extinction of and local fractures in the quartz. In the Fredericksburg portion of the area the rock is a shade darker in color than most of the same type in the Richmond portion. The texture is the same for the two localities, but in the quarries near Richmond there is a perceptible variation in the depth of the blue-gray color.

The dark blue-gray granite is quarried in the vicinity of Richmond and Fredericksburg for monumental stock. Uniformity in color and texture make it a most desirable granite for this purpose.

LIGHT-GRAY MUSCOVITE GRANITE OF THE FREDERICKSBURG AREA.

Light-gray granite occurs about 1 mile west of Fredericksburg on Hazel Run. It is made up of anhedra averaging about 2 millimeters in size and is essentially a muscovite granite containing considerable biotite closely associated with the potash mica (muscovite), distributed through the rock. It somewhat resembles the light-gray biotite-bearing muscovite granite of Stone Mountain, Ga. Here and there a crystal of red garnet is observed in the rock.

The effects of dynamic metamorphism are manifested in the rock in a thinly foliated structure which is discernible only on close examination. Thin sections of the granite show quartz, orthoclase, microcline, plagioclase (oligoclase), muscovite, biotite, apatite, rutile, and zircon. Chlorite and muscovite are the principal secondary minerals. Muscovite is partly primary and partly secondary. Microcline and plagioclase are present in large amount. Intergrowths of the feldspars and of the feldspars with quartz are numerous. Micropoikilitic structure in the larger feldspar individuals is strongly marked. Partial orientation of the mica along parallel directions, an occasional bent and broken muscovite shred, fractured quartzes with wavy extinction, and the perfect granulation of the quartz-feldspar individuals are pressure effects plainly marked in the thin sections.

DARK-GRAY HORNBLENDE-BIOTITE GRANITE OF THE FALLS CHURCH AREA.

The granites in the vicinity of Falls Church, Fairfax County, are of two varieties. One is a medium to finely crystalline rock and contains dominant biotite with some muscovite as a third essential constituent, and is similar in mineral composition to the Richmond types of granite. The other, a light and dark speckled rock, is a fraction more coarsely crystalline and is a hornblende-biotite granite; except for the small granite area near Saxe (p. 112), this is the only hornblende granite yet found in the State, and its affinities somewhat closely ally it with quartz diorite. It is closely associated in the field with diorite masses on the one hand and with foliated mica granites on the other; the associated diorites are partly altered to metadiorites. Petrographically it more properly belongs with the granodiorites, differing from the diorites proper in containing more quartz and potash feldspar. Thin sections show quartz, plagioclase, orthoclase, green and brown hornblende, biotite, apatite, rutile, and the secondary minerals epidote, sericite, garnet, chlorite, and kaolin. Hornblende is one of the most abundant constituents and in places it completely incloses shreds of the biotite. Microcline does not occur. Plagioclase is probably slightly more abundant than orthoclase. Pressure effects are indicated in the optical disturbance of the quartz and feldspar in fractures crossing the quartz, in the curved and bent lamellæ of a part of the plagioclase, and in the marked distortion of the cleavage angle of the hornblende.

YELLOW-GREEN AND PINK EPIDOTE GRANITE—UNAKITE.

Unakite derives its name from the Unaka Mountains in western North Carolina and eastern Tennessee, where it was first observed.[a] Until very recently knowledge of it in Virginia was limited to a single locality—Milams Gap, in the Blue Ridge, near Luray, but it has lately been noted near Troutdale, Grayson County.[b] The mineral composition of the rock from the Virginia and North Carolina-Tennessee localities places it among the granites with epidote as an essential constituent, but according to the analysis by Phalen [c] of specimens from Milams Gap the rock is relatively basic for a granite.

The rock is a moderately coarse but irregular crystallization of red feldspar, quartz, and green epidote. Irregular crystallization of the

[a] Bradley, F. H., Am. Jour. Sci., 3d ser., vol. 107, 1874, pp. 519, 520.
[b] Watson, T. L., Am. Jour. Sci., 4th ser., vol. 22, 1906, p. 248.
[c] Phalen, W. C., Smithsonian Misc. Coll., vol. 45, 1904, pp. 306-316.

rock is shown in its range from masses that are more than two-thirds red feldspar through all gradations to masses composed of quartz and epidote without feldspar (epidosite)[a]. Thin sections of the unakite from Milams Gap show epidote, orthoclase, quartz, iron oxides, zircon, and apatite. The epidote is secondary, replacing pyroxene and feldspar, both plagioclase and orthoclase.

The unakite-bearing rock at Milams Gap is, according to Phalen, a hypersthene akerite (hypersthene-quartz-diallage syenite), a coarse-grained dark grayish-green aggregate consisting essentially of feldspars and black pyroxenes. Thin sections of the syenite reveal the following minerals: Orthoclase, plagioclase, orthorhombic and monoclinic pyroxene, quartz, microcline, iron ore, apatite, and zircon, with the alteration products epidote, chlorite, and sericite. Hornblende is essentially absent in the thin sections. Phalen regards the unakite as having originated from the akerite by hydrometamorphism aided by dynamic disturbances.

The following analyses of the unakite and the unakite-bearing rock (akerite) are quoted from Phalen (p. 313):

Analyses of unakite and akerite from Milams Gap, Virginia.

[W. C. Phalen, analyst.]

Constituents.	Unakite.	Hypersthene akerite.
SiO_2[a]	58.32	60.52
Al_2O_3	15.77	16.99
Fe_2O_3	6.56	.60
FeO	.89	6.53
MgO	.09	1.59
CaO	11.68	4.58
Na_2O	.32	2.83
K_2O	4.01	3.91
H_2O	1.73	.88
P_2O_5	.48	.74
MnO	.13	.25
Cr_2O_3	....	Trace.
ZrO_2	Trace.	Trace.
	99.98	99.42

[a] Including TiO_2.

PORPHYRITIC GRANITE.

Unlike the crystalline region of North Carolina and Georgia, Virginia contains few porphyritic granites. The best developed and most typical area in the State is that bounding the eastern margin of the Richmond coal basin near Midlothian, 13 miles west of Richmond, and extending about 20 miles in a north-south direction. It marks the western limits of the even-granular granite quarried around Richmond and Petersburg. The porphyritic and even-granular granites are both biotite granites and differ from each other only in texture.

[a] Phalen, W. C., op. cit., p. 312.

The rock in the vicinity of Midlothian is a coarse biotite granite, the porphyritically developed mineral of which is potash feldspar. The phenocrysts are of large size, in part twinned on the Carlsbad law, as a rule idiomorphic and flat tabular in habit and are orientated in a general north-south direction from flowage of the rock. The ratio of phenocrysts to groundmass is variable. The porphyritic texture with variations is traced as far north as Gayton, Henrico County, and as far south as Winterpock, Chesterfield County. The evidence seems clear that the porphyritic granite underlies in part the eastern portion of the Richmond coal basin, but its relations to the crystalline rocks on the west can not be stated, for the line of contact is concealed beneath the cover of Newark rocks of the coal basin.

No quarries have been opened in the porphyritic granite.

GNEISSES.

INTRODUCTORY STATEMENT.

Gneisses of granitic composition make up one of the principal rock types in the Virginia Piedmont complex. Many of these gneisses were derived from original massive granites, and they are usually of the mica variety. In mineral composition the granite gneisses are essentially identical with the massive granites, except that hornblende is associated with biotite in the gneisses of the Richmond and Fredericksburg areas. In some of the thin sections hornblende is largely in excess of the biotite. The gneisses differ from the granites principally in having a banded structure, produced through pressure metamorphism. The banding may be fairly regular, but as a rule it is very irregular; in either case the rock is composed of alternating bands of light and dark minerals. The individual bands may vary much in thickness. The structural features of the rock of this type in the Virginia area render it unsuitable for use in any except the rough grades of work, and it is but little quarried in the State.

Between the entirely massive granite and the typical granite gneiss intermediate grades of schistosity are easy of differentiation over parts of the Virginia region. This undoubtedly means that in some of the areas a less schistose granite may grade into a more schistose granite. In other areas this interpretation is not possible, for the massive granites are sharply defined structurally from the schistose granites, and wherever contacts were found it was entirely clear that the massive rock was younger and had been intruded into the schistose rock.

GNEISS OF THE RICHMOND-FREDERICKSBURG AREA.

The gneiss is the oldest of the granitic rocks in the Richmond and Fredericksburg area, and it is invaded by both the medium-gray and the dark blue-gray massive granites. Figure 3 shows the relation between the dark blue-gray granite and the gneiss at the McGowan quarry south of Manchester. Similar relations prevail between the granite and the gneiss in the Cartright & Davis quarries 3 miles northwest of Fredericksburg. The period of deformation, inducing the schistose structure in the gneiss, preceded that of the intrusion of the massive granite, as shown by the fact that the massive granites cut across the schistosity of the gneiss and contain inclusions of the gneiss which preserve perfectly the gneissic structure.

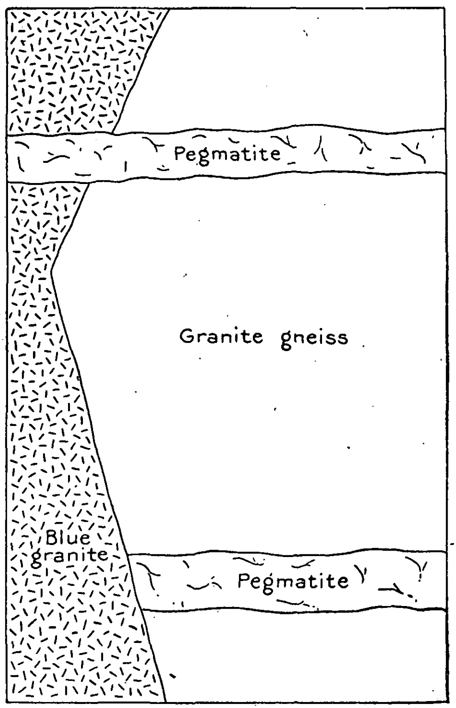


FIGURE 3.—Contact of hornblende-biotite gneiss with granite at McGowan quarry, south of Manchester, Va.

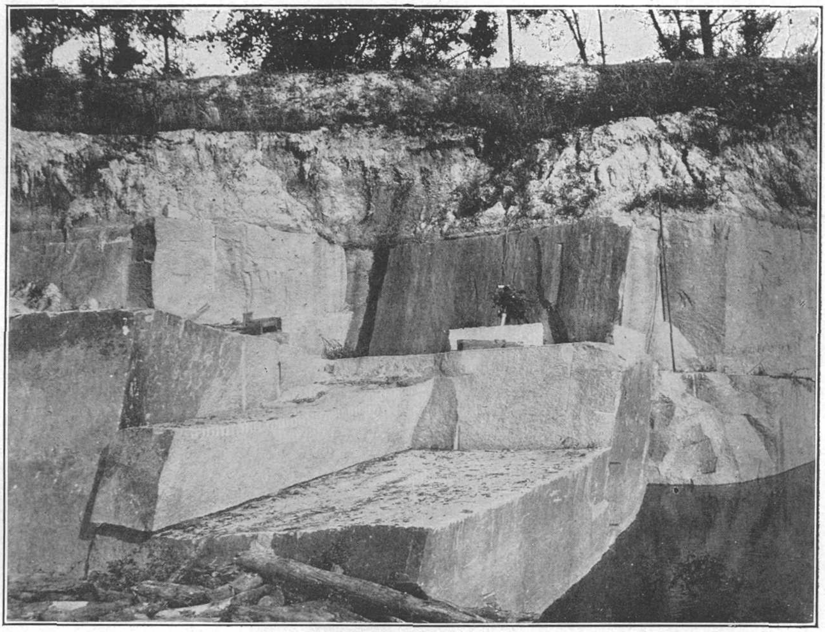
The gneiss is a hornblende-biotite gneiss of medium-coarse texture and irregular banding. It is much coarser in texture than the granites and consists of irregular alternating bands of essentially the dark and light minerals. Its principal minerals are quartz, orthoclase, plagioclase, hornblende, and biotite, with accessory titanite and apatite. Chlorite occurs as an alteration product from biotite.

A thin section of one of the dark bands showed a preponderance of brown and green hornblende with less black mica (biotite), largely altered to chlorite. Some potash feldspar (orthoclase) and soda-lime feldspar (oligoclase), quartz, and much titanite were present. Microcline does not occur. The principal accessory minerals noted in the granite are also present in the gneiss.

Thin sections of one of the coarse-textured, light-colored bands of the gneiss showed the minerals to be quartz, potash feldspar (orthoclase) and soda-lime feldspar in nearly equal amounts, a little black mica (biotite), and several pieces of nearly colorless hornblende. Microcline is not present.

A. GNEISS QUARRY NEAR LYNCHBURG, VA.

Showing regular banding of the gneiss.



B. COOK QUARRY, NEAR PETERSBURG, VA.

Photograph by H. Ries.

The gneiss, which is older than the granite, differs essentially from the latter in having a banded or schistose structure; in the presence of hornblende, which exceeds biotite in amount in some of the thin sections; in the absence of microcline—a mineral always present in the massive granites; and in coarseness of texture. It is unsuited for the higher grades of work for which granite is used, but for other uses it will probably serve equally well. Though good quarry sites are procurable, the gneiss has not been quarried.

GNEISS OF LYNCHBURG, VA.

Extending from the north and east limits of the city of Lynchburg is an extensive body of gneiss cut across by James River and lying partly in Amherst County and partly in Campbell County. Its limits are unknown. Excellent exposures are found along James River and some of its tributaries near the city. Numerous quarries have been opened and the product is used for general building and street purposes in Lynchburg. The quarries are located along the north side of the James, in Amherst County, opposite Lynchburg, where the river has cut directly across a broad anticline of the gneiss; and to the southeast of Lynchburg, in Campbell County, along the tributaries of the James.

The rock is a biotite gneiss of dark blue-gray color and fine grain. It is of doubtful origin, and in places appears to be composed of alternating layers of gneiss and schist of a prevailing gray color. Quartz and mica are the predominant minerals in the schist. The gneiss splits readily into slabs, is hard but easily dressed, and is very resistant to atmospheric agents.

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

GNEISSES OF FAIRFAX AND ALEXANDRIA COUNTIES.

Extending southward from Potomac River and covering much of Fairfax and Alexandria counties are two extensive belts of gneiss, of which one is a metamorphosed granite and the other is of doubtful origin. The former, granite gneiss, is of fairly uniform color and texture; the latter is rather irregular in color, texture, and composition.

The granite gneiss has been quarried from time to time for local use from the ledges along and on the south side of the Potomac. When fresh the rock is a dark bluish-gray gneiss of rather fine grained, uniform texture. The principal minerals are quartz, orthoclase, plagioclase, muscovite, and biotite, with small amounts of garnet, chlorite, hornblende, tourmaline, and pyrite.

The gneiss of doubtful origin, designated by Keith the Carolina gneiss, is composed of alternating layers of gneiss and schist of a prevailing gray color, dark bluish gray when fresh. The bands vary in thickness. Quartz and mica are the predominant minerals in the schist; quartz, feldspar, and mica in the gneiss. So far as the writer is aware the Carolina gneiss has not been quarried in this area.

OTHER GNEISS AREAS.

Gneiss has been quarried also in Fluvanna, Bedford, Franklin, and Pittsylvania counties. These are feldspar-quartz-mica gneisses. The Virginia gneisses are usually well adapted to the rougher grades of work, such as for certain kinds of street work, for concreting and ballast, for retaining walls and foundations, and for road material. Where quarries have thus far been opened, the product has been used strictly for local purposes.

STRUCTURAL RELATIONS IN THE RICHMOND-FREDERICKSBURG AREA.

GENERAL STATEMENT.

Three types of rocks of granitic composition are represented in the Richmond area; two are massive granites; the third is a schistose granite or granite gneiss. The two massive granites are designated the medium-gray granite and the dark blue-gray granite. Three periods of intrusion are represented, in the following order, beginning with the earliest: (1) The granite gneiss; (2) the medium-gray granite; and (3) the dark blue-gray granite. This succession is plainly indicated in the field.

CONTACTS.

The numerous quarries worked in the vicinity of Richmond afford excellent opportunity for studying the contacts between the fresh granites of the three types named above. As noted in the descriptions of the three types (p. 80), the differences in color, texture, and structure render them easy of differentiation. Not one of the large number of contacts examined has shown the presence of contact minerals. Several of the contacts show inclosures of the older granite in the newer one. At one of the contacts between the medium-gray and the dark blue-gray granites in the Netherwood quarry the younger or dark blue-gray granite contains numerous irregular fragments of varying size of the medium-gray granite, as shown in figure 4. Other exposures in the same quarry reveal the true relations of the two granites. As shown in figure 5 the dark blue-gray granite invades the gray granite in two separate, nearly vertical dikelike arms.

The same relation of these two types is equally well shown in the dark blue-gray granite penetrating the medium-gray granite in the Philadelphia quarries, at the head of the settling basin, near Richmond (fig. 13).

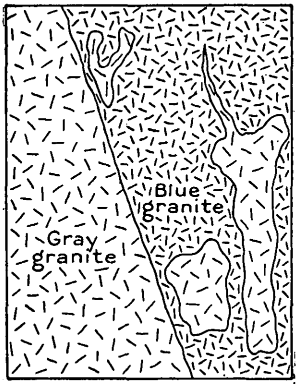


FIGURE 4.—Contact between blue and gray granites at Netherwood quarry, near Richmond, Va., showing inclusions of the gray in the blue.

At the McGowan quarry, several miles south of Richmond (fig. 3), and at the Cartwright & Davis quarries (fig. 14), 3 miles north of Fredericksburg, contacts between granite gneiss and dark blue-gray granite are beautifully shown. At both places the granite cuts directly across the schistosity of the gneiss.

APOPHYSES.

At the Cartwright & Davis quarries, 3 miles north of Fredericksburg, the sloping floor of the granite gneiss in one of the openings contains numerous large and small dikes or tongues of the dark blue-gray granite penetrating the gneiss (fig. 14). These have the texture, color, and composition of the parent mass, and they conform in part with the schistosity of the inclosing gneiss and in part cut directly across

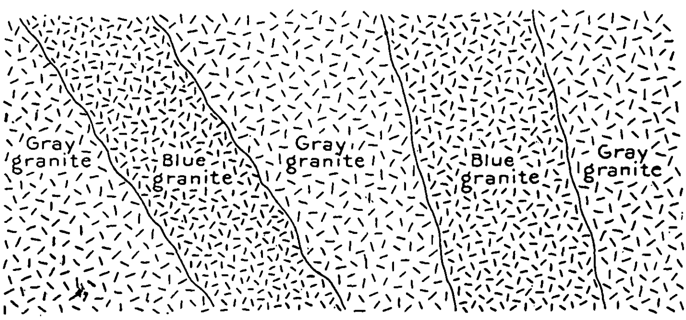


FIGURE 5.—Relations of blue to gray granite, as shown at Netherwood quarry, near Richmond, Va.

it. Similar conditions exist at the McGowan quarry, several miles south of Richmond. The Fredericksburg quarries furnish the best illustration of granite tongues penetrating from the parent mass into the inclosing rock.

INCLUSIONS.

The inclusions correspond, in composition and otherwise, with the inclosing rock and plainly represent fragments of the country rock torn off during the intrusion of the granite containing them. In the Richmond-Fredericksburg area the dark blue-gray granite in some of the quarries contains inclusions of the massive light-gray granite (fig. 4) and of the gneiss (Pl. XII, *B*). The foliation of the gneiss inclusions is entirely preserved. No appreciable metamorphism was observable at the contacts of the inclosing granite and the inclusions.

BASIC SEGREGATIONS (KNOTS).

Dark-gray or black segregations of the iron-magnesian minerals principally, biotite usually, and less quartz and feldspar have scant development in the more productive granite areas of Virginia. The composition of the knots corresponds entirely with that of the inclosing granite, except that biotite is very largely in excess. The granites of Richmond, Petersburg, and Fredericksburg show comparative freedom from knots. Where observed in the quarries around these cities the knots were invariably of small size, usually an inch or less in diameter, and oval. A stronger tendency toward the formation of minute segregations of biotite is shown in the dark blue-gray granite near Fredericksburg than in the granite around Richmond and Petersburg.

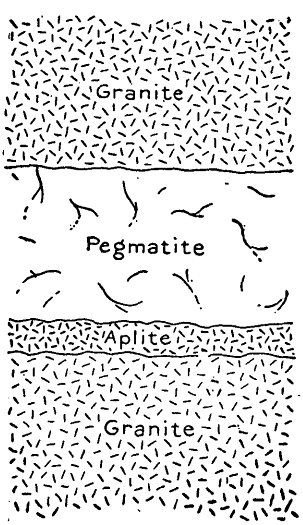


FIGURE 6.—Banded aplite-pegmatite dike in blue granite at McGowan quarry, south of Richmond, Va.

In the hornblende-biotite granite and the diorite of the Falls Church area, in Fairfax County, both large and small, nearly black, oval-shaped knots are common. In some of the undeveloped exposures of the rock the knots are so numerous and so large as to disfigure the stone.

JOINTS.

The Virginia granites are intersected by three systems of joints—a vertical set, a diagonal set, and a horizontal set. These may be widely or closely spaced. Usually the spacing is sufficiently wide to admit of dimension stone being quarried. The vertical set of joints is in general more strongly developed than the diagonal; some of the granite masses are cut by both sets.

Measurements of the joint courses made in the quarries can be summarized as follows: Two sets of joints whose planes lie in the northeast and southwest quadrants compose the major jointing, and the minor sets strike east-west and north-south. The strike of the joint planes in the northeast and northwest quadrants shows the limits of variation to be N. 5° E. or W. to N. 80° E. or W. Only a few of the planes strike east-west and north-south.

The inclined joints are less abundant than the vertical ones, and they dip at angles varying from 20° to 82°. The dips are toward the northeast, east, southeast, northwest, and southwest. Plates X, *A*, *B*, and XI, *A*, show the two systems of vertical and inclined joints. Some movement in the granite masses since the formation of the joints is indicated in the development of slickensides on the joint surfaces. Polished and striated surfaces are fairly abundant.

As a rule, joints approximating horizontality in position are strongly developed in the granites of Virginia. Probably the most noteworthy exception is the granite exposed in the quarry of the Richmond Granite Quarrying Company, where vertical jointing is well developed but horizontal jointing is not apparent. The thickness of the sheets produced by this set of joints varies greatly, ranging from 6 inches to several feet. Ordinarily the planes separate the granite into thinner sheets at or near the surface and into thicker sheets at greater depth. (See Pl. XI, *B*.)

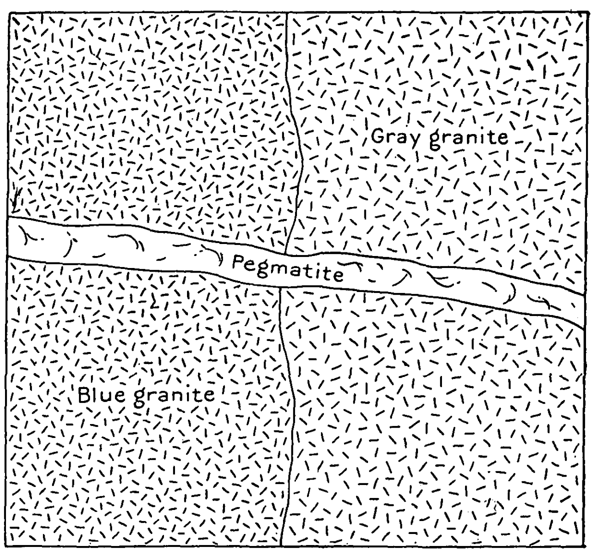


FIGURE 7.—Contact between blue and gray granites, showing pegmatite cutting both, at Netherwood quarry, west of Richmond, Va.

DIKES.

APLITES.

Aplites are uncommon in the Virginia granite areas, and have been noted by the writer only in the Richmond area. A banded aplite-pegmatite dike of small dimensions, shown in figure 6, penetrates the dark blue-gray granite of the McGowan quarry, south of Richmond. In the vicinity of Midlothian, 13 miles west of Richmond, the porphyritic biotite granite is cut by a number of small aplite dikes. Where these have been observed they are plainly of an intrusive nature, cutting the granite proper and not the inclosing gneisses.

PEGMATITES.

Pegmatites are abundantly developed in the Richmond-Fredericksburg areas, and some of them are of large size. Only in one or two places do they seriously interfere with quarrying operations. They are of granitic composition and no unusual or rare minerals have been noted in them; they cut alike the granites and gneisses. They have been worked to a moderate extent in several places in the Richmond area, but they have not yet become of economic importance.

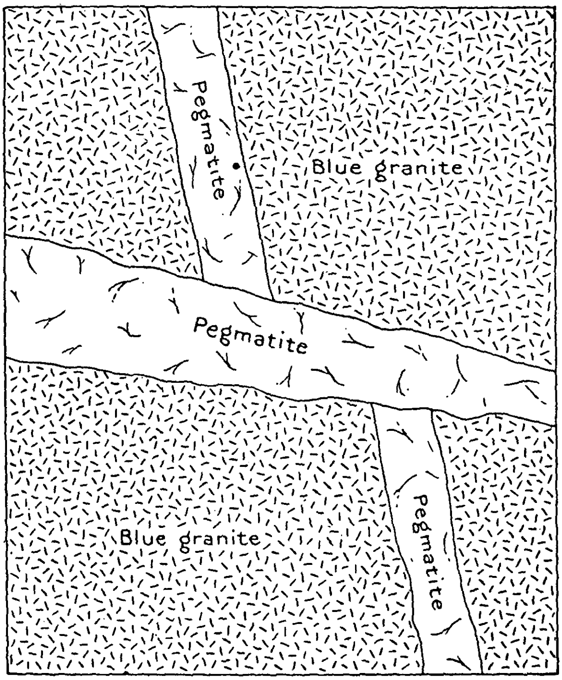


FIGURE 8.—Faulted pegmatite intersecting blue granite at Donald quarry, near Richmond, Va.

The pegmatites consist of coarse aggregates of feldspar and quartz with more or less black biotite and a little muscovite. In the Fredericksburg quarries of dark blue-gray granite, where the pegmatites are particularly abundant, massive granular magnetite and large and small perfect red crystals of garnet are not uncommon constituents. The dodecahedron and trapezohedron are the commonest forms of the garnet. The feldspar exhibits a variety of colors from opaque white and pink to a decided medium green, the former two being the prevailing shades. An acidic plagioclase is present in some of these dikes.

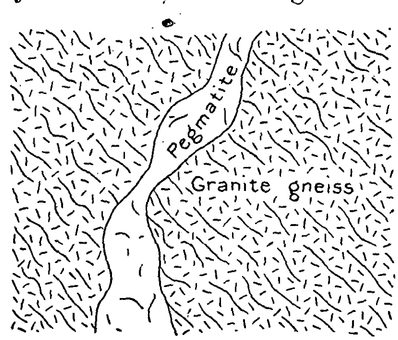
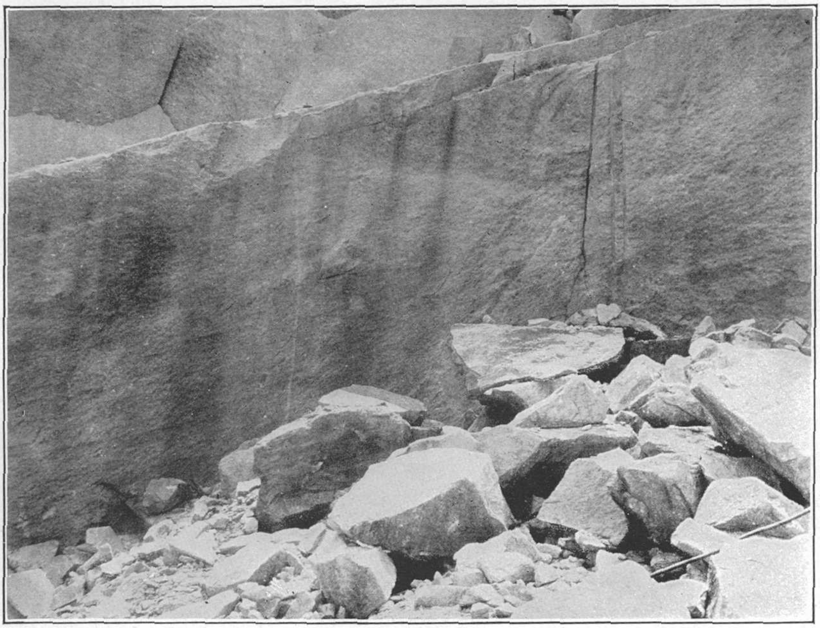


FIGURE 9.—Pegmatite cutting across schistosity of granite gneiss at Middendorf quarry, west of Manchester, Va.

The numerous quarries in the Richmond area afford excellent opportunity for studying the pegmatites and some interesting data bearing on their comparative age relations have been obtained. It



A. MONUMENTAL GRANITE, DONALD QUARRY, NEAR RICHMOND, VA.

Photograph by H. Ries.

B. PEGMATITE DIKES CUTTING GRANITE, DONALD QUARRY, NEAR RICHMOND, VA.

Photograph by H. Ries.

has been shown above that there are three granites, including the granite gneiss, in this area, representing as many periods of intrusion. The order of these intrusions, beginning with the oldest, has been shown to be (1) granite gneiss, (2) light-gray granite, and (3) dark blue-gray granite. As shown in figures 3, 7, and 10, the granite of each intrusion was accompanied by the formation of pegmatitic material. Some of the pegmatites intersecting the dark blue-gray granite, the latest of the granite intrusions, also penetrate the light-gray granite and, locally, the earliest of the intrusions, granite gneiss. These conditions are well illustrated in figures 3 and 7, which show the latest formed pegmatites intersecting the dark blue-gray granite, the light-gray granite, and the granite gneiss. Figure 3 shows a pegmatite associated with the earliest granite (granite gneiss), abruptly cut off by the intrusion of the later dark blue-gray granite into the granite gneiss. Those pegmatites which are characteristically associated with the dark blue-gray granite intersect one another in such manner as to indicate earlier and later formation. Figure 8, which shows this feature, also shows that the older or intersected pegmatite is faulted along the younger or intersecting pegmatite.

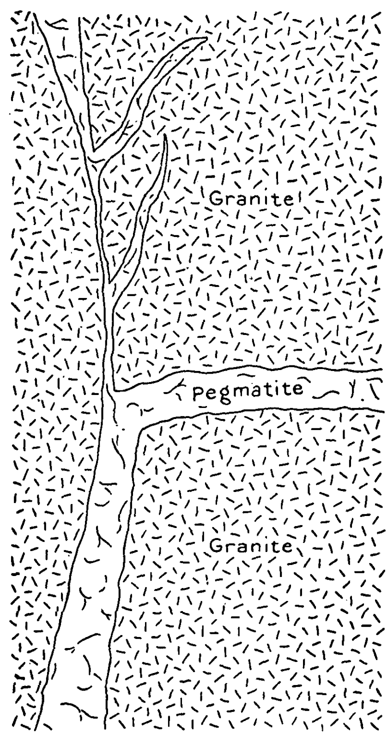


FIGURE 10.—Pegmatites showing irregularities of outline and width at Richmond Granite Quarrying Company's quarry, $4\frac{1}{2}$ miles north of Richmond, Va.

The pegmatites that intersect the granite gneiss may coincide with the schistosity, as in figure 3, or may cut across the schistosity, as in figure 9. Figure 10, sketched from a portion of the Richmond Granite Quarrying Company's quarry, illustrates the irregularities of form and width of many of the pegmatites. Plate IX, *B*, shows pegmatite cutting the dark blue-gray granite in a quarry near Richmond.

Where observed the pegmatites are sharply defined from the inclosing rock; they show no banding parallel to the walls; their composition is essentially similar to that of the inclosing granite; and they are massive without evidence of pressure metamorphism.

This massive character has an important bearing on the question of the relative periods of formation of the pegmatites and the granite gneiss which they intersect. If the gneiss represents an original massive granite, which seems reasonably sure, it must follow that the massive pegmatites which characterize it were formed after the period of deformation which induced the banded or schistose structure in the gneiss. Again, this series of pegmatites must have formed prior to the periods of intrusion of the light-gray and the dark blue-gray granites, as shown in figure 3.

Pegmatite dikes assume large dimensions in many of the Virginia Piedmont counties. The economic value of these bodies has been proved in Amelia, Bedford, Hanover, Henry, and Nelson counties. As indicated in the analyses below, the feldspar of the Virginia pegmatite dikes is, with one exception, potassic.

Analyses of feldspar from Virginia pegmatites.

	1.	2.	3.	4.
Silica (SiO_2)	64.12	65.37	67.06	63.25
Alumina (Al_2O_3)	16.84	18.74	21.72	20.33
Iron oxide (Fe_2O_3)	2.28	.13	....	....
Magnesia (MgO)	.32	....	.03	....
Lime (CaO)	.26	.27	1.59	....
Soda (Na_2O)	1.88	2.49	10.01	1.35
Potash (K_2O)	13.34	12.98	.38	12.85
	99.04	99.98	100.79	97.78
Specific gravity	2.564	2.501	2.618	....

1. Potash feldspar from pegmatite dike near Amelia Court-house, Va.; C. C. Page, analyst.
2. Potash feldspar from pegmatite dike near Amelia Court-house, Va.; E. B. Sloan, analyst.
3. Albite feldspar from pegmatite dike near Amelia Court-house, Va.; R. Robertson, analyst.
4. Potash feldspar from pegmatite dike near Bells, Bedford County, Va.; Golding Sons Co., analyst.

INDIVIDUAL QUARRY AREAS.

PETERSBURG AREA.

GENERAL STATEMENT.

The Petersburg granite area includes the extreme northeastern portion of Dinwiddie County and the contiguous southeast corner of Chesterfield County. The area is crossed by Appomattox River near Petersburg, and quarries are operated to the north and south of the stream. The principal quarries, shown on the map (Pl. VII), include the Lassiter and Petersburg Granite Company's quarries, on the west side of Petersburg, and the Cook quarry, on the north side.

The granite of this area, as shown in the quarries, varies in texture from fine to medium, and in color from light to medium gray. It is a biotite granite and a little muscovite is usually associated with the biotite in variable amount. Thin sections of granite from the individual quarries show some variation in the ratio of the mineral constituents, more especially that of biotite to muscovite, and that of the different species of feldspar. In descending order the principal minerals are potash feldspar (orthoclase and variable microcline), soda-lime feldspar (oligoclase), quartz, biotite, and muscovite, with accessory magnetite, titanite, apatite, and zircon, and secondary chlorite, white mica, and epidote. An occasional grain of pyrite is observed in some of the sections, but in such minute quantity as to be entirely negligible as a deleterious constituent in the rock.

Plagioclase (soda-lime feldspar) may equal or in places exceed orthoclase (potash feldspar) in amount. Excess plagioclase over potash feldspar is indicated in some of the thin sections cut from specimens of granite from the Cook quarry. Microcline varies greatly in amount, but is usually subordinate to both orthoclase and plagioclase. Intergrowths of the different feldspars with one another and of quartz with feldspar and twinning of the feldspars on the Carlsbad and albite laws are common microstructures to all the thin sections. Biotite, partly altered to chlorite, is subject to some variation, both in size of shred and in amount, the rock being, according to the proportion of biotite, either lighter or darker in color. The granite from the Cook quarry contains less biotite than that from other quarries in the area, and is accordingly lighter in color. The effects of pressure metamorphism, shown principally in the peripheral granulation of the quartz and feldspar, occasional bent and fractured plagioclase, undulous extinction and fracturing of the quartz, and a tendency toward orientation of the minerals, especially mica, are rather strongly indicated in the thin sections of the granite from this area.

The stone from the quarries in the Petersburg area is of excellent quality and is used for monuments, general building, and street work. It is of homogeneous texture and good permanent color, and contains no harmful mineral. The joint planes are widely spaced, readily permitting the quarrying of dimension stone.

DESCRIPTIONS OF QUARRIES.

The *Cook quarry* is located about 2 miles north of Petersburg, immediately on the west side of the Seaboard Air Line Railway, within 300 feet of the crossing of this road by the Belt Line. Some stone was quarried as early as 1837, but extensive quarrying was not begun until 1887. Pl. VIII, *B*, shows a view in the quarry.

The rock is a biotite granite of light-grayish color and medium-fine, even grain. It consists of potash feldspar (orthoclase and microcline) and soda-lime feldspar (oligoclase) in nearly equal amount (the oligoclase exceeding the potash feldspars in one section), quartz, and black mica (biotite), associated with a sprinkle of white mica (muscovite), together with accessory magnetite and titanite, and secondary chlorite and epidote. Biotite is present in smaller amount than in the granite of other quarries in this area, and the color of the rock is correspondingly lighter. Pressure effects are manifest in peripheral mashing or granulation of the quartz and feldspars.

The sheets at this quarry average from 2 to 9 feet in thickness and are approximately horizontal. Pegmatites do not occur. Joints in a small exposure above the quarry strike N. 30° to 50° E. In the main quarry opening the joints strike N. 50° to 70° E. and N. 10° to 55° W., and vary in dip from vertical to as much as 65°. The sap does not exceed 4 to 6 inches in thickness. In places oxidation along joint surfaces extends to the depth of working.

The granite is admirably adapted to the uses made of it, which comprise general building purposes; street work of all forms, including blocks, curbing, and crushed stone; and wall, bridge, and culvert work in the rough and dressed state. A crusher is operated at the quarry for working up the quarry waste, mainly for concrete work. The largest-size waste is made into paving blocks, the second into rubble paving, and the balance is crushed for concrete. The product is shipped as far north as New York and as far west as Cincinnati, but practically no shipments are made south of Virginia.

The *Lassiter quarries*, comprising three or four openings made close together, are located about 1½ miles west of Petersburg, immediately on the line of the Virginia Passenger and Power Company, within a quarter of a mile of the Seaboard Air Line Railway. Some stone is reported to have been quarried here more than fifty years ago. During the summer of 1906 two of the openings were being operated by separate parties.

The rock is a biotite granite of medium dark-gray color and medium fine grain. The feldspar has a decided pinkish cast. The minerals, in descending order of abundance, are feldspar (the potash varieties, orthoclase and microcline, and the soda-lime variety, oligoclase, the latter in amount but slightly less than orthoclase and microcline), quartz, black and white micas (biotite and muscovite), with accessory titanite, magnetite, apatite, and zircon and secondary chlorite and epidote. Crushing effects are strongly marked in peripheral granulation of the quartz and feldspar and in occasional bent and fractured plagioclase individuals. Thin sections of the sap (partly decayed granite) show a somewhat advanced stage of decay in the principal minerals, which are extensively discolored by yellow iron oxide liberated from the iron-bearing minerals.

Joints intersecting the granite in the Walsh opening strike N. 70° to 80° E., N. 15° to 30° W., and east-west, and dip 70° S. The joint surfaces are slickensided from subsequent movement and are coated with a greenish altered mica. Joints measured in one of the other openings strike N. 70° E. and N. 20° to 70° W. and dip from vertical to about 80° ESE. Pegmatite dikes, from 1 inch to 5 or 6 inches wide, composed mostly of pinkish feldspar and less quartz, with little or no mica, intersect the granite. These are not so abundant as to interfere with quarrying. The joints are usually widely spaced, and blocks of granite 20 feet and more in length are frequently quarried. The depth of stripping necessary will average about 5 feet, being greater in some places and less in others. The partly decayed granite (sap) is likewise variable in thickness and will probably average several inches.

The granite works well under the hammer and is susceptible of a high polish. It is extensively used in the monument and building trades, principally in the former. The quarry waste is broken up and used for rubble. As monumental stock this granite is used in Virginia and adjoining States and as far west as Denver, Colo., and as far north as Pennsylvania and New Jersey.

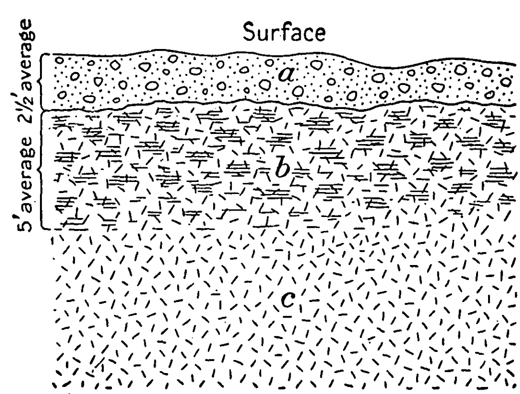


FIGURE 11.—Section at the Petersburg Granite Company's quarry No. 2, 2 miles west of Petersburg, Va.

The *Petersburg Granite Company's quarries*, comprising two principal openings about three-quarters of a mile apart, are located about 2 miles west of Petersburg and about half a mile west of the Lassiter quarry, immediately along the line of the Petersburg Passenger and Power Company. The two openings are designated No. 1, known as the Asylum quarry, and No. 2, known as the Dibble quarry. About 5 feet of stripping, comprising sand, gravel, and decayed granite, must be removed before the quarrying of fresh granite can begin (fig. 11). The openings are large and are made in flat surface exposures of the granite.

The rock is 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 accessory magnetite, titanite, apatite, and zircon and secondary chlorite, epidote, and muscovite. Muscovite is closely associated with the biotite and is partly primary and partly secondary. Intergrowths of the feldspars with each other and of feldspar with quartz are numerous. Pressure effects are plainly marked in the thin sections, in the way common in the granite of the other quarries in this area, as already described.

Pegmatites occur only here and there and are of slight dimensions. The best-developed joints and the only ones measured strike N. 10° to 25° W. and dip from 55° to vertical. A few very small segregations (knots) of black mica (biotite) were observed in the granite. True sheeting does not occur, and the stone appears in the quarry in nearly massive form. The joints are widely spaced, and dimension stone of almost any size is obtainable.

During the summer of 1906 quarry No. 1 was being operated under lease by a Baltimore firm (Guilford and Waltersville Granite Company), and the stone used almost exclusively for building purposes in Petersburg. Some of it is used for coping in cemetery work. Quarry No. 2 has not been worked for six years or more. A large quantity of the granite has been quarried and used for various purposes.

The *Petersburg Passenger Company's quarry*, located at the dam across Appomattox River, 7 miles west of Petersburg, was opened and operated for local purposes during the summer of 1905.

RICHMOND AREA.

GENERAL STATEMENT.

The Richmond granite area, including parts of Chesterfield and Henrico counties, in the immediate vicinity of the cities of Richmond and Manchester, is the largest producing area in the State. Figure 12, a generalized section about 15 miles long through Richmond and

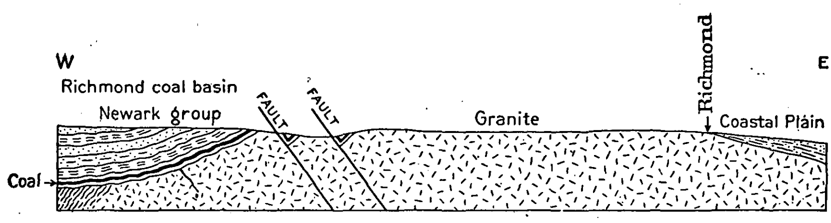


FIGURE 12.—Section from Richmond west to Midlothian, Va., and beyond.

Midlothian, shows the relations of the granite to the Coastal Plain formations on the east and to the Newark rocks of the Richmond coal basin on the west.

The quarrying of granite in this area began in the early part of the last century, and a large number of quarries have been opened and worked since that time. The quarries are opened chiefly in the granite bluffs along James River, extending in a general westerly direction from the city of Richmond for a distance of more than 5 miles. Quarries have been opened to a smaller extent north and south of Richmond, in the low granite ledges exposed along the smaller streams and in flat-surface exposures on the interstream areas. Many of the quarries are very extensive and have been worked to a depth of nearly 200 feet. In some of these the depth reached in quarrying is below the river level. The quarries are well located with reference to transportation facilities and admit of easy working.

The location of this granite area, at the head of navigation on James River, affords water transportation either north or south.

KINDS OF GRANITE.

Mineralogically, the granites of the Richmond area are mica granites, but on a textural and color basis two kinds are distinguishable—a medium-grained light-gray granite and a fine-grained dark blue-gray granite. This distinction is recognized commercially, and accordingly two grades of the stone are quarried, each differing in the principal use made of it. The coarser-textured light-gray granite, elsewhere described by the writer as the Richmond-Petersburg light-gray granite,[a] is admirably suited for general building purposes. The finer-textured dark blue-gray granite, described as the Richmond-Fredericksburg dark-blue granite,[b] is extensively used for monument stock. (See Pl. IX, *A*.) Both are homogeneous even-granular granites possessing good working qualities.

The coarser light-gray granite is the older of the two and is penetrated in several of the quarries by dikelike masses of the finer dark blue-gray granite. Figures 4, 5, and 7 show the structural relations between the two granites as exposed in the Netherwood quarry west of Richmond.

STRUCTURAL FEATURES.

The structural relations of the two granites in the Richmond area have been stated above. Both granites are intruded into an irregularly banded hornblende-bearing biotite gneiss of granitic composition.

Joint structure and pegmatite dikes are well developed in the granites of this area. Each of these structures is described in some detail on pages 84–88. The joint planes are usually spaced sufficiently far apart to permit the quarrying of stone of almost any size, and the pegmatites are rarely numerous enough to cause waste in quarrying.

[a] Bull. Geol. Soc. America, vol. 17, 1906, pp. 526–528.
[b] Idem, pp. 528–529.

MINERAL COMPOSITION.

The two types of granite distinguished above do not differ essentially in mineral composition, although they bear little or no resemblance to each other in the hand specimens. Both are biotite granites, locally containing a little muscovite. The coarser light-gray type consists of anhedra which range in size from 1 to 5 millimeters. Variation in the size of anhedra here given is a noticeable feature in the rock of this type in the quarries opened around Richmond and Petersburg. The dark blue-gray granite is more finely crystalline and its anhedra are more uniform in size, averaging less than 0.5 millimeter.

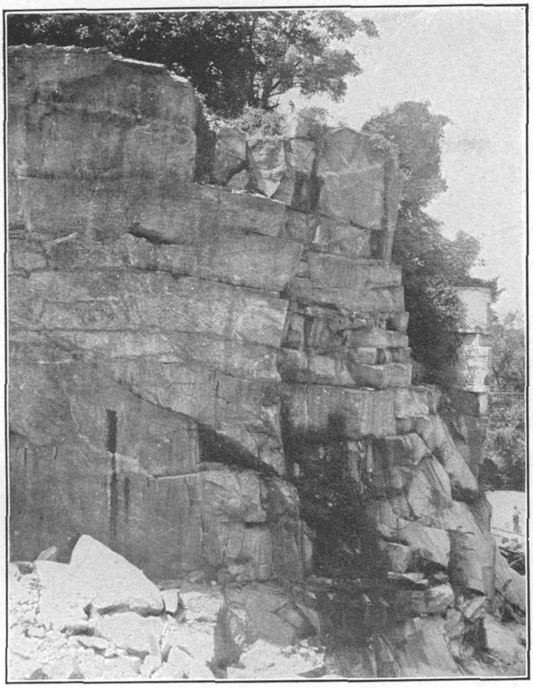
The principal minerals in the two types are orthoclase, microcline, plagioclase near oligoclase, quartz, biotite, a little muscovite, titanite, magnetite, apatite, and zircon. The usual alteration minerals occur, chief among which are chlorite, muscovite, and kaolin. Quartz and either of the feldspars present are frequently intergrown in granophyric structure. Microcline or plagioclase may either equal or exceed orthoclase in amount. These granites usually contain much plagioclase, which occurs in large, short laths and is characterized by the twinning striæ in basal sections. Extinction angles measured against the twinning striæ usually indicate a plagioclase near oligoclase. Twinning on the Carlsbad law is common among the feldspars, both in thin sections and in hand specimens.

Biotite, the third essential constituent, is brown in color and strongly pleochroic. Its distribution in the fine-grained, dark blue-gray granite is probably more uniform than in the light-gray rock, and in the latter it is subject to some variation, both in size of shred and in amount. In both types a little primary muscovite is as a rule intimately associated with the biotite, locally as parallel growths; and in places the two micas penetrate each other, always preserving sharp and clear-cut boundaries. Chlorite occurs as an alteration product of the biotite. Epidote is not abundant but appears in many of the sections as an alteration product from the interaction of the biotite and the feldspars; it is usually associated with the biotite.

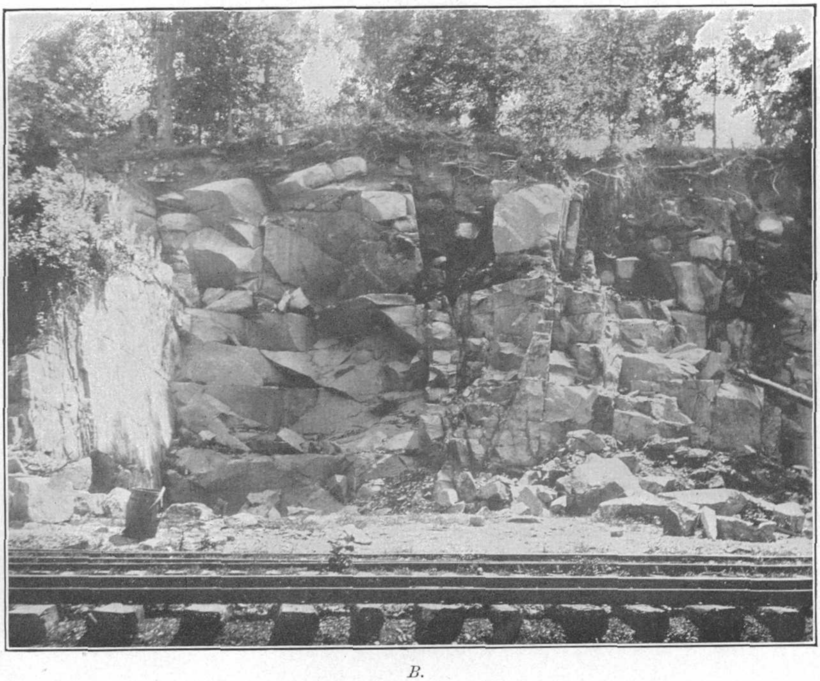
The remaining minerals occur only in very subordinate amount and present no special interest.

Pressure effects of the usual kind are pronounced in the thin sections of the light-gray granite, and are only slightly discernible in the thin sections of the dark blue-gray type. They are more marked in the granite from the Petersburg part of the area than in that from the Richmond area proper.

Some of the large blocks of the light-gray granite, quarried at the Netherwood quarry during the summer of 1905, showed a fairly well developed schistose structure. Ordinarily the rock belonging to this type from this quarry and from the Richmond area in general appears



A.



B.

JOINTING IN NETHERWOOD QUARRY, NEAR RICHMOND, VA.

A. In gray granite. *B.* In blue-gray granite, which intrudes the gray. Photographs by H. Ries.

massive. In the Petersburg area the pressure effects in the granite of the same type are most pronounced in the thin sections and a tendency toward parallel arrangement of the minerals is indicated in an incipient schistose structure.

DESCRIPTIONS OF QUARRIES.

The Richmond area includes about twenty-five quarries. Of this number less than ten were being operated during 1905 and 1906. These were the McCloy, McGowan, McIntosh, Middendorf, Netherwood, Richmond Granite Company, Winston & Co., and Wray. Some of the others have not been worked for many years, and in part they include the most extensive openings in the area. This is particularly true of the Westham and the Old Dominion Granite Company's quarries.

CHESTERFIELD COUNTY (SOUTH OF JAMES RIVER).

The *Netherwood quarry* is opened in the high granite bluff on the south side of James River about 2½ miles southwest of Richmond. It is one of the largest quarries in the Richmond area, and is reported to have been worked as early as 1845.

Two types or grades of granite, the structural relations of which are shown in figures 4, 5, and 7, are quarried, both of which are biotite granites. One is a medium-textured, light-gray rock; the other a fine-textured dark blue-gray rock. They are essentially similar in mineral composition. The principal minerals are feldspar (orthoclase, microcline, and plagioclase, in variable amounts), quartz, biotite, and a little muscovite. Chlorite, epidote, kaolin, and a light-colored mica are secondary minerals derived from the alteration of the biotite and feldspars. The feldspars all show intergrowths with quartz. Accessory titanite, apatite, and zircon occur. An occasional garnet was noted in all the sections of the fine-textured, dark blue-gray granite. Pyrite is rare; it occurs sparingly along the joint surfaces and occasionally in the granite, but nowhere in a harmful amount.

The quarry has a working face of about 65 feet. Though located only a short distance from James River, its greatest depth is considerably above the stream level and the drainage is good. The stripping consists of about 2 feet of red clay.

The sheets are from 2 to 6 feet thick. Vertical joints strike N. 45° to 65° E. and N. 15° to 75° W. (See Pl. X, *A*, *B*.) The surfaces of some of the joints show slickensides and are coated to some degree in places with pyrite, which shows the movement in the striated and flattened masses of the mineral. Coarse pegmatite dikes up to 12 inches and more in width cut the granite irregularly. Dimension stone is readily obtained and little or no waste is occasioned by the pegmatites.

The granite has an extensive market in and out of the State and is used for general constructional and monumental purposes, curbing, blocks for paving, and crushed stone in all uses made of it. Its principal use is for building and city street work, for which the light-gray type is mostly used. The dark blue-gray, fine-textured granite takes a fine polish and it is a desirable stone for monumental stock.

The *Wray quarry*, opened in the high granite bluffs on the south side of James River, is located about 3 miles southwest of Richmond and about half a mile west of the Netherwood quarry. It has been operated since 1895 for monumental stock exclusively.

The rock is a biotite granite of medium dark color and fine, even grain. Its minerals are potash feldspar (orthoclase and microcline), soda-lime feldspar (oligoclase), quartz, and biotite. The rock contains accessory apatite and titanite, and secondary chlorite and a light-colored mica. Intergrowths of the quartz with the feldspars and of the feldspars with one another are noted. Twinning structure in the feldspars is marked.

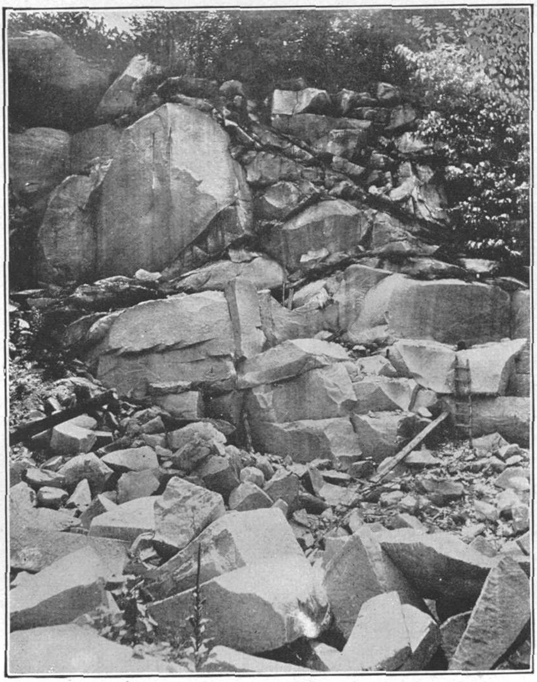
The joints strike east-west and north-south and are so spaced as to admit of dimension stone being quarried. (See Pl. XI, *A*.) Slickensides are developed along the surfaces of the joints, indicating some movement along these directions. Several pegmatite veins or dikes up to 3 inches wide occur.

This granite is practically limited in sale to the principal cities in the State for monument stock.

The *Donald quarry* is located similarly to the Netherwood and Wray quarries, on the south side of James River about 500 yards east of the Belt Line railroad bridge. It is a short distance west of the Wray quarry and farther up the river.

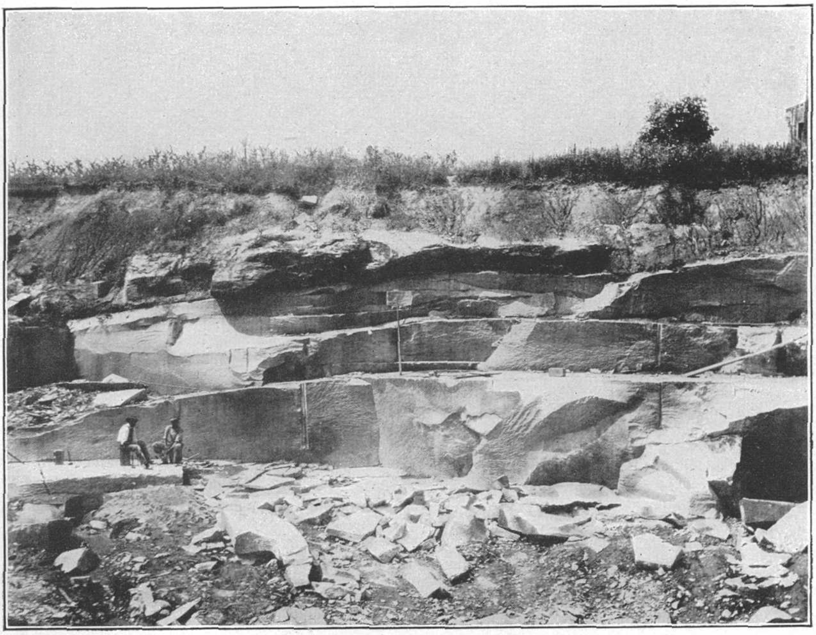
The rock is a biotite granite of fine, even grain and in large part of dark blue-gray color. A zone 6½ feet wide of very light gray granite, containing little or no biotite, of the same fine, even-grained texture as the dark blue-gray rock is exposed near the west half of the quarry. The contacts made by the two granites are entirely sharp and distinct. The minerals of the dark blue-gray granite are potash and soda-lime feldspars (orthoclase, microcline, and oligoclase in variable proportion), quartz, and biotite, with rarely a scale of muscovite. The feldspars are twinned and are intergrown partly with one another and partly with quartz. Accessory apatite and titanite occur and some secondary chlorite and light-colored mica are developed in some of the thin sections. The zone of light-gray granite differs from the dark blue-gray only in the amount of biotite present.

The granite is traversed by joints which strike north-south, east-west, N. 50° to 60° E., and N. 55° W. Slickensides developed along many of the joint surfaces indicate some subsequent movement along



A. WRAY QUARRY, WEST OF RICHMOND, VA.

Showing joint systems. *Photograph by H. Ries.*



B. McGOWAN QUARRY, SOUTH OF MANCHESTER, VA.

Showing sheeting. Photograph by H. Ries.

these directions in the granite. Pegmatite dikes, ranging in thickness up to 12 inches and more, are somewhat numerous in parts of the quarry and traverse the granite in nearly all directions (Pl. IX, *B*). In several places intersecting of the dikes has resulted in slight displacement (faulting) of the intersected by the intersecting dike, as shown in figure 8.

The quarry has not been worked for several years.

The *McGranigan quarry* is about three-eighths of a mile east of Granite, a station on the Southern Railway, and about one-eighth of a mile west of the Belt Line railroad bridge. The quarry comprises the stripping of an irregular sloping granite surface to a maximum depth of 20 feet, extending back from the water's edge of James River.

The rock is a biotite granite of medium-gray color and medium, even grain. Its minerals are potash feldspar (orthoclase and microcline), soda-lime feldspar (oligoclase), quartz, and biotite, with accessory apatite and zircon. The feldspars are partly altered to a little kaolin and a light-colored mica. Chlorite and epidote are noted to some extent as secondary minerals.

Joints strike N. 25° E. and N. 65° W. Several pegmatite dikes of small dimensions intersect the granite. There are a few knots of small size. This quarry has not been worked for some years.

The *Granite Development Company's quarries* comprise a number of small openings several hundred yards west of the McGranigan quarry and about one-fourth mile east of Granite station. The rock is a biotite granite of the same color and texture as that of the McGranigan quarry. Its mineral composition is the same, with perhaps soda-lime feldspar in larger amount. The principal vertical joints strike north-south and N. 65° E.

The *Hawkins quarry*, reported to have been one of the first quarries opened in the Richmond area, is located between James River and the Southern Railway, a few paces east of Granite station. The rock is a biotite granite of medium, even grain resembling that of the Granite Development Company's quarries. Quarrying was confined to the stripping of a gently sloping granite surface to only a shallow depth. It is said that much of the stone was used in the form of riprap for river work about Williamsburg, Portsmouth, Norfolk, and other towns in eastern Virginia. This quarry has been idle for many years.

The *Old Dominion Granite* (*Middendorf*) *quarries* comprise two large openings very close together, located several hundred yards south of west from Granite station. The openings are extensive, affording every evidence that large quantities of stone have been quarried from them, but they have not been worked for some years, and at the time of examination in 1906 they were nearly filled with water.

The rock is a biotite granite of medium-gray shade and medium, even grain. Vertical joints strike N. 60° E. and N. 5° W. Pegmatite dikes traverse the granite in places, but they are not numerous enough to cause waste in quarrying. Small, irregular knots are developed to a minor degree.

The *Krimm quarry* is located several hundred yards southwest of the Old Dominion Granite (Middendorf) quarries. The quarry has not been worked for some years, and it was nearly filled with water at the time of examination in 1906. A mantle of light-gray decayed granite and soil, 8 to 12 feet thick, must be stripped before the fresh granite is reached.

The rock is a biotite granite of similar color and texture to that of the Old Dominion Granite (Middendorf) quarries. Its minerals are potash feldspar (orthoclase and microcline), soda-lime feldspar (oligoclase), quartz, and biotite, with scattered muscovite shreds, and secondary chlorite, epidote, and light-colored mica.

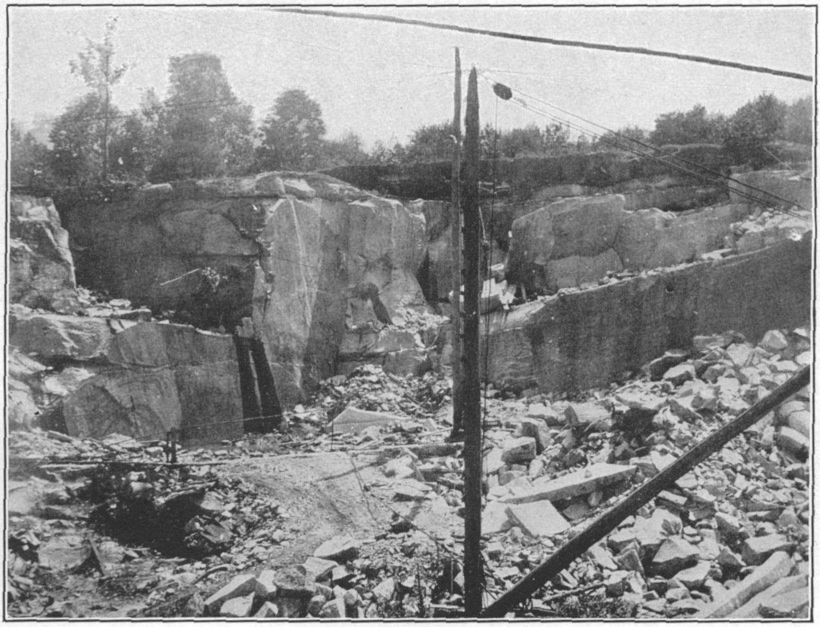
The joints strike N. 55° to 65° E. and N. 15° W., the latter set being somewhat more closely spaced than the former. Very few pegmatite dikes were noted.

The *McIntosh quarry,* formerly known as "flat rock," has been operated for about twenty years and is one of the most extensive working quarries in the State. It is located about three-eighths of a mile southwest of Granite, a station on the Southern Railway 5 miles west of Richmond.

Two types of granite are represented. The principal and dominant type is a biotite granite of medium-gray color and medium-coarse grain. Its minerals are potash feldspar (orthoclase and microcline), soda-lime feldspar (oligoclase), quartz, and biotite, together with accessory apatite, zircon, and ilmenite and secondary chlorite, epidote, and colorless mica. An occasional grain of pyrite occurs. Orthoclase is intergrown with plagioclase as microperthite. Intergrowths of feldspar and quartz as micropegmatite, feldspar twinning on the Carlsbad law, and micropoikilitic structure in some of the larger feldspar individuals are common. The second type of granite is a biotite granite of dark blue-gray color and fine-grained texture. In mineral composition it conforms entirely with the dominant, medium-gray granite just described.

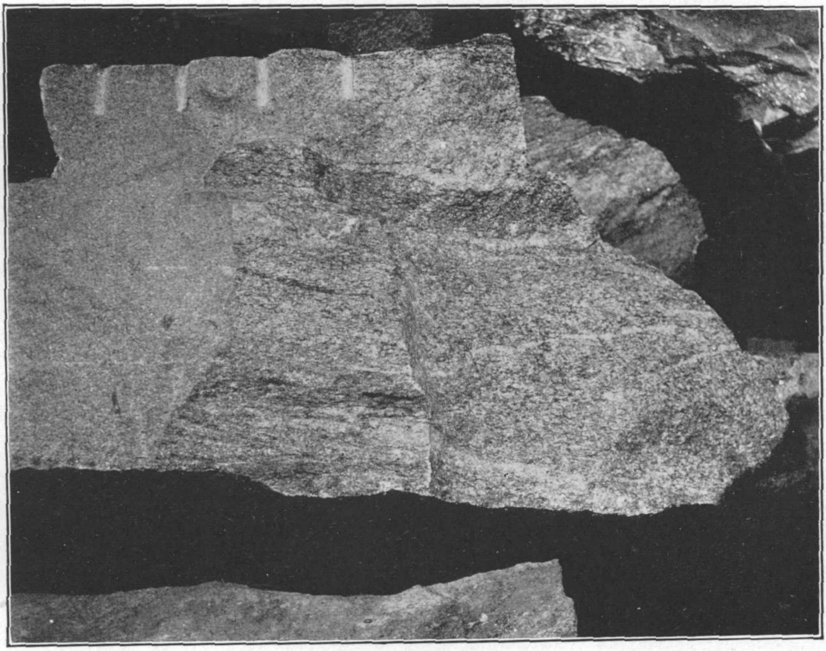
The quarry opening measures about 250 feet long by 125 feet wide and 45 feet deep. Stripping, where necessary, varies up to 8 feet in thickness.

The sheets are curved and range from a few inches to 5 feet in thickness. There is some "toeing in," owing to the overlapping of lenses. Vertical joints strike N. 85° E., N. 10° W., N. 60° to 65° W., and north-south, and are spaced at intervals of a fraction of an inch up to 6 feet and more. Many of the joint faces are slickensided and



A. McGOWAN QUARRY, SOUTH OF MANCHESTER, VA.

Photograph by H. Ries.



B. GNEISS INCLUSION IN GRANITE AT McGOWAN QUARRY, NEAR MANCHESTER, VA.

Photograph by H. Ries.

are coated with a reddish mineral substance. At the south end of the quarry the granite shows pronounced schistose structure and close jointing.

The product is used principally for street purposes in the form of curbing and blocks, for general building purposes, and for crushed stone, mainly in concreting. It has had a moderate use in monuments.

The *Westham quarries*, comprising a large number of openings along the south side of James River in Chesterfield County, are about 4 miles a little north of west from the city hall in Richmond. The openings are made in the escarpment extending for a distance of about a mile along the river front. Several more recent openings have been worked a short distance from the river to the south and southwest of the old quarries.

The rock is a biotite granite of medium-gray color and medium, inclining to coarse, even grain. The minerals are potash feldspar (orthoclase, with variable but usually much microcline), soda-lime feldspar (oligoclase) in considerable quantity, quartz, and black mica (biotite), with a few intergrown shreds of white mica (muscovite) and accessory titanite, magnetite, zircon, and apatite. The feldspar shows some alteration to kaolin and a colorless mica, and the biotite is partly altered to chlorite. Epidote occurs as an alteration product. The feldspars show some intergrowths with quartz, are twinned on the Carlsbad and albite laws, and contain rounded inclosures of quartz and feldspar.

These are among the largest if not the largest quarries in the Richmond area and supplied the stone from which the State, War, and Navy building in Washington, D. C., was constructed. The largest openings average about 800 by 200 feet by 180 feet deep. The depth of the quarries is considerably below the river level. Quarrying was suspended about 1897. When active, 500 to 800 men were employed and the granite was marketed extensively outside of the State.

In the larger openings the vertical joints strike N. 60° to 65° E. and N. 15° to 60° W. The size of stone quarried was limited to the capacity for handling the stone. Dark-gray knots are noted to a slight extent in places.

The *McGowan quarry* is located in Chesterfield County about 2 miles south of Manchester and about 300 yards east of the Petersburg turnpike. (See Pl. XII, *A*.) It has been worked continuously for about thirteen years and the stone is used exclusively for monumental stock. The quarry waste is worked into blocks for paving.

The rock is a biotite granite of dark blue-gray color and fine, even grain. Its minerals are potash feldspar (orthoclase with some microcline), soda-lime feldspar (oligoclase), quartz, black mica (biotite), a few shreds of white mica (muscovite), together with accessory apatite, zircon, and titanite. Filaments of rutile are abundant in the quartz. Secondary minerals are chlorite, epidote, and a colorless mica. The feldspars are intergrown with each other and with quartz, and they are twinned on both the Carlsbad and the albite laws.

The sheets, from 4 to 6 feet thick, are thinnest at the top. (See Pl. XI, *B*.) Vertical joints are not so conspicuously developed and are spaced at wide intervals, striking N. 80° E. and N. 30° W. Pegmatite dikes, ranging in thickness up to 5 feet, cut the granite indiscriminately. The principal feldspar in these dikes is orthoclase, containing rounded inclosures of other feldspars and quartz. Black mica (biotite) is sparingly present. A single aplite-pegmatite dike was noted, the relations of which are shown in figure 6. A thin section of the aplite showed predominant plagioclase (oligoclase), the potash feldspars (orthoclase and microcline), and quartz, with an occasional reddish garnet. Some large blocks, measuring several feet across, of a banded granite gneiss were inclosed in the granite (fig. 3; Pl. XII, *B*). A thin section of the gneiss revealed orthoclase and plagioclase (oligoclase) in about equal amount, quartz, biotite, and hornblende, with accessory apatite and titanite and secondary chlorite.

An average depth of about 5 feet of stripping of soil and granite decay is necessary. The granite takes a fine polish, and it has an extensive sale as monumental stock in many States.

The *Middendorf quarry* is located west of Manchester, on the Belt Line Railway, about 760 feet north of the Petersburg turnpike. Several acres of ground has been stripped to a depth of about 25 feet.

The rock is a banded biotite granite gneiss of gray color and medium to coarse, even grain. Its minerals comprise about equal amounts of potash feldspar (orthoclase) and soda-lime feldspar (oligoclase), quartz, and biotite, with some microcline, occasional muscovite, and the usual accessories.

The joints strike N. 65° E. and N. 45° W. and have slickensided surfaces indicating subsequent movement in the granite mass. Pegmatite dikes up to several feet thick are numerous; in direction they may coincide with or cut across (fig. 9) the banding of the gneiss and in dip may vary from nearly vertical to nearly horizontal. The average strike of the gneiss banding (schistosity) is N. 65° E.

The product is used locally for ballast and paving blocks, largely the former.

The *Tidewater Quarry Company's quarry* is located 2 miles southeast of Manchester, immediately on the west side of James River and about 500 yards from the Seaboard Air Line Railway. The quarry was opened prior to the civil war and was last worked in 1905. The stone was shipped by water, being loaded by derricks directly from the quarry into the boats.

The rock is a biotite granite of medium-gray color and medium-fine, even grain. The minerals are potash feldspar (orthoclase and microcline in about equal amounts), soda-lime feldspar (oligoclase), quartz, biotite, and scattered muscovite scales, together with accessory apatite, zircon, and rutile and secondary chlorite and epidote. The feldspars are considerably altered. The orthoclase is intergrown, in part, with a plagioclase.

The principal direction of vertical jointing is N. 10° W. Several zones of very close jointing occur, but in other parts of the quarry the joints are spaced at intervals sufficiently wide to permit the quarrying of dimension stone. Pegmatite dikes of varying thicknesses traverse the granite.

Stripping of 5 to 12 feet is necessary. The quarry has been worked to a depth of 30 to 40 feet. During its last period of working the stone was shipped to Norfolk, Hampton, Old Point, and Newport News, in the form of crushed rock for roads and for use in foundations and granolithic work. A No. 7½ Gates crusher was operated at the quarry for crushing and sizing the stone.

The *Old Dominion Granite Company's quarry*, formerly known as the State quarry and now owned by Mr. Middendorf, is located about 300 yards N. 30° E. of Granite station and about 100 yards north of the Southern Railway. The quarry comprises two large openings within 100 paces of each other and a smaller one lower down on James River. The largest opening is 600 by 225 feet by 100 feet deep. The larger openings were worked for some time by the State, hence the name State quarry. Neither of the openings has been worked for some years.

The rock is a biotite granite of medium-gray color and of medium-coarse, even grain. The minerals are potash feldspar (orthoclase with much microcline), soda-lime feldspar (oligoclase), quartz, and biotite, with a little muscovite, accessory apatite, zircon, magnetite, and titanite, and secondary chlorite, kaolin, and epidote. The feldspars are partly clouded from alteration. Much microperthite is present.

Several thin sections of the altered granite (sap) were examined. The principal changes were opacity of the feldspars from kaolinization; the liberation of much yellow hydrated ferric oxide as a stain from the iron-bearing minerals, biotite and iron ores; and more or less spacing along the cleavages of the feldspars and the sutures of the individual minerals, the first stage in crumbling or granulation.

The granite in the large openings is parted horizontally into sheets of varying thickness near the top, which pass below into massive granite. Vertical joints strike N. 55° E. and north-south. Pegmatite dikes up to several inches in thickness and a few small knots occur.

A large mass of banded gneiss was observed on the lower side of the large opening. Whether this is an inclusion in the granite or an exposure of the country rock (gneiss) in contact with the granite it was impossible to determine, because of failure to reach it for examination. A stripping of 3 to 8 feet of decayed granite and soil is necessary.

Old Dominion Iron and Nail Works quarry, comprising two openings near together which were opened in April, 1902, is located on Belle Island between the cities of Richmond and Manchester.

Two types of granite are represented. The principal one is a biotite granite of medium light-gray color and irregular medium-coarse grain. The second is a biotite granite of dark blue-gray color and fine grain. The principal minerals in both types are potash and soda-lime feldspars, quartz, and biotite.

The larger opening is 480 feet long by 100 feet wide and 65 feet deep. The depth of stripping at the center is 15 feet, with a 50-foot face of granite below. The second opening, made in dark blue-gray granite, is a small one and was not being worked at the time of the writer's visit in October, 1908.

In the large opening vertical joints are widely spaced, and their faces are slickensided. Very few pegmatite dikes occur, and most are of small width. Basic segregations (knots) up to 6 and 8 feet in length are present. The coarse-textured light-gray granite is irregularly banded in places, a feature especially noticeable near the contact with the fine-grained dark blue-gray granite which penetrates it along the contact in well-defined dikes or apophyses, and is accordingly the younger. A uniformly fine-grained light reddish-gray aplite dike, 2 inches thick and having a nearly horizontal position, is observed in an apophysis of the dark-gray granite near the contact with the coarse gray granite.

Vertical joints in the fine-textured dark blue-gray granite of the small opening strike N. 50° to 60° E. and N. 30° W., and are spaced at intervals varying from less than 1 foot up to 6 feet. Pegmatite dikes occur, ranging from 1 to 8 inches in thickness, usually averaging 1 to 2 inches. The feldspar of the small dikes is white; that of the 8-inch dike is of a pronounced red color. Biotite is the mica associated with the feldspar and quartz in these dikes. Knots were not observed in the granite of this opening.

The product is used almost entirely in the form of crushed stone for concrete and ballast. A little of it has been used for road making and for paving blocks. Two crushers, a No. 6 Gates and a No. 4 McCulloch, are operated at the quarry. The stone is quarried by blasting.

HENRICO COUNTY (NORTH OF JAMES RIVER).

The *Richmond Granite Quarrying Company's quarry* is located 4½ miles north of Richmond and about 250 yards east of the Richmond, Fredericksburg and Potomac Railroad. A spur track is operated between the quarry and the main line of the railway. The quarry, opened about eighteen years ago in a bowldery exposure of the granite, measures 500 by 100 feet by 50 feet deep.

The rock is a biotite granite of medium-gray color, and medium, even grain, consisting of potash feldspar (orthoclase and microcline in approximately equal amount), soda-lime feldspar (oligoclase) quartz, and black mica (biotite), together with accessory apatite, zircon, and titanite, and secondary chlorite and kaolin. Plagioclase nearly equals in amount the potash feldspars. A thin section of the decayed granite (sap) shows the feldspars partly altered to kaolin and much stained from the liberation of yellow hydrous iron oxide derived from the alteration of the iron-bearing minerals. Much of the biotite is altered to chlorite.

The granite is not sheeted, but is massive for the entire depth of the quarry. Vertical joints strike N. 30° to 35° E., N. 10° to 70° W., and east-west. The dip varies from vertical to 35° SE. The joints are spaced from 2 to 8 feet or more apart. The joint surfaces usually display well-developed slickensides. Pegmatite dikes up to 8 inches in thickness and of irregular outline (fig. 10) traverse the granite, but are not very numerous.

A second opening, about 400 yards east of the main quarry, in a similar exposure of the granite, was begun late in the summer of 1905.

The stone is shipped to various points in Virginia, Maryland, and Pennsylvania, and to Washington, D. C. It is used for building and monuments and for street work in the form of blocks and curbing. The waste is crushed and sized at the quarry for crushed stone.

The *Smith quarry*, opened in the bluff facing James River, is located at the 5-mile locks west of Richmond, within a few feet of the canal. It was worked many years ago and was last operated in 1903 for riprap used in the river.

The rock is a biotite granite of gray color and medium-coarse, even grain. The minerals are potash feldspar (orthoclase with much microcline), soda-lime feldspar (oligoclase), quartz, and black mica (biotite), with accessory apatite, iron ore, and zircon and secondary chlorite, epidote, kaolin, and a colorless mica. Intergrowths of quartz with feldspar and of the feldspars with each other (microperthite) are abundant. The feldspars contain rounded inclosures of quartz and other feldspars.

The quarry has a working face of 40 to 50 feet. The sheets vary from 4 to 10 feet in thickness. Vertical joints strike N. 30° E. and N. 5° to 30° W. Slickensides are developed along the joint-plane surfaces. In parts of the quarry decay extends to the entire depth of the opening. The product shows little or no evidence of oxidation, but is mostly a light-gray granitic sand formed chiefly by physical decay—granulation.

Winston & Co.'s quarry, formerly known as the Mitchell & Copeland quarry, is located at the settling basin, about three-quarters of a mile east of the Smith quarry. Mitchell & Copeland first opened the quarry many years ago and operated it for a period of twelve years. Winston & Co. began working the quarry about 1900 to supply crushed stone and riprap for the construction of the settling basin. The quarry is opened in the bluff facing James River on the north side, and measures 200 by 200 feet by 75 to 100 feet deep.

The rock is a biotite granite of light to medium gray color and medium-coarse even grain. The minerals are potash feldspar (orthoclase with much microcline), soda-lime feldspar (oligoclase), quartz and black mica (biotite), together with accessory apatite, titanite, magnetite, zircon, and muscovite. Secondary chlorite and epidote occur, the latter sparingly.

The granite is separated into horizontal sheets, which are thick and massive at the bottom of the quarry and thinner near the top. Vertical joints strike N. 30° to 70° E., N. 5° W., and eastwest. Pegmatite dikes up to several feet in thickness intersect the granite, but are not numerous.

The stone obtained for building the settling basin was quarried by blasting with powder and dynamite. It was conveyed by tram cars and overhead cranes from the quarry to the crusher near by.

The *Philadelphia quarries*, comprising three large openings close together, are located at the extreme east end of the settling basin, less than a mile south of east from Winston & Co.'s quarry, about 100 yards north of James River, on the north side of the Chesapeake and Ohio Railway. The quarries were last worked about seventeen years ago, and at the time of the writer's examination the openings were so nearly filled with water that not much information could be obtained from a study of them.

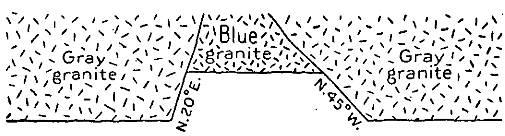


FIGURE 13.—Section at Philadelphia quarries, near Richmond, Va., showing relations between the blue and gray granites.

Two grades of granite were quarried—one of medium-gray color and medium-coarse grain, the other of dark blue-gray color and fine grain. The relations of these two granites are shown in figure 13. The fine-grained dark-gray granite is intruded into the coarser, lighter-gray granite. Mineralogically the two granites are essentially alike; they are biotite granites.

The fine, even-textured granite contains potash feldspar (orthoclase and microcline in nearly equal amount), soda-lime feldspar (oligoclase), quartz, and black mica (biotite), with accessory apatite, magnetite, and occasional scales of muscovite. The medium-gray and medium, even-textured granite contains potash feldspar (orthoclase with much microcline), variable soda-lime feldspar (oligoclase), quartz, and black mica (biotite), with accessory apatite, zircon, and magnetite. The secondary minerals are chlorite, kaolin, and a light-colored mica. The feldspars exhibit the usual twinning and are intergrown with one another and with quartz.

The openings are reported to have been worked to a depth of 90 feet. Vertical joints strike N. 20° to 70° E. and N. 20° to 45° W. Slickensides are developed along the joint surfaces and the jointing is sufficiently spaced to allow the quarrying of dimension stone. The granite is intersected by pegmatite dikes, but these are not numerous.

The city hall in Richmond was built in part from the granite of these quarries. Much of the product was shipped to Washington, D. C., and to Philadelphia for use as a building and street stone.

The *McCloy quarry*, opened in a flat-doming surface exposure of granite, is located about 300 yards from the James River branch of the Richmond, Fredericksburg and Potomac Railroad, and about a quarter of a mile west of the new reservoir. The quarry opening covers nearly an acre of ground, worked to an average depth of less than 18 feet.

The rock is a biotite granite of medium dark-gray color and fine, even grain. Its minerals are potash feldspar (orthoclase with much microcline), soda-lime feldspar (oligoclase), quartz, and black mica (biotite) intergrown with occasional shreds of white mica (muscovite), together with accessory apatite, zircon, and magnetite. Secondary chlorite and a light mica occur. The orthoclase is intergrown in part with a plagioclase.

The granite is massive and is not sheeted horizontally. The vertical joints strike N. 10° to 75° E. and N. 5° to 85° W. and dip from vertical to 55° NW. A minor set of joints strikes north-south. Slickensides are developed along the joint planes. Very few pegmatite dikes were observed, and these measured less than an inch in thickness.

The granite is decayed in places to a depth of 3 or 4 feet, and this material must be removed before the fresh stone can be obtained. The principal uses made of the product are for monuments and building and for street work as blocks and curbing. The quarry waste is crushed and utilized for street concrete or cement work. The product is marketed in a number of States. The quarry has been worked for about eight years.

FREDERICKSBURG AREA.

INTRODUCTORY STATEMENT.

The Fredericksburg area includes the region west and north of the city of Fredericksburg in Spottsylvania and Stafford counties. The granite exposed along Rappahannock River northwest of Fredericksburg extends across the river for some distance into Stafford County, but no quarries have yet been opened in that county.

Two types of granite have been quarried in the Fredericksburg area—one a very light gray, medium-textured muscovite granite, the other a dark blue-gray, very fine textured biotite granite. The latter is identical in texture and composition with the fine-grained dark blue-gray granite quarried in the Richmond area and extensively used for monument stock. The granite in the Fredericksburg area is a shade darker in color than the granite in the Richmond area; it is an excellent monumental stone and has wide use for that purpose. The dark blue-gray granite of the Richmond and Fredericksburg areas has been described elsewhere.[a]

DESCRIPTIONS OF QUARRIES.

Hazel Run quarry.—A light-gray muscovite granite of medium texture is exposed along Hazel Run, a tributary of Rappahannock River, about a mile west of Fredericksburg. It resembles somewhat the light-gray muscovite granite of Stone Mountain, 16 miles east of Atlanta, Ga., which has been and is used so extensively for general building purposes. In the spring of 1879 an opening was made in the exposure immediately on the south side of Hazel Run, about a mile west of Fredericksburg, and enough stone was quarried to build the Presbyterian Memorial Chapel in Fredericksburg. None of the stone has been quarried since. The joint planes are widely spaced; the best-developed ones strike N. 75° W. and north-south.

Thin sections of the granite show potash feldspars (orthoclase and microcline), soda-lime feldspar (oligoclase), quartz, the white and black micas (muscovite and biotite), apatite, rutile, and zircon. The principal secondary minerals are chlorite and muscovite, the former derived from the alteration of the biotite. Muscovite is partly primary and partly secondary. Biotite is very subordinate in amount. Microcline and plagioclase are abundant. Intergrowths of the feldspars and of the feldspars with quartz are numerous. Partial orientation of the mica along parallel directions, an occasional bent and broken muscovite shred, fractured quartz with wavy extinction, and the perfect granulation of the quartz-feldspar individuals are pressure effects plainly marked in the thin sections.

[a] Watson, T. L., Lithological characters of the Virginia granites: Bull. Geol. Soc. America, vol. 17, 1906, p. 528.

On close examination a thinly foliated structure is discernible in hand specimens of the rock and an occasional red garnet may be seen.

Cartwright & Davis quarries.—About 3 miles northwest of Fredericksburg the granite is exposed along the Rappahannock in steep bluffs and low bowlder ledges, which offer good quarry sites. On the Spottsylvania County (south) side of the river the Cartwright & Davis quarries are opened in the granite bluffs immediately along the river. Numerous openings have been worked, extending along the river front for half a mile or more.

The rock is a biotite granite of dark blue-gray color and fine-grained texture. In color it is a shade darker than the rock of the same type in the Richmond area. It consists of potash feldspar

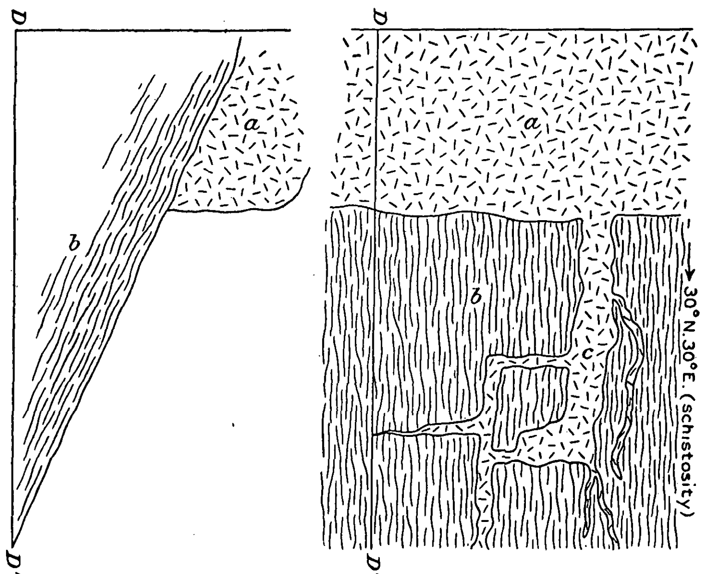


FIGURE 14.—Sketch in Cartwright & Davis quarry, near Fredericksburg, Va., showing relation of granite to gneiss.

(orthoclase and some microcline), soda-lime feldspar (oligoclase), quartz, black mica (biotite), and accessory muscovite, apatite, rutile, and zircon. The feldspar is partly intergrown with quartz in granophyric structure, indicating overlapping of the periods of formation of the two minerals. Orthoclase and plagioclase are present in nearly equal amounts, but microcline is very scant. The quartz contains abundant threadlike inclusions of rutile, and the biotite is largely altered to chlorite.

The granite is intruded into an irregular hornblende-biotite gneiss (fig. 14) The general strike of the schistosity of the gneiss is N. 25°. to 40° E. The granite is cut by several sets of joints so spaced as to admit of the stone being quarried in blocks of any size. The strike of the principal joint planes in the quarry openings is north-south, dipping 40° E.; N. 60° to 80° E., dipping 10° to 30°; and N. 20° to 80° W. Pegmatites are abundantly developed in places and occasion considerable waste in quarrying.

The granite is quarried exclusively for the monument trade. The monuments have an extensive market both in and out of the State. The granite takes a fine polish, the durability of which is favored by the uniformly small size of the biotite scales. No dimension stone is sold in the rough, but it is all worked up at the yards near the northern limits of Fredericksburg, where the equipment is ample for all grades of polished and dressed work. The stone is conveyed from the quarries to the yards by canal. A crusher is operated at the yards for sizing the waste, which is utilized for local purposes.

FAIRFAX COUNTY AREA.

INTRODUCTORY STATEMENT.

A complex of igneous rocks, largely altered, comprising chiefly granite, granite gneiss, gabbro, and diorite, mapped by Williams and Keith as Archean,[a] extends southwestward from Maryland and the District of Columbia across the Potomac into Fairfax County, Va., passing immediately west of Washington. This rock complex has been extensively altered by metamorphism and much of the original massive material has been rendered schistose. Massive granites and basic igneous rocks occur within the area, but they are subordinate in extent to their schistose equivalents. Because of the structure, rocks of the schistose class are less desirable for commercial purposes than the massive types. Granite gneiss is the most abundant rock type and many portions of it furnish good material for foundations and similar rough work. It is easy to quarry and is strong and durable. In many places it contains pyrite, unfitting it for ornamental use. Rock is also quarried from the less schistose portions of the granite masses at a number of places in the county. It is homogeneous, of even texture and good color and works out readily into stones of moderate size. Some portions of the rock in the Falls Church area are colored by pink feldspar.

DESCRIPTIONS OF QUARRIES.

Granite has been quarried in Fairfax County to a small extent in the vicinity of Falls Church and Annandale, strictly for local use.

FALLS CHURCH AND VICINITY.

The granites in the vicinity of Falls Church are of two varieties. One is a medium to fine grained rock and contains dominant biotite,

[a] Washington folio (No. 70), Geol. Atlas U. S., U. S. Geol. Survey, 1901.

with some muscovite as a third essential component. The ratio of muscovite to biotite is variable, but muscovite occurs in considerable amount at a few places. The microscope shows that the granite of this type contains principally orthoclase and quartz, some microcline, and a small but variable amount of soda-lime feldspar (oligoclase), with biotite and muscovite and the usual accessory minerals. The biotite is largely altered to chlorite and the muscovite is, in part, at least, secondary. An occasional garnet is noted in some of the thin sections. Pressure effects of the usual kinds are plainly seen on microscopic examination.

The second variety of granite occurring near Falls Church, a light and dark colored rock, is more coarsely crystalline than that just described and is a hornblende-biotite granite. It is somewhat closely allied to quartz diorite and is closely associated in the field with diorite masses on the one hand and with foliated mica granite on the other. It more properly belongs with the granodiorites, differing from the diorites proper in increased quartz and potash feldspar. Thin sections show quartz, plagioclase, orthoclase, green and brown hornblende, biotite, apatite, rutile, and the secondary minerals epidote, sericite, garnet, chlorite, and kaolin. Hornblende is one of the most abundant constitutents, and in places it completely incloses shreds of the biotite. Microcline does not occur. Plagioclase feldspar is probably a little more abundant than orthoclase. Pressure effects are indicated in the optical disturbance of the quartz and feldspar; in fractures crossing the quartz; in curved and bent lamellæ of a part of the plagioclase; and in the marked distortion of the cleavage angle of the hornblende.

The *Trip quarry*, located about a mile south of Falls Church, has supplied considerable stone for local use, principally for foundations and buildings. The rock is a massive granite of medium grain and variable light-gray color, depending on the amount and distribution of the mica present. Several sets of joints are developed which usually cut the granite at close intervals and limit the size of stone that can be quarried. The directions of these joints are N. 10° to 80° E. and N. 10° to 80° W. The Presbyterian and Catholic churches at Falls Church were constructed of the granite in the rough from this quarry.

ANNANDALE AND VICINITY.

The granite quarried several miles west of Annandale is a medium-gray, medium-grained, massive biotite granite, intermediate in color and texture between the Richmond light-gray and dark blue-gray types described on pages 74–76. It is similar in mineral composition to the Richmond types. Orthoclase is the dominant feldspar. Considerable microcline is present, but plagioclase is less abundant than elsewhere. A sprinkle of idiomorphic sections of garnet is noted.

Crushing effects are discernible under the microscope in the partial granulation of the quartz and feldspar, with the fine mosaic filling the interspaces of the unmashed portions of the two minerals.

The *Hoffman & Miller quarry*, located about 2 miles west of Annandale, is opened at about water level directly on the west side of Accotink Creek. The opening was made in a bowlder ledge exposure. Stripping of 8 to 10 feet of soil and red clay is necessary for the quarrying of fresh granite. The strike of the joint planes is north-south and N. 50° to 80° W.; they are spaced widely enough to permit the quarrying of dimension stone.

BLUE RIDGE REGION.

GENERAL DISCUSSION OF THE GRANITES.

In the northern Blue Ridge of Virginia granite has wide distribution, extending from Maryland across the Potomac southward for some distance southeast of Front Royal. As a rule, the granite areas are distributed in long, narrow belts, which vary in width up to 6 miles. The outcrops of granite increase in number and extent southward from the Potomac in Virginia.

According to Keith,[a] the mineralogical composition of the granite is fairly constant over large areas. Six varieties are distinguished, each having a considerable areal extent. The essential minerals given by Keith are quartz, orthoclase, and plagioclase feldspar. By the addition to these of biotite, garnet, epidote, blue quartz, and hornblende, five types are formed. Texturally the granite ranges from coarse to very fine grained. Keith gives the following microscopic description of the different types:[b]

Epidote granite, 3 miles west of Aldie, Va., is composed of fine-grained quartz, plagioclase, orthoclase, and biotite both unaltered and altered to chlorite. Accessory minerals are magnetite, a little eipdote, and some doubtful allanite. Another specimen from the same locality shows a coarse holocrystalline mass of quartz, orthoclase, a little plagioclase, and epidote. The epidote is both granular and crystalline and is associated with quartz (rarely feldspar) in groups of crystals. A third specimen from the same locality shows epidote in bunches of crystals and as inclusions in the feldspar.

Garnetiferous granite from the Potomac River 1 mile east of Harpers Ferry shows quartz, orthoclase, plagioclase, garnet, epidote, and apatite; all except the last two are in large crystals. Dynamic action has caused considerable alteration of feldspar to quartz, muscovite, and chlorite, and cracks in the quartz, which are cemented with chlorite. A specimen from the granite 4 miles southwest of Hillsboro, Va., contains quartz, plagioclase, orthoclase, pink garnet, magnetite, and a little chloritized biotite.

Granite from 1 mile northwest of Browntown, Va., shows quartz, orthoclase, plagioclase, hornblende, a little biotite, magnetite, and, along the feldspar cleavage, chlorite. Another specimen from the same locality shows the same minerals in larger crystals. A third specimen contains a large amount of garnet in rude crystals and fragments, a little apatite and pyrite, and but very little orthoclase.

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[a] Fourteenth Ann. Rept. U. S. Geol. Survey, pt. 2, 1894, p. 299; Harpers Ferry folio (No. 10), Geol. Atlas U. S., U. S. Geol. Survey, 1894.

[b] Fourteenth Ann. Rept. U. S. Geol. Survey, pt. 2, 1894, p. 300.

The biotite variety is far the most common. The biotite is always small in amount and often absent, so that the rock has a prevailing light-gray color. Its minerals are quartz, orthoclase, plagioclase, biotite, magnetite, and usually a little secondary muscovite and chlorite from feldspar decomposition.

The varieties of granite characterized by blue quartz do not differ under the microscope from other varieties containing biotite. As a macroscopic constituent, however, the blue quartz is very striking, and the brilliancy of its color renders it noticeable wherever seen. It occurs both as original crystals disseminated through the mass and as veins and patches.

The granite of the Blue Ridge region is usually light gray in color and has been extensively altered by pressure. According to the degree of alteration the rock is granite, gneiss, or quartz schist. No quarries have been opened in the granite, but where bowlders could be obtained without much labor they have been worked up and the granite used locally.

UNAKITE.

The name unakite was applied by Bradley[a] in 1874 to a variety of granite from the Unaka Mountains in North Carolina, composed of the essential minerals yellow-green epidote, pink feldspar, and quartz. Unakite has since been noted at two localities in Virginia—(1) at Milams Gap, near Luray, in Page and Madison counties,[b] in the Blue Ridge of northern Virginia, and (2) about 2½ miles south of Troutdale, Grayson County,[c] in the Blue Ridge region of southwestern Virginia.

The mineral composition of the unakite from the Virginia and North Carolina–Tennessee localities places it among the granites, with epidote as an essential constituent, but, according to an analysis by Phalen, quoted below, of specimens from Milams Gap, Virginia, the rock is relatively basic for a granite.

In the Milams Gap locality the unakite is a moderately coarse but irregular crystallization of red feldspar, quartz, and green epidote. Irregular crystallization of the rock is shown in the variation from masses composed of more than two-thirds of the red feldspar through all gradations to masses composed of quartz and epidote without feldspar—epidosite.[d] Thin sections of the unakite from Milams Gap show epidote, orthoclase, quartz, iron oxide, zircon, and apatite. The epidote is here secondary, as in the other localities, replacing pyroxene and feldspar, both plagioclase and orthoclase. The unakite from Grayson County, Va., shows deeper-colored feldspar and epidote than that from Milams Gap. Analyses of the unakite and the unakite-bearing rock at Milams Gap are given on page 78.

[a] Bradley, F. H., Am. Jour. Sci., 3d ser., vol. 7, 1874, pp. 319, 320.

[b] Merrill, G. P., Stones for building and decoration, 1903, p. 86. Phalen, W. C., Smithsonian Misc. Coll., vol. 45, 1904, pp. 306–316.

[c] Watson, T. L., Am. Jour. Sci., 4th ser., vol. 22, 1906, p. 248.

[d] Phalen, W. C., op. cit., p. 312.

The strikingly beautiful combination of colors produced by the peculiar green of the epidote and the pink or rose red of the feldspar makes the rock especially desirable for use, when polished, in certain forms of interior ornamental work. Should the rock be found to exist in quantity, the quarrying of it would certainly prove profitable.

AREA IN NOTTOWAY AND PRINCE EDWARD COUNTIES.

In the northwest corner of Nottoway County and in the adjacent portion of Prince Edward County is a promising area of massive gray granite of fine-grained texture and uniform color, which has been opened and quarried for local use at a single point in each county. The granite is exposed at the surface in flat-doming masses and as bowlders. This area lies close to the Southern and the Norfolk and Western railways, which afford ready transportation facilities.

The *Wingo quarry*, in Nottoway County, located between Jennings and Jetersville on the east side of the Southern Railway, was operated on a small scale some years ago for ballast. The rock is a fine-grained, massive, medium-gray biotite granite of uniform color and texture.

In the vicinity of Rice Depot, Prince Edward County, granite was quarried some years ago for use in bridge construction along the Norfolk and Western Railway.

CHARLOTTE COUNTY.

The *State Test Farm quarry* is located on the state farm on the southeast side of the Richmond and Danville division of the Southern Railway, near Saxe station. A very small amount of stone has been quarried here from a bowlder-ledge exposure strictly for local use.

The granite is a hornblende-biotite granite of pronounced red color and medium grain. It has a marked schistose structure imparted by the orientation of hornblende and biotite. Very small miarolitic cavities occur in the granite. The feldspar is entirely of red color, to which is due the pronounced red color of the rock. Hornblende is considerably altered in places, partly to chlorite and epidote and partly to iron oxide.

The stone quarried from this outcrop was used in the construction of bridges over some of the small streams in the neighborhood.

FLUVANNA AND GOOCHLAND COUNTIES.

The *Cowherd quarries* are located on the north side of James River, along the James River division of the Chesapeake and Ohio Railway, partly in Goochland County and partly in Fluvanna County, at Columbia.

The rock is a biotite granite gneiss of medium dark-gray color, fine grain, and fine, regular, straight banding. Its principal minerals are feldspar (potash and soda-lime varieties), quartz, and biotite.

A steep slope paralleling the river and the railroad for a distance of 1,500 feet has been worked by irregular stripping. No work has been done on the Fluvanna County side for more than twenty-five years. On the Goochland County side quarrying operations were suspended about 1900.

The strike of the schistosity (gneissic banding) is N. 45° E. The vertical joints are widely spaced, striking N. 10° E., N. 35° W., and N. 55° W. Quartz veins of irregular bulbous shape, varying from a fraction of an inch up to 2 feet in thickness, are numerous. These are seamed with knife-edge layers of biotite altered to chlorite occupying central and contact positions, which both cut across and conform with the schistosity of the inclosing granite gneiss. That these veins were formed prior to the period of deformation inducing schistosity in the inclosing rock is shown in the fracturing of many of the quartz masses in directions coincident with that of the schistosity, as indicated in figure 15. A few knots up to 6 or 8 feet long occur.

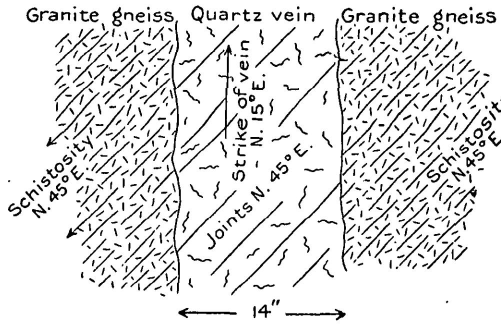


FIGURE 15.—Quartz vein in Cowherd quarries, Columbia, Va., showing jointing coincident with schistosity of inclosing gneiss.

LUNENBURG COUNTY.

The *Kenbridge quarry*, located on the north side of the Virginian Railway, near Kenbridge, in Lunenburg County, was opened about five years ago to supply crushed stone for railroad ballast. The writer has not visited the quarry, but specimens of the rock show it to be a biotite granite gneiss of medium color and texture.

PRINCE WILLIAM COUNTY.

Several granite quarries are opened close together immediately on the northwest side of Occoquan Creek, opposite Occoquan village, in Prince William County (Pl. VII). The rock is a thinly foliated biotite granite of medium gray color and texture. It is used principally in the form of crushed stone for concrete, and locally for building. The rock is crushed and sized at the quarry and shipped to Washington, D. C., for use in concrete.

OTHER GRANITE AREAS.

In addition to the areas described above, many other counties of the Virginia crystalline region contain granite that is suitable for general building and other purposes, but in none of these has it been developed. So far as these undeveloped areas have been examined, the granite conforms to one or the other of the types of the developed areas. They are prevailingly mica granites, containing biotite either with or without muscovite, fine to medium in texture, and usually some shade of gray in color.

CHAPTER IV.

THE GRANITES OF NORTH CAROLINA.

DISTRIBUTION OF THE GRANITE.

Granites are distributed over about one-half the total area of North Carolina, but the productive part of this area is considerably less. Openings from which some granite has been quarried have been made in most of the counties in which granite occurs, but only a few quarries are being systematically worked at present.

Geographically, granites are distributed over parts of each of the three larger physiographic provinces of the State—the Coastal Plain, the Piedmont Plateau, and the Appalachian Mountains. The areas are fewer and smaller in the Coastal Plain region, and more numerous and larger in the Piedmont Plateau region, where granite forms one of the dominant rock types.

For convenience of description the granites and gneisses may be divided into the following belts, the location of which is indicated on the accompanying map (Pl. XIII):

I. The Coastal Plain region.
II. The Piedmont Plateau region.
  (1) The northeastern Carolina granite belt.
  (2) The Carolina metamorphic slate and volcanic belt.
  (3) The Carolina igneous or main granite belt.
  (4) The Western Piedmont gneiss and granite belt.
III. The Appalachian mountain region.

This division of the State into belts is essentially the same as that adopted by the State Geological Survey, and the map is the one compiled from the records of the State Survey to accompany Nitze and Hanna's report on the gold deposits of North Carolina.

SCIENTIFIC DISCUSSION.

KINDS OF GRANITE.

On the basis of texture and structure three types of granite are distinguished—(1) the massive even-granular (normal) granites; (2) the porphyritic granites; and (3) the banded or schistose granites (granite gneiss). Field and laboratory study develops close similarity of mineral composition in the three types. The even-granular and porphyritic textures represent different phases of the same rock mass.

The granite gneisses differ essentially from the massive granites in having a pronounced schistose structure, induced by pressure metamorphism.

On the basis of mineral composition, the granites of North Carolina are divisible into four principal types—(1) biotite granite, which may or may not contain a little muscovite (usually scant muscovite is present), to which most of the granites of the State belong, including those of the Mount Airy, Dunns Mountain, and Greystone areas; (2) hornblende-biotite granite, represented by a part of the granites in the northern and southern parts of Mecklenburg County; (3) muscovite granite, with or without biotite, represented by a small area near Warren Plains, in Warren County; and (4) the epidote granite (unakite) of Madison County, N. C., and Cocke County, Tenn.

MINERAL COMPOSITION.

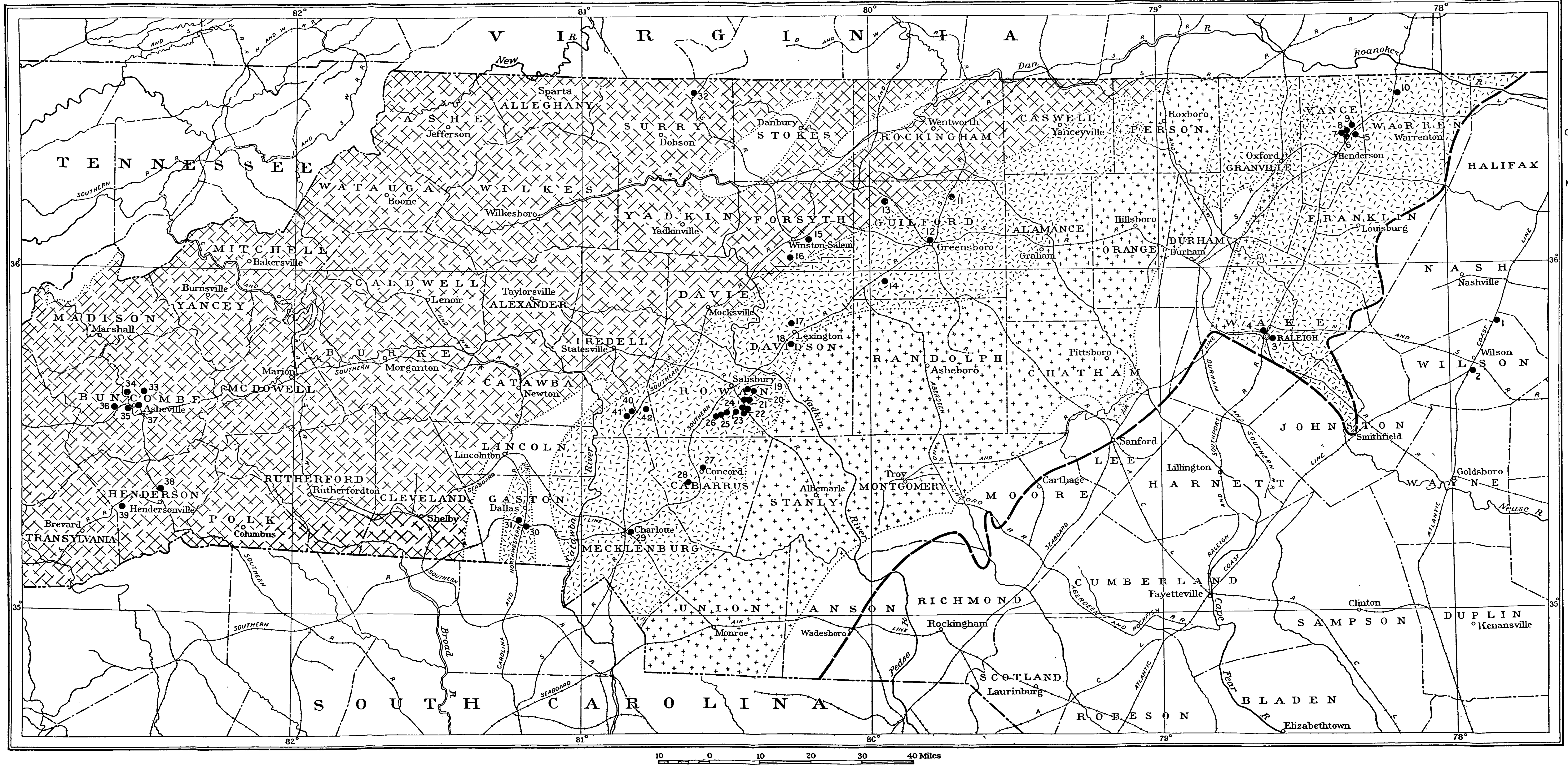
The granites of North Carolina conform in mineral composition to those of the other States in the southern Appalachian region. There are mixtures of feldspars and quartz, with biotite as the third essential mineral in the most important areas. Muscovite in association with biotite is present in small amount in many of the biotite granites of the State, and it is an important component in the area near Warren Plains, in Warren County. Hornblende is an important constituent in a part of the granites near and east of Davidson, and 5 miles south of Charlotte, in Mecklenburg County. It is sparingly noted in the biotite granite near Elm City (Toisnot), in the extreme northern part of Wilson County. It does not occur in the commercially more important granites of the State. Epidote is a principal constituent of the granite known as unakite, in Madison County. The epidote is entirely secondary.

The feldspathic constituent includes orthoclase, microcline, and acidic plagioclase, either oligoclase or albite or both. In most places the soda-lime feldspar exceeds in amount the potash feldspars, but in others it may be equal or less. As a rule, the North Carolina granites are relatively rich in plagioclase. Microcline is variable in quantity and in places is entirely lacking.

The common accessory minerals include apatite, zircon, titanite, magnetite, ilmenite, and here and there other minerals in very sparing amounts.

CHEMICAL COMPOSITION.

Very few chemical analyses of North Carolina granites have been made. Those available are from widely separated areas, and, though not so complete with respect to all the constituents as the present-day analyses, they serve to indicate two important points—the acidity and the character and ratio of the feldspathic constituents.



LEGEND

Granite quarries (*numbers refer to list*)

Granite, diorite, and other rocks, largely igneous

Gneiss, granite, and other rocks of both sedimentary and igneous origin

Metamorphic slates and schists including volcanic rocks

Fall line

East of fall line: Coastal Plain formations (sands, clays, marls). West of fall line: Triassic sandstones and shales; metamorphic quartzites, schists, limestones, etc., of unknown age

QUARRIES

1 Elm City (Toisnot)
2 Contentnea Creek
3 City (Raleigh)
4 Penitentiary
5 Seaboard Air Line Railway
6 Old Greystone
7 New Greystone
8 Greystone Granite and Construction Co.
9 Middleburg
10 Paschal
11 Walker
12 City (Greensboro)
13 Gamble
14 Modlin
15 Maston
16 Charles
17 Concord
18 Sink
19 Hartman & Hodge
20 Duncan & Floyd
21 McCauless (Dunns Mountain Granite Co.)
22 Rowan Granite Co.
23 Balfour Quarry Co.
24 Consolidated Granite Co.
25 Phillips Mountain
26 Powlers Mountain
27 Reid (City)
28 Balfour Quarry Co.
29 City (Charlotte)
30 Gastonia
31 Jenkins
32 North Carolina Granite Co.
33 DuBose
34 Owenby
35 Montford
36 County (Buncombe)
37 City (Asheville)
38 Balfour Quarry Co.
39 Name not known.
40 McNeely
41 Breed
42 Biddell

GEOLOGIC MAP OF NORTH CAROLINA SHOWING DISTRIBUTION OF GRANITE QUARRIES.

Based on maps of North Carolina Geological Survey, Bulletin 2, 1906.

Partial analyses of North Carolina granites.

Constituents.	1.	2.	3.	4.
Silica (SiO_2)	75.14	70.70	69.28	66.01
Lime (CaO)	.93	2.96	2.20	1.44
Soda (Na_2O)	5.82	4.56	3.64	5.06
Potash (K_2O)	2.57	2.45	2.76	3.16

1. Pink granite from Pink Granite Company's quarry, Dunns Mountain, Rowan County: First Bienn. Rept. North Carolina Geol. Survey, 1893; p. 89.
2. Light-gray granite from Mount Airy quarry, Surrey County: Idem, p. 94.
3. Gray granite from City quarry, Raleigh, Wake County: Geology of North Carolina, vol. 1, 1875, p. 122.
4. Gray granite from Johnson quarry, near Mooresville, Iredell County: First Bienn. Rept. North Carolina Geol. Survey, 1893, p. 87.

STRUCTURAL FEATURES.

JOINTS.

With possibly one or two exceptions, the North Carolina granites are characterized by a strong development of vertical joints, which break the rocks into polygonal blocks of different sizes. The most noteworthy exception is the extensive granite area near Mount Airy, Surrey County, in which vertical jointing is not visible. Measurements of the vertical joints were made in all the openings and quarries of granite in the State, and the results show four sets—the major joints, whose planes lie in the northeast and northwest quadrants, and two minor sets, whose planes strike east-west and north-south. The major joints vary in strike from N. 10° E. or W. to N. 80° E. or W. Of the total number of vertical joints measured 56 lie in the northeast quadrant, 45 in the northwest quadrant, 19 have a north-south strike, and 16 east-west.

The surfaces of the vertical joints usually show smooth, somewhat polished and striated faces, which indicate some movement in the granite masses since the formation of the joints. Striæ are developed in a thin coating or skin of yellow to yellowish-green mineral, which probably is damourite in most places, but locally, epidote, or a mixture of the two derived from certain original minerals of the granite, and caused probably by the rubbing together of the two sides along the plane.

BASIC SEGREGATIONS (KNOTS).

The distribution of knots in the granite is subject to much variation. From some quarries they are entirely absent, in others they occur only here and there, and in others still they are so abundant as to disfigure the granite and preclude its use in certain higher grades of work. The knots vary in size from a fraction of an inch to more than a foot across. They are of irregular outline, varying from those that are roughly oval or round to those that are greatly elongated.

DIKES.

Genetically, the intersecting materials are of two kinds—true dikes and true veins. These are strongly contrasted in some places, and everywhere they show differences to some degree in both texture and composition.

BASIC IGNEOUS DIKES.

Dikes of basic igneous rocks, chiefly diabase or its altered form, penetrate the granites of most of the important areas in the State. Thinly schistose dikes of amphibolite, composed largely of hornblende with accessory feldspar and quartz, are common in some of the quarries.

The widest dikes exposed in the granite openings do not exceed 50 feet and many are less than 6 feet. Where a number of dikes are exposed the intervals between them vary greatly. Within a zone of 12 to 15 feet two or more dikes may occur, always parallel and coincident with the vertical joints in that direction. More commonly, however, the intervals at which the dikes intersect the granite are considerably greater. The dip of the dikes is vertical or departs only a few degrees from the vertical, a feature likewise characteristic of the joints.

The following table makes clear the relationship between the strike of the dikes and that of the vertical joints:

Strikes of dikes and vertical joints in granites of North Carolina.

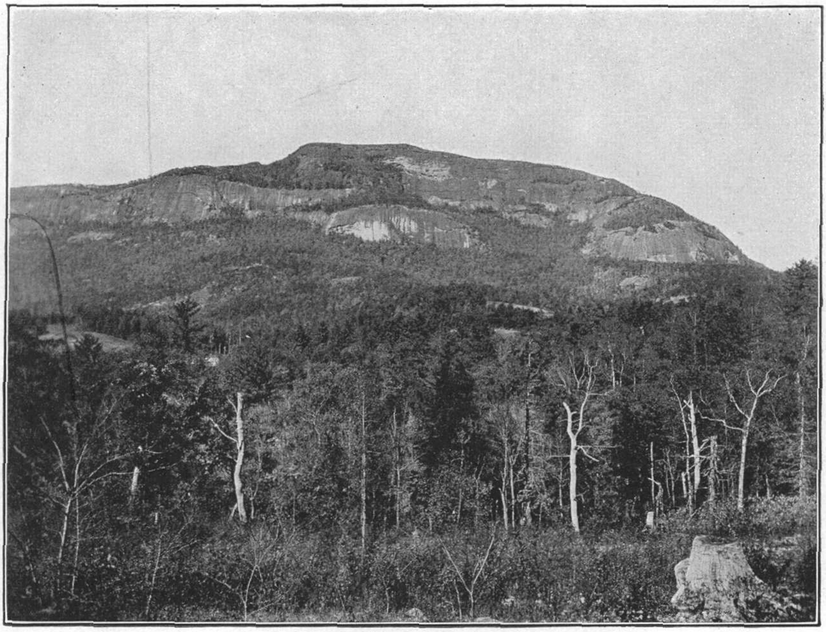
Locality.	County.	Strike of dikes.	Strike of joints.
Charlotte City quarry	Mecklenburg	N. 40° E.	N. 40° E., N. 35-50° W.
Greensboro, 1½ miles north of	Guilford	N. 20° E.	N. 20° E., N. 50° E., N. 20° W.
Jamestown, ½ mile southeast of	do	N. 40° W.	N. 40° W., N. 20° E.
Davidson, ½ mile east of	Mecklenburg	N. 15-20° W.	N. 20° W., N. 70° E.
Rolesville, ¾ mile southwest of	Wake	N. 20° E.	N. 20° E., east-west.
Lilesville, ¼ mile north of	Anson	N. 20° W.	N. 20° W., N. 70° E., north-south.

GRANITE DIKES.

True granite dikes of normal composition and usually of fine grain are numerous in certain areas, but only one or two have been observed penetrating the granite masses. In the main granite belt of the Piedmont region dikes of this character, penetrating the surrounding rocks, are common, and are regarded as apophyses from the granite masses. As a rule, they are irregular in outline and fine grained, and are composed of quartz and light to pink feldspar, with mica subordinate, if present at all. They range from a few inches to several feet in thickness.

A. PEGMATITE VEIN WITH QUARTZ CENTER.

Harris clay mine, northeast pit, $2\frac{1}{4}$ miles north of Bryson, N. C.



B. WHITESIDE MOUNTAIN, A GRANITE DOME, JACKSON COUNTY, N. C.

The principal localities where the granite dikes have been noted are northeast of Concord, in Cabarrus County, for several miles along the Concord–China Grove road; near Concord and to the east along the Mount Pleasant road; along the east and west roads leading out of Salisbury, a short distance from the town; 5 miles west of Barber Junction, near Elmwood, Iredell County; in the cuts of the Southern Railway near Lexington, Davidson County; and in the railroad cuts north and south of High Point, Guilford County.

PEGMATITES.

Pegmatite dikes intersect the granite in most of the quarries in the State. They are so abundant in parts of some quarries that dimension stone is difficult to obtain. This is especially true of the granite in the Raleigh City quarries, where hardly a block of granite can be quarried that is entirely free from the quartz-feldspar dikes, a feature strikingly shown in the state capitol in Raleigh, built of this stone. In some quarries pegmatites are but sparingly developed, and in others they are entirely absent.

Where observed they are characterized by the usual coarse texture, and are composed principally of feldspar and quartz with subordinate stout platy black biotite (Pl. XIV, *A*). The feldspars are partly pink and partly white in color, are highly lustrous, with a good cleavage development, and are commonly twinned on the Carlsbad law.[a] Feldspar is the most abundant constituent, the quartz locally diminishing to a very subordinate amount. Biotite is usually present in large, stout platy forms, in some places irregularly distributed between the feldspar and quartz, in others distributed along a central axis in the vein or dike. Muscovite has been observed in the pegmatite bodies only occasionally, and tourmaline, garnet, and the rarer minerals associated with some pegmatite dikes are strikingly absent.

Some of the pegmatites are very extensive, though usually narrow, apparently deep seated, and of aqueo-igneous origin. Others are of minor extent and are surrounded entirely by the granite, being probably true veins of segregation. In the Raleigh City quarry, where the only true aplite dikes have been observed, the aplite and pegmatite are associated as banded aplite-pegmatite. As a class the pegmatites are irregular in outline, conforming to no definite or fixed direction, but cutting the granite at random and at all angles.

In the Raleigh City quarry, the Carrigan quarry, 3 miles northeast of Mooresville, Iredell County, and the Walker quarry, 1½ miles southeast of Ridge Summit station, Guilford County, many of the pegmatites intersect one another, producing a faulted condition of several inches displacement.

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[a] See analyses of feldspars, p. 170.

APLITES.

Aplite dikes have been observed at only one locality in the State, the City quarry at Raleigh, where they number less than half a dozen in all. They do not exceed 6 inches in width, and most of them are not more than 2 inches. Some of them are in contact with pegmatite on one side and the inclosing granite on the other. Megascopically, the aplite is very light in color, being composed of a fine-grained crystallization of quartz and feldspar, through which are irregularly distributed subordinate minute flecks of black biotite.

Microscopically, the aplite is strikingly similar in mineral composition to the inclosing granite, except that it is much finer grained and contains a much smaller proportion of biotite and plagioclase feldspar. The mineral composition places it with the potash aplites.

QUARTZ VEINS.

Quartz veins of small dimensions cut the granite in a number of quarries, usually where pegmatite intrusions are strongly developed. The two sets of intersecting bodies are more or less closely associated. The quartz veins are not numerous in any of the openings, and as a rule they do not measure more than a few inches across.

Quartz veins of large dimensions are numerous over the crystalline area of the State. Many of them are readily traced over the surface for considerable distances by the partly disintegrated outcrops and the abundant fragments which litter the surface. In cross section they vary from 25 feet to several hundred yards. In some localities the veins form true fissure veins, are metalliferous, and mark many of the most important gold and copper mines in North Carolina

RELATIONSHIP BETWEEN THE JOINTING AND THE BASIC DIKES.

Careful measurement and tabulation of the vertical joints and the dikes of basic igneous rocks show a marked parallelism in certain directions between the joints and dikes. The planes of most of the joints and the strikes of most of the dikes are in the northeast and northwest quadrants. Moreover, in nearly every quarry where basic dikes are exposed the strike of the dikes and that of the joints for a given direction is coincident, apparently indicating that in those places, at least, the jointing has exercised some influence on the cutting direction of the dikes. Not only is this true for the dikes penetrating the granite in the quarries, but it is also true of the Triassic sandstone belt, where the same relation between the joints and the dikes is shown. Whether this statement will apply in general to the dikes beyond the limits of the fresh-rock exposures it is not possible to say, as the jointing is entirely obscured by the deep residual decay covering the fresh rock, but presumably it does.

Probably the basic dikes, so far as they have been observed, do not belong to a single period of intrusion but are to be referred to different ages. The observations recorded denoting coincidence in the directions of dike and joint include both the massive, unaltered, igneous intrusive rock and the perfectly schistose, more or less altered, basic dike. If these observations are correct, clearly the jointing in the granites preceded the intrusion of the basic rocks forming the dikes.

INDIVIDUAL QUARRY AREAS.

EVEN-GRANULAR GRANITES.

DISTRIBUTION.

Granites of even-granular type have wide distribution and compose the bulk of the granites occurring in North Carolina. They range from massive to partly schistose rocks, are fine to medium in texture, rarely coarse, and are pink to gray in color, the prevailing color being light to medium and dark gray.

Mineralogically, the even-granular granites are mixtures of potash feldspar (orthoclase chiefly, with variable microcline), palgioclase (oligoclase or albite), and quartz, with a variable quantity of biotite and, in several areas, some additional hornblende as the characterizing accessories. The prevailing large amount of plagioclase feldspar in the rocks is a noteworthy feature; rarely does this constituent sink to very subordinate proportions; usually it is approximately equal to or even exceeds the potash feldspars. In many areas the poverty of the rocks in the ferromagnesian constituent is a striking feature, a fact well illustrated in the extensive and important granite area known as Dunns Mountain, in Rowan County.

The even-granular granites are described below under (1) Coastal Plain granites; (2) Piedmont Plateau granites; and (3) Appalachian Mountain granites.

COASTAL PLAIN GRANITES.

GENERAL STATEMENT.

In places near the boundary between the Coastal Plain with the Piedmont Plateau, but extending well within the Coastal Plain, the thin veneer of loose unconsolidated sands and gravels has been stripped from the surface, exposing small, irregular, somewhat elongated areas of the crystalline rocks. Many of these areas are composed either wholly or in part of granites of good quality. This stripping of the Coastal Plain sediments from the crystalline rocks has taken place mostly along the courses of the larger streams. In such areas the granitic rocks are usually exposed in ledge and bowlder form and as flat-surfaced masses, a short distance back from the stream.

Some of the schists and gneisses composing parts of the inliers of crystalline rocks are derived from original igneous masses. They include both acidic and basic types.

The principal areas of even-granular granite lie in Wilson, Edgecomb, and Nash counties to the east of Raleigh. In each of these counties small openings have been made in the granites and some of the rock has been quarried for local use. None of the openings, however, are sufficiently large to be called quarries, and no systematic work has yet been undertaken, though the granite is of good quality, is readily accessible, and can be easily worked.

The rocks are massive biotite granites, in one place hornblende bearing, varying from fine to coarse grained in texture and from gray to pink in color. Jointing is usually well developed, intersecting the rock in three general directions—northwest, northeast, and north-south. The granites are younger than the schists and gneisses into which they have been intruded, as shown by the nature of the contacts, in the partial decay of the rocks, and by their massive structure as contrasted with the completely schistose structure of the surrounding rocks.

The granites of the North Carolina Coastal Plain region occur in three principal areas—(1) the Contentnea Creek area; (2) the Elm City area; and (3) the Rocky Mount and Springhope area.

DESCRIPTIONS OF QUARRY AREAS.

CONTENTNEA CREEK AREA.

About 3 miles south of Wilson granite is exposed in large bowlders and flat-surfaced masses for several miles along and near Contentnea Creek. A small opening was made some years ago near the creek where it is crossed by the Wilmington and Weldon Railroad.

The rock is a biotite granite of pinkish-red color and coarse grain, with a marked porphyritic tendency. Feldspar is largely in excess of the other minerals. The larger feldspar individuals are 1 to 2 inches long and are pinkish in color, exhibiting good cleavage development and twinning on the Carlsbad law. The feldspathic constituent has been estimated to amount to 82 per cent, proportioned as follows: Orthoclase, including a little microcline, 50 per cent; plagioclase (albite), 32 per cent. Quartz is the next most abundant mineral. Biotite is only sparingly present and is largely altered to chlorite. Accessory apatite and magnetite and secondary kaolin, calcite, and a light-colored mica are present.

The vertical joints strike N. 50° E., N. 70° W., and north-south. No veins nor segregations were observed. The granite takes a good polish.

ELM CITY (TOISNOT) AREA.

The Elm City area is located in the extreme northern part of Wilson County, 3 miles north of Elm City. The granite is exposed in the form of bowlder outcrops, and one opening has been worked to an average depth of about 30 feet. The decayed granite, which requires stripping for the quarrying of fresh rock, averages 6 to 8 feet in depth.

The rock is a biotite granite of light-gray color and medium-coarse grain. The minerals are potash feldspars (orthoclase and a little microcline), much soda-lime feldspar (very acidic oligoclase), quartz, and biotite with occasional hornblende, together with accessory zircon, apatite, a little titanite, and ilmenite and secondary chlorite, kaolin, and light-colored mica.

The vertical joints, rather closely spaced, strike N. 40° E. and N. 80° W. and have slickensided surfaces. A dike of very fine grained amphibolite schist carrying much pyrite penetrates the granite, striking approximately northwest and southeast and ranging from 4 to 20 feet in thickness. Quartz veins trending north and south also cut the granite. Two of these veins, observed on the west side of the quarry, are about 12 inches wide and are wrapped with films of hornblende.

The poor working qualities of the granite, coupled with the close jointing and the numerous veins, render the stone unsuited for general constructional purposes.

ROCKY MOUNT AND SPRINGHOPE AREA.

About a mile north of Rocky Mount, in Edgecombe County, bowlder outcrops and small flat-surfaced exposures of granite can be traced along Tar River for some distance westward into Nash County. The granite is associated with crystalline schists which were derived in part from original igneous rocks. Contacts between the granite and the schists were not observed, but the field evidence clearly suggests that the granite is the younger rock.

At the cotton mill on Tar River, 1 mile north of Rocky Mount, several small openings were made in the granite some years ago. The rock is a biotite granite of gray color and medium grain. Its minerals are potash feldspars (orthoclase and microcline in about equal amount), soda-lime feldspar (oligoclase), quartz, and black mica (biotite), with accessory apatite, zircon, and magnetite and secondary chlorite and epidote.

The vertical joints strike northeast-southwest, N. 30° W., N. 80° W., and north-south. The joints cut the granite at intervals which vary from only a few inches in some places to many feet in others. Pegmatite dikes, ranging in thickness from a fraction of an inch to more than 6 inches, intersect the granite. All gradations exist between veins containing mostly feldspar to those containing mostly quartz.

PIEDMONT PLATEAU GRANITES.

GENERAL STATEMENT.

The North Carolina Piedmont region is composed of a number of belts, approximately parallel to one another and crossing the State in a general northeast-southwest direction (Pl. XIII), composed as a rule of unlike rocks of different ages.

The granites and gneisses of commercial importance in North Carolina are most widely distributed within the Piedmont Plateau region, where they occur in considerable variety and abundance. They are biotite bearing, with additional hornblende in several areas, and muscovite in very subordinate amount if present at all. Some shade of gray prevails, though pink is largely characteristic of certain areas.

In most places the granite is of good quality and readily accessible, and as a rule it can be easily worked. Numerous quarries have been opened over many parts of the plateau region, to which the granite industry of the State is confined almost exclusively.

The Piedmont Plateau granites are described below under four geologic divisions—(1) the northeastern Carolina granite belt, comprising the counties of Wake, Franklin, Vance, Granville, and Warren; (2) the metamorphic slate and schist and volcanic belt; (3) the central granite belt, including Mecklenburg, Gaston, Cabarrus, Iredell, Rowan, Davie, Davidson, Forsyth, Guilford, and Alamance counties; and (4) the western gneiss belt, comprising the counties of Surry, Wilkes, Alleghany, Alexander, and Cleveland.

NORTHEASTERN CAROLINA GRANITE BELT.

INTRODUCTORY STATEMENT.

The position and limits of the northeastern Carolina belt are shown on the map (Pl. XIII). It comprises parts or the whole of five counties, located in the extreme northeastern portion of the North Carolina Piedmont region, extending northward from Raleigh. With but few exceptions the granites show a partial schistose structure. Biotite, the chief accessory mineral, is variable in quantity, imparting accordingly either a light or a dark gray color to the rock. In places the feldspars are of a pronounced pinkish hue and with the subordinate amount of biotite present the rock assumes more or less of a mixed pinkish-gray color. The granites are prevailingly even granular, though a porphyritic tendency is somewhat emphasized in places They do not differ essentially in mineral composition, although hand specimens of the granite from different portions of the area may show no resemblance to each other.

FRANKLIN COUNTY.

Granite exposures are numerous over the middle and eastern portions of Franklin County, especially in the vicinity of Louisburg, the county seat. Usually the rock is deeply decayed, though fairly fresh granite is exposed in large bowlder outcrops and small irregular surfaced masses. Porphyritic granite occurs at one or two places. Quarries have not been opened at any locality in the county, but several small openings have been made along Tar River at Louisburg for stone to supply a local demand.

The rock is a biotite granite of light-gray color and even, fine to medium-coarse grain. In places the feldspars have a pronounced pinkish tint, imparting a similar color to the granite. The minerals are orthoclase, microcline, acidic plagioclase, quartz, biotite, muscovite, apatite, zircon, iron oxide, chlorite, and kaolin. Orthoclase is the dominant feldspar, with little microcline but much acidic plagioclase. A thin section from a specimen 3½ miles west of Louisburg differed in composition from that above given in the absence of microcline and in containing a smaller amount of plagioclase.

The vertical joints are spaced at irregular intervals, close together in some places, but as a rule sufficiently far apart to yield dimension stone. On the road near the Louisburg bridge the joints strike N. 80° E., N. 20° W., and north-south.

GRANVILLE COUNTY.

Granite bowlders of light-gray color and medium grain occur in the vicinity and to the east of Oxford, the county seat of Granville county. No quarries have been opened, but some of the larger bowlders have been split and used locally for curbing and foundation stone and for other purposes.

VANCE COUNTY.

The granite of Vance County is perhaps among the best known in North Carolina, and some of the quarries compare favorably with the most extensive ones elsewhere in the State. The area is a large one, confined principally to the central and eastern parts of the county. Quarries are worked at several places in the county along the Seaboard Air Line Railway, chiefly at and near Greystone and Middleburg stations. The quarries at Greystone have been worked almost continuously since they were opened, about thirty years ago. Those near Middleburg have only recently been opened. Several years ago a little of the granite was quarried at Henderson, the county seat, for use on the streets.

The granite has been used mostly for street purposes in the form of blocks, for coping and bridges, and to a less extent as a building stone. It has been shipped to numerous places in Virginia and

North Carolina, especially in the eastern parts of the two States. The quarry waste is used for macadam and ballast.

Greystone area.—The Greystone quarries, located at Greystone, a station on the Seaboard Air Line Railway, are the largest and best known in eastern North Carolina. As shown in the individual descriptions, the rock is a schistose granite that is admirably suited for street purposes, for which there has been a large demand over the eastern Carolina-Virginia territory.

The principal quarries are the Old Greystone, New Greystone and those of the Greystone Granite and Construction Company and the Seaboard Air Line Railway.

The rock is a biotite granite of gray to pinkish-gray color and fine to medium grain. The schistose structure, apparent in the hand specimens, is usually indicated in the thin sections. Orientation is less apparent in the light-colored minerals than in the biotite. The principal minerals are orthoclase, microcline, plagioclase (oligoclase), quartz, biotite, a little muscovite, zircon, and apatite. Much chlorite and kaolin and a light-colored mica are developed from the alteration of the biotite and feldspars. The feldspars are more or less clouded from irregular patches and areas of kaolin and minute scales of a light mica. Intergrowths of quartz and feldspar are frequent.

The *Old Greystone quarry*, the largest in the county, is located near the depot at Greystone and was continuously worked for fifteen years from the date of opening, about thirty years ago. The quarry opening covers about 2 acres and is worked to an average depth of 35 feet.

The rock is a foliated biotite granite of fine grain and pronounced porphyritic tendency. It is dark gray in color, with a pinkish cast imparted by the prevailing pink-colored feldspars.

The decayed granite at the surface, including soil, averages about 3 feet in thickness, but is as much as 15 feet in places. Near the top of the opening the granite weathers into thin horizontal sheets, which become much less well defined lower down, attaining near the bottom a thickness of 12 feet or more. Vertical joints striking N. 60° E. cut the granite at irregular intervals, in some places being spaced close together, in others at wide intervals. Slickensides are developed on the surfaces of the joints. Dikes of pegmatite and of fine-grained granite are somewhat numerous, varying in thickness from a fraction of an inch to many inches and conforming as a rule to a north-south direction. Small, irregular, roughly rounded, dark-colored segregations (knots) chiefly of biotite occur here and there.

The *New Greystone quarry*, opened in 1902, is about 150 yards west of the Old Greystone quarry. It averages less than 12 feet in depth. The fresh rock is covered to a depth of 3 to 6 feet with soil and decayed granite.

The rock is a biotite granite similar in all respects to that of the Old Greystone quarry, except that the schistosity is less marked. The vertical joints strike N. 5° to 10° E. and N. 60° E. Occasional small grains of pegmatite cut the granite.

The *Greystone Granite and Construction Company's quarry* is about three-fourths of a mile northwest of the depot at Greystone. The hill slope back of the quarry rises about 25 to 30 feet above the opening. The quarry was first opened in 1889 and was worked constantly for about six years, but has been idle for some time. At the time of working it was well equipped with the necessary modern machinery for quarrying and handling the stone, and a spur track was laid and operated between Greystone and the quarry. The opening is a large one; it averaged nearly 250 feet each way and was worked to a depth of about 25 feet.

The opening shows along the face a zone of decayed material from the surface downward for 2 to 10 feet, composed largely of a granite soil of red to light-gray color and thin, partly decayed, nearly horizontal sheets of moderately firm rock. As in the Old Greystone quarry, the horizontal parting planes are less well defined down in the fresh rock, although they are variable, separating the rock into layers or sheets 8 or 10 feet thick.

The granite is essentially the same as that of the Greystone quarries already described. It is somewhat lighter in color, but has a pinkish tone. It ranges from fine to medium grain in texture and is distinctly schistose in a general north-south direction. The feldspars average larger than the other mineral constituents, are white or of light color, and show the usual porphyritic tendency.

Two sets of vertical joints of about equal development and intersecting at right angles cut the granite in approximately north-south and east-west directions. These are spaced sufficiently far apart to admit the quarrying of blocks of any desirable size. Pegmatite dikes 6 to 8 inches across penetrate the granite and strike in a general north-south direction. Small irregular knots of black mica are noted here and there in the rock.

The *Seaboard Air Line Railway quarry* is about 2 miles northeast of Greystone station. In all several acres of surface has been stripped to a moderate depth over the gentle slopes on both sides of a small stream. The quarry was opened about 1896. A spur track is laid from the main line near Greystone to the quarry, a distance of about 1⅛ miles.

Three rather strongly contrasted phases of the granite are developed in the quarry. One, which comprises the main body of the rock, is the typical granite of the Greystone area, dark gray with a faint pinkish tone and generally fine grained. In the hand specimens the schistose structure is much less marked than in the Greystone rock proper, and it exhibits a pronounced porphyritic tendency. Another phase is a medium-textured, uniformly light-pink granite containing a much smaller amount of biotite than the phase just described. The rock is decidedly schistose in structure and highly feldspathic, and the biotite is distributed along roughly parallel disconnected bands of knife-edge thickness. As nearly as could be determined, the width of this zone as exposed in the opening is not less than 600 feet, with a north-south direction. The porphyritic tendency is not shown in this phase of the granite. A third phase is a dark blue-gray biotite granite, generally finer grained than the other two and containing a larger amount of biotite. This phase of the rock is usually developed between the pink and the gray granite as a narrow zone from 2 to 6 feet across.

The three phases of the granite are alike schistose in structure, the schistosity striking north and south; and the jointing is likewise continuous through them in the same general directions. The quarry is not sufficiently developed to show conclusively the exact relations and significance of these three variations in the rock, but such data as were available seemingly indicate that they are phases of the same rock and not separate intrusions. The differentiation was possibly begun with the cooling of the magma and completed by the intense dynamic metamorphism to which the granite has been subjected. Indeed, banding on a small scale, due to metamorphism, differentiating the rock into dark and light-colored bands, is distinctly noticeable in some parts of the quarry.

Vertical joints intersect the granite, striking north-south, east-west, and northwest-southeast. The joints in the east-west direction form the major set and their surfaces are usually slickensided after the fashion of those in the Old Greystone quarry described above. Pegmatite dikes varying from 1 inch to more than 6 inches across and mostly striking N. 10° E. are numerous.

The stone quarried from this opening is reported to have been used for ballast and for street purposes.

One other exposure of the granite near Greystone station, between the main track of the railroad and the New Greystone quarry, was recently opened to a small extent, but was soon abandoned on account of the numerous veins and the irregular texture of the rock.

Middleburg area.—Two quarries, near together, have been opened on the west side of the Seaboard Air Line Railway, 1 mile west of Middleburg station and about 3 miles north of Greystone. The granite is essentially the same as that quarried at Greystone. On the whole it probably contains a very little more biotite and is correspondingly darker. The feldspars are chiefly light in color—nearly white, with the barest pinkish cast. The rock is fine grained, displaying a marked porphyritic tendency in the feldspathic constituent. The biotite is distributed in fine black shreds along parallel lines arranged in the direction of their longer axis. Hand specimens from the two openings are indistinguishable.

The rock is a biotite granite, distinctly schistose, and composed of the same minerals in practically the same proportions as the granite at Greystone. Feldspar predominates, consisting of the potash varieties, orthoclase and microcline, with microperthitic intergrowths, and an acidic plagioclase. Some alteration to kaolin and muscovite is indicated in the cloudy and opaque areas over the feldspar surfaces. Micropoikilitic structure in the potash feldspars is common and Carlsbad twinning is occasionally observed. Intergrowths of quartz and feldspar, indicating the overlapping of the periods of separation from the magma of these two minerals, are common. Biotite is largely altered to chlorite and it is identical in occurrence and microscopic properties with that in the granite at Greystone. The microscopic accessories are the same in the granite from the two areas.

The first quarry was opened in 1899. The opening averages about 400 by 199 feet, and has been worked to an average depth along the quarry face of 25 feet. A 22-foot quarry face is developed lengthwise of the opening, covered at the top by an average depth of about 4 feet of soil derived from the decay of the granite.

Only one set of joints cuts the granite; they strike east and west, and are spaced some distance apart, less than half a dozen planes being visible in the entire quarry. Very few seams were noted. A tendency toward banding is indicated in places, separating the rock into alternating darker and lighter layers in a direction N. 20° E., which is the prevailing strike of the schistosity.

The rock is a biotite granite of dark-gray color and fine grain. It contains perhaps a slightly larger proportion of biotite than that quarried at Greystone. The feldspars are mostly white and show much less of the pink color so characteristic of the former area.

A second opening was made in 1903 in an outcrop of the same granite 100 yards south of the quarry described above. The jointing and schistosity are the same in the two openings.

WAKE COUNTY.

The principal exposures of granite in Wake County in which openings have been made are in the Raleigh area and the Wyatt-Rolesville area.

Raleigh area.—The only quarries worked in the Raleigh area are within the eastern limits of the city of Raleigh, about 1½ miles from the statehouse. Two large openings near together were first made more than seventy-five years ago. From 1833 to 1836 stone was quarried to build the statehouse. The north opening, which is the larger, is 850 feet long in a north-south direction, 75 feet wide, and 30 to 35 feet deep. The south opening is 330 feet long, 75 feet wide, and 25 feet deep.

The rock is a biotite granite of medium-gray color and even, fine grain. It is not entirely massive, but displays a partial schistose structure. The minerals are the potash feldspars (orthoclase and microcline in nearly equal amounts), an excess of acidic plagioclase, quartz, black mica (biotite), and a little white mica (muscovite), together with accessory apatite and zircon and secondary chlorite, epidote, and colorless mica. Intergrowths of the feldspar and quartz are common. Peripheral granulation of the quartz and feldspar is indicated, being a result of mechanical stress or pressure. A partial chemical analysis of this granite is given on page 117.

An average depth of about 3 feet of deep red clay derived from the decomposition of the granite is exposed at the top of the openings. Below this is a zone of less advanced decay, 10 feet thick, exposing partly decayed granite in thin sheets. Within this zone the rock along the horizontal parting planes and the vertical joints is broken down into light-red granitic clay and the middle portion of the sheets is composed of moderately hard though deeply decayed granite. Below this second zone of weathering the granite is hard and fresh to the depth of working.

Joints occur at fairly close intervals, but the planes are not so close as to prevent the quarrying of dimension stone. The principal joints strike approximately east and west and their surfaces are slickensided.

Pegmatite dikes up to several feet in thickness are very abundant. Dimension stone free from these dikes can not be obtained, as attested by the stone used in the statehouse. Slight faulting is shown in some of the dikes, with an extreme displacement of 6 inches. A single dike of banded aplite-pegmatite was observed. Thin sections show it to be a potash aplite.

Along the west side of the north opening is a large diorite mass sharply defined from the granite and cut in all directions by pegmatites and true granite veins, much crumpled and contorted. The pegmatites are largest in the diorite mass but are large also in the granite on the east side of the quarry. The line of contact between the granite and the diorite seems to be sharp but exceedingly irregular. The exact relations between the diorite and the granite were not plain. Thin sections show the rock to be a quartz diorite, composed of the principal minerals hornblende, plagioclase feldspar, and quartz.

At the state prison, 1½ miles west of the capitol, a quarry 300 to 350 feet in diameter and worked to a depth of 60 feet was opened in 1868 to furnish stone for the foundations and walls of the prison building. The rock is a biotite granite gneiss of irregular color and texture. The vertical joints strike N. 80° W. and north-south.

Wyatt-Rolesville area.—The Wyatt-Rolesville granite area is about 14 miles north of Raleigh and about 4 miles south of Wake Forest, extending eastward from Wyatt, a station on the Seaboard Air Line Railway, to Rolesville, a distance of about 5 miles. Flat-surfaced outcrops several acres in extent are exposed near Wyatt station and near Rolesville. As indicated below, the granite is biotite bearing, but differs in some respects from that farther south in the Raleigh area. No quarries have been opened.

The rock is a biotite granite of light-gray to pinkish-gray color and fine to medium grain. Muscovite is more plentiful in the granite at Wyatt station and the feldspar is of a pinkish cast over the entire area. Thin sections of the granite near Rolesville showed the minerals to be orthoclase, microcline, acidic plagioclase, biotite, occasional muscovite, apatite, and zircon and secondary chlorite, kaolin, and iron oxide. Microcline is variable in quantity, nearly equaling the orthoclase in one section. Plagioclase nearly equals potash feldspar in amount in some sections and is considerably less in others.

Pyrite and garnet are both present in the granite at Wyatt, the latter locally in considerable quantity. Pyrite appears also in the granite at Rolesville. Vertical joints in the granite at Wyatt strike N. 20° E., N. 80° E., and north-south, and at Rolesville N. 20° E. and east-west. The spacing between the joints varies but is usually sufficiently great to yield dimension stone. Pegmatite dikes ranging in thickness from a fraction of an inch to several inches cut the granite in places.

WARREN COUNTY.

The most important exposures of granite in Warren County are found at Warrenton, the county seat, and to the north and northwest of Wise siding, on the Seaboard Air Line Railway. Some stone has been quarried in each locality.

Near the west limits of Warrenton an irregular dark-gray biotite-hornblende gneiss has been quarried for local use. It is not a desirable rock for any but the rougher grades of work. Vertical joints strike N. 60° E. and N. 30° W. Scattered crystals of pyrite are noted in the rock.

About a quarter of a mile east of the Richmond division of the Seaboard Air Line Railway, 1 mile northwest of Wise siding, a muscovite-bearing biotite granite is quarried for general building and street purposes.

The rock is a medium light-gray massive biotite granite of medium grain. Biotite is regularly distributed through the rock; much red garnet is present in places, and, indeed, is so abundant in some of the hand specimens that it imparts a mixed pink and gray color to the rock. The principal minerals are potash feldspar (orthoclase and and microcline), soda-lime feldspar (oligoclase), quartz, biotite, and a little muscovite, together with the accessories apatite, zircon, titanite, and rutile and secondary chlorite and light-colored mica.

About 2 miles north of Warren Plains a small opening was made some years ago in a light-colored muscovite granite. It is of even, fine-grained texture, and is composed of orthoclase, much acidic plagioclase, a little microcline, and muscovite. Some garnet and iron oxide occur. The vertical joints strike N. 10° E., N. 45° E., and N. 60° W. and are too closely spaced, as a rule, to permit the quarrying of reasonably good dimension stone.

SUMMARY OF GRANITES OF NORTHEASTERN CAROLINA BELT.

Within the five counties composing this belt there are large workable areas of different grades of granite suited for nearly all classes of work in which granite is used, except for monumental stock. Systematic quarrying has been limited chiefly to areas in two counties—the Raleigh area in Wake County and the Greystone and Middleburg area in Vance County. Granite outcrops are fairly numerous and are usually of sufficient size to admit of quarries being opened without much surface stripping. The vertical joints are rarely spaced so close as to prevent the quarrying of dimension stone. Pegmatite dikes are so abundant in one or two localities as to make it impossible to obtain dimension stone free from them.

The granites show but slight variation in mineral composition over the entire belt. With one exception they are biotite granites containing occasional muscovite and, in two places, hornblende. They range from fine to medium grained in texture, with a porphyritic tendency in places. Structurally they vary from massive to schistose rocks. In color they are some shade of gray, with a pronounced pinkish tone, imparted by a pink feldspar, over much of the area.

METAMORPHIC SLATE AND VOLCANIC BELT.

The belt composed of metamorphic slates and schists and altered volcanic rocks extends in a general southwesterly direction across the middle portion of the State and forms a part of the eastern Piedmont region. Its width varies from 8 to 50 miles. It is included between the Carolina igneous belt on the west and the Triassic belt, chiefly, on the east.

Rocks of granitic composition and texture have been noted in only one county (Orange) within this belt. The principal exposures occur a short distance to the north, south, and east of Chapel Hill. They are biotite granites with much variation in color, texture, and structure. Nowhere has the rock been quarried, and except for certain grades of rough work it seems to be of doubtful commercial value.

CAROLINA IGNEOUS OR MAIN GRANITE BELT.

INTRODUCTORY STATEMENT.

The main granite belt of North Carolina, as shown on the map (Pl. XIII), occupies a nearly central position in the Carolina portion of the Piedmont Plateau. It crosses the State in a general northeast-southwest course, beginning at a point east of Danville, Va., and extending southwestward into South Carolina. In width it probably averages from 15 to 50 miles. It is traversed for most of its length by the main line of the Southern Railway and is crossed at rather close intervals by many of the principal railroads which join the main line of the Southern, being thus one of the most accessible areas in the State.

The southeast border of the belt can, as a rule, be traced with comparative readiness along an irregular line marking the contact with the belt of metamorphic slates and volcanic rocks. On the northwest it is bounded by an extensive belt of gneisses and schists of the western Piedmont region, and the line of differentiation between the two belts is less easily determined.

Granite and diorite constitute the two principal rock types of this belt. These may be either massive or more or less mashed, squeezed, and schistose. They are penetrated by dikes of granite and diabase and other basic intrusive rocks. Areas of variable schists are scattered over the belt, in many places forming the country rock.

The area is further traversed by very many intersecting quartz veins, large and small. These are usually concealed by the deep covering of rock decay, but their abundance is indicated by the innumerable angular fragments of quartz strewn over the surface.

Two phases of the granite are prominently developed over many parts of the area, the porphyritic and the even granular, which nearly everywhere grade into each other. A zone of porphyritic granite extends in a northeasterly direction through a number of counties along the western margin of the belt. This zone and other areas of porphyritic granite in the igneous belt are described on pages 164–170. With only one or two exceptions the even-granular granites are biotite granites of some shade of gray, and they vary from fine to coarse in texture.

Some of the largest and most important granite areas in the State are included in the Carolina igneous belt. As a rule, the rocks are deeply decayed, but outcrops of nearly fresh granite occur in every county within the belt. The decayed material is in general characteristic of the underlying rocks from which it has been derived, and the granites can thus usually be traced with considerable accuracy by means of the overlying soil.

The belt includes either the whole or a part of each of the following counties, named in order from south to north: Gaston, Mecklenburg, Cabarrus, Rowan, Iredell, Davidson, Davie, Forsyth, Guilford, Alamance, and Caswell. Granite has been quarried to some extent in each of these counties except Caswell.

GASTON COUNTY.

Numerous exposures of granite occur in the central and middle eastern portions of Gaston County. The rock is usually deeply decayed, yielding a characteristic light-gray soil, by which the granite is readily traced.

The rock is a biotite granite of light to medium dark-gray color and fine to medium-coarse grain. At Belmont the granite has a decided pinkish cast. With only few exceptions, the granites over most of the area show a pronounced porphyritic tendency. The principal minerals are potash feldspar (orthoclase and microcline, usually in nearly equal amount), soda-lime feldspar (oligoclase), quartz, and biotite, with accessory apatite and zircon and secondary chlorite, epidote, and a light-colored mica. Soda-lime feldspar is lacking in some thin sections of the granite near Gastonia, but is present in large amount in the granite near Belmont.

The granite has been quarried for local use from numerous small openings in and near Gastonia and from a small opening 3 miles northwest of Belmont, a station on the Southern Railway 10 miles south of east from Gastonia. As measured in the openings, the vertical joints show the strike of N. 20° to 30° E., N. 40° to 60° E., N. 60° to 70° W., N. 80° W., north-south and east-west. Usually not more than two sets of joints are developed in any one of the openings, and in several only one set was observed. The joints are sufficiently far apart to permit dimension stone to be quarried. Slickensides are developed on the surfaces of the joints at the opening 3 miles northwest of Belmont.

A few knots of small size occur, and in several openings pegmatite dikes 1 to 2 inches thick were observed.

MECKLENBURG COUNTY.

Granite occurs very generally over Mecklenburg County, but comparatively few quarries have been opened. The areas in which some granite has been quarried are the Charlotte area, the Morning Glade Church area, and the Davidson area.

Charlotte area.—The Charlotte area includes all known granite localities within a radius of 5 or 6 miles of the city of Charlotte. Openings have been worked within and just beyond the city limits at several places about 4 miles to the east; at Belmont Springs, also on the east; and at several places about 5 miles to the south.

The *City quarry*, located near the freight depot in the southeastern part of Charlotte, is 350 by 400 feet and is worked to a depth of 50 feet. The rock is too extensively crushed and jointed and too variable in color and texture to be used for any purpose except for road metal and ballast. The product is used principally for macadamizing the city streets in Charlotte.

The rock is a biotite granite of bluish-gray color and generally of fine grain. Potash feldspar (orthoclase and microcline) and very little plagioclase compose the feldspar content. Two principal sets of vertical joints, striking N. 40° E. and N. 35° to 50° W., cut the granite at close intervals. The joint surfaces are slickensided. A series of dark-greenish, schistose, fine-grained diabase dikes, varying from 12 inches to several feet across, cut the granite coincident with the N. 40° E. set of joints.

The *Oders quarry*, just beyond the southeastern limits of Charlotte, comprises two small openings, in a biotite granite of the same color and texture as that of the City quarry. The granite is crushed and intersected by closely spaced vertical joints, striking N. 10° W. and N. 60° W. The product can be used in the form of crushed stone.

Several small openings 4 miles east of Charlotte are near the Seaboard Air Line Railway, in a biotite granite of variable texture. The granite is more or less schistose and is cut by dikes of diabase. The product can be used only for the rougher grades of work.

Bowlder exposures of a hornblende-biotite granite occur over a large area on both sides of the Nation Ford road, 5 miles south of Charlotte. A number of small openings have been made in different places and some of the largest bowlders have been partly worked off. The rock is a hornblende-biotite granite of blue-gray color and medium grain. The principal minerals are potash and soda-lime feldspars, quartz, hornblende, and biotite, with much titaniferous magnetite. Hornblende and biotite are partly altered to chlorite. Pyrite occurs here and there. Small and large knots are so abundant in the Kirkpatrick openings as to render the stone unfit for the better grades of work.

At Belmont Springs, 1½ miles east of Charlotte, a dike of quartz porphyry, whose width nowhere exceeds 25 feet and which has been appropriately named leopardite,[a] intersects the biotite granite. It is a dense, hard, tough, and compact cryptocrystalline rock,

[a] Genth, F. A., Am. Jour. Sci., 2d ser., vol. 33, 1862, p. 198.

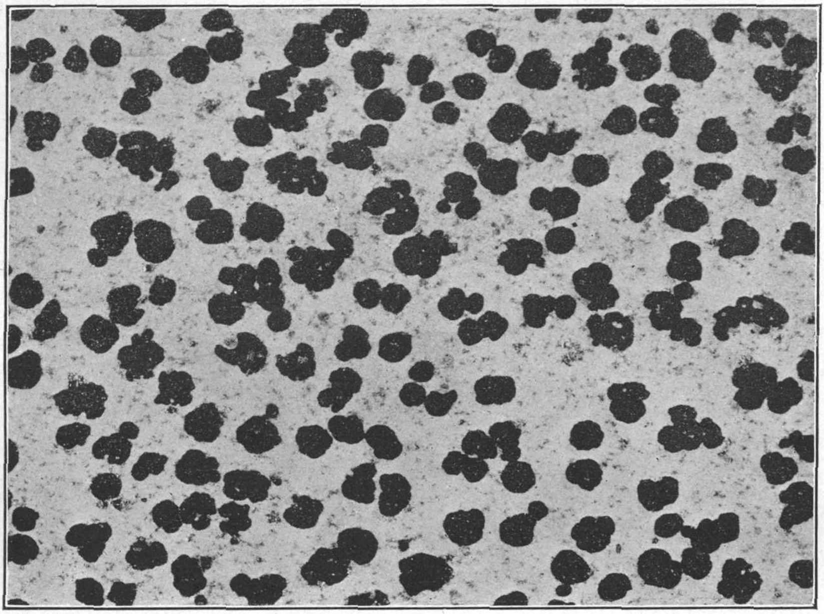
which breaks with a conchoidal fracture. It is nearly white, tinged a faint greenish in places, and is penetrated by long parallel streaks or pencils of black color. (See Pl. XV.) When broken at right angles to the streaks the surface is dotted with rounded irregular black spots, varying in diameter from that of a pin head up to half an inch. These pencils are entirely absent from some portions of the rock and are closely crowded together in others. The rock is composed essentially of a crystalline aggregate of feldspar (potash and soda-lime varieties) and quartz, with less colorless mica. Idiomorphic phenocrysts of quartz and feldspar of small size are distributed through the groundmass. The black streaks or pencils are composed of the oxides of manganese and iron. The rock is susceptible of an excellent polish and could be used with splendid effect in inlaid work.

Morning Glade Church area.—The Morning Glade Church granite area is 10 miles east of Charlotte and 4 miles east of south from Newells station. One of the large bowlders on the Cross place has been quarried, and this constitutes the only development. The rock is a biotite granite of light-gray color and medium-grained texture. The largest bowlders are from 20 to 30 feet high and proportionately large in other dimensions.

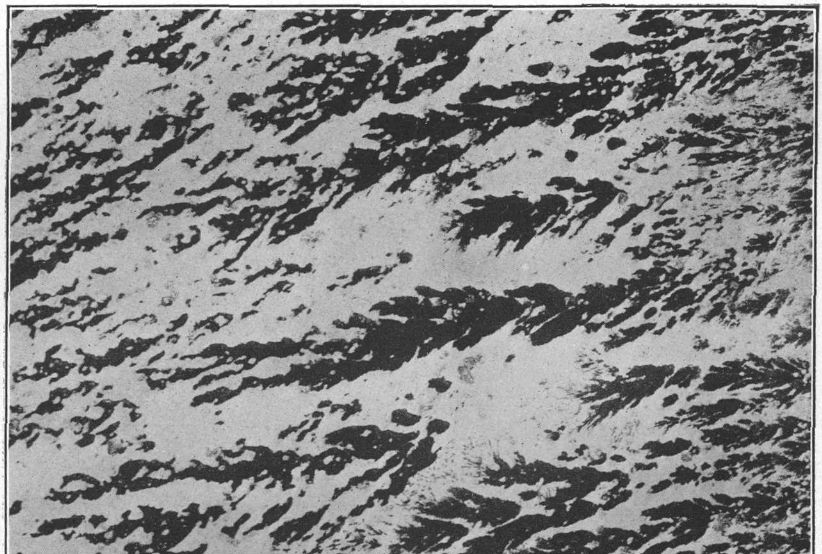
Davidson area.—The Davidson granite area is located mainly in the extreme northern part of Mecklenburg County, but extends northward into Iredell County and eastward into Cabarrus County. Numerous small openings east, south, and southwest of Davidson have been made at different times to obtain stone for local use, but no regular quarries have been worked. The earliest quarrying in the area was done prior to the civil war, to obtain stone for foundations, steps, and sills in the early buildings of Davidson College. The stone was quarried from the immense bowlder outcrops of biotite granite, on West Fork of Rocky River, 5 miles east of Davidson, located partly in Mecklenburg and partly in Cabarrus County.

Two varieties of granite occur in the Davidson area. The dominant variety is a biotite granite of light to dark gray color and fine to medium grain. The minerals are potash feldspar (orthoclase and microline), soda-lime feldspar (oligoclase), quartz, and biotite, with titanite, magnetite, apatite, and zircon. Epidote and chlorite occur as secondary minerals. Pressure effects are plainly visible in the granite from the various openings. At the Knox quarry four sets of vertical joints cut the granite, spaced at close intervals and striking N. 20° E., N. 45° W., north-south and east-west. The joint planes are slickensided, indicating subsequent movement in the granite mass.

The second variety is a biotite-bearing hornblende granite of medium-gray color and medium grain. It is exposed in large bowlders and low ledges along a small stream on the Caldwell place, 1 mile



A.



B.

LEOPARDITE (QUARTZ PORPHYRY) NEAR CHARLOTTE, MECKLENBURG COUNTY, N. C.

A. Section across black streaks. *B*. Section along black streaks.

east of Davidson. Some of the stone was quarried many years ago for foundations in several of the Davidson College buildings. The hornblende is distributed through the rock as irregular grains and lath-shaped crystals, measuring as much as 1¼ inches long by one-fourth inch wide. The minerals are potash and soda-lime feldspars (the latter in excess), quartz, hornblende, biotite, and a little magnetite, with some secondary chlorite and epidote.

The vertical joints strike N. 70° E. and N. 20° W., and are sufficiently far apart for the quarrying of dimension stone. Numerous areas of dark-colored knots occur in places, measuring 2 to 10 inches in length by 1 to 3 inches across.

CABARRUS COUNTY.

Even-granular granites occur over many parts of Cabarrus County, but except at several small openings near Concord no quarrying has been attempted. The rock is a biotite granite varying from gray to pink in color, fine to medium grained in texture, and massive to schistose in structure. The exposures are in the form of bowlders, ledges, and flat-surfaced masses.

Four miles southwest of Concord the Balfour Granite Company opened a quarry in a large bowldery ledge outcrop of augite-hornblende-biotite syenite of dark-gray color and coarse texture (Pl. XVI, *B*). Its principal minerals are orthoclase, microcline, oligoclase, green augite (diopside), hornblende, biotite, magnetite, pyrite, and kaolin. The feldspar very largely predominates in the form of large, irregular bluish-gray grains. The opening is 150 by 225 feet, worked to a depth of 25 feet. The vertical joints strike N. 40° E. and N. 40° W., with slickensided surfaces. The stone is quarried by blasting and the product is used for ballast.

ROWAN COUNTY.

One of the most important granite areas in the State is that near Salisbury, in Rowan County. The area marks a nearly continuous ridge beginning about 4 miles east of Salisbury and extending southwestward for a distance of more than 12 miles. Numerous quarries have been worked in many places on the ridge, and the stone has been widely used in North Carolina and the adjoining States. The first quarries were opened many years prior to the civil war and quarrying has been continued at intervals to the present time. Both a light-gray, nearly white granite and a pink granite of uniform color and texture and of most desirable quality are quarried on the ridge.

Dunns Mountain area.—Dunns Mountain, 4 miles east of Salisbury, forms a part of a conspicuous granite ridge 12 to 14 miles in length, trending in a general northeast-southwest direction. The ridge character is more or less apparent throughout its course, but it becomes less well defined toward the southwest. Dunns Mountain is the northern part of the ridge and the highest point, its elevation being about 900 feet above sea level and about 150 feet above Salisbury. Similar but less elevated portions of the ridge are locally known as Phillips Mountain, 6 miles nearly south of Salisbury, and Powlers Mountain, which forms a part of the extreme southwest extension of the ridge, about 9 miles southwest of Salisbury.

Over many parts of the ridge, especially Dunns Mountain proper and Phillips Mountain (Pl. XVII, *A*), the granite is exposed in huge bowlders 10 to 30 feet high and proportionately large in the other dimensions. At other points on the steeper slopes and near the top the loose residual material has been stripped from the surface, exposing large and continuous areas of the hard and bare rock surface. At still other places, where the ridge character is less pronounced, large and continuous flat-surfaced areas of the hard, nearly fresh rock are exposed. Over the intervening areas nearly fresh granite outcrops in smaller bodies, but the rock is mostly overlain by a variable mantle of residual material, from 1 to 10 feet thick, which on account of the slope can as a rule be easily stripped. In many places the exposures are sufficiently large to yield immense quantities of granite without stripping.

Two distinct and important grades of granite are quarried—a very light gray, nearly white variety, and a decided pink or flesh-colored granite. Both have the same texture and mineral composition and are closely similar in other less important particulars. The difference in color is shown only in the northeast half of the ridge, a distance of 5 miles or more. The granite has more or less of a pronounced pinkish tone over all parts of Dunns Mountain proper, but farther south this grades into the light-gray granite. Between Dunns Mountain and the village of Faith most of the rock is light gray, although several quarries have been worked within these limits in the pink granite. From Phillips Mountain, near Faith, southwestward the granite is entirely of the light-gray color.

After a careful study of the area, the writer is convinced that the light-gray and the pink granite are phases of the same rock. The light-gray granite is as strong and durable as the pink granite, but the latter is more desirable for certain classes of high-grade work.

The granite has been extensively quarried and has had a wide use both in and out of the State. Beginning at the extreme northeast end of Dunns Mountain and extending southwestward the principal quarries are those on the north slope of Dunns Mountain, the Dunns Mountain (McCanless) quarries, the Rowan Granite Company's quarries, the Balfour Quarry Company's quarries, the Consolidated Granite Company's quarries, the Phillips Mountain quarries, and the Powlers Mountain quarries. Many other small openings have been made over the ridge, but practically no stone has been quarried from them.

Microscopically the granite is an aggregate of interlocking feldspar and quartz, through which is distributed very subordinate biotite. Plagioclase equals and in many sections exceeds the potash feldspar. Microcline is usually very small in amount. Feldspar intergrowths are numerous. Biotite is sparingly present and is usually either partly or entirely altered. Scattered grains of magnetite and garnet and a few other minor accessory minerals occur. Pressure effects are plainly marked in fine mosiacs of crushed feldspar and quartz, and in strain shadows and fractures in the larger individuals. Some of the plagioclase individuals are broken across, the parts being separated and in some places bent and curved.

On the north slope of Dunns Mountain, 4 miles east of Salisbury, a number of quarries have been worked on both sides of the Stokes Ferry road. Of these the principal ones were worked during 1908 by Hartman & Hodge and by Duncan & Floyd, chiefly for dimension stone.

The granite is of medium grain and varies in color from faint pink to light gray, nearly white. More or less pinkish feldspar is usually present. The sap or partially decayed and discolored granite is very thin. The vertical joints, which are spaced at wide intervals, strike N. 50° to 70° E. and N. 25° W. Over the summit and north slope of the mountain pronounced shear zones of crushed and laminated rock, not exceeding 2 feet in width and lying at considerable distances apart, are developed in the granite. At the picnic grounds on top of the mountain the strike of the shear zones is N. 55° E. The surfaces are usually slickensided and coated with a thin veneer of yellowish-green mineral substance, which in part is epidote. A partial chemical analysis of the granite is given on page 117.

The *Dunns Mountain (McCanless) Granite Company's quarries*, which are 4½ miles southeast of Salisbury, include 45 openings, large and small, from most of which no stone has been quarried. Quarrying has been confined to three large openings, the largest one of which is 267 by 100 feet and 30 feet deep. The sap or partly decayed granite exposed in this opening averages 12 to 14 feet in thickness. The largest dimension stone shipped averaged 14 feet long by 6 feet thick. One hundred pieces, each 6 by 8 by 2 feet, were shipped to Reading, Pa.

The granite is light gray in color, the feldspars assuming a pinkish cast in places, and is of medium grain. The two principal sets of vertical joints strike N. 15° to 20° E. and N. 30° to 40° W. The planes of both sets are slickensided and are spaced at wide intervals.

The principal use made of the stone has been in buildings, as blocks and curbing for street purposes, and as macadam and ballast. In

July, 1908, the granite was being quarried for blocks to supply a Chicago contract. It has been shipped for use to various points in the Carolinas, Virginia, and Georgia, to Reading, Pa., and to Washington, D. C. The rock works well under the hammer, takes a good polish, and is susceptible of fine carved work, as displayed in some completed pieces at the quarries.

The *Rowan Granite Company's quarries* are located within a few hundred yards of Granite Quarry station on the Yadkin Railroad, about 4½ miles southeast of Salisbury. Some 12 to 15 openings are made in different places. The two largest openings are within 200 yards of each other, they are about 200 feet long by 150 feet wide, and are worked to an average depth of 32 feet. (See Pl. XVI, *A*.) Dimension stones weighing 70 to 100 tons each, were quarried from the southwest opening, quarry No. 2, in the summer of 1903, and used in the construction of the dam across Yadkin River.

The rock is a light-gray biotite granite, more or less speckled in places with a pinkish feldspar, not so pink nor so uniformly distributed through the rock as to modify the light-gray color appreciably, except at very close range and on close scrutiny. The stone possesses good working qualities, dresses well under the hammer, and is well suited for the various uses made of it.

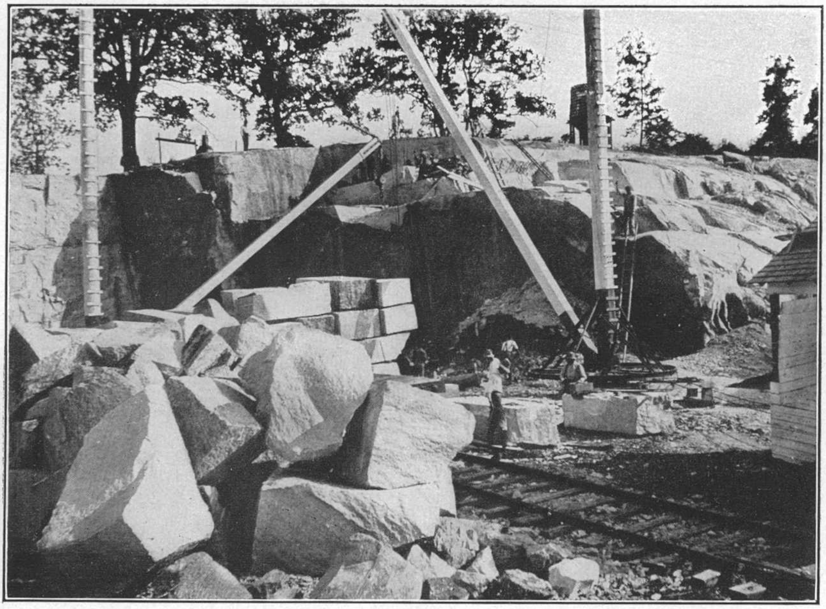
Vertical joints break the stone into polygonal blocks of different sizes, but the planes are usually spaced far enough apart to permit the quarrying of blocks of almost any dimensions. Measurements made of the strike of the joints in the principal openings gave the following results:

N. 80° E.	N. 25° E.	N. 70° W.
N. 65° E.	N. 20° E.	N. 50° W.
N. 45° E.	N. 15° E.	N. 45° W.
N. 40° E.	N. 10° E.	N. 40° W.
N. 35° E.		

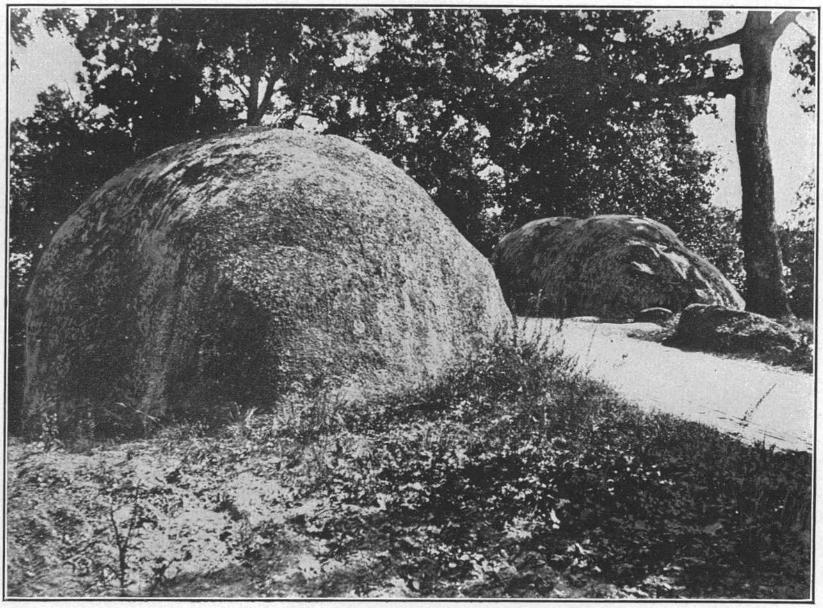
In the two large openings the joints strike as follows: Quarry No. 1, N. 40° E. and N. 40° W.; quarry No. 2, N. 35° to 45° E. and N. 45° to 50° W.

In quarries Nos. 1 and 2 the granite shows in places an advanced stage of decay, varying in depth as a rule from 5 to 6 feet, though in quarry No. 1 the granite is completely decayed at one point to a depth of more than 10 feet. The weathered material at this point consists of concentric layers of light-red and gray granitic sand and clay. The entire mass is reduced to a soft siliceous clayey material, in which the layered structure is completely preserved and which can be easily removed with the pick and shovel.

The product has been used as a general building stone, for street work in the form of curbing and blocks, as crushed stone for ballast, and to a slight extent in monumental stock. It has been shipped



A. ROWAN GRANITE COMPANY'S QUARRY NO. 2, NEAR SALISBURY, ROWAN COUNTY, N. C.



B. BOWLDER OUTCROP OF SYENITE SOUTHWEST OF CONCORD, CABARRUS COUNTY, N. C.

for use to Washington, D. C., to the most important points in Virginia and North Carolina, and to a minor extent to several other States.

These quarries were idle at the time of the writer's visit in July, 1908.

The *Balfour Quarry Company's quarries* are located less than half a mile south of the Rowan Granite Company's quarries, about 5 miles N. 20° W. of Salisbury and 2 miles northeast of Faith. Two openings have been made near together, the smaller one of which is in light-gray granite of the same color, texture, and composition as that quarried by the Rowan Company described above.

The principal opening, known as the Balfour pink quarry, is in a beautiful pink granite, in a ledge exposure having a slope of about 25°. Practically no soil covers the granite except on the east side, where slight stripping is necessary before quarrying. On the southeast side of the opening the partly discolored granite extends for several feet from the surface downward; on the north side fresh granite begins practically at the surface. Oxidation resulting in a reddish discoloration of a thin outer layer of the rock is observed along the joint surfaces.

Two sets of vertical joints strike N. 10° E. and N. 70° W. and are spaced sufficiently far apart to admit of quarrying stone of almost any size. The joint surfaces show slickensides. So far as quarrying operations have extended in depth, the rock appears to lie in sheets which vary in thickness from 2 to 10 feet, with a probable average of 8 feet. The rock contains both large and small knots of dark-gray color. The feldspar of the knots is of a pronounced pink color and in the larger segregations it shows a marked porphyritic tendency.

The rock is a biotite granite of uniform pink color and should prove to be an excellent stone for all purposes that require granite of the best grades. Its susceptibility to a high polish makes it a most desirable stone for monumental and decorative stock. The texture is medium grained and is similar to that of the light-gray granite. Biotite is very sparingly present and the feldspathic constituent, uniformly colored pink, is evenly distributed through the stone. The working qualities of the rock are excellent.

Stone from this quarry was used in the building of the Catholic University and the new municipal court building, in Washington, D. C. This grade of pink granite is in much demand in Chicago and other northern and central cities for use as monumental stock. During the summer of 1905 the nearly white granite was quarried, chiefly for use in paving, and was shipped principally to Cincinnati, Ohio. The product from this quarry was used during 1908 for monumental stock, building stone, blocks, and crushed stone.

The *Consolidated Granite Company's quarries*, 5½ miles south of Salisbury, near the village of Faith, include a large number of openings.

Quarrying is reported to have begun some years prior to the civil war. Large areas of fresh granite practically free from decay are exposed and the loose residual material, where present, is of slight depth and can be easily removed.

Two grades of granite are quarried—a light-gray granite of the same color and texture as that quarried by the Rowan Granite Company and a pink granite of the same depth of color and texture as that quarried by the Balfour Quarry Company.

Vertical joints are strongly developed in the various openings, the planes being usually spaced at intervals sufficient to allow the quarrying of stone of any desirable size. Measurements of the joints in the openings gave the following results:

N. 80° E.	N. 50° W.	North-south.
N. 40° E.	N. 40° W.	East-west.
N. 10° E.	N. 30° W.	

The *Phillips Mountain quarries* are situated on Phillips Mountain, a large, low, conical peak about 1 mile southwest of Faith, which marks the southwestward extension of the Dunns Mountain ridge. The granite is exposed over the surface of the peak in the form of huge bowlder masses in which numerous quarries have been worked. (See Pl. XVII, *A*.)

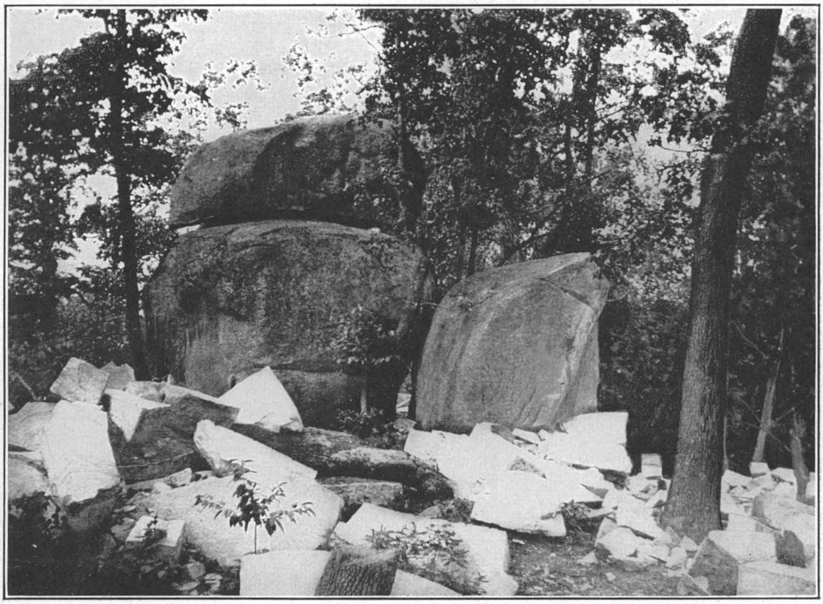
The rock is a biotite granite of very light-gray, nearly white color, and medium grain. The color and texture are fairly uniform over the area and the granite is a desirable stone for nearly all grades of work. Blocks of almost any size can be readily quarried. The stone works well under the hammer and is free from blemishes and harmful minerals.

The principal quarry operating on Phillips Mountain during the summer of 1908 was that of the Peeler Bame Company, which extracted stone for building and curbing.

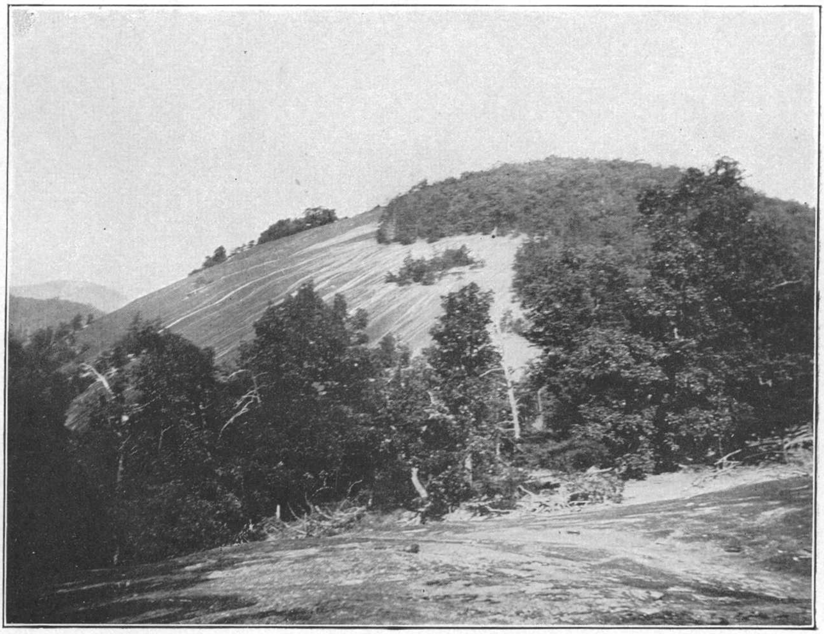
The *Powlers Mountain quarries* are situated on a low dome of granite 3 miles southwest of Faith and 9 miles southwest of Salisbury, locally known as Powlers Mountain, which marks the southwest extension of the granite ridge in Rowan County. It does not exceed 100 feet in elevation above the surrounding plain. The granite is exposed in irregular hummocky surfaces, bare of loose residual material over much of the area but covered in places by a variable depth of the weathered product.

The rock is a biotite granite of light-gray color and medium grain. It is composed largely of feldspar and quartz, with very subordinate biotite.

Several openings were made in places on the slopes of the dome many years ago, and the surface raises were worked off. Examination of these ledges shows the rock to be considerably weathered, though still fairly hard and firm. The feldspars present a lusterless



A. BOWLDER QUARRY, PHILLIPS MOUNTAIN, NEAR FAITH, ROWAN COUNTY, N. C.



B. STONE MOUNTAIN, A GRANITE DOME, WILKES COUNTY, N. C.

appearance from kaolinization, and entirely fresh hand specimens of the rock could not be obtained. Two sets of joints, which strike N. 20° E. and N. 70° W., break the granite into blocks of different sizes. The N. 70° W. set is especially well developed and cuts the granite at closer intervals than the other set.

Woodleaf area.—In the northwest corner of Rowan County numerous outcrops of a biotite granite occur in and around Woodleaf station, 11 miles northwest of Salisbury. A little of the granite has been quarried from a number of small openings for local use.

The rock is a biotite granite of medium-gray color and fine grain. The feldspathic constituent includes orthoclase and microcline, the former predominating.

The vertical joints strike N. 20° E. and N. 60° E. Abundant pyrite crystals are developed on the surfaces of the joints. There are some small dark knots. A slight schistose structure is developed in places.

IREDELL COUNTY.

The Mooresville granite area, located in the southern part of Iredell County, furnishes probably the most desirable granite for monument stock in the State. A number of quarries have been worked near the town of Mooresville, from which the area derives its name.

Both even-granular and porphyritic granites occur. From the field evidence it appears that these are not simply textural phases of the same rock, but that the even-granular granite is the younger of the two and is intrusive into the porphyritic granite. Both are biotite granites and differ from each other chiefly in texture.

The *McNeely quarry,* 1 mile northwest of Mooresville, comprises several small openings made in flat bowlder outcrops, worked to a depth of less than 10 feet. The granite bears a striking resemblance to the dark blue-gray granite at Oglesby, Elbert County, Ga. (pp. 218–223).

The rock is a biotite granite of dark blue-gray color and fine grain. Its minerals are potash feldspar (orthoclase and microcline), soda-lime feldspar (oligoclase), quartz, and biotite, with accessory titanite, apatite, and zircon and secondary chlorite and epidote. Abundant feldspar and quartz intergrowths occur. Biotite manifests a tendency to segregate in minute blotches containing several shreds to the area, similar to that of the granite at Oglesby, Ga.

A few knife-edge veins of feldspar were noted in places. Only one visible set of vertical joints intersect the granite in the openings, striking N. 65° W. The granite is of good quality and is susceptible of a high polish.

The *Breed quarry,* 2 miles southwest of Mooresville, includes two openings that have been worked at intervals since 1886. The larger opening, about 200 feet in length, is in a ledge outcrop along a small stream at the base of a moderate hill slope, the top of which rises probably 20 to 25 feet higher. Stripping to a depth of 8 to 10 feet is necessary in places.

The rock is a biotite granite of dark blue-gray color and fine grain. In hand specimens it can not be distinguished from that of the McNeely quarry, to which it is similar in mineral composition. A partial chemical analysis of the granite from the west (Johnson) opening is given on page 117.

Vertical joints strike east-west, north-south and N. 45° W., the last set being less prominent than the first two. About midway of the opening a zone of close jointing about 30 feet wide is exposed, from which dimension stone can not be quarried. With this exception the joints are usually spaced 18 to 20 feet apart. Horizontal joints divide the granite into sheets 3 to 8 feet thick. Beautiful contacts between the fresh even-granular and the porphyritic granites are exposed in the east opening.

The *Biddell quarry*, 3 miles northeast of Mooresville, comprises several small openings made in 1891. The product is reported to have been shipped to Pennsylvania for use as building stone. The largest opening is about 150 feet long and is worked to a depth of about 15 feet.

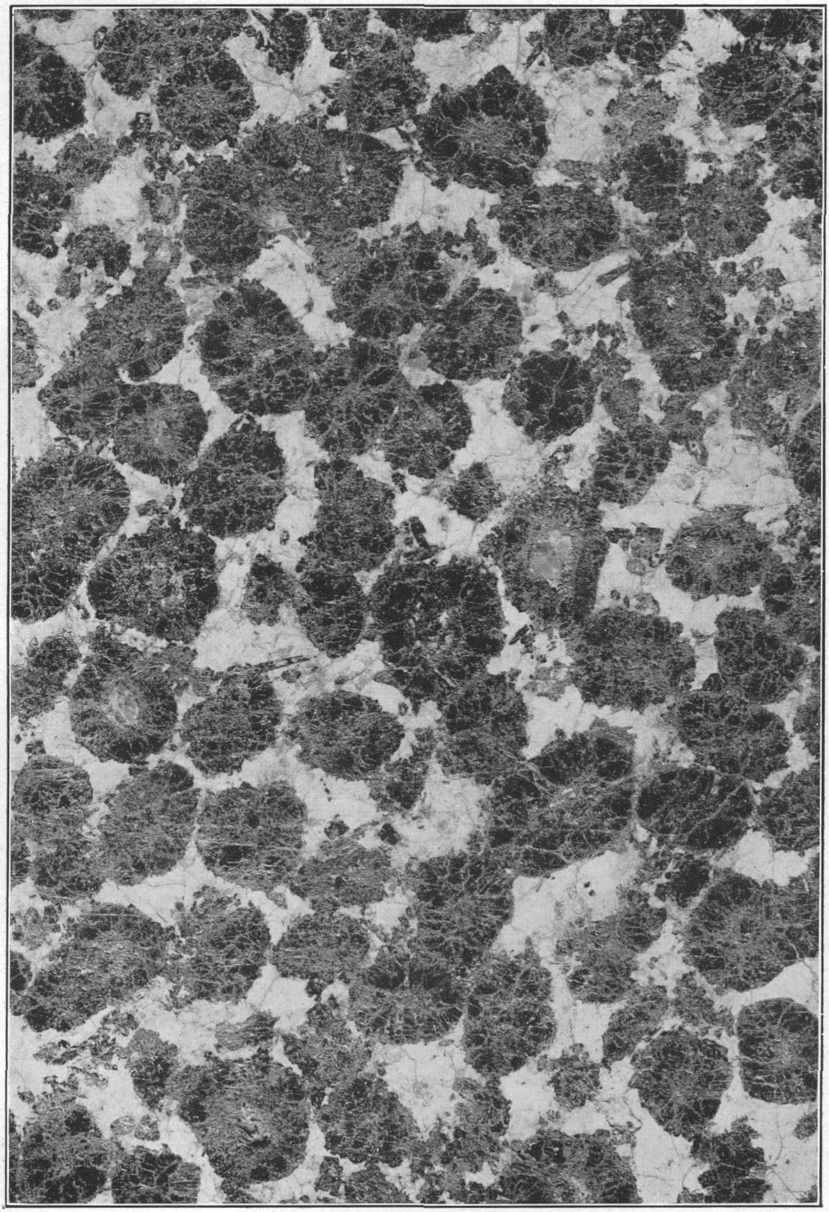
The rock is a biotite granite of medium blue-gray color and medium to fine grain. The same minerals are present as in the granite of the McNeely quarry (p. 143). Microcline is the dominant feldspar. There are a few small grains of magnetite.

Vertical joints, striking north-south and N. 65° E., are spaced at wide intervals. Pegmatite dikes, varying in thickness from 1 inch to more than 12 inches, cut the granite indiscriminately. These are so numerous that hardly a block of the granite of any size can be quarried that would be entirely free from them. Light and dark wavy streaks or bands, suggesting flowage, appear in places. Because of this irregularity and the abundance of pegmatite dikes the granite is more restricted in its use than that from the McNeely and the Breed quarries.

DAVIDSON COUNTY.

Granites occupy extensive areas over much of Davidson County. They are biotite granites of gray color, ranging from even granular to porphyritic in texture and from massive to schistose in structure. The two textures represent different facies of the same granite mass, as the porphyritic granite grades into the even-granular rock of the same mineral composition.

The granites have not been regularly worked, but some stone has been quarried from time to time at a number of places as needed to supply the local demand. The openings are all small and are located in the vicinity of Lexington, the county seat, where the rock has been



SURFACE OF ORBICULAR GABBRO-DIORITE, DAVIE COUNTY, N. C.

principally used. The earliest quarrying was done in 1856, when stone was taken out on the Conrad and Fritts places, 1¼ miles north of Lexington, for use in the court-house at Lexington. The minerals are potash feldspar (orthoclase), soda-lime feldspar (oligoclase), quartz, and biotite, with accessory apatite, zircon, and magnetite and secondary chlorite, a colorless mica, epidote, and rutile.

A fine-grained biotite granite of schistose structure has been quarried to a small extent 2 miles south of Lexington, on the Sink place. The opening is about 100 feet long by 36 feet wide and 25 to 40 feet deep.

DAVIE COUNTY.

The principal granite areas of Davie County are limited to the eastern half of the county and represent the westward extension of the Davidson County granite area. Both even-granular and porphyritic granites of the biotite variety are known. No quarries of granite have been worked in Davie County.

On the Hairston place, 10 miles west of Lexington, there are exposures of orbicular gabbro-diorite.[a] The rock is of dark color with a greenish cast imparted by the hornblende and diallage. It presents a pronounced mottled appearance, being made up of dark-green areas of hornblende, varying from an eighth of an inch to several inches in diameter, set close together, with the interstices filled with white feldspar. (See Pl. XVIII.) On a polished surface of the stone the effect is unique and beautiful, and the rock should prove of value for ornamental and decorative purposes.

FORSYTH COUNTY.

The Winston granite area, extending over the south-central portion of Forsyth County, is the most important area in the county. Even-granular and porphyritic biotite granites are represented. These grade one into the other, representing different facies of the same mass of similar mineral composition. No quarries have been regularly worked, but several small openings have been made a few miles to the east and south of Winston to supply a local demand for stone in Winston-Salem. Quarrying has been limited to the porphyritic granite, which is described on page 169.

GUILFORD COUNTY.

Of the granite distributed in numerous areas over the northern, central, and western portions of Guilford County, but little is specially desirable for the higher grades of work. Regular quarries have nowhere been worked, but numerous small openings have been made to obtain stone of a certain grade for local use. Some stone

[a] Watson, T. L., Orbicular gabbro-diorite from Davie County, N. C.: Jour. Geology, vol. 12, 1904, pp. 294-303.

has been quarried in five localities—the Brown Summit area, the Summerfield area, the Friendship area, the Jamestown area, and the Greensboro area.

The granites are biotite granites, and with the sole exception of a porphyritic granite occurring near Friendship, they are even granular in texture and more or less schistose in structure.

Brown Summit area.—The Brown Summit area is located near the Southern Railway, 10 miles north of Greensboro. On the Walker place is a single opening in a light-gray foliated granite, from which a little stone was first quarried prior to the civil war.

The rock is a biotite granite, containing much muscovite in places, and of variable texture and color. Potash feldspars (microcline and orthoclase) and quartz are the principal minerals; soda-lime feldspar (oligoclase) occurs but sparingly. The effects of pressure metamorphism are pronounced in the thin sections.

Abundant pegmatite dikes, most of which strike N. 60° E., penetrate the granite. Some of them intersect, with a displacement of several inches. The principal set of vertical joints strikes N. 60° E. and the surfaces of the joints are slickensided. This granite can be used only in the lower grades of work.

Summerfield area.—Another area is located 12 miles northwest of Greensboro, at Summerfield station. Several openings have been made to obtain granite for macadamizing roads and for street work in Greensboro. The principal openings are on the Hoskins and Gamble places, within a mile of Summerfield.

The rock is a biotite granite of variable color, texture, and structure. At the Gamble opening the porphyritic texture predominates over the even granular. Soda-lime feldspar (plagioclase) is but sparingly present in the thin sections of the granite from both places. At the Gamble place dark knots occur in the granite. Vertical joints at the Hoskins opening strike N. 10° E. and N. 70° E.

Friendship area.—This area lies 10 miles west of Greensboro, near Friendship station. The only stone quarried has been the porphyritic granite described on page 169.

Jamestown area.—Half a mile southeast of Jamestown, on Bull Run, several small openings are made in a porphyritic granite. The rock is dark gray, fine grained, and thinly schistose. It is composed of a very fine-grained groundmass of quartz and feldspar with some biotite, largely altered to chlorite, much epidote, and a colorless mica, in which are embedded porphyritic crystals of oligoclase, orthoclase, and quartz. Bluish opalescent quartzes characterize the hand specimens of the rock. Vertical joints, striking N. 20° E. and N. 40° W., cut the granite porphyry at close intervals. A single diabase dike, striking N. 40° to 50° W., penetrates the granite porphyry several hundred feet north of the opening.

At the Oakdale cotton mills, on Deep River, 1 mile southeast of Jamestown, are extensive exposures of granite, which was quarried for use in building the cotton-mill dam at that point. It is a biotite granite of gray color and medium grain, somewhat schistose in structure. Soda-lime feldspar (oligoclase) nearly equals in amount the potash feldspar (orthoclase). Very little microcline is present. Dark knots, principally of segregated biotite, of irregular outline and variable size, are abundant in the granite. A number of parallel dikes of diabase, striking N. 20° E., intersect the granite at the mill site.

Some granite has been quarried on the Modlin place, 1½ miles southeast of Jamestown. It is a biotite granite of dark-gray color and medium grain. Its uniformity of color and texture make it a desirable stone for many purposes. Orthoclase and oligoclase are nearly equal in amount. Microcline was not observed in the thin sections.

Greensboro area.—Two quarries, one in granite the other in diorite, are worked for macadam just beyond the northern limits of Greensboro. The granite is a biotite granite of medium-gray color and medium-coarse grain. Nearly equal plagioclase and orthoclase, with a little microcline, quartz, and biotite, make up the essential minerals in the thin sections.

Vertical joints, spaced at close intervals, strike N. 20° E., N. 50° E., and N. 20° W. Slickensides are well developed along the joint surfaces. The granite is further penetrated by dikes of dark greenish-black amphibolite, varying from a few inches to 18 inches in thickness and striking N. 20° E. The granite is very uniform in color and texture, but dimension stone can not be quarried because of the close jointing.

ALAMANCE COUNTY.

Granites of irregular color and texture are found in the vicinity of Burlington, the county seat of Alamance County, principally to the north, east, and southeast of the town. They are biotite bearing, schistose in places, and of little value except for the lower grades of work. According to the amount of biotite present the color varies from very light to medium and dark gray. In texture the rock ranges from fine to moderately coarse.

A number of small openings have been made in places to obtain stone for purely local purposes. About 4 miles north of Burlington small quantities of the granite have been quarried for window and door sills in factories of that vicinity. Two miles east of Burlington granite of variable color, texture, and structure has been quarried for use as macadam. Near the southeast limits of Burlington a small quantity of granite has been quarried, but the rock at this point lacks uniformity in color and texture.

An area of syenite porphyry is exposed along Haw River and its tributaries, at the Altamahaw and Ossipee cotton mills, about 7 miles northeast of Burlington. The rock is a compact, exceedingly hard, fine-grained, dark-gray syenite porphyry. The feldspar phenocrysts are not large nor conspicuously developed in the rock. Named in order of abundance the minerals of the groundmass are orthoclase, oligoclase, biotite, muscovite, epidote, magnetite, pyrite, and a little quartz. Oligoclase, some orthoclase, and less biotite are the porphyritically developed minerals.

Vertical joints strike N. 10° E. and N. 60° to 70° W. A few pegmatite dikes occur. Several small openings have been made and a little of the stone has been quarried for use as granite.

WESTERN PIEDMONT GNEISS AND GRANITE BELT.

INTRODUCTORY STATEMENT.

The rocks of the western Piedmont in North Carolina are composed largely of schists and gneisses of the mica type. They show considerable variation in composition and texture where examined, and are probably in large part of sedimentary origin. Some of the gneisses, however, are certainly altered igneous masses whose structural resemblances to sedimentary rocks are due to the effects of dynamometamorphism.

Besides these there are areas of both acidic and basic igneous rocks invading the gneiss-schist complex. Among the acidic igneous rocks are massive and foliated granites that are workable in many parts of the belt, the more important areas being in Surry, Wilkes, Alleghany, and Alexander counties. There are other granite areas in this belt, but so far as known they are of little economic importance.

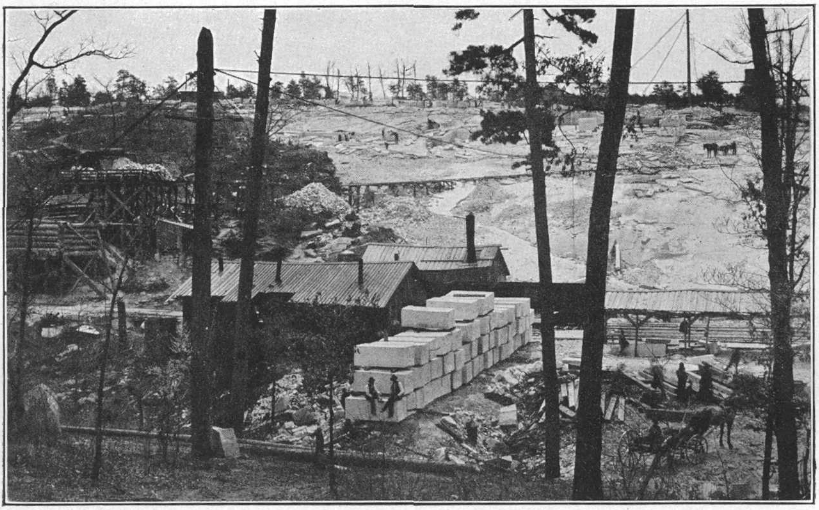
At present granite quarrying in the belt is limited exclusively to Surry County, where, in the vicinity of Mount Airy, one of the largest quarrying industries in the State is developed.

GRANITE.

Surry County.—The principal outcrops of granite in Surry County are found in the northern part of the county near the Virginia line, in the vicinity of Mount Airy, the county seat. The granite is exposed in flat-surfaced masses in rather an advanced stage of decay, immediately to the north and south of Mount Airy, where quarrying on an extensive scale has been conducted for some years.

The *North Carolina Granite Corporation's* (*Mount Airy*) *quarries*, located less than 1 mile northeast of Mount Airy, were opened in 1889 and the first shipment of stone from them was made in July, 1890. The total shipment of granite from these quarries from 1890, when 135 carloads were shipped, to 1904, when 1,282 carloads were shipped, was 13,232 carloads. (See Pl. XIX, *A*, *B*.)

Quarrying is confined to a 40-acre tract of continuously exposed granite over the slope and top of a long hill, which rises about 125 feet



A.

B.

MOUNT AIRY GRANITE CORPORATION'S QUARRIES, SURRY COUNTY, N. C.

above the valley bottom. The company holds more than 200 acres additional of ground over which granite is exposed. Quarrying has extended over practically the entire 40-acre tract, the greatest depth of working being about 30 feet.

The rock is a biotite granite of very light gray, nearly white color and medium grain. The biotite is not, except in one opening, equally distributed through the granite, but is entirely absent from some parts of it, is uniformly distributed through others, and shows a marked tendency to segregation in still other parts. Quartz-feldspar areas of extreme whiteness, ranging from several inches to as many feet in diameter, in which biotite is entirely lacking or represented by only a few shreds, are common through the granite. This unequal distribution of the characterizing accessory (biotite) renders the granite in places less uniform in color than might be desirable for some purposes. The granite that has a uniform color is most pleasing in appearance and forms excellent and desirable stone for all uses except for monumental stock, for which the contrast of color between the cut and polished faces is not great enough.

Microscopically the principal minerals are potash feldspar (orthoclase and microcline), soda-lime feldspar (oligoclase), quartz, and biotite, with accessory apatite and zircon, and secondary chlorite, epidote, light-colored mica, and iron oxide. Plagioclase feldspar exceeds the potash feldspars in amount. Zonary structure and Carlsbad twinning are beautifully developed in some of the feldspars. Intergrowths of the feldspars with one another and with quartz are abundant. A partial chemical analysis of the granite is given on page 117.

The crushing strength of the granite is well shown in the following tests, made on specimens of the stone by different parties and at different places:[a]

Crushing strength of 2-inch cubes of granite from quarries at Mount Airy, N. C.

Marks.	1.		2.	
	Crushed at—	Strain per square inch.	Crushed at—	Strain per square inch.
	Pounds.	*Pounds.*	*Pounds.*	*Pounds.*
M. A. 1	80,725	20,488	79,900	19,750
M. A. 4	86,450	21,292	80,350	20,088
M. A. 7	90,780	22,469	81,600	20,400
M. A. 10	84,410	20,686	....	....
M. A. 13	80,000	19,703	....	....
M. A. 16	74,870	18,384	....	....
Mean	....	20,497	....	20,076

1. U. S. Navy-Yard, Washington, D. C., April 16, 1896; Charles O'Neil, commander, U. S. N., and Bureau of Ordnance, U. S. N.
2. Testing department of the Philadelphia Scale and Testing Machine Works, Philadelphia, Pa., November 4, 1895; Riehle Bros.

[a] Bull. North Carolina Geol. Survey, No. 2, 1906, pp. 155–156.

The specimens broke suddenly with a loud report, several large pieces and a lot of fine material resulting from each test.

Two tests made by Prof. F. P. Venable, of the University of North Carolina, at Chapel Hill, October 24, 1895, as to the capacity of the granite from Mount Airy for absorbing water, yielded the following result:

Weight, in grams, of water absorbed by granite from Mount Airy, N. C.

	1.	2.
Weight when dried	830.4	1,001.7
Weight after being soaked in water 24 hours and then allowed to dry in air 24 hours	830.8	1,002.1
Weight of water absorbed in 24 hours	.4	.4

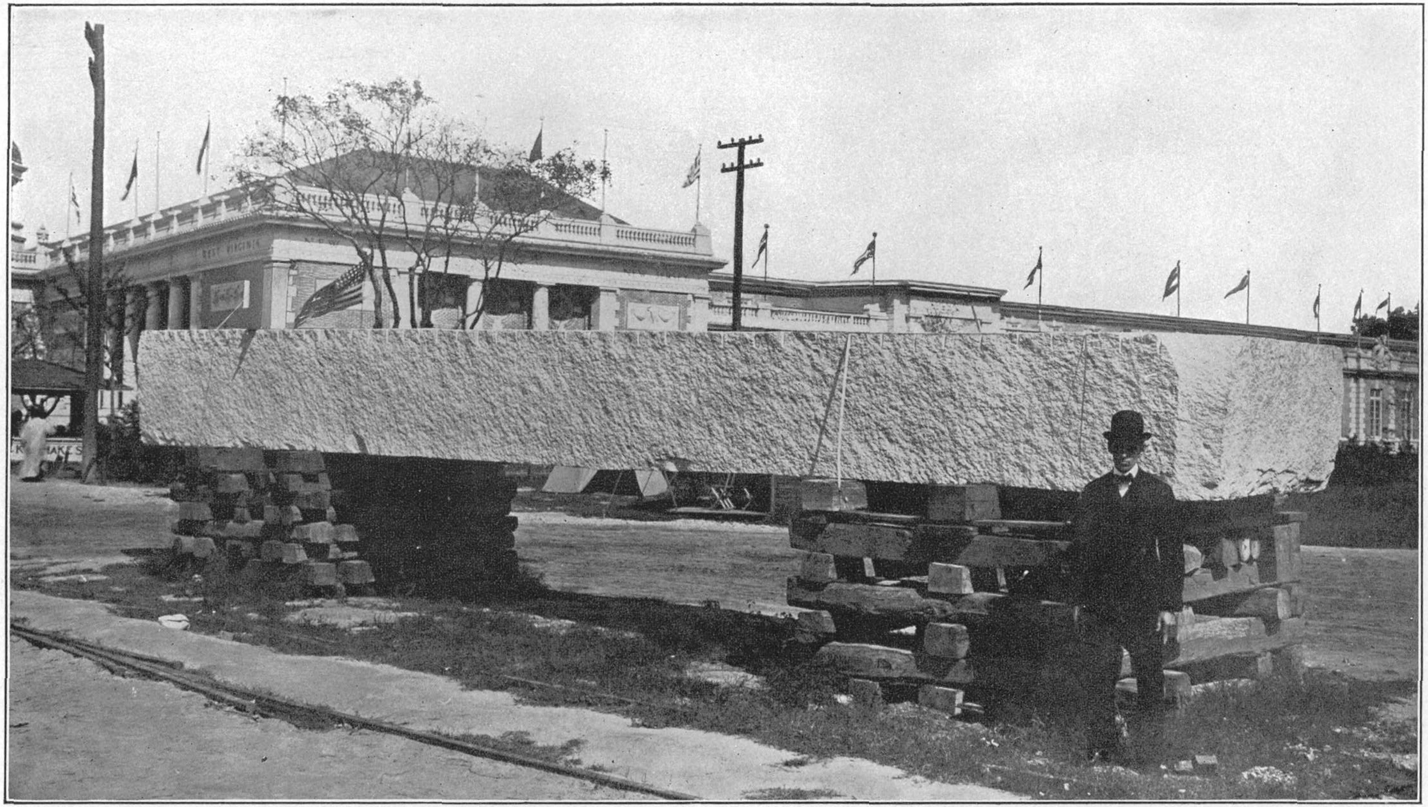
The veins and dikes found in most granites are not seen in the Mount Airy quarries, and visible vertical jointing is almost entirely lacking.

The company is adequately equipped with all necessary modern machinery and appliances for quarrying and handling the stone. In 1905 a large stone-cutting plant was erected. The stone is carried from the quarries to the railway cars by a system of inclined cableways, run by gravity. The limit in size of dimension stone is the capacity of the railroad cars. Blocks weighing 20 tons are reported to have been frequently shipped from the quarries. (See Pl. XX.)

The product is marketed over a large territory, chiefly in the States south of New York. It is used for general building and paving purposes. The quarry waste is utilized for concreting, roofs on cotton mills, macadam on streets and roads, ballast along the railroads, and granolithic work. All the stone used in the large dry dock at Newport News, Va., and the concreting material used in the Fort Caswell fortifications, Cape Fear River, North Carolina, came from the Mount Airy quarries.

The method of quarrying the granite[a] consists in drilling a hole about 3 inches in diameter perpendicular to the surface to a depth equal to the thickness of the stone desired, usually 5 to 7 feet, and then firing a succession of light blasts. The operation is begun by discharging about one-fourth of a pound of dynamite in the bottom of the hole; this small charge pulverizes the stone slightly and forms a small chamber. The tamping is then cleaned out and the hole is recharged in the same manner, this time, however, with about a handful of powder. Small charges of powder are exploded in the hole until a small seam has been started at the bottom, extending parallel with the surface. To determine if this has been done, a small steel rod bent at the lower end and sharpened to a point is

[a] Bull. North Carolina Geol. Survey, No. 2, 1906, pp. 157-160.



GRANITE MONOLITH FROM MOUNT AIRY, SURRY COUNTY, N. C.

passed up and down the hole until the crack is located. After the crack has once been started the charges are gradually increased until it extends a distance of 75 feet or more from the hole. The use of explosives is then discontinued, and a water-tight connection to the hole is made by fastening a piece of iron pipe in the hole with melted sulphur. To this connection is attached an ordinary hand force pump, and water is pumped into the crevice formed by the explosives. The crevice is extended by continuous pumping for a few hours until finally it covers an area of perhaps 2 acres and the pressure finds vent by tearing the rock out to thin edges on the side of the hill. This method is used in the warmest weather, when the surface of the rock is naturally somewhat expanded and more easily raised. It is very doubtful whether it could be employed during cold weather; experience shows that the hotter the weather the easier the work. Sheets of stone covering areas of 1 to 2 acres and from 6 to 8 feet thick close to the hole are easily raised by this method. It is found necessary to clean off a ledge of stone made in this manner before attempting to form or raise another sheet on the surface below. For this reason the quarry covers considerably more area than one having natural seams—horizontal sheeting.

In another method now used the sheets are split off with compressed air, which has been found to be even more effective than water. The method of employing compressed air, according to Mr. Thomas Woodroffe, vice-president of the company, is as follows:

The procedure is the same as that just described, until the crevice extends a distance of 75 feet or more from the hole in all directions. A pipe is then cemented into the hole and connected by means of a globe valve to an air pipe line from an air compressor. Compressed air at a pressure of 70 to 80 pounds is gradually admitted and the crack is rapidly extended until it comes out on the hillside. A sheet several acres in extent may be raised in this manner, affording a bed plane approximately horizontal, to which the quarrymen can work, thus obtaining stone of any required thickness. The first time this method was used, air under a pressure of 80 pounds was admitted into the cavity which had previously been extended to a distance of 100 feet from the lift hole. The power of the air, however, was too great for the easily splitting stone and the cleavage turned abruptly to the surface. In the next hole, however, the compressed air was admitted very gradually and the stone could soon be heard cracking in all directions, and in about half an hour the cleavage came to the surface of the hillside about 225 feet from the lift hole. To extend the cleavage by means of powder for 100 feet would require from six to twelve days and with water from three to five hours, whereas with compressed air a larger area was split in half an hour.

Wilkes and Alleghany counties.—Lying partly in the northeastern portion of Wilkes County and partly in the adjacent southeastern portion of Alleghany County are numerous closely grouped large granite bosses or dome-shaped residual masses. One of the largest of these is Stone Mountain (see Pl. XVII, *B*), 20 miles slightly east of north of Wilkesboro, the county seat of Wilkes County. Some of the other large masses are Little Stone Mountain, Cedar Rock, Wolf Rock, and Beauty Falls Rock.

These granite masses vary in height from 100 to 600 feet and in circumference at the base from 2 to 6 miles. There are eight or ten of them, characterized by steep, nearly precipitous slopes rising from narrow intervening valleys. Both the tops and the slopes are usually covered with a scant veneer of soil, sufficient in many places to maintain a fair growth of trees. In some of them, however, the tops and the slopes are entirely bare, exposing the hard though partly decayed granite.

These residual masses are composed of granite of similar color, texture, and composition. It is a biotite granite of light-gray, nearly white color and medium grain, a trifle coarser grained than the granite from the Mount Airy quarries, which it otherwise closely resembles. Fresh specimens of the granite could not be obtained, as no quarries have been opened. Dark areas (knots) chiefly of segregated biotite, are somewhat abundant in certain portions of the granite. Like the granite of the Mount Airy quarries, the rock of these bosses is largely free from vertical joints. Less than half a dozen joint planes were observed in the Stone Mountain mass; their strike was northeast and northwest. In the narrow valleys separating the large masses the granite is broken by two principal sets of closely spaced vertical joints, which have general northeast and northwest strikes.

GNEISS.

The western Piedmont belt is composed largely of gneisses of variable composition and texture, which in many places could be quarried and used to advantage in certain grades of work. One of the most promising bodies of gneiss, commercially, in this belt is Rocky Face Mountain, in Alexander County, about 6 miles northeast of Taylorsville, the county seat. This mountain is an elliptical dome-shaped mass of granite gneiss rising to an elevation of not less than 500 feet above the surrounding plain and measuring several miles around the base. It has an approximate northeast-southwest trend and generally steep slopes.

The rock is a biotite granite gneiss of light-gray color and medium grain. The banding is of irregular thickness though generally thin.

The principal minerals are potash feldspar (orthoclase and microcline), soda-lime feldspar (oligoclase), quartz, and biotite, with the usual accessories. Feldspar intergrowths (microperthite) are abundant. Red garnet in small grains and crystals is a common mineral in places. Recrystallization and crushing of the rock minerals are pronounced in the thin sections.

Vertical joints, spaced at wide intervals and of inconspicuous development, strike N. 30° E. and N. 80° E. A few quartz veins, contorted and crushed from pressure metamorphism, penetrate the rock in places.

No quarries have been opened, but stone has been stripped from the surface in several places for local use. The rock is closely similar to the contorted biotite granite gneiss at Lithonia, DeKalb County, Ga., and at Beverly, Pickens County, S. C., described on pages 197–198, 253-262, and should prove equally desirable.

APPALACHIAN MOUNTAIN GRANITES.

GENERAL DESCRIPTION.

In North Carolina the Appalachian Mountains include an irregular mountainous region lying between the steep southeastern slope of the Blue Ridge and the northwestern slope of the Great Smoky Mountains. The region has an approximate area of 6,000 square miles and an average elevation over all parts of its surface of 2,700 feet. Many of the peaks rise to elevations of more than 5,000 feet, and Mount Mitchell, the highest one, has an elevation of 6,711 feet.[a]

The principal rocks are gneisses, granites, schists, slates, limestones, quartzites, and conglomerates, cut in places by basic eruptive rocks.

Five of the geologic folios [b] published by the United States Geological Survey cover a considerable part of the North Carolina mountain province and show that it contains extensive areas of gneiss and granite suitable for building stone. With only one exception—the Whiteside granite, in the southeastern portion of the Pisgah quadrangle, covering parts of North and South Carolina—the granites and gneisses of this region are assigned by Keith to the Archean. The granite and gneiss formations in the five quadrangles, with their general character and age, are tabulated below.

[a] Bull. North Carolina Geol. Survey, No. 2, 1906, p. 164.

[b] Cranberry (No. 90), 1903; Asheville (No. 116), 1904; Mount Mitchell (No. 124), 1906; Nantahala (No. 143), and Pisgah (No. 147), 1907.

Granite and gneiss formations of Appalachian Mountains in North Carolina.

CRANBERRY QUADRANGLE.

Archean:
- Beech granite.........Coarse, light-reddish porphyritic granite.
- Blowing Rock gneiss..Chiefly dark coarse porphyritic gneiss.
- Cranberry granite.....Mainly granite and granite gneiss.
- Roan gneiss...........Chiefly hornblende gneiss and diorite.
- Carolina gneiss.........Chiefly mica gneiss and mica schist; includes other gneisses, granite, and diorite.

ASHEVILLE QUADRANGLE.

Archean:
- Max Patch granite.....Coarse or porphyritic, light gray or red.
- Cranberry granite.....Mainly granite and granite gneiss.
- Roan gneiss............Chiefly hornblende gneiss and diorite
- Carolina gneiss.........Chiefly mica gneiss and mica schist; includes other gneisses, granites, and diorites and small lenses of marble.

MOUNT MITCHELL QUADRANGLE.

Archean:
- Henderson granite.....Porphyritic granite and gneissoid granite.
- Cranberry granite......Mainly granite and granite gneiss.
- Roan gneiss.............Chiefly hornblende gneiss and diorite.
- Carolina gneiss........Chiefly mica gneiss and mica schist; includes other gneisses, schists, granite, diorite, and small lenses of marble.

NANTAHALA QUADRANGLE.

Archean:
- Granite..................Granite and gneissoid granite.
- Roan gneiss............Hornblende gneiss, hornblende schist, and diorite.
- Carolina gneiss.........Mica gneiss and mica schist.

PISGAH QUADRANGLE.

Post-Cambrian:
- Whiteside granite.....Biotite-muscovite granite, slightly schistose.

Archean:
- Henderson granite.....Porphyritic granite and gneissoid granite.
- Roan gneiss............Chiefly hornblende gneiss and schist.
- Carolina gneiss........Chiefly mica gneiss and mica schist; includes other gneisses, granite, and diorite.

The principal characters of these formations, beginning with the oldest, as mapped and described by Keith, are briefly summarized below.

CAROLINA GNEISS.

The Carolina gneiss, so named because of its great extent in North and South Carolina, is the oldest formation in the region. It is the most extensive formation in the mountain region and consists of an immense series of interbedded mica gneiss, mica schist, and fine granitoid layers of light or dark gray color. In places granite masses up to 100 feet thick cut through the gneiss at all angles. These are massive, fine grained, uniform in texture, and of light-gray color, and are composed of quartz, orthoclase, and plagioclase feldspar, biotite, and muscovite, the last usually in subordinate amount. The mica schists are rarely coarse grained, and are composed of quartz, muscovite, a little biotite, and a very little feldspar. The granitoid layers contain quartz and feldspar, with muscovite and biotite in small amounts; in the light-colored bands the biotite and most of the muscovite are lacking. The granitoid layers and schists alternate in bands varying from a few inches up to 50 feet in thickness. Bands similar in composition and from one-tenth of an inch to 1 inch thick form the banded gneisses.

As a rule, the Carolina gneiss is too irregular in texture and structure to be of value as a building stone. Many of its bands can be used for rough work, such as retaining walls, foundations, macadam, and ballast. The granite and gneiss bands in the Carolina gneiss are quarried in the vicinity of Asheville and are used chiefly for road material. The roads in the vicinity, and especially those of Asheville, are constructed of rock from this formation and are reported to be very satisfactory.

ROAN GNEISS.

The Roan gneiss, so named from Roan Mountain, on the boundary of North Carolina and Tennessee, consists chiefly of hornblende gneiss, hornblende schist, and diorite, with some interbedded mica schist and gneiss similar to the Carolina gneiss. It is younger and very much less extensive than the Carolina gneiss, and as yet has proved of no value as a building stone.

CRANBERRY GRANITE.

The Cranberry granite, named from Cranberry, Watauga County, N. C., consists of granite of varying texture and color and of schists and granite gneisses derived from granite. A broad belt of this granite passes diagonally through the Asheville quadrangle, extending southwestward through the Mount Guyot quadrangle and northeastward through North Carolina and far into Virginia. Its principal minerals are quartz, orthoclase and plagioclase feldspar, biotite, muscovite, and in places hornblende. Minor accessory minerals are magnetite, pyrite, ilmenite, garnet, and epidote. Feldspar greatly predominates, imparting a light-gray color to the granite, as a rule.

The granite varies from light gray, nearly white, to red in color and from a fine, even-grained rock to a coarse-grained porphyritic granite in texture and is schistose in structure. The Cranberry granite is one of the most desirable in the mountain region of the State for building stone, and its areas afford abundant opportunity for the location of quarries.

Southeast of Hayesville, Clay County, in the Nantahala quadrangle, is a belt of biotite granite which Keith states is probably to be correlated with the Cranberry granite. It is of fine or medium grain, mostly massive but partly gneissoid and schistose in structure, and composed chiefly of orthoclase and plagioclase feldspar, quartz, biotite, and muscovite, named in the order of abundance. Minor accessory minerals are hornblende, pyrite, magnetite, and garnet. This granite is probably too variable in texture and color and in places too schistose to yield desirable building stone.

BLOWING ROCK GNEISS.

The Blowing Rock gneiss derives its name from a large body of gneiss exhibited in Watauga County, near Blowing Rock. It extends southward into Caldwell County. "The formation consists entirely of gneiss of two varieties, one with large, porphyritic crystals, the other of very fine, even grain. The former consists of large orthoclase crystals embedded in a groundmass of feldspar, quartz, biotite, and muscovite; the latter consists of the same minerals in crystals of uniform size and granitoid appearance."[a] The feldspar phenocrysts are commonly twinned and range in length up to 3 inches. Owing to the large amount of biotite present, the gneiss is of dark-gray or blackish-gray color. In some places the porphyritic and even-grained gneisses grade into each other; in others they are interbedded. Because of its schistose structure the Blowing Rock gneiss yields easily worked slabs, which split readily along the planes of foliation. Keith mentions this rock as an ornamental stone.

BEECH GRANITE.

A large area of the Beech granite occupies the southwestern portion of Watauga County in Beech Mountain, from which it derives its name, and extends westward into Tennessee. It is a coarse-grained porphyritic granite composed of orthoclase and plagioclase feldspar, quartz, biotite, and very little muscovite. Orthoclase is the porphyritic mineral, the phenocrysts measuring 2 inches in length. Feldspar is largest in amount and usually imparts a light color to the rock. Biotite is abundant in the more massive portions of the rock, giving a spotted appearance to the granite because of the large size of its crystals. Near the border of the area a coarse red granite occurs, the red color being due to the pink or red feldspar present in the rock. This granite has been squeezed and mashed until it has acquired a pronounced gneissoid structure.

MAX PATCH GRANITE.

The Max Patch granite is displayed in ten or more areas in Madison and Haywood counties, N. C., chiefly the former, and extends into Cocke and Unicoi counties, Tenn. The largest area surrounds Max

[a] Pisgah folio (No. 147), Geol. Atlas U. S., U. S. Geol. Survey, 1907, p. 3.

Patch Mountain, from which the formation derives its name, near the Tennessee–North Carolina boundary, in the extreme southwest corner of Madison County. Keith describes the Max Patch granite as follows:[a]

The formation consists almost entirely of coarse granite, in places porphyritic and in places of uniform grain. The minerals which compose the rock are orthoclase and plagioclase feldspar, quartz, biotite, and a very little muscovite. Accessory minerals are magnetite, pyrite, and epidote, the latter being, for the most part, in secondary veins and patches. Porphyritic crystals of orthoclase feldspar whose lengths exceed 1 inch are not infrequently to be seen. These are most common north of Big Laurel Creek, where the formations cross the state boundary into Tennessee. The other masses, particularly that around Bluff Mountain, are composed of the uniform massive variety, which is more characteristic of the formation as a whole. In the porphyritic varieties the feldspars make by far the greatest part of the rock, giving it a light-gray or dull-whitish color. In the massive parts of the formation biotite is prominent and causes a decidedly spotted appearance by the large size of its crystals.

Another variety of great extent is a coarse red granite. This appears to be a modification of the usual massive rock, from which it differs only in having many red or pink feldspars. These give a very marked red color to the whole rock.

The feldspar is in places partly altered into epidote and saussurite. In the extreme stage of alteration the feldspar has been so far replaced by the epidote that this mineral composes one-third or one-half of the bulk of the rock. This is especially noticeable on Max Patch Mountain, but it is by no means restricted to that locality. Practically all the feldspars have been so altered in other places. Likewise the biotite is altered into chlorite and fibrous hornblende. Besides these processes there was a considerable growth of epidote in small veins and segregated patches, described under unakite below.

Like the Cranberry granite, the Max Patch granite has been squeezed and mashed until at many places it has developed a pronounced gneissoid structure. Those portions of the Max Patch granite which are marked by red feldspar and yellow-green epidote should prove desirable for ornamental stone. The porphyritic portions of the granite also present a striking appearance and might be used to advantage for the same purpose. Opportunities for quarrying are abundant, especially along the streams, where fresh rock can be readily obtained.

UNAKITE.

A type of granite occurring in this area is the unique and beautiful variety known as unakite, composed of yellow-green epidote, dull pink or red feldspar, and quartz. It occurs in small narrow veins and segregated patches in the Max Patch granite described above. The unakite where observed is not uniform in color and composition but shows pronounced gradations into a pink feldspathic rock on the

[a] Asheville folio (No. 116), Geol. Atlas U. S., U. S. Geol. Survey, 1904, p. 4.

one hand and a yellow-green epidote rock on the other. The several phases of the rock here described usually occur in the same "vein," the unakite proper occupying, as a rule, the middle portion and grading toward the sides, next to the inclosing granite, into either a feldspathic or an epidote rock or both. The typical unakite portions of the "veins" show a coarse massive rock of even texture and of light-pink and green color.

The exposure best showing the relations between the unakite and the Max Patch granite was seen along Roaring Fork, a short distance above its entrance into Meadow Fork. At this point the vein character of the unakite was entirely apparent. The other exposures examined were almost entirely covered by decayed material which obscured the contacts between the unakite and the inclosing rock, and therefore revealed little or nothing of the real relations between the two.

Microscopically, the unakite-bearing (Max Patch) granite is composed of orthoclase and microcline in nearly equal proportions, a little plagioclase, quartz, a little biotite, zircon, apatite, rutile, magnetite, and a few small grains of pyrite. The secondary minerals are a colorless and a green mica, epidote, chlorite, and kaolin. The epidote is clearly an alteration product derived from the interaction of the ferromagnesian constituent and the feldspar. It occurs in the form of minute microscopic granules, thickly crowded together in large and small areas in the feldspar, next to the biotite where that is present. The quartz contains innumerable long lines of threadlike inclusions of rutile, broken into very many minute segments but always perfectly aligned. In addition to the epidote the colorless mica derived from the feldspar almost completely obscures, in a few places, the original mineral.

Some peripheral shattering is manifested in the small interstitial areas and the narrow border zones of a fine-grained mosaic. The effect of dynamic forces is further shown in strain shadows and lines of fracture in the quartz and feldspar. In some places the larger feldspar grains are much fractured and the lines are filled with another mineral; in others alteration has progressed along these lines and patches of deep-green mica are developed in them.

A thin section of the unakite shows a moderately coarse-grained granite composed of orthoclase, quartz, and epidote, with titaniferous iron oxide largely altered to leucoxene, rutile inclusions, and secondary muscovite. The quartz and feldspar individuals are considerably fractured, and they show additional strain shadows with some peripheral shattering, indicative of intense dynamic deformation.

The epidote shows, from its mode of occurrence and association in the thin sections, that it is entirely a secondary mineral. It occurs in large masses composed of minute microscopic granules, many of them replacing the entire feldspar individuals, and as continuous and irregular disconnected bands and areas of large and small size, following the fractures in both the feldspar and the quartz but most extensively developed in the feldspar. The development of epidote along the breakage lines can be continuously traced in many places from the larger areas or masses replacing the entire feldspar individuals across or into contiguous feldspars. In still other places the feldspar shows scattered granules of epidote over its surface. All gradations between these two extremes of epidotization appear. Hardly any of the feldspar in the sections examined was entirely free from some epidotization.

Besides epidote, the other (secondary) mineral matter consists mostly of quartz, which locally fills the cracks in the larger quartz and feldspar grains made by the fracturing. Some of the less epidotized feldspar shows additional alteration into a colorless mica and some kaolin. No plagioclase and no ferromagnesian minerals were recognized in any of the sections of the unakite.

HENDERSON GRANITE.

The Henderson granite derives its name from the extensive areas and exposures of the granite in Henderson County, N. C. It crosses the Pisgah quadrangle (Henderson and Transylvania counties) in a northeast-southwest direction, in a belt 6 or 8 miles wide, and extends southwestward into South Carolina. The granite is composed chiefly of orthoclase and plagioclase feldspar, quartz, muscovite, and biotite, named in the order of their abundance. Biotite is usually subordinate in amount but is subject to much variation. Both porphyritic and even-granular varieties of the granite are common, grading into each other. The granite is gray in color and generally gneissoid in structure, although small areas of massive rock, usually fine or medium grained and containing very little biotite, occur here and there. In the gneissoid portions of the porphyritic granite the feldspar phenocrysts are drawn out to more than twice their original length, few of the unaltered crystals being more than an inch long.

Extensive outcrops of the Henderson granite are common throughout the area, especially near French Broad River, in cliffs and steep slopes which afford available quarry sites. Keith states that the stone dresses well and is exceedingly hard and durable. Much of the granite has been quarried at the following places on or near the French Broad: At Johnson Bridge or Horseshoe, Henderson County; several miles north of Hendersonville, at Balfour station, by the Balfour Quarry Company; less than 2 miles east of the Transylvania-Henderson county line, near Etowah, in Henderson County; and at several points near Wilson Bridge in Transylvania County. The product was used locally in bridges and buildings and for railroad ballast and macadam.

WHITESIDE GRANITE.

The Whiteside granite derives its name from Whiteside Mountain, where, according to Keith, it forms a series of enormous cliffs. (See Pl. XIV, *B*.) There are 2 acres of the granite lying on the east and west sides of the Henderson County line, extending southeastward into South Carolina and southwestward into South Carolina and Georgia. It is a biotite-muscovite granite of light-gray color and fine to medium grain, and is generally massive in structure. Because of its massive character and because it cuts the other rocks of the region, Keith refers it doubtfully to post-Cambrian age and states that it may be as late as Carboniferous. Named in the order of their importance, the principal minerals are orthoclase and plagioclase feldspar, quartz, muscovite, and biotite. Minor accessory minerals are magnetite, ilmenite, pyrite, and garnet. Feldspars are the dominant minerals. Biotite varies considerably in amount and in places is entirely lacking. A porphyritic phase of the granite occurs in places along the border portions of the area.

Regarding the economic features of this granite Keith says:[a]

> The Whiteside granite yields excellent stone of a more massive texture than the Henderson. Its color is light gray or white, and its grain is medium and very uniform through large bodies. It splits out in thick sheets and dresses very well. Its durability is shown by its enormous cliffs in Table Rock and Lookingglass Mountain. Along the Blue Ridge are found the best natural outcrops, but quarries could be developed readily at nearly any locality in the areas. The cover of soil is seldom heavy over the rock and weathering is not deep. The stone has been used for dams, chimneys, and abutments.

SUMMARY OF THE GRANITES OF THE MOUNTAIN REGION.

Granites are widely distributed over many parts of the mountain region of North Carolina. As a rule, they are gneissoid in structure as a result of intense pressure metamorphism, although massive forms are by no means uncommon. In color they range from nearly white through different shades of gray to deep reddish pink, and in texture from fine or medium, even granular, to coarse porphyritic. The principal minerals are potash and plagioclase feldspars, quartz, biotite, and muscovite, with a little hornblende in places. Much epidote and chlorite are present locally as secondary minerals derived from the alteration of the feldspars and micas. With but few exceptions the granites are pre-Cambrian in age.

There are in the region extensive areas of gneiss, principally micaceous and hornblendic, having variable composition and texture. In addition to the rocks of granitic composition, volcanic rocks of both acidic and basic types, massive and schistose in structure, are found, some of which are of commercial value.

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[a] Pisgah folio (No. 147), Geol. Atlas U. S., U. S. Geol. Survey, 1907, p. 8.

Numerous extensive exposures of the granite afford desirable locations for quarries. Some of the exposures are accessible and can be quarried; other areas are at present inaccessible to lines of railway and must remain undeveloped except to supply a strictly local demand. Many small openings have been made in places to supply stone for local uses. The product has been used in buildings and bridges but mainly for ballast and macadam. Much of the granite is suitable for building and ornamental purposes. Dimension stone of uniform color and texture can be quarried and some of it is susceptible of a handsome and durable polish.

PORPHYRITIC GRANITES.

GENERAL STATEMENT.

Porphyritic granites are intimately associated in places with the even-granular granites of the Coastal Plain, Piedmont, and Mountain provinces. They are widely distributed, rather extensive areas occurring in nine of the Piedmont counties (Cabarrus, Davidson, Davie, Forsyth, Franklin, Gaston, Guilford, Iredell, and Rowan) and two in the Coastal Plain (Anson and Richmond).

Regular quarries have nowhere been opened in the porphyritic granite, but in most of the areas small openings have been made from which granite has been quarried to supply a local demand. Reasonably good exposures of the porphyritic granite occur in places, but as a rule the rock is more or less deeply decayed and is readily traced by the kaolinized feldspar phenocrysts in the residual material.

A striking similarity is shown in the different areas of granite of this type. The porphyritic granites of the Coastal Plain and Piedmont provinces are massive in structure, light to dark gray in color, and medium to coarse grained in texture. Those of the Mountain province are usually more or less foliated as a result of pressure metamorphism. The ratio of phenocrysts to groundmass is variable, almost every gradation being traceable between normal and even-granular granite, in which phenocrysts are entirely absent, to a typical porphyritic granite in which phenocrysts of feldspar predominate.

In mineral and chemical composition the porphyritic granites are identical with the even-granular granites, the only essential difference being that of texture. Gradation from one into the other could readily be traced in many of the areas, indicating that they are simply different textural facies of the same rock mass.

MICROSCOPIC CHARACTERS.

Microscopically, the porphyritic granites are biotite granites containing the same essential and accessory minerals as the even-granular granites. They are mixtures of feldspar and quartz with biotite, these minerals occurring in descending abundance in the order named.

The groundmass ranges from a medium to a coarse-grained biotite granite. Orthoclase is usually the dominant feldspar, although microcline or plagioclase may equal or in some places exceed it in amount. Intergrowths of the potash feldspar with plagioclase (microperthite), and with quartz in micrographic structure, are abundant. Micropoikilitic feldspars, chiefly from other included feldspars, are common. Quartz and biotite are the other essential minerals. Apatite, zircon, magnetite, and locally titanite occur as accessory minerals. Chlorite, epidote, and a light-colored mica are the usual secondary minerals, derived chiefly from the alteration of the biotite and feldspars.

Only the potash feldspars, orthoclase, and microcline, are porphyritically developed. They range from white and opaque through flesh-colored to pink in color; from 1 inch to 2 inches in length by one-fourth to 1 inch in width; from flat-tabular idiomorphic (with crystal faces) to irregular rounded allotriomorphic (without crystal faces) individuals in outline. Many of them are twinned on the Carlsbad law and as a rule they contain inclosures of biotite. The flat-tabular idiomorphic forms of white color usually prevail. They are generally of conspicuous development, rarely showing gradation into the groundmass feldspar, and in a number of specimens a rude tendency toward orientation is displayed. Like the phenocrysts of the Georgia porphyritic granites, described on pages 216, 238–250, those of the North Carolina areas show an origin in place rather than an intratelluric origin.

COASTAL PLAIN PORPHYRITIC GRANITES.

ANSON AND RICHMOND COUNTIES.

The Wadesboro-Rockingham area, located in the Coastal Plain region south of east from Charlotte, near the South Carolina boundary, has an east-west length of approximately 14 miles, lying partly in Richmond and partly in Anson County. For the extension of the same granite into South Carolina see pages 191–193. About 1 mile east from the western exposure of the granite the Triassic sandstones first appear, overlying unconformably the crystalline schists. The area between the granite and the sandstone is composed of crystalline schists of variable mineral composition. Irregular stretches of the Coastal Plain sands cover the granite over many of its parts. Outcrops of the fairly fresh granite are somewhat numerous, largely in the nature of huge bowlders, ledges, and flat-surfaced masses, the last containing several acres of surface in the largest exposures. Exposures of the fresh and weathered granite are seen to advantage in the cuts of the Seaboard Air Line Railway.

The granite is a coarse-textured, porphyritic biotite granite of pronounced pinkish-gray color, tinged a delicate yellowish green which is more decided in some places than in others. The rock derives its gray color from the presence of black biotite; the pink and yellow tints are imparted by the feldspars of those shades. Over most of the area the granite has a peculiar resinous luster imparted by the feldspathic constituent.

The groundmass is a medium coarse-grained dark-gray biotite granite. Biotite is less abundant in some of the exposures and the granite is correspondingly lighter in color. This is especially true of the exposures in the cut of the Seaboard Air Line Railway about 1 mile west of Lilesville. Here the mica occurs in small hexagonal plates, deep black in color and highly lustrous. The biotite is distributed through the groundmass as single individuals and aggregates occupying distinct areas. In other places the biotite occurs as shreds and plates usually crowded close together and freely distributed through the groundmass, thus imparting a darker color to the granite.

The phenocrysts are potash feldspars with good cleavage development and having a pronounced pinkish color, in places of a decided yellowish cast. Twinning on the Carlsbad law is characteristic. The phenocrysts are more or less of idiomorphic form (with crystal outline), flat-tabular, and much elongated, although irregular rounded allotriomorphic outlines are rather common among them. They range from more than an inch in length with proportionate width down to the size of the groundmass constituents, into which they grade in places. Inclusions of biotite are somewhat conspicuous in the phenocrysts. The ratio of phenocrysts to groundmass is somewhat variable, a probable average being, as nearly as could be estimated, about 1 to 3.

Under the microscope thin sections of the granite show soda-lime feldspar (oligoclase) equal to or greater in amount than the potash feldspars (orthoclase and microcline). A thin section of the granite prepared from the exposure in the Seaboard Air Line Railway cut 1 mile west of Lilesville showed absence of microcline.

The area is readily accessible, and almost any of the large outcrops offer good quarry sites, but less than half a dozen small openings have been made. The granite is susceptible of a fine polish, and that showing the deep pink and yellowish shades should prove a desirable stone for interior work.

Vertical joints are well developed; 1¼ miles north of Lilesville the granite is cut by three sets of joints striking N. 70° E., N. 20° W., and less conspicuously north-south. At the "flat rock," 2½ miles south of Wadesboro, two sets of joints are developed, striking N. 30° E. and N. 60° W. Dikes of diabase, 25 to 300 feet wide and trending northwest, penetrate the granite in several places. Black segregated areas or bunches (knots), chiefly of biotite, are abundantly developed in some of the openings. They range from roughly rounded oval areas to much-elongated ones in which the length is several times that of the width. The largest ones are from 8 to 12 inches long by 2 to 4 inches across. Pyrite is sparingly present at the opening 3 miles west of Rockingham, where Hitchcock Creek is crossed by the Seaboard Air Line Railway.

The granite is deeply decayed in many places, but it is easily traced by the partly decayed (kaolinized) broken fragments of the large feldspar phenocrysts rather thickly strewn over the surface. Favorable sections for studying the decayed granite occur in the railroad cuts 1 mile east and 2 miles west of Lilesville. An advanced stage of decay to a depth of 15 to 20 feet is indicated.

FRANKLIN COUNTY.

About 4 miles northeast of Franklinton occur small exposures of a porphyritic biotite granite. The rock is coarse grained, light gray, and in an advanced stage of decay at the surface. The feldspar phenocrysts are large, pink, and more or less idiomorphic in form and contain inclusions of biotite. No stone has been quarried. A porphyritic tendency is indicated in the granite occurring west of Louisburg.

The fine-grained biotite granite gneiss (see pp. 125–129) quarried at Greystone, Vance County, to the north of the Franklinton porphyritic granite area, has a pronounced porphyritic tendency in many of the quarries.

PIEDMONT PLATEAU PORPHYRITIC GRANITES.

GENERAL DESCRIPTION.

Two facies of granite, porphyritic and even granular, are prominently developed over many parts of the plateau region. Usually they grade into each other. The even-granular granites of this region are described on pages 124–152. A pronounced zone of porphyritic granite extends in a northeasterly direction through a number of counties along the western margin of the Carolina igneous belt of the Piedmont region. It begins to the southwest in Gaston County, near Gastonia, the county seat, and passes northeastward through Iredell County, where large areas are exposed around Mooresville and Mount Mourne; thence to the west of Salisbury, in Rowan County, along Yadkin River, in Davie County, and to the southeast of Winston-Salem in Forsyth County. In Rowan County the porphyritic granite has a width of 4 to 8 miles. In places the feldspar phenocrysts almost entirely die out, reappearing within a short distance in proportions equaling and locally exceeding the groundmass.

Where observed within this area the porphyritic granite preserves nearly constant characteristics. It is a coarse-grained medium to dark gray porphyritic biotite granite. The feldspar phenocrysts are persistently marked by idiomorphic outlines and are of large size, measuring in extreme cases more than 2 inches in length by 1 inch across. They are usually white, though pink feldspars are not uncommon, and they almost invariably contain some included biotite as large in size as that of the groundmass constituent. Twinning after the Carlsbad law is very common and the cleavage is pronounced. Marked orientation of the phenocrysts was not apparent.

In the absence of exposures the porphyritic granite is readily traced by its decay. The feldspar phenocrysts are abundantly scattered over the surface in a partly kaolinized condition, and many of the individuals are split into smaller fragments along the cleavage lines.

A second very prominent area of porphyritic granite, similar to that described above, lies in Cabarrus County, north and northwest of Concord, the county seat. About 3½ miles southwest of Concord is an area of coarse-grained syenite (see p. 137), which possibly grades into even-granular and porphyritic granite to the northeast and southwest.

DESCRIPTION OF INDIVIDUAL AREAS.

GASTON COUNTY.

Beginning at Gastonia and extending for about 2½ miles east-northeastward along the Gastonia-Charlotte macadam road is a belt of gray coarse-grained porphyritic granite. The feldspars make up at least 50 per cent of the rock mass and in places more. The phenocrysts are white, opaque, and large, some of them measuring more than an inch in length. They are usually flat-tabular, and idiomorphic in outline and contain biotite inclusions. A tendency toward orientation in the phenocrysts is exhibited in places. The rock in an advanced stage of decay is exposed in shallow cuts along the road. The phenocrysts observe essentially the same position and characteristics in the decayed material as in the fresh rock, except that they are dull in luster and largely altered to kaolin. Only one quarry has been opened in the porphyritic granite of this area.

The *Jenkins quarry*, located 2 miles northwest of Gastonia, comprises two openings. The rock is a porphyritic biotite granite of gray color and medium grain, with a fairly well-defined schistose structure developed in a N. 10° E. direction. The granite readily splits along this direction into curbing 10 to 12 feet long, for which the stone is principally used.

The feldspar phenocrysts are somewhat sparingly distributed; both idiomorphic and allotriomorphic forms appear, the former exhibiting flat-tabular outlines and measuring as much as 2 inches long by half an inch across. The phenocrysts are further characterized by inclosures of biotite and are of faint pinkish color.

Thin sections show much lath-shaped plagioclase. Chlorite, a colorless mica, iron oxide, and some epidote occur as alteration products derived from biotite. The phenocrysts consist entirely of potash feldspar, and the larger individuals are characterized by micropoikilitic structure.

Two sets of vertical joints, spaced at wide intervals, strike N. 20° to 30° E. and N. 80° W.

IREDELL COUNTY.

Porphyritic granite constitutes the principal type of granite in the Mooresville area. It extends east of north from Mooresville along the Salisbury road for about 5 miles. To the south, southwest, and west of Mooresville it has been traced for approximately 3 miles in each direction. It is exposed in a number of large flat-surfaced outcrops near Mount Mourne, 2½ miles south of Mooresville. Over the entire area the porphyritic granite maintains remarkable uniformity in both color and texture.

Where exposed the groundmass of the porphyritic granite is a biotite granite of dark-gray color and medium-coarse grain. It is composed of the essential minerals feldspar, quartz, and biotite.

The phenocrysts are of potash feldspar, usually twinned on the Carlsbad law; are chiefly flat-tabular and idiomorphic in outline; range from one-half inch to 2 inches in length by one-eighth to three-eighths of an inch across; and are either white or pink. As a rule the phenocrysts do not grade into the groundmass constituent, and are without marked orientation so far as observed, though at several exposures a slight tendency toward it was somewhat apparent. The phenocrysts contain included biotite, much of it in bodies as large as that of the groundmass. The ratio of the phenocrysts to the groundmass is approximately 1 to 1, with but little variation from this in any of the outcrops examined.

In the fresh rock many of the phenocrysts are of a pronounced pinkish color, but in the weathered granite they are entirely white and opaque from partial kaolinization. Over much of the area the granite is more or less deeply decayed, and the texture of the rock is preserved in the decayed material. In such material the phenocrysts are usually white and unstained and with the loose scattered crystals over the surface they afford a means of readily tracing the underlying fresh granite.

The best exposures of the fresh porphyritic granite are north of Mount Mourne and at the Breed quarry, 1½ to 2 miles southwest of

Mooresville. Outcrops of the partly or completely decayed rock are numerous over the entire area.

A small opening was made in a flat-surfaced exposure of the porphyritic granite half a mile north of Mount Mourne, where a little stone was quarried prior to the civil war. Microscopically, the minerals of the rock at this locality are potash feldspar (microcline and orthoclase), soda-lime feldspar (oligoclase), quartz, and biotite. Titanite, apatite, and magnetite occur as accessory minerals, together with a little secondary chlorite and epidote derived from the alteration of biotite. Microcline is the porphyritically developed feldspar and exhibits micropoikilitic structure. Intergrowths of quartz and feldspar are numerous.

At this point the porphyritic granite is cut by a dike of fine-textured dark blue-gray biotite granite similar to the even-granular granite quarried near Mooresville, described on page 143. The dike is irregular in outline, varying from 6 to 12 inches across, with a general northeast strike, and is regarded as an apophysis from the main body of the granite quarried near Mooresville.

The *Breed quarry*, 2 miles southwest of Mooresville, shows beautiful contacts between the fresh porphyritic granite and the even-granular granite. Thin sections of the porphyritic granite from the Breed quarry are identical in mineral composition with the Mount Mourne porphyritic granite described above. The field relations of the two granites in this area strongly indicate that they are not different facies of the same rock mass, grading one into the other, but that the even-granular granite is intrusive into the porphyritic granite, and is therefore younger.[a]

CABARRUS COUNTY.

Landers, a station on the main line of the Southern Railway in the extreme southern part of Rowan County, near the Cabarrus County line, is adopted for the name of a large area of porphyritic granite exposed over the middle northern part of Cabarrus County.

On Schulenberger Branch, where crossed by the Concord road, about three-fourths of a mile south of Landers, there are flat-surfaced exposures of a porphyritic biotite granite of gray color and medium-coarse grain. The rock can be traced continuously by scattered small outcrops of the moderately fresh granite and its residual material to a point within 4 or 5 miles north of Concord. The proportion of groundmass to phenocrysts is large and the porphyritic feldspars are white or very light in color. The phenocrysts exhibit both idiomorphic and allotriomorphic outlines, without apparent orientation. They are composed of potash feldspar and those of irregular outline pass by decreased size into the similar groundmass

[a] Bull. North Carolina Geol. Survey No. 2, 1906, pp. 88, 89.

constituent. Biotite inclusions are common in the phenocrysts and twinning on the Carlsbad law is prevalent.

A thin section cut from a specimen of the porphyritic granite 5½ miles north of Concord indicated a biotite granite composed principally of potash feldspar (orthoclase and microcline), much soda-lime feldspar (oligoclase), quartz, and biotite. The biotite is much altered to chlorite and is in places crowded with inclusions. The feldspar contains a considerable proportion of small included particles of black iron oxide. Crystals of titanite are noted here and there in the thin sections.

No openings have been made in the porphyritic granite. The vertical joints are spaced at wide intervals. Scattered dark-colored areas of biotite (knots) and local thin veins of feldspar are observed in the rock. Pyrite is sparingly developed in small scattered grains and crystals, but it has not been noted in sufficient amount in any exposures to injure the stone seriously.

ROWAN COUNTY.

Beginning about 2 miles northwest of Salisbury, on the Wilkesboro road, is an extensive belt of coarse-grained porphyritic biotite granite, which can be traced continuously by its residual material northwestward along the road to a distance of about 8 miles from Salisbury. The porphyritic granite grades in many places into an even-granular granite of the same composition. Exposures of the fresh rock were observed only at a point about 3 miles northwest of Salisbury, immediately on the road, where a small opening had been made and a little of the stone quarried for macadam.

The groundmass of the rock is a biotite granite of moderately dark-gray color and medium grain. The phenocrysts are composed of potash feldspar, usually idiomorphic in outline and twinned on the Carlsbad law. As a rule, they are very large, from 2 inches or more long by one-half to 1 inch wide. They contain inclusions of biotite and in one or two places show a tendency toward orientation.

The rock is deeply weathered into a light-gray granitic sand, in a few places deeply colored by staining from iron oxide. The large phenocrysts, more or less kaolinized, are rather thickly strewn over the surface and offer a very sure means of tracing the rock. Some of them are split into smaller pieces along the cleavage directions, distributed through the decayed granite in the same position as in the fresh rock.

DAVIDSON AND DAVIE COUNTIES.

About 3½ miles west of Lexington, on the Mocksville road, partly decayed light-gray biotite granite of fine to coarse grain, with a slight porphyritic tendency in places, is exposed. Within a short distance westward the rock becomes typically porphyritic and can be continuously traced along the road by means of its decayed material in Davie County to Advance and beyond, a distance of 18 miles west of Lexington. Exposures of the fresh granite were not seen, but the porphyritic texture of the fresh granite is preserved in the decayed product. In color the decayed granite ranges from light gray to yellowish red, with the feldspar phenocrysts still intact but much kaolinized. In the lighter-colored residual material the biotite has suffered but little alteration, but in the deeper-colored areas much chemical alteration of this constituent is evident.

The phenocrysts are mostly of large size and flat-tabular to irregular in outline, and they exhibit the usual Carlsbad twinning. Inclusions of biotite are conspicuous.

The decayed material indicates a porphyritic biotite granite, of medium-coarse grain, resembling in all respects the porphyritic granite of Gaston, Iredell, Cabarrus, and Rowan counties described above.

FORSYTH COUNTY.

About 5 miles south of Winston, near the Lexington road, an opening was made in porphyritic granite and the stone quarried for use in Winston-Salem.

The rock is a porphyritic biotite granite of light-gray color and medium-coarse grain. Most of the feldspar phenocrysts are roughly rounded and of irregular outline, and by decrease in size grade into the same groundmass constituent. Many of the phenocrysts, however, show idiomorphic, flat-tabular outlines, one-half inch in length by one-eighth inch across; they exhibit Carlsbad twinning and contain biotite inclusions.

The principal minerals are potash feldspar (orthoclase and microcline), soda-lime feldspar (oligoclase), quartz, and biotite. Secondary muscovite, chlorite, and epidote, with a slight sprinkling of minor accessories, complete the list of minerals. In the larger feldspar individuals the micropoikilitic texture is well developed, the inclosed minerals consisting largely of feldspar. Intergrowths of quartz and feldspar and of feldspars with each other are freely distributed through the thin sections.

The vertical joints strike N. 50° E. and N. 45° W. A slightly foliated structure is developed in the granite in places.

GUILFORD COUNTY.

The Guilford County granite area is a large one, extending from Summerfield to Friendship, a distance of 10 miles, and lying about 10 miles northwest and west of Greensboro. Several small openings have been made in the vicinity of Summerfield and Friendship to supply a local demand for stone.

The rock is a porphyritic biotite granite of variable gray color and medium to coarse grain. It grades into the even-granular granite at a number of points. The principal minerals are orthoclase, some microcline, plagioclase in variable amount, quartz, and biotite. Apatite, zircon, and titanite are the primary accessories, and chlorite and colorless mica the secondary minerals. The feldspar phenocrysts are both irregular, roughly rounded in outline and flat-tabular, half an inch to 2 inches long by half an inch wide, and many of them are twinned on the Carlsbad law.

Several dikes of diabase penetrate the granite between Summerfield and Friendship.

Supplementary note.—In the table below are given the percentages of silica, alumina, lime, soda, and potash in feldspars quarried from pegmatite dikes in North Carolina.[a]

Analyses of North Carolina feldspars.

	1.	2.	3.	4.	5.	6.	7.	8.	9.
Silica (SiO_2)	64.25	63.52	63.55	62.95	64.75	65.15	64.55	64.85	65.18
Alumina (Al_2O_3)	18.34	21.20	20.20	19.66	19.24	19.04	22.26	19.90	21.60
Lime (CaO)	.08	Trace.	Trace.	Trace.	Trace.	.12	1.41	None.	.64
Soda (Na_2O)	5.95	3.62	6.65	7.64	7.85	7.00	7.91	10.04	8.35
Potash (K_2O)	11.66	9.50	8.73	8.39	7.55	7.28	3.94	2.91	.04

1. Young mine, Dobag, Yancey County.
2. Irby mine. near Spruce Pine, Mitchell County.
3. Ray mine, near Burnsville, Yancey County.
4. Averys Meadow mine, Plumtree, Mitchell County.
5. Tolly Bend mine, near Micaville, Yancey County.
6. Flat Rock mine, Flat Rock, Mitchell County.
7. Charlie Robertson mine, near Micaville, Yancey County.
8. Wiseman mine, near Spruce Pine, Mitchell County.
9. Cloudland mine, near Bakersville, Mitchell County.

[a] Pratt, J. H., Economic paper No. 6, North Carolina Geol. Survey, 1902, pp. 49-50.

CHAPTER V.

THE GRANITES OF TENNESSEE.

The occurrence of granite in Tennessee is limited to the extreme middle-eastern and northeastern portions of the State, immediately along the North Carolina boundary, in the rugged mountain belt. The areas, including the westward extensions of some of the principal ones in western North Carolina, are of minor extent. They include the Cranberry and Beech granites and Carolina gneiss in Carter and Johnson counties,[a] and the Max Patch and Cranberry granites in Cocke and Sevier counties.[b] According to Keith these are all of Archean age. They are described in some detail on pages 153–161.

Owing to the meagerness of the areas of granite and the general character of the granite itself, it is very doubtful if granite quarrying will ever assume any great importance in this State. At present the areas are somewhat inaccessible and much of the granite is not suitable for the better grades of work. Merrill states that quarries of a coarse dull-pink biotite granite have been opened recently on Ripshin Mountain, on Doe River.[c]

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[a] Keith, Arthur, Cranberry folio (No. 90), Geol. Atlas U. S., U. S. Geol. Survey, 1902.

[b] Keith, Arthur, Asheville folio (No. 116), Geol. Atlas U. S., U. S. Geol. Survey, 1904.

[c] Merrill, G. P., Stones for building and decoration, 3d ed., New York, 1903, p. 83.

CHAPTER VI.

THE GRANITES OF SOUTH CAROLINA.

THE SOUTH CAROLINA CRYSTALLINE REGION.

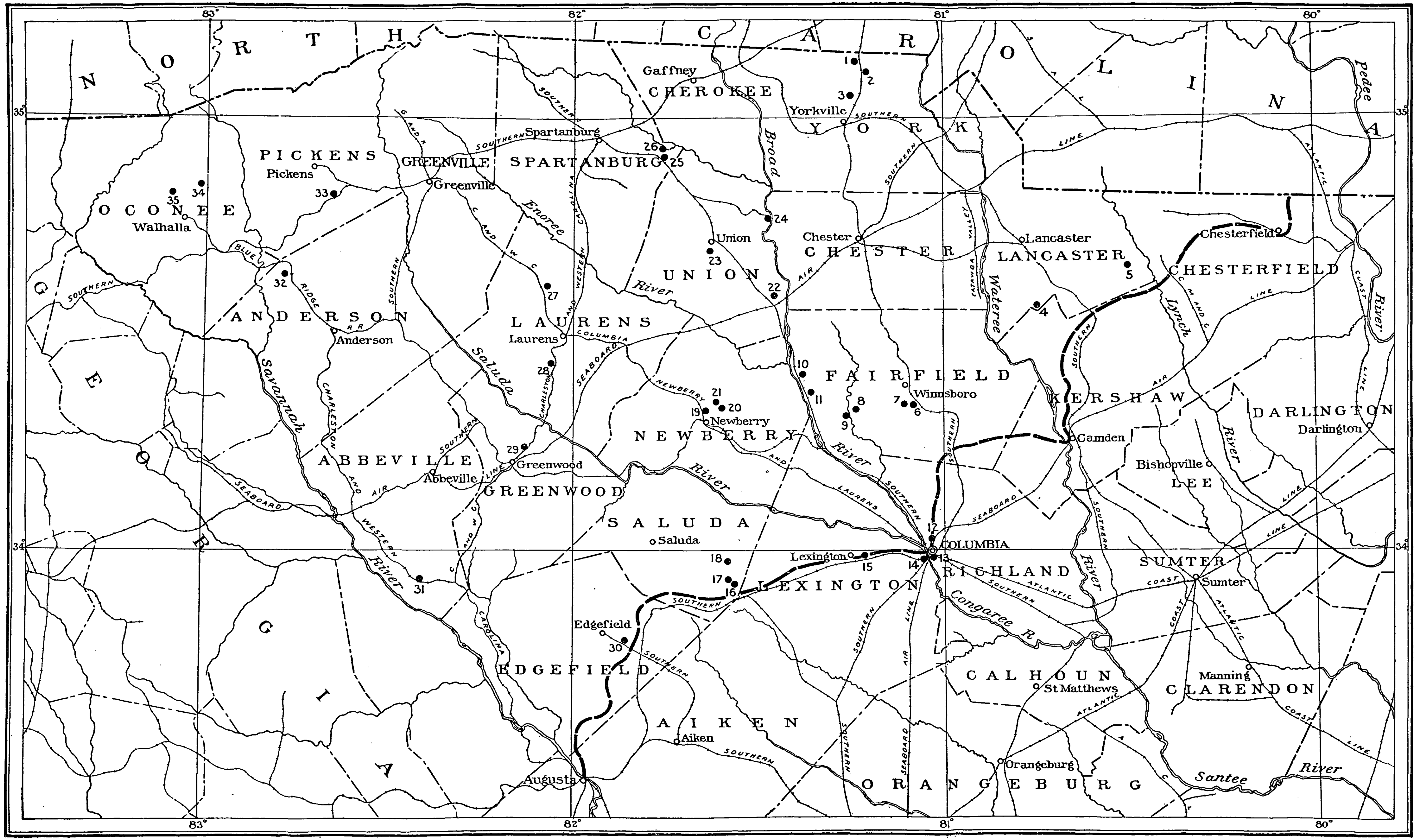
The South Carolina crystalline region embraces a roughly triangular area which is included within the fall line on the southeast, Savannah River and the northeastern boundary of Georgia on the southwest and west, and the southern boundary of North Carolina on the north. The fall line, characterized by extreme irregularity, extends in a general southwestward direction across the State, passing through or near Chesterfield, Kershaw, Camden, Columbia, and Trenton, S. C., and Augusta, Ga. (See Pl. XXI.)

The extreme northwestern portion of the crystalline region comprises a narrow belt (part of the Blue Ridge), not exceeding 30 miles wide, of mountainous topography, the higher peaks rising to an elevation of 3,500 feet. Between this mountainous belt on the northwest and the fall line on the southeast is included the greater portion of the crystalline region, the Piedmont province, which does not essentially differ from the parts of the same province to the northeast and southwest. Its principal features are the broad, rolling upland surface, the valleys carved in the upland, and the minor residual masses which rise above the upland.

According to Sloan, the higher elevations of the Piedmont region range from 700 to 900 feet above sea level and the beds of the major streams are 200 feet lower (500 to 700 feet). The surface gradually lowers toward the fall line to elevations of less than 120 feet in the major valley bottoms to 680 feet on the upland between Savannah and Congaree rivers, and to 597 feet between Wateree and Pedee rivers.[a]

The major rock types of the South Carolina crystalline region are similar to those of the southeastern Atlantic crystalline region in general, as described on pages 35–37. They include both igneous and sedimentary masses, usually much altered from metamorphism. The principal types comprise micaceous and hornblendic gneisses and schists, granites, and slates, with numerous masses of crystalline limestone, chiefly dolomitic, and quartzite. Surface volcanic rocks and their pyroclastic equivalents (tuffs), especially the latter, much

[a] Sloan, Earle, A catalogue of the mineral localities of South Carolina: Bull. South Carolina Geol. Survey, ser. 4, No. 2, 1908, p. 408.



10 0 10 20 30 40 Miles

MAP OF SOUTH CAROLINA, SHOWING LOCATION OF GRANITE QUARRIES.

LEGEND

Granite quarries (numbers refer to list)

Fall line

QUARRIES

1 Ford
2 Jackson
3 Whiteside
4 Excelsior (Southern Granite Co.)
5 Taxshaw
6 Stewart
7 Rion (Winnsboro Granite Co.)
8 Anderson (Winnsboro Granite Co.)
9 Leiper-Davis.
10 Blair
11 Strother
12 Smiths Branch (County)
13 Lipscomb (Morris & Co.)
14 Ross
15 Casparis Stone Co.
16, 17 Bates
18 Whittle
19 Level
20 Spears (Baxter)
21 Leitzsey
22 Flatrock
23 City (Union)
24 Lockhart
25 Pacolet Granite Co. (Johnson)
26 Keystone Granite Co.
27 Entrekin
28 Cold Point Granite Co.
29 Benjamin
30 Edgefield
31 Bordeaux
32 Hanckel
33 Beverley
34 Lays Mill
35 Tunnel Hill

altered from metamorphism, are extensively developed in places. Intrusions in the form of dikes of acidic and basic composition cut the rocks of this crystalline complex. With the exception of the massive granites and the dikes of igneous rocks, the rock types mentioned above are greatly altered by metamorphic changes and usually show pronounced schistose structure.

At Hornsboro, in Chesterfield County, is a small area of Triassic (Newark) rocks composed of brownish-red to gray sandstones, penetrated by dikes of diabase. This is an extension into South Carolina of the Wadesboro, N. C., area of Newark rocks.

DISTRIBUTION OF THE GRANITES.

The granites of South Carolina are limited to the crystalline area, which includes the whole or a part of Abbeville , Anderson, Cherokee, Chester, Chesterfield, Edgefield, Fairfield, Greenville, Greenwood, Kershaw, Lancaster, Laurens, Lexington, Newberry, Oconee, Pickens, Richland, Spartanburg, Saluda, Union, and York counties. Some granite has been quarried—usually a very small quantity strictly for local use—in one or more localities in each of these counties, and during the summer of 1908 quarrying operations were in progress in nine of them. The principal producing areas were Columbia, in Richland County; Lexington, in Lexington County; Edgefield, in Edgefield County; Winnsboro, in Fairfield county; Heath Springs, in Lancaster County; and Beverly, in Pickens County.

SCIENTIFIC DISCUSSION.

MINERAL COMPOSITION.

The granites of South Carolina are mixtures of feldspar and quartz, with biotite as the third essential component. Muscovite as a primary constituent is practically absent in many of the granites. It occurs as a very subordinate constituent, associated with biotite, in a part of the granites of Edgefield, Fairfield, Oconee, and York counties, and as a principal constituent in a reddish-gray granite found near Liberty Hill village in Kershaw County. Hornblende has been noted in the granite of only one locality, 1 mile south of Winnsboro, on the Winnsboro-Rockton road. Thin sections of this granite reveal sufficient hornblende to designate the granite a hornblende-bearing biotite granite.

The feldspars include nearly equal mixtures of potassic (orthoclase and microcline) and lime-soda (plagioclase) varieties. Orthoclase is the dominant potassic feldspar, with microcline equal to or greater in amount in some sections and entirely absent in others. Microperthite, an intergrowth of orthoclase with a second feldspar (plagioclase), is very constantly present. Plagioclase is usually present, in most places being equal to or greater in amount than the potassic feldspar. This is shown by the high soda content in the table of chemical analyses given below, and is confirmed by the microscopic study of thin sections of the granites.

The granites contain, besides the principal constituents enumerated above, accessory apatite, zircon, magnetite, titanite, and rutile, together with secondary chlorite, epidote, and a light-colored mica, and locally some other minerals.

CHEMICAL COMPOSITION.

The subjoined analyses of even-granular and porphyritic granites and granite gneisses show the range in composition of the South Carolina granites. A study of the analyses indicates that these granites correspond closely in chemical composition with the granites of the southeastern Atlantic States in general. In conformity with the other granites described in this report the South Carolina rocks are soda-rich granites (quartz monzonites). In 13 of the 19 analyses soda (Na_2O) approximately equals or is but slightly less than potash (K_2O), in five soda exceeds potash, and in only one is there a great excess of potash over soda. On the basis of potash-soda ratio the South Carolina granites correspond more closely to quartz monzonites than to normal granites.

Another feature shown by these analyses is the constant presence of titanium in very appreciable amount, ranging in the form of TiO_2 from a minimum of 0.24 per cent to a maximum of 0.84 per cent. Manganese and phosphorus are also reported in every analysis, either in traces or in larger amounts.

Chemical analyses of South Carolina granites.[a]

	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.
SiO_2	68.70	68.71	68.80	68.90	69.52	69.74	70.11	70.20	70.54	70.77
Al_2O_3	15.49	15.41	15.73	15.75	16.77	13.72	15.76	14.22	14.56	14.89
Fe_2O_3	1.10	1.85	2.14	1.16	.95	3.64	1.07	1.14	1.06	.75
FeO	3.73	1.59	1.57	1.49	1.56		1.76	1.24	1.62	1.24
MgO	.86	1.25	1.16	.74	.75	.22	.62	.48	.78	.43
CaO	1.70	1.64	1.64	2.66	1.82	1.54	1.84	2.14	1.28	2.08
Na_2O	3.09	3.48	3.45	4.76	3.43	5.39	3.39	5.39	3.97	4.47
K_2O	3.36	4.61	4.54	3.49	4.10	4.98	4.27	4.82	5.37	4.70
Ignition	.81	.34	.33	.18	1.43	....	.45	.33	.27	.19
TiO_2	.84	.60	.45	.36	.36	....	.45	.24	.60	.36
MnO	Trace.	Trace.	Trace.	Trace.	Trace.	....	Trace.	Trace.	Trace.	Trace.
P_2O_5	Trace.	Trace.	Trace.	Trace.	Trace.	....	Trace.	Trace.	Trace.	Trace.
SO_3	.13	Trace.	Trace.	Trace.	Trace.	....	Trace.	Trace.	.06	Trace.
	99.51	99.46	99.81	99.49	99.69	99.23	99.72	100.20	100.11	99.88

[a] Sloan, Earle, op. cit., pp. 167-225, 250-255.

1. Porphyritic biotite granite, Clouds Creek, 4.7 miles north of Batesburg, Saluda County.
2. Porphyritic biotite granite, Flatrock (old Dekalb granite), Kershaw County.
3. Biotite granite, Cold Point station, Laurens County.
4. Biotite granite, Jackson quarry, 0.5 mile north of Clover, York County.
5. Biotite granite, Leitzsey quarry, 5 miles northeast of Newberry, Newberry County.
6. Biotite granite, Anderson quarry (Winnsboro Granite Company), 8.5 miles from Rion, Fairfield County.
7. Biotite granite, Excelsior granite quarry, 5.2 miles southwest of Heath Springs, Lancaster County.
8. Biotite granite, Flatrock quarry, 2 miles north of Carlisle, Union County.
9. Biotite granite, Benjamin quarry, 4 miles east-northeast of Greenwood, Greenwood County.
10. Muscovite-bearing biotite granite, Whiteside quarry, 2 miles west of Filbert, York County.

Chemical analyses of South Carolina granites—Continued.

	11.	12.	13.	14.	15.	16.	17.	18.	19.
SiO_2	70.90	71.20	72.19	72.22	73.26	62.34	65.72	68.15	73.10
Al_2O_3	15.25	17.04	14.06	14.51	15.39	17.22	17.22	14.30	13.82
Fe_2O_3	1.52	3.48	.70	1.28	1.24	1.75	1.70	2.44	.93
FeO	1.53		1.80	1.52		2.49	2.67	2.49	1.43
MgO	.63	.11	.84	.58	.38	1.30	1.45	1.04	.51
CaO	2.40	....	1.88	1.32	1.36	3.28	2.80	2.80	1.72
Na_2O	4.32	2.32	3.46	3.21	.55	5.28	3.68	3.80	3.04
K_2O	2.85	4.70	3.94	4.30	6.89	5.14	3.80	3.84	5.06
Ignition	.17	.63	.18	.52	....	.28	.35	.28	.23
TiO_2	.42	....	.48	.24	....	.60	.72	.60	.24
MnO	Trace.	....	.16	Trace.	....	Trace.	Trace.	.11	Trace.
P_2O_5	Trace.	....	Trace.	Trace.	....	Trace.	Trace.	Trace.	Trace.
SO_3	Trace.	....	Trace.	....	....	Trace.	.08	Trace.	Trace.
	99.99	....	99.69	99.70	99.07	99.68	100.19	99.85	100.08

11. Muscovite-bearing biotite granite, Blair quarry, 0.4 mile east of Blair, Fairfield County.
12. Biotite granite, Keystone Granite Company's quarry, 2.5 miles north of Pacolet, Spartanburg County.
13. Biotite granite, Ross quarry, near Columbia, Lexington County.
14. Biotite granite, Southern Granite Company's quarry, 6.8 miles southwest of Heath Springs, Kershaw County.
15. Biotite granite, Rion quarry (Winnsboro Granite Company), Rion, Fairfield County.
16. Biotite granite gneiss, Hanckel quarry, 1.7 miles southwest of Pendleton, Anderson County.
17. Biotite granite gneiss, Ware Shoals, Laurens and Abbeville counties.
18. Biotite granite gneiss, Beverly quarry, Beverly station, Pickens County.
19. Biotite granite gneiss, Bates quarry, near Batesburg, Lexington County.

TYPES OF GRANITE.

GENERAL STATEMENT.

The granites of South Carolina, in common with those of the southeastern Atlantic States in general, vary in structure from massive to schistose and in texture from even granular to porphyritic. Accordingly, three types of the rocks may be distinguished: (1) Even-granular massive granites, (2) porphyritic granites, and (3) schistose or foliated granites or granite gneisses.

The even-granular and porphyritic granites are textural variations of the same rock mass and are locally present in the same quarry, but in such places the porphyritic texture is likely to be of a less pronounced type than is observed elsewhere. The granite gneisses were derived from massive granites, from which they differ principally in the pronounced schistose structure secondarily induced in them by dynamic metamorphism.

As described above, under "Mineral composition," the South Carolina granites are, with one exception, mica granites, and are prevailingly biotite granites. Sloan[a] reports the occurrence of both augite and hornblende granites in the State, but remarks that they are of doubtful commercial value, especially the augite granite. The writer did not observe the occurrence of either one of these types.

On the basis of mineral composition, then, the South Carolina granites are divisible into (1) biotite granite, which may contain little or no muscovite in addition to biotite, and under which the greater part of the granites of the State may be grouped; (2) musco-

[a] Sloan, Earle, op. cit., pp. 170–171.

vite-bearing biotite granite, of which there are only a few representatives; and (3) muscovite granite, of which the single occurrence near Liberty Hill village, Kershaw County, is the only representative yet observed.

EVEN-GRANULAR GRANITE.

Even-granular granites have wide but variable distribution throughout the crystalline area of the State. They vary from fine to medium grained, being rarely coarse grained. Hardly without exception they are of some shade of gray in color; light, medium, and dark blue-gray shades are common. In many localities a part of the feldspathic constituent is of slight or pronounced red color and imparts a mixed reddish-gray color to the rock, the depth of which is proportional to the intensity of the red of the feldspar.

With but few exceptions the granites are biotite granites. Muscovite, though present in places, is very subordinate, and hornblende is practically lacking. The principal minerals are orthoclase, microcline, plagioclase (oligoclase), quartz, biotite, a little muscovite, magnetite, apatite, and zircon. Titanite is a common accessory in many localities. The usual secondary minerals occur, chief among which are chlorite, epidote, muscovite, and kaolin. These are the normal minerals in granite and are so familiar that details are unnecessary here.

Micropegmatitic intergrowths of the quartz and the feldspars are common, indicating that the period of formation of the quartz clearly began before that of the feldspar closed. Orthoclase is the dominant potash feldspar, but microcline, which is usually present but variable in amount, may exceed it. Carlsbad twins are frequently seen both in thin sections and in hand specimens of the rocks. The plagioclase is invariably characterized by polysynthetic twinning striæ. Extinction angles of the plagioclase usually indicate oligoclase. The presence of considerable lime in the analyses tends to confirm the microscopic study. Microperthitic intergrowths of the feldspars are indicated in most of the thin sections studied. Many of the larger feldspar individuals are micropoikilitic, the inclosures consisting of both quartz and feldspar.

Biotite, though always present, is subject to some variation in amount. It is of deep-brown color and strongly pleochroic. It is usually altered to chlorite and less commonly to epidote; both minerals are present, chlorite being the more abundant. Muscovite, where present, is somewhat closely associated with biotite.

Magnetite, apatite, zircon, and titanite are the most common primary accessories. Much of the magnetite shows crystal boundaries and it occurs locally in irregular crystalline grains. The apatite and zircon present no noteworthy features. Titanite is present in many of the sections, both as irregular grains and aggregates and as rhombic crystals. It varies from nearly colorless to reddish brown, with noticeable pleochroism in the deeper-colored individuals.

PORPHYRITIC GRANITE.

Porphyritic granites are common over many parts of the South Carolina crystalline region, but extensive continuous areas of them in which pronounced porphyritic texture is developed are apparently less numerous than in Georgia and North Carolina. Though porphyritic texture is freely developed in many of the granite areas, it either grades within rather short intervals into the more dominant even-granular texture or else is not of a pronounced type. In some areas the ratio of phenocrysts to groundmass is very small—that is, the phenocrysts are not abundant and are scattered irregularly at wide intervals through the groundmass. In other areas where the phenocrysts are abundant they may grade into the groundmass feldspar, thus imparting to the rock a less pronounced porphyritic texture than if the phenocrysts were sharply differentiated. There are exceptions, however, and typical porphyritic granites occur in which the phenocrysts are sharply defined from the similar groundmass constituent.

Like the even-granular granites into which they grade, the porphyritic granites are biotite granites and differ from the former only in texture. The porphyritically developed mineral is potash feldspar. The phenocrysts vary in size, form, and color. They rarely exceed 1 inch in length, are both of irregular (allotriomorphic) and regular (idiomorphic) outline, and are white or pink in color. They are in places twinned on the Carlsbad law, and inclusions of biotite in them are common. Marked orientation of the phenocrysts has not been observed in any of the areas.

GRANITE GNEISS.

The gneisses quarried in South Carolina and described in this bulletin have closely similar chemical and mineral compositions to the massive granites. The principal minerals are orthoclase (largely microperthite), microcline, soda-lime feldspar (oligoclase), quartz, biotite, a little muscovite, apatite, zircon, titanite, and secondary chlorite and epidote. Granulation of the quartz and the feldspar is usually pronounced, and orientation of the biotite is shown. The only essential difference between the gneisses and the massive granites is a structural one—the gneisses are schistose. For these reasons and from the field evidence, these gneisses are believed to have been derived from original granites and are therefore designated granite gneisses.

The banding of the gneisses may be fairly regular, but as a rule it is rather irregular and highly contorted; in either case the bands are alternating ones of light (chiefly feldspar and quartz) and dark (chiefly biotite) minerals. The individual bands are subject to considerable variation in thickness. Like the massive granites, the gneisses vary in color and texture.

Both even-granular and porphyritic textures are common, the latter in places imparting a true augen gneiss appearance to the rock. The porphyritic mineral is invariably a potash feldspar, commonly microcline, and locally it is of pronounced reddish or pink color.

Of the numerous granite gneisses occurring in the State, probably that quarried by the Greenville Granite Company at the Beverly quarry, in Pickens County, is one of the most typical. It very closely resembles the well-known contorted biotite granite gneiss extensively quarried at Lithonia, Ga. (pp. 253–262), and a similar one composing Rocky Face Mountain in Alexander County, N. C. (pp. 152–153).

STRUCTURAL FEATURES OF THE GRANITES.

DIKES.

Dikes of granitic composition in the South Carolina quarries are of two kinds—extremely fine-grained granite (aplite) and very coarse grained granite (pegmatite). Dikes of basic composition, chiefly diabase, have also been observed penetrating the granites in a number of localities, but have not been noted at any of the quarries, though they occur not uncommonly in the granite quarries of North Carolina (p. 118).

APLITE.

Aplite dikes are present only here and there in the South Carolina granites. They have been noted by the writer only at the Smith Branch (County) quarry, near Columbia; the Anderson quarry, 5 miles west of Rion, in Fairfield County; and the Casparis Stone Company's quarry, near Lexington.

At the Smith Branch quarry aplite dikes, ranging in thickness from a fraction of an inch to 4 feet, are rather numerous. In color they are reddish brown, and in texture are so dense and fine grained that the mineral particles can not be distinguished with the unaided eye. The largest dike, 4 feet wide, is exposed on opposite sides of the opening (about 50 feet wide) and trends in a northeast-southwest direction, observing a general southwesterly steep dip. It consists of potash feldspar (orthoclase chiefly, with some microcline), soda-lime feldspar (oligoclase), quartz, a little biotite, accessory apatite, and secondary chlorite and epidote.

At the Anderson quarry there are several aplite dikes which range in thickness from 1 to 12 inches. Most of these are associated with pegmatite dikes, as banded aplite—pegmatite, after the fashion shown in figures 16 and 17, page 188. The aplite proper is very fine grained and light gray, with scant biotite visible to the unaided eye. The aplite consists of potash feldspar (microcline and orthoclase, partly perthite), some soda-lime feldspar (oligoclase), quartz, very little biotite and muscovite, accessory zircon, and secondary chlorite and epidote. Muscovite is partly secondary.

At the Casparis Stone Company's quarry a single aplite dike 2 inches wide was noted. The dike is very fine grained and light gray and contains no mica visible to the naked eye.

PEGMATITE.

Pegmatites are present in great numbers in some quarries and practically absent in others. They do not attain very large size, ranging from a fraction of an inch to 18 inches in width, but are usually narrow. Nowhere do they seriously interfere with quarrying operations. They are of granitic composition, consisting of the usual coarse crystallizations of feldspar and quartz, with subordinate mica, usually biotite, though some muscovite is commonly present. In the Peek quarry, near Pacolet, black tourmaline is a constituent of some of the pegmatites.

The feldspar of the pegmatites is generally white but locally of reddish or pink color. It shows good cleavage development and is twinned on the Carlsbad law. It is the most abundant constituent and is composed usually of potash feldspar (orthoclase or microcline, or both) and a less amount of acidic soda-lime feldspar.

The pegmatites apparently do not conform to any fixed direction or directions of strike, but show great variation. In the large exposures of granite on the Adams place near Clover, York County, faulting of the pegmatites was observed at one point, the displacement amounting to about 12 inches.

Over parts of the crystalline area, notably in Abbeville, Anderson, Greenville, Oconee, and Pickens counties, the pegmatites assume large dimensions, being 9 to 20 feet thick. Several of these dikes have become of economic importance within recent years for their mica and feldspar content, more especially the mica. As is indicated in the analyses below, the feldspar of these pegmatites belongs to the potassic variety.

Analyses of feldspar from South Carolina pegmatites.[a]

	1.	2.	3.	4.
SiO_2	60.79	62.26	65.60	67.30
Al_2O_3	22.57	20.41	19.45	18.21
Fe_2O_3	.18	.31	.71	.79
CaO	.24	.19	.18	.14
MgO	.23	.78	.13	.14
Na_2O	2.72	1.41	2.02	2.41
K_2O	11.01	12.71	11.34	11.14
Ignition	1.90	1.54	.63	.06
TiO_2	....	Trace.	Trace.	Trace.
P_2O_5	.09	....	....	....
SO_3	Trace.	....	Trace.	....
	99.73	99.61	100.19	100.19

[a] Sloan, Earle, op. cit., pp. 142-149.

1. Potash feldspar from the Miller place, 8.5 miles S. 23° E. of Greenville, Greenville County, S. C.
2. Potash feldspar from point 12.5 miles northwest of Walhalla, Oconee County, S. C.
3. Potash feldspar from point 3.7 miles N. 71° W. of Pickens, Pickens County, S. C.
4. Potash feldspar from old powder mill, Oconee County, S. C.

QUARTZ VEINS.

Quartz veins are exceptional in the South Carolina granite quarries but have general though variable distribution throughout the crystalline area of the State. The few small ones observed in several of the quarries are unimportant and do not merit description. The quartz veins attain considerable size in many localities beyond the quarry limits, notably near Saluda in Saluda County, Oldtown in Newberry County, Ridgeway in Fairfield County, and Kings Creek in Cherokee County.

JOINTS.

Two systems of joints intersect the granite of the South Carolina quarries—a vertical set and a horizontal set. These not everywhere have the same degree of development, nor are the two systems present in all the quarries.

VERTICAL JOINTS.

The most common type of joint has an approximate vertical position, but joints with other inclinations (50° to 60°) occur. As a rule the joints are straight, but here and there they are curved or show other irregularities. The spacing of the joints varies greatly. The large number of measurements made indicate that the spacing of the joints, where well developed, is usually between 2 feet and 8 feet. In some quarries, however, zones of close jointing were observed, and the spacing was measured in inches. In others the joints were 30 to 50 feet or more apart.

Measurement made by compass of the strike of joint courses at fourteen South Carolina granite quarries yielded the following results:

N. 5°–10° E.	N. 3°–10° W.	East-west.
N. 20°–35° E.	N. 20°–35° W.	North-south.
N. 40°–50° E.	N. 45°–60° W.	
N. 60°–70° E.	N. 65°–80° W.	

In the northeast quadrant the joints which extend approximately north-northeast and east-northeast are of about equal development; in the northwest quadrant those which extend approximately west-northwest form the dominant system. Only a few of the joints measured extend east-west and north-south.

HORIZONTAL JOINTS.

Horizontal joints which, in general, follow the surface configuration of the rock are less commonly developed in the granite of the South Carolina quarries than at the quarries of the other Southern States. In some of the South Carolina quarries no horizontal joints were observed. This system of joints is especially well developed in the quarries of Morris & Co., near Columbia; the Keystone and Peek quarries, near Pacolet; and the Benjamin quarry, north of Greenwood. They are apparently surface phenomena and diminish in number rapidly with increasing depth. The spacing between the joints is invariably closest nearest the surface, ranging from a few inches to 8 feet.

SLICKENSIDES.

Polished and striated or grooved faces (slickensides) characterize many of the joints at the quarries, indicating movement in the rocks. This movement may have been caused by more or less faulting along the joint directions; if so, further evidence of it is lacking, as discontinuity in the granite masses along the joints has not been observed. A thin veneer or coating of white, reddish, and yellowish mineral substance is developed on the faces of many of the joints. It is derived probably from the original granite minerals by the rubbing of the walls on each other.

BASIC SEGREGATIONS (KNOTS).

Dark basic segregations (knots), so common in granite and believed to have formed from the cooling magma, have but scanty development in most of the South Carolina granites. They were not observed at all at many of the quarries, and only here and there at the other quarries with perhaps one or two exceptions. They are of small size, ranging from a fraction of an inch to several inches across, and usually of irregular oval outline. They are invariably of darker color and finer grain than the inclosing granite and are composed of dominant biotite with less quartz and feldspar.

INCLUSIONS.

Inclusions of foreign (country) rock incorporated into the granite during its intrusion are exceptional in the South Carolina quarries. The only such inclusion noted by the writer is at the quarry of the

Cold Point Granite Company, near Cold Point station, in Laurens County. In the main quarry opening is a mass of thinly but perfectly foliated, nearly black biotite gneiss about 30 feet long and 15 feet wide. It is entirely surrounded by the massive granite, and where observed the contacts between the two rocks are pronounced and sharp. The gniess inclusion is composed essentially of dominant black lustrous biotite, white feldspar, and a little quartz. It has a pronounced porphyritic texture in places.

PHYSICAL TESTS.

SPECIFIC GRAVITY AND ABSORPTION.

Tests of the specific gravity and the ratio of absorption of the South Carolina granites have been made by Earle Sloan, of the South Carolina Geological Survey, as follows:

Specific gravity and ratio of absorption of South Carolina granites.[a]

Rock.	Locality.	Specific gravity.	Ratio of absorption.
Biotite granite	Benjamin quarry, Greenwood County	2.65	....
Do	Cold Point station, Laurens County	2.65	0.344
Porphyritic biotite granite	Clouds Creek, Saluda County	2.73	[b] 3.41
Biotite granite	Brown quarry, Newberry County	2.64	.405
Do	Leitzsey quarry, Newberry County	2.65	.57
Do	Flat Rock quarry, Union County	2.63	.389
Do	Blair quarry, Fairfield County	2.66	.314
Do	Strother quarry, Fairfield County	2.66	.247
Do	Ross quarry, Lexington County	2.68	....
Do	Whitesides quarry, York County	2.65	.292
Do	Anderson quarry, Fairfield County	2.64	.440
Do	Leiper-Davis quarry, Fairfield County	....	.338
Do	Rion quarry, Fairfield County	2.62	.360
Do	Jackson quarry, York County	2.66	.468
Muscovite granite	Liberty Hill, Kershaw County	2.62	.43
Biotite granite	6.8 miles S. 45° W. of Heath Springs, Kershaw County.	2.63	.310
Do	Excelsior quarry, Lancaster County	2.66	.380
Porphyritic biotite granite	Flat Rock, Cleyburn, Kershaw County	2.65	.129
Do	Oro quarry, Chesterfield County	2.66	....
Biotite granite gneiss	Pendleton quarry, Anderson County	2.68	.288
Do	Beverly quarry, Pickens County	2.66	.398
Do	Ware Shoals, Laurens and Abbeville counties	2.68	.321
Do	Paris Mount Granite Co., Greenville County	2.72	.304
Do	Bates quarry, Lexington County	2.64	.202

[a] Sloan, Earle, op. cit., pp. 174-225.

[b] Probably a misprint for 0.341.

Examination of the table shows the range in specific gravity to be from 2.62 in the massive fine-grained granites of Fairfield County to 2.73 in the coarse-grained porphyritic biotite granite of Clouds Creek, Saluda County, and in ratio of absorption from 0.129 in the porphyritic granite of Kershaw County to 0.57 in the massive fine-grained granite of Newberry County.

COMPRESSIVE STRENGTH.

Tests to ascertain the compressive or crushing strength have been made, so far as the writer is aware, on very few of the South Carolina granites. Through the courtesy of Mr. B. H. Heyward, general manager of the Winnsboro Granite Corporation, the results of four tests made by the United States Ordnance Department to determine the compressive strength of the gray granite of the Rion quarry are given below.

Compressive strength tests of granite from Rion quarry, South Carolina.

Dimensions.		Sectional area.	First crack.	Ultimate strength.	
Height.	Compression surface.			Total.	Per square inch.
Inches.	*Inches.*	*Sq. in.*	*Pounds.*	*Pounds.*	*Pounds.*
3.55	3.41x3.54	12.07	317,000	386,000	31,980
3.53	3.57x3.51	12.53	350,000	369,900	29,520
3.54	3.50x3.53	12.36	350,000	417,000	33,740
3.56	3.54x3.54	12.53	305,000	325,000	25,940

Sloan[a] gives the minimum, maximum, and average results of four tests made by the United States Ordnance Department to determine the compressive strength of the blue granite of the Anderson quarry, as 24,700, 26,080, and 25,585 pounds per square inch, respectively.

Tests to determine the compressive strength of the Keystone Granite Company's gray granite, near Pacolet station, in Spartanburg County, gave 21,420 pounds per square inch.[b]

INDIVIDUAL QUARRY AREAS.

DISTRIBUTION.

The map (Pl. XXI) shows the location of the principal quarries or prospects, which include 33 separate openings. Of these 11 were operated in 1908. The principal quarries are on or near railroads. A few are located some distance from the principal railroad lines, but most of these are connected with the main lines by spur tracks. The names and locations of these quarries are given in the subjoined list.

Granite quarries in South Carolina.

Name.	County.	Location.
Quarries operating during 1908.		
Anderson (Winnsboro Granite Corporation).	Fairfield	8.5 miles west of Rion.
Beverly (Greenville Crushed Stone Company).	Pickens	Beverly.
Casparis Granite Company	Lexington	1.5 miles, N. 75° E., of Lexington.
Cold Point Granite Company	Laurens	Cold Point.
County (Smith Branch)	Richland	2 miles, N. 25° W., of Columbia.
Entrekin	Laurens	0.7 mile east of Graycourt.
Excelsior (Southern Granite Company)	Lancaster	5.2 miles southwest of Heath Springs.
Lipscomb (Morris & Co.)	Richland	Columbia.
Rion (Winnsboro Granite Corporation)	Fairfield	Rion.
Ross	Lexington	2 miles south of Columbia.
Whittle (Moore Creek)	do	4 miles northwest of Batesburg.

a Sloan, Earle, op. cit., p. 210.

b Idem, p. 198.

Granite quarries in South Carolina—Continued.

Name.	County.	Location.
Quarries operated prior to 1908.		
Bates	Lexington	1 mile north of Batesburg.
Bauman	Greenville	Greenville.
Benjamin	Greenwood	0.5 mile, N. 10° W., of Quarry.
Blairs	Fairfield	Blairs.
Bordeaux	Abbeville	Bordeaux.
Bowling Green	York	Bowling Green.
Edgefield	Edgefield	3 miles east of Edgefield.
Flat Rock	Union	2 miles north of Carlisle.
Happerfield	York	1.5 miles southeast of Yorkville.
Jackson	do	0.5 mile north of Clover.
Keystone Granite Company	Spartanburg	2.5 miles, N. 20° W., of Pacolet.
Leiper-Davis	Fairfield	5.5 miles northeast of Alston.
Leitzsey	Newberry	5 miles northeast of Newberry.
Oro	Chesterfield	9 miles west of Ruby.
Pacolet Granite Company (Johnson)	Spartanburg	0.75 mile northwest of Pacolet.
Pendleton	Anderson	1.7 miles southwest of Pendleton.
Shelor	Oconee	1 mile west of Walhalla.
Stewart	Fairfield	2.5 miles west of Rockton.
Strothers	do	Strothers.
Ware Shoals	Abbeville	6 miles northeast of Donalds.
Westminster	Oconee	Westminster.
Whitesides	York	3 miles west of Filbert.

DESCRIPTIONS OF QUARRIES.

ABBEVILLE COUNTY.

The *Bordeaux quarry* is located several hundred feet north of Bordeaux station. The writer was unable to visit this quarry, and the description which follows is taken from Sloan's report.[a] The principal type of rock is a biotite granite gneiss of gray color and fine grain, but a fair proportion of the quarry face is a massive granite of light-gray color and fine grain. The minerals are potash feldspar (orthoclase and microcline), a little soda-lime feldspar (oligoclase), quartz, biotite, and muscovite, together with accessory apatite and magnetite and secondary chlorite and kaolin. Pegmatite dikes and knots occur. The quarry has not been worked for some time.

The *Ware Shoals Manufacturing Company's quarry* is located at Ware Shoals, on Saluda River, about 6 miles northeast of Donalds. The rock is a biotite granite gneiss of gray color and fine grain. The principal minerals are potash feldspar (microcline and orthoclase), soda-lime feldspar (oligoclase), quartz, and biotite, with accessory apatite, zircon, and magnetite. A chemical analysis of the granite quarried adjacent to the power house at Ware Shoals is given on page 175 (No. 17). According to Sloan the absorption ratio of this granite is 0.321 and the specific gravity 2.68.

ANDERSON COUNTY.

No granite has been quarried in Anderson County in recent years. The *Hanckel quarry*, about 2 miles southwest of Pendleton, was last worked, according to the owner, C. Hanckel, about fifty years ago, to

[a] Sloan, Earle, op. cit., pp. 182-183

supply stone for the construction of culverts and bridges on the Blue Ridge Railway. The rock varies from a porphyritic biotite granite of reddish-gray color and medium-coarse grain to a biotite granite gneiss of light-gray color and fine grain. The principal minerals are potash feldspar (orthoclase and microcline), soda-lime feldspar (oligoclase), quartz, biotite, and accessory apatite, titanite, and magnetite. The porphyritic feldspar is reddish and is commonly twinned on the Carlsbad law. A chemical analysis of this granite is given on page 175 (No. 16). According to Sloan the absorption ratio of the porphyritic granite is 0.288 and of the granite gneiss 0.448. The specific gravity of the granite is 2.68.

CHESTERFIELD COUNTY.

The *Oro quarry* is located 9 miles west of Ruby. The rock is reported to be a biotite granite of red-gray color and of coarse-grained to porphyritic texture. According to Sloan the feldspars are red, imparting a similar color to the granite, and partial alteration to epidote (epidotization) in some portions of the rock affords a greenish tint which heightens the effect. The granite has a specific gravity of 2.66, and is said to be susceptible of an excellent polish.

EDGEFIELD COUNTY.

The *Edgefield quarry* is about 0.5 mile north of the Edgefield-Trenton Railway, 3 miles east of Edgefield, and about the same distance from Trenton. The rock is a biotite granite of uneven color, usually pinkish gray, and medium grain. Its principal minerals are potash feldspar (orthoclase and microcline), soda-lime feldspar (oligoclase), quartz, a little biotite, apatite, and garnet. The feldspar has a faint reddish cast. The quartz is decidedly smoky and ranges from minute grains up to irregular masses an inch or more across. Biotite occurs in very subordinate quantity. Red garnets are visible in the hand specimens.

The quarry is about 700 feet long from north to south by about 100 feet wide and from 50 to 60 feet deep. The abundant quartz streaks or masses in this granite render it unsuitable for dimension stone. The product has been used principally for government jetty work at Charleston and Georgetown, S. C.

On the west side of the town of Edgefield an irregular muscovite-bearing biotite gneiss of dark-gray color and porphyritic texture has been quarried. The porphyritic feldspars are without distinct crystal boundaries, usually show good cleavage, and are pink in color.

FAIRFIELD COUNTY.

The granites of Fairfield County, especially those of the Rion and Anderson quarries of the Winnsboro Granite Corporation, are probably the South Carolina granites best known beyond the limits of the

State. They are mica granites but show variation in color and texture and are naturally grouped commercially into those most desirable for (*a*) building stone and (*b*) monumental stock. The product from the Rion quarry (gray granite) is used chiefly as a building stone; that from the Anderson quarry (blue-gray granite) is used exclusively for monuments. These two quarries were the only ones operating in Fairfield County at the time of examination in July, 1908.

The *Rion quarry* is located at Rion, 5½ miles southwest of Winnsboro, and is connected by a standard-gage spur track with Rockton, a station on the Columbia, Spartanburg and Asheville division of the Southern Railway 4½ miles to the east. (See Pl. XXII, *A*.)

The rock is a biotite granite of light-gray color and medium grain. Its minerals are potash feldspar (orthoclase, in large part intergrown with plagioclase as microperthite, and microcline), soda-lime feldspar (oligoclase), quartz, and biotite, together with accessory apatite, zircon, and iron oxide and secondary chlorite, epidote, and colorless mica. Intergrowths of feldspar (microperthite) and of feldspar and quartz (micropegmatite) are abundant. The potash feldspar shows Carlsbad twinning. Inclosures of irregular rounded quartz, feldspar, and quartz-feldspar intergrowths (micropegmatite) are numerous in the larger feldspar individuals. The soda-lime feldspar shows more alteration than the potash varieties, chiefly into kaolin and colorless mica.

The following chemical analysis of the granite was made by Booth, Garrett & Blair, of Philadelphia, for the corporation:

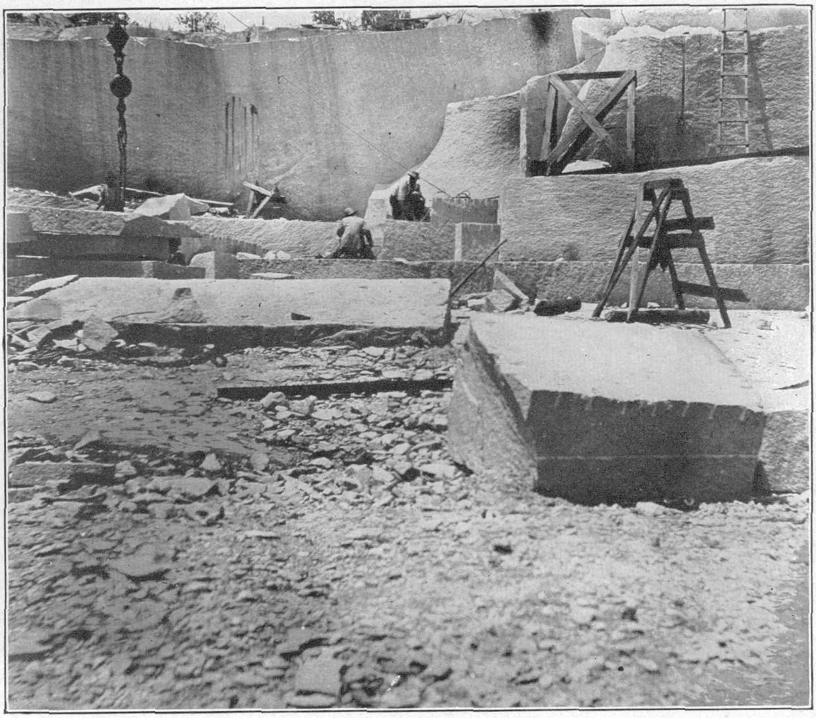
Analysis of granite from Rion quarry.

Silica (SiO_2)	73.26
Alumina (Al_2O_3)	15.39
Iron oxide (Fe_2O_3)	1.24
Magnesia (MgO)	.38
Lime (CaO)	1.36
Soda (Na_2O)	.55
Potash (K_2O)	6.89
	99.07

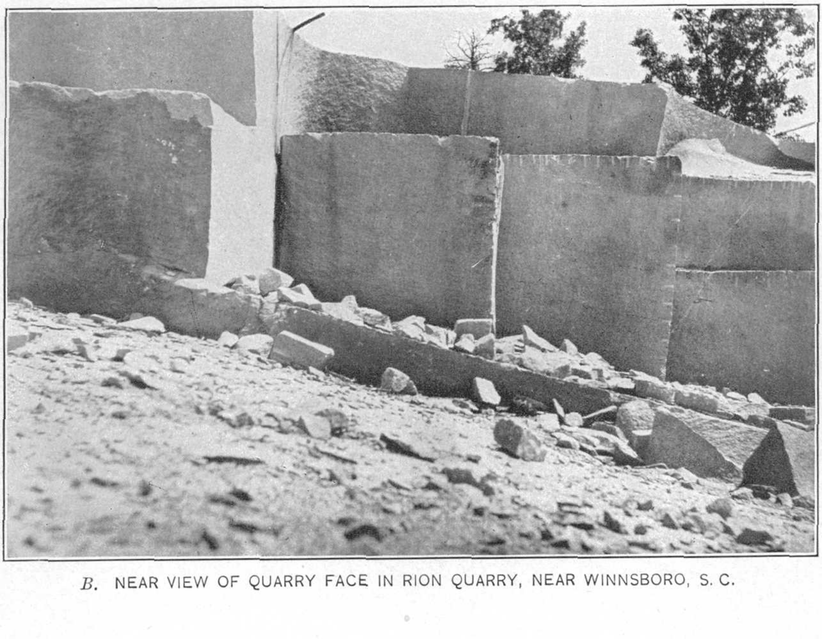
The specific gravity is 2.62. Tests of the compressive strength are given on page 183.

The quarry was opened about 1883, but systematic quarrying did not begin until fifteen years later. The quarry face is 300 feet long and 20 feet deep. (See Pl. XXII, *B*.) There is no stripping in the direction of working of the present quarry face. In other places the granite is decayed to a depth of 3 to 6 feet.

The principal set of vertical joints, striking approximately north and south, with a dip of 65° E., are widely spaced. Their faces are slickensided, and in places there is an abundant development of pyrite.



A. RION QUARRY OF WINNSBORO GRANITE CORPORATION, NEAR WINNSBORO, S. C.



B. NEAR VIEW OF QUARRY FACE IN RION QUARRY, NEAR WINNSBORO, S. C.

Knots are abundant in a few places and are of irregular shapes (rounded to much elongated, stringer-like forms) and sizes.

The working qualities of the granite are excellent and it is splendidly adapted to architectural work, for which it has had an extensive sale, as indicated in the following list of prominent structures in which it has been used: United States court-house and post-office buildings, Wilmington, N. C., Asheville, N. C., Statesville, N. C., and Opelousas, Ala.; post-offices, Charleston, S. C., Durham, N. C., Chillicothe, Ohio, Traverse City, Mich., Florence, S. C., and Charlottesville, Va.; bank building, Goldsboro, N. C.; Fidelity Title and Trust Company Building and Hussey Building, Pittsburg, Pa.; New Land Title and Trust Company Building, Philadelphia, Pa.; United States custom-house, Baltimore, Md.; building No. 1, commandant's office, navy-yard, Charleston, S. C.; Fairmont Trust Company, Fairmont, W. Va.; and Empire Bank Building, Clarksburg, W. Va.

In addition to its principal use in architectural work, the product is used for monument bases. The dry docks at Charleston, S. C., were built of this stone, 200,000 cubic feet being used. Extensive cutting and polishing yards are operated at the quarry.

The *Anderson quarry* is about 6 miles west of Rion, and is connected by a standard-gage track via Rion with Rockton, on the Southern Railway (Columbia, Spartanburg and Asheville division).

The rock is a biotite granite of dark blue-gray color and fine grain. It is closely similar to the dark blue-gray granites at Oglesby, Ga., (p. 218); at Heath Springs (Excelsior quarry), S. C. (p. 191); and at Richmond and Fredericksburg, Va. (p. 76). Of these, the granite at Heath Springs is the finest grained. The minerals of the Anderson rock are potash feldspar (orthoclase and much microcline), soda-lime feldspar (oligoclase), quartz, and biotite, together with accessory apatite, zircon, and magnetite and secondary chlorite and colorless mica. The orthoclase is partly intergrown with plagioclase as microperthite; the oligoclase is altered in part to a white mica and kaolin and the biotite to chlorite. Intergrowths of quartz and feldspar (micropegmatite) occur. Carlsbad twinning is observed in the potash feldspar.

The following analysis of the granite was made by Booth, Garrett & Blair, of Philadelphia, for the corporation:

Analysis of granite from Anderson quarry.

Silica (SiO_2)	69.74
Alumina (Al_2O_3)	13.72
Iron oxide (Fe_2O_3)	3.64
Magnesia (MgO)	.22
Lime (CaO)	1.54
Soda (Na_2O)	5.39
Potash (K_2O)	4.98
	99.23

The specific gravity is 2.64. Four tests of compressive strength of granite from the Anderson quarry, made by the United States Ordnance Department, gave the following results: Maximum, 26,080 pounds per square inch; minimum, 24,700 pounds; average, 25,585 pounds.

The quarry, opened about 1898, comprises a number of openings made in a large granite boss which rises to an elevation of nearly 100 feet above Mill Creek. The angle of slope averages from 10° to 20°, flatter in some places and steeper in others. No stripping is required over much of the boss.

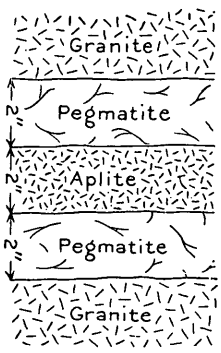


FIGURE 16.—Banded aplite-pegmatite at Anderson quarry, near Rion, S. C.

The vertical joints strike N. 20° E., N. 35° to 40° E., N. 45° to 50° W., and N. 80° W. and are spaced at varying intervals. Several zones of close jointing were observed in places where the granite had not been opened. Pegmatite dikes, from a fraction of an inch to 8 inches thick and composed of white feldspar, glassy quartz, and scant biotite, occur in the granite. Aplite dikes, up to 12 inches thick, of light-gray color and fine grain and containing scant biotite, are also present. In some places the aplites and pegmatites are banded, as shown in figures 16 and 17. The principal banded aplite-pegmatite in the large opening strikes N. 65° W. There are a few small knots composed entirely of biotite.

The granite is uniform in color and texture, possesses good working qualities, is susceptible of a high polish, and is admirably adapted to monumental purposes. The product is used chiefly for monumental stock, and is reported to have been so used in twenty-four States.

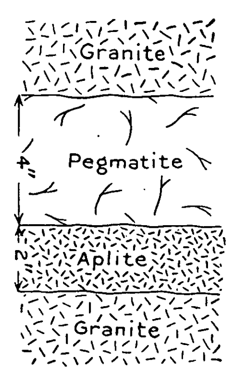


FIGURE 17.—Banded aplite-pegmatite at Anderson quarry, near Rion, S. C.

The *Strother quarry* is located half a mile south of Strother, on the east side of the Columbia, Spartanburg and Asheville division of the Southern Railway, with which the quarry is connected by a spur track. The rock is a biotite granite of light-gray color and irregular fine to coarse grain. Its minerals are potash feldspar (microcline and orthoclase), soda-lime feldspar (oligoclase), quartz, biotite, a little muscovite, and accessory apatite and magnetite. The product has been used for rubble masonry at the Charleston navy-yard.

The *Blair quarry* is about half a mile east of Blair, a station on the Columbia, Spartanburg and Asheville division of the Southern Railway. The rock is a biotite granite of gray color and fine grain, with a porphyritic tendency in places. The minerals are the same as those at the Strother quarry. A chemical analysis of this granite is given on page 175 (No. 11). Its specific gravity is 2.66. A few pegmatite dikes and knots occur in the granite.

The *Leiper-Davis quarry,* comprising two openings about 500 feet apart, is located about 5 miles northeast of Alston, close to Little River. The rock is a biotite granite of medium-gray color and medium-fine grain. The principal minerals are potash and soda-lime feldspars, quartz, and biotite. The granite possesses good working qualities, is susceptible of a good polish, and was extensively used at one time for monumental stock.

The *Stewart quarry* is located about 2½ miles west of Rockton. The rock is a biotite granite of light-gray color and medium-fine grain. The principal minerals are potash and soda-lime feldspars, quartz, and biotite. The quarry had not been worked for some time prior to the writer's visit in July, 1908, and very little could be seen. The granite is reported to contain numerous knots of large and small size.

About a mile south of Winnsboro, immediately on the Winnsboro-Rockton highway, are exposures of a hornblende-bearing biotite granite of slightly pinkish medium-gray color and medium grain. Much titanite is visible in the hand specimens. This granite is the only one of those examined by the writer in the State in which hornblende is present. The minerals are potash feldspar (orthoclase and microcline), soda-lime feldspar (oligoclase), quartz, biotite, and hornblende, together with accessory titanite, apatite, zircon, and iron oxide and secondary chlorite, kaolin, and light-colored mica. Plagioclase is in excess of potash feldspar. Intergrowths of feldspar (microperthite) and of feldspar and quartz (micropegmatite) are common. Irregular rounded inclosures of feldspar and quartz are contained in some of the larger feldspar individuals. Feldspar twinning on the Carlsbad law is shown.

GREENVILLE COUNTY.

The only granite quarried in Greenville County has been a small quantity obtained from the western slope of Paris Mountain, about 6 miles north of Greenville, the county seat, by the Paris Mountain Granite Company, of Greenville. The rock is a biotite granite of gray color, medium-fine grain, and indistinct gneissoid structure. The minerals are potash feldspar (microcline and orthoclase), soda-lime feldspar (oligoclase), quartz, biotite, muscovite, and accessory apatite, titantite, and magnetite. Titanite is visible in hand specimens of the granite. Quartz and feldspar are locally intergrown in micropegmatitic structure. The granite apparently possesses good working qualities under the hammer and chisel. According to Sloan its specific gravity is 2.72 and its ratio of absorption 0.304.

A somewhat similar granite is exposed on the southern slope of Piny Mountain, about 2 miles northeast of Greenville, within 300 yards of the Atlanta and Charlotte division of the Southern Railway. This rock is a biotite granite of gray color, medium grain, and gneissoid structure. It has not been developed.

GREENWOOD COUNTY.

The *Benjamin quarry*, comprising a number of openings in bowlders and bowlder-ledge exposures grouped rather close together, is about 4 miles east-northeast of Greenwood and less than a mile north of Quarry station.

The rock is a biotite granite of medium-light pinkish-gray color and dense, medium-coarse grain. The feldspars in the hand specimens have a decided light-pink color. The minerals are potash feldspar (microcline and orthoclase, the latter partly microperthite), soda-lime feldspar (oligoclase), quartz, and biotite, together with accessory titanite, zircon, apatite, and iron oxide and secondary chlorite, epidote, and light-colored mica. The quartz contains threadlike inclusions of rutile. Microcline and oligoclase are the dominant feldspars. Much accessory titanite occurs. Small areas of micropegmatitic intergrowths of quartz and feldspar are shown.

A chemical analysis of the granite is given on page 174 (No. 9). The specific gravity is 2.65.

The sheets are from 4 to 8 feet thick, and the vertical joints are widely spaced. The decay is usually deep, necessitating at the two largest openings a stripping of several feet. The quarry had not been worked for some time prior to the writer's examination in July, 1908.

KERSHAW COUNTY.

Practically no quarrying of granite has been attempted in Kershaw County. Mica granites of excellent grade, possessing good working qualities and susceptible of a high polish, occur in the northwestern part of the county in the vicinity of Liberty Hill post-office.

About 7 miles southwest of Heath Springs and about 1½ miles southeast of the Excelsior granite quarry, in Lancaster County, are exposures of a biotite granite of medium-gray color and fine grain, similar to that quarried by the Southern Granite Company at the Excelsior quarry. The minerals are potash feldspar (microcline and orthoclase), soda-lime feldspar (oligoclase), quartz, biotite, a little muscovite, together with accessory apatite and magnetite and secondary chlorite, kaolin, and iron oxide. Oligoclase and microcline are the dominant feldspars, the former showing considerable alteration, principally to kaolin. A chemical analysis of this granite, according to Sloan,[a] is given here for reference.

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[a] Sloan, Earle, op. cit., p. 219.

Analysis of granite 7 miles southwest of Heath Springs.

Silica (SiO_2)	72.22
Alumina (Al_2O_3)	14.51
Ferric oxide (Fe_2O_3)	1.28
Ferrous oxide (FeO)	1.52
Magnesia (MgO)	.58
Lime (CaO)	1.32
Soda (Na_2O)	3.21
Potash (K_2O)	4.30
Ignition	.52
Manganese oxide (MnO)	Trace.
Titanic oxide (TiO_2)	.24
Phosphoric oxide (P_2O_5)	Trace.
	99.70

The specific gravity is 2.63. This granite is uniform in color and texture, works well under the hammer and chisel, is susceptible of a high polish, and is one of the most desirable granites in the State for monumental purposes.

About half a mile north of Liberty Hill post-office, on the property of Mrs. Richards, is an outcrop of red-gray muscovite granite of medium-fine grain. Its principal minerals are oligoclase, orthoclase, microcline, quartz, muscovite, very little biotite, and accessory apatite. Soda-lime feldspar (oligoclase) is the principal feldspar and is considerably altered to kaolin.

The granite of Flatrock (old Dekalb granite), near Cleyburn, has been quarried to a moderate extent. It is a biotite granite of red-gray color and coarse-grained porphyritic texture. The principal minerals are orthoclase (partly microperthite), oligoclase, quartz, and biotite, with accessory apatite and magnetite. A chemical analysis of this granite is given on page 174 (No. 2). The specific gravity is 2.65.

LANCASTER COUNTY.

Two grades of granite occur in Lancaster County, but are limited principally to the southern part of the county, near the Kershaw County line. One is a biotite granite of dark-gray color and fine grain, and is used chiefly for monumental stock; the other is a biotite granite of coarse-grained porphyritic texture. Only the dark-gray fine-grained granite has been quarried to any great extent. Both are described below.

The *Excelsior quarry* of the Southern Granite Company, including two openings made in 1902, is located about 6 miles by rail (6½ miles by wagon road) southwest of Heath Springs, near the Kershaw County line. The rock is a biotite granite of dark blue-gray color and fine grain. Its minerals are potash feldspar (orthoclase and microcline), soda-lime feldspar (oligoclase), quartz, and biotite, together with accessory apatite, zircon, and iron oxide and secondary chlorite, epidote, colorless mica, and kaolin. The orthoclase is intergrown in part with plagioclase. Much microcline is present. Intergrowths of quartz and feldspar as micropegmatite occur. A chemical analysis of this granite, as reported by Sloan,[a] is given below.

Analysis of granite from Excelsior quarry.

Silica (SiO_2)	70.11
Alumina (Al_2O_3)	15.76
Ferric oxide (Fe_2O_3)	1.07
Ferrous oxide (FeO)	1.76
Magnesia (MgO)	.62
Lime (CaO)	1.84
Soda (Na_2O)	3.39
Potash (K_2O)	4.27
Ignition	.45
Manganese oxide (MnO)	Trace.
Titanic oxide (TiO_2)	.45
Phosphoric oxide (P_2O_3)	Trace.
Sulphuric oxide (SO_3)	Trace.
	99.72

The specific gravity is 2.66.

The main quarry opening is worked to a depth of 35 feet. Prior to its opening in 1902 many of the numerous large granite bowlders exposed over most of the tract of 1,093½ acres were quarried.

Vertical joints are few and widely spaced in the lower opening, which was being worked in July, 1908. They strike N. 3° W. and N. 80° W., and are sufficiently far apart to permit the quarrying of columns 25 to 60 feet long. Many 25-foot columns used in the construction of the president's house near the quarry were examined, and one 58 feet 5 inches long was loaded on the car at the time of the writer's visit. The joint faces are slickensided and coated with a whitish mineral substance, indicating some movement in the granite mass. Vertical joints in the abandoned opening on top of the knoll are rather numerous, striking N. 20° E., N. 10° W., and N. 45° W., and, as a rule, are closely spaced. Their faces are slickensided and coated with a reddish mineral substance. Here and there a pegmatite dike less than 1 inch thick is observed and there are a very few knots.

The granite is entirely uniform in color and texture, possesses good working qualities, is susceptible of a high polish, and is especially adapted to high-grade monumental stock, for which it is now used exclusively. The product has been shipped as far north as Brooklyn, N. Y., and west to Denver, Colo., and Portland, Oreg.

The quarry is connected with Heath Springs, on the Southern Railway, by a standard-gage railway track.

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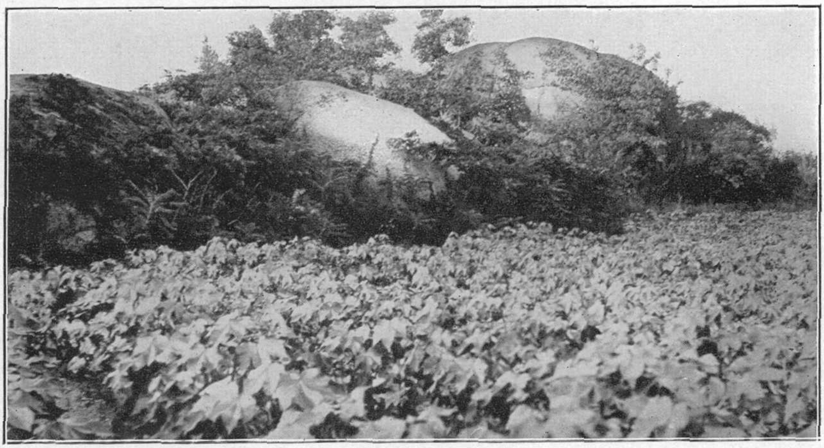
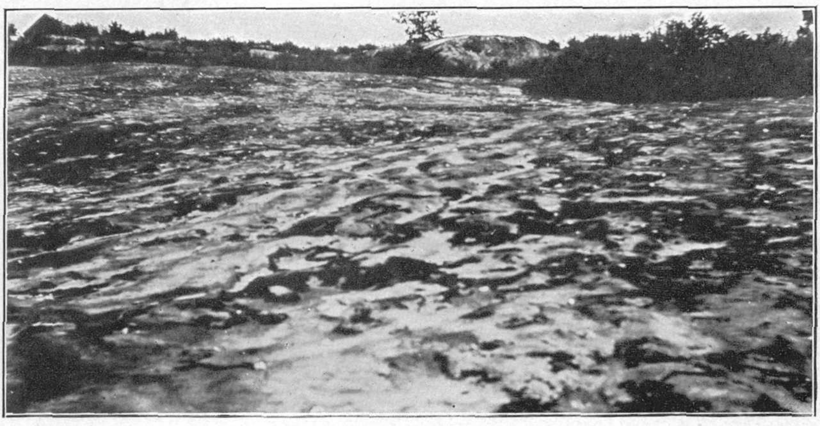
[a] Sloan, Earle, op. cit., p. 222.

A. BOWLDER OUTCROP OF GRAY GRANITE, RION QUARRY, FAIRFIELD COUNTY, S. C.



B. BOWLDER OUTCROP OF COARSE-GRAINED GRANITE 3 MILES SOUTHWEST OF HEATH SPRINGS, S. C.



C. BARED SLOPE OF GRANITE GNEISS, BEVERLY QUARRY, BEVERLY STATION, PICKENS COUNTY, S. C.

Beginning about 1½ miles southwest of Heath Springs and extending for a considerable distance along the highway to the Excelsior quarry is a coarse-grained porphyritic biotite granite of a mixed greenish-yellow and reddish-gray color, similar to that near Lilesville, Anson County, N. C., described on page 162. As shown in Plate XXIII, *B*, the granite is exposed in places in large bowlder outcrops. It has not been quarried, but its color and texture are such as to render it of value as a decorative stone. Its minerals are potash feldspar (orthoclase and microcline), much soda-lime feldspar (oligoclase), quartz, and biotite, together with accessory apatite, zircon, and iron oxide and secondary chlorite, epidote, a little colorless mica, and kaolin. The potash feldspar shows Carlsbad twinning. The plagioclase feldspar, which is equal to or greater in amount than the potash feldspar, is partly altered.

Sloan[a] has described porphyritic biotite granite of coarse grain from two other localities in Lancaster County—6½ miles west of Jefferson and 6½ miles northeast of Kershaw. The granite west of Jefferson is reported to have been used formerly for millstones.

LAURENS COUNTY.

Two grades of granite are quarried in Laurens County, one a fine-grained massive granite of light pinkish-gray color, the other a coarse-grained granite gneiss of medium dark-gray color. The granite is quarried at Cold Point station, south of Laurens, and the granite gneiss at Graycourt station, a little west of north from Laurens.

The *Cold Point Granite Company's quarry*, opened in 1904, comprises a principal opening and several smaller ones. It is located on the west side of the railroad less than half a mile north of Cold Point station. The rock is a biotite granite of light reddish-gray color and fine grain. The feldspar is of faint though marked reddish color. Biotite is present in small amount. The minerals are potash feldspar (orthoclase and microcline, the former largely microperthite), soda-lime feldspar (oligoclase), quartz, and biotite, together with accessory apatite, titanite, and zircon and secondary chlorite, epidote, and colorless mica. The orthoclase is intergrown with plagioclase. The larger feldspar individuals inclose irregular grains of quartz and feldspar.

According to Sloan[b] the absorption ratio of this granite is 0.344 and the specific gravity 2.65. A chemical analysis of the granite is given on page 174 (No. 3).

In the main quarry opening, worked to a depth of 40 feet, occurs an inclusion, 15 by 30 feet, of a thinly foliated dark (nearly black) gneiss. It is composed of dominant black lustrous biotite and some

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[a] Sloan, Earle, op. cit., pp. 224-225.

[b] Idem, p. 190.

white feldspar and quartz and in places shows a partial porphyritic texture. The granite is sheeted in places near the surface but grades into massive rock at slight depth. The vertical joints strike N. 50° E. and N. 70° E. and are spaced at varying intervals. Some pegmatites and knots occur. From 4 to 6 feet of stripping is necessary in places. A No. 5 Austin crusher is operated at the quarry for crushing and sizing the stone. Blasting is employed for breaking down (quarrying) the rock. The product, in the form of crushed stone, blocks, and curbing, is used almost exclusively in the State.

The *Entrekin quarry* is located less than a mile east of Graycourt station. The rock is a biotite granite gneiss of medium dark-gray color and coarse grain. Its minerals are potash feldspar (orthoclase and microcline), soda-lime feldspar (oligoclase), quartz, and biotite, together with accessory apatite and zircon and secondary chlorite and epidote. Intergrowths of quartz and feldspar (micropegmatite) in small irregular areas are noted. There is considerable granulation of the quartz and feldspar, forming distinct areas of finer-grained mosaics. The quartz and feldspar further show strain effects in undulous extinction and fractures. The white feldspars, smoky vitreous quartz, and black lustrous biotite contrast strongly in the hand specimens. The resemblance of the granite gneiss from this quarry to that of the Beverly quarry (p. 197) is very striking. The minerals are segregated into alternating dark (dominant biotite) and light (dominant feldspar and quartz) bands, of irregular thickness and more or less contorted. Pegmatite dikes, quartz veins, and knots occur. The product is used principally for curbing, lintels, etc.

LEXINGTON COUNTY.

The granite quarries in Lexington County are near Columbia, in Richland County, and near Lexington, the county seat, 12 miles west of Columbia.

The *Ross quarry* is about 2 miles south of Columbia, on the opposite side of Congaree River from Morris & Co.'s (Lipscomb) quarry. The quarry is a large one, but at the time of examination, in July, 1908, it was idle and nearly filled with water. Preparations were then in progress for draining it preparatory to resuming operations for a contract to supply stone for government jetty work. The rock is a biotite granite of gray color and fine to coarse grain. Two facies of the granite are represented, similar to those at Morris & Co.'s quarry (p. 198). A chemical analysis of the granite is given on page 175 (No. 13). Its specific gravity is 2.68.

The *Casparis Stone Company's quarry*, opened about 1902, is located about 1½ miles N. 75° E. of Lexington station and about 300 yards north of the Columbia and Augusta division of the Southern Railway. The rock is a biotite granite of light reddish-gray color and medium grain, with a pronounced porphyritic tendency in places. The feldspars are pinkish and are in places elongated and flat tabular in outline. The granite from this quarry resembles that from the Smith Branch (County) quarry, near Columbia, except that it is of finer-grained texture. Its resemblance to the granite from the Bates quarry, in Saluda County, is also very striking. The minerals are potash feldspar (orthoclase and microcline), soda-lime feldspar (oligoclase), quartz, biotite, and a little pyrite, with secondary chlorite, epidote, colorless mica, and kaolin. The feldspars show considerable alteration. Biotite is partly altered to chlorite. Intergrowths of the feldspars with each other (microperthite) and of the feldspars with quartz (micropegmatite) are indicated.

The quarry is of circular shape, about 200 feet in diameter and 50 feet deep. The vertical joints strike N. 5° to 10° E., N. 35° E., and N. 20° W.; several minor sets were not measured. They dip at various angles and are so closely spaced as to prevent the quarrying of dimension stone. The joint faces are slickensided and coated with a reddish mineral substance. An aplite dike 2 inches thick, of light-gray color and fine grain, was noted. Pegmatites and knots were not observed. From 1 foot to 5 feet of stripping is required.

The product is used chiefly in the form of crushed stone; in July, 1908, it was used for government jetty work at Savannah, Ga. The quarry is connected with the Lexington station by a standard-gage track.

NEWBERRY COUNTY.

Extending north, northeast, and northwest from the town of Newberry is an extensive area of granite. The exposures are chiefly in the form of large and small bowlder masses, which have been worked in many places to supply the local demand for stone in buildings and monuments. No extensive quarries have been opened, the work done consisting in the quarrying of some of the larger bowlders, in places to considerable depth below the surface.

The three quarries described below are the most recently operated ones and are worked when a local demand for stone arises. Other similar openings of long standing have been made at several places in the Newberry granite area.

The *Leitzsey quarry*, opened in a bowlder exposure of granite, is about 5 miles northeast of Newberry. The rock is a biotite granite of medium-gray color and fine grain. Its minerals are potash feldspar (orthoclase, largely microperthite, and microcline), soda-lime feldspar (oligoclase), quartz, biotite, and very little muscovite, together with accessory apatite, zircon, and magnetite and secondary chlorite, epidote, colorless mica, and kaolin. Orthoclase is intergrown with plagioclase as microperthite. Small roundish areas of quartz-feldspar intergrowths (micropegmatite) are common. A chemical analysis of this granite is given on page 174 (No. 5). Its specific gravity is 2.65.

The vertical joints strike N. 45° E. and N. 70° W., and are widely spaced. A few pegmatites, 1 to 2 inches thick, occur. The working qualities of the granite are good and it is susceptible of a very high polish. The product has been used extensively for monuments.

The *Spears (Baxter) quarry,* comprising two openings in large bowlder exposures of the granite, is about 4 miles northeast of Newberry. The rock is a biotite granite of medium-gray color and fine grain. The minerals are potash feldspar (orthoclase, chiefly microperthite and microcline), soda-lime feldspar (oligoclase), quartz, and biotite, together with apatite, zircon, and magnetite and secondary chlorite, epidote, colorless mica, and kaolin. The orthoclase is intergrown with a second feldspar (plagioclase). Numerous small rounded areas of quartz-feldspar intergrowths (micropegmatite) occur. Some of the feldspar shows zonal structure; twinning on the Carlsbad law is noted.

The vertical joints are widely spaced. Several pegmatite dikes, a fraction of an inch to 1½ inches thick, occur. Knots were not observed. The granite works well under the hammer and chisel and is susceptible of a high polish. The product has been used locally in buildings and in monuments.

The *Level quarry,* opened in large bowlder exposures of granite, is about 3½ miles northwest of Newberry and about half a mile northwest of the Columbia, Newberry and Laurens Railway. An old opening of very long standing, filled with water at the time of examination in July, 1908, is near by. The rock is a biotite granite of medium-gray color and fine grain. Its minerals are potash feldspar (orthoclase, chiefly microperthite, and microcline), soda-lime plagioclase (oligoclase), quartz, and biotite, together with apatite and zircon and secondary chlorite, colorless mica, and kaolin. The orthoclase is intergrown with soda-lime feldspar. The oligoclase shows considerable alteration to a colorless mica and kaolin. Pegmatites and knots were not observed. The granite is susceptible of a high polish and works well under the hammer.

OCONEE COUNTY.

Gneisses which afford strong evidence of having been derived from original granites by metamorphic processes, chiefly granulation and recrystallization, are extensively distributed over parts of Oconee County. A quarry was opened in an exposure of the gneiss near the state line and stone was obtained for use as piers and abutments in the Southern Railway bridge over Tugaloo River.

At Tunnel Hill and Lays Mill, about 6 miles northwest and 7 miles northeast of Walhalla, respectively, are exposures of biotite gneiss of medium-gray color and fine grain. The porphyritic texture is usually distinct, imparting an augen effect to the gneiss; the porphyritic mineral is pink microcline. Muscovite is usually present, associated with the biotite. These minerals show marked orientation, to which is due the banding of the gneiss. Thin sections of the rocks from these localities indicate derivation from porphyritic granites, chiefly by granulation and recrystallization.

PICKENS COUNTY.

The *Beverly quarry*, operated in 1908 by the Greenville Crushed Stone Company, is located at Beverly station, on the northwest side of the Atlanta and Charlotte division of the Southern Railway. The railroad extends along the southeastern base of the doming ridge in which the quarry is opened. The rock is a contorted biotite granite gneiss of medium to dark gray color and medium grain. It consists of white potash feldspar (orthoclase and microcline), white soda-lime feldspar (oligoclase), clear or barely smoky quartz, black mica (biotite), and a little white mica (muscovite), together with accessory titanite, zircon, apatite, and iron oxide and secondary chlorite, epidote, and colorless mica. Orthoclase is partly intergrown with a second feldspar as microperthite. Microcline shows evidence of having been derived in part from orthoclase. Micropegmatite intergrowths as small areas are indicated, and some of the larger feldspar individuals show micropoikilitic structure (inclosures of rounded quartz chiefly). Granulation of the quartz and feldspar is pronounced and orientation of the biotite is usually well marked. In the hand specimens much titanite is visible in association with the biotite. Here and there pyrite is noted.

The following analysis of granite gneiss from the Beverly quarry, quoted from Sloan's report,[a] will indicate the general chemical composition of the rock:

Analysis of granite gneiss from the Beverly quarry.

Silica (SiO_2)	68.15
Alumina (Al_2O_3)	14.30
Ferric oxide (Fe_2O_3)	2.44
Ferrous oxide (FeO)	2.49
Magnesia (MgO)	1.04
Lime (CaO)	2.80
Soda (Na_2O)	3.80
Potash (K_2O)	3.84
Ignition	.28
Titanic oxide (TiO_2)	.60
Manganese oxide (MnO)	.11
Phosphoric oxide (P_2O_5)	Trace.
Sulphur oxide (SO_3)	Trace.
	99.85

[a] Sloan, Earle, Bull. South Carolina Geol. Survey, ser. 4, No. 2, 1908, p. 181.

The specific gravity is 2.66. Sloan gives the absorption ratio as 0.398.

The quarry was opened about 1894 and is approximately 300 by 405 feet, with a vertical face of 80 feet, the greatest depth of working. Sheeting does not occur and pegmatites and knots have very scanty development, only a few small ones being observed. There is no stripping. (See Pl. XXIII, *C*.)

The vertical joints are widely spaced. The principal set trends N. 60° E. with dips of N. 50° E. and N. 58° W. Slickensides are developed on the joint faces, and are coated locally with a yellowish mineral substance, indicating movement in the granite mass since the formation of the joints.

The rock is composed of alternating more or less continuous dark (dominant biotite) and light (dominant feldspar and quartz) bands of variable thickness and highly contorted. As a rule the dark bands are much thinner and less continuous than the light ones. A marked tendency toward porphyritic texture is observed in places, imparting to the rock somewhat the appearance of an augen gneiss. The granite gneiss from the Beverly quarry closely resembles a similar granite gneiss quarried at Lithonia (p. 253) and Odessadale (p. 262), Ga., and Rocky Face Mountain (p. 152), Alexander County, N. C. The Beverly rock is coarser grained than that of the Georgia localities.

This quarry, located directly on the railroad, possesses excellent advantages for operating. The entire product is crushed at the quarry and is used principally for concrete work and roofing gravel.

RICHLAND COUNTY.

The granite quarries in Richland County lie near the city of Columbia, on the south and northwest sides. The granites are mostly concealed beneath a thin cover of the Coastal Plain gravel, sand, and clay, and in position are very similar to those of areas in North Carolina, Virginia, and Maryland on the north and in Georgia on the south.

The *Morris & Co.* (*Lipscomb*) *quarry*, opened about 1883, is located about 1½ miles south of Columbia, on the east side of and near Congaree River. Two facies of the granite, which usually grade into each other without sharp definition, occur in the quarry. The dominant one is a biotite granite of medium-gray color and medium-coarse grain, with a pronounced porphyritic tendency in places. Its minerals are potash feldspar (orthoclase and microcline), soda-lime feldspar (oligoclase), quartz, and biotite, together with accessory apatite, zircon, and iron oxide and secondary chlorite, epidote, light-colored mica, and kaolin. A part of the feldspar is twinned on the Carlsbad law. Some of the larger feldspar individuals inclose irregular rounded grains of quartz and feldspar. Micropegmatite areas are numerous.

The second facies is a biotite granite of medium dark-gray color and fine grain. Here and there porphyritic feldspar is conspicuously developed and twinned on the Carlsbad law. The minerals are the same as in the dominant facies just described. Carlsbad twinning and micropoikilitic and micropegmatitic structures are common.

The quarry is a large one, measuring approximately 750 by 500 feet and 50 to 75 feet deep. The sheets, 6 inches to 4 feet thick, are horizontal and grade into massive granite with increasing depth. The vertical joints strike north-south, N. 70° E., N. 10° W., and N. 50° W., and as a rule are spaced at intervals of 2 to 4 feet. The joint faces are slickensided, being coated with a reddish to greenish-yellow mineral substance. Pegmatite dikes, from a fraction of an inch to 6 inches thick, are common. The feldspar of the pegmatite dikes is white; biotite is present, though very subordinate in amount. Knots occur but rarely.

The granite is of good quality and is suitable for a wide range of uses. It has had an extensive use in government jetty work. The entire product at present goes into crushed stone, the average production of which during the summer of 1908 was between 4,000 and 5,000 tons a month. A large crushing plant is operated at the quarry.

The *Smith Branch* (*County*) *quarry* is located on the north side of Smith Branch, about 300 yards west of the Seaboard Air Line Railway and about 2 miles N. 25° W. of Columbia. The rock is a biotite granite of mixed reddish-gray color and coarse grain. The feldspars are of a pronounced pinkish color and much of the quartz is of the dark smoky variety. Both of these minerals are larger in size than the biotite. The minerals are potash feldspar (orthoclase and microcline), soda-lime feldspar (oligoclase), quartz, and biotite, together with accessory apatite and magnetite and secondary chlorite, epidote, colorless mica, and kaolin. The soda-lime feldspar is equal to or greater than the potash feldspar. Twinning on the Carlsbad law is noted.

The quarry is roughly circular in shape, measuring approximately 50 by 60 feet and 40 feet deep. The decayed granite extends to a depth of 10 to 15 feet. The vertical joints strike N. 60° E., dip about 50° NW., and are widely spaced. The joint faces are slickensided, being coated with a yellowish mineral substance. Brownish-red aplite dikes of exceedingly dense, fine-grained texture, without visible mica, are rather abundant. The largest one, a dike 4 feet thick, strikes northeast and dips to the southeast. The mineral composition is identical with that of the inclosing granite—orthoclase, a little microcline, much oligoclase, quartz, a little biotite, accessory apatite, and secondary chlorite and epidote. The potash feldspar is apparently in excess of the soda-lime feldspar.

SALUDA COUNTY.

The only granite area in Saluda County in which quarries have been opened is in the extreme southeast corner of the county, near the Lexington County line, extending northward from a point half a mile north of Batesburg to and beyond Clouds Creek, a distance of 5½ miles. In this area are large exposures of granite, chiefly in bowlder and flat-surfaced masses. Variation in texture, color, and structure is observed. A decided porphyritic tendency is very generally shown. No systematic quarrying has been attempted in this area, the openings are small, and the consumption of the product is local.

The *Bates quarry* includes numerous small openings widely separated, located from half a mile to a mile north of Batesburg. The rock is a biotite granite of pinkish-gray color and medium to coarse grain. The feldspars are of larger size than the other components and impart a porphyritic appearance to the rock. They are of irregular outline and are partly pink in color. A partial parallel arrangement of the biotite is discernible in places and the granite shows an indistinct foliation. The minerals are potash feldspar (orthoclase chiefly and microcline), soda-lime feldspar (oligoclase), quartz, and biotite, together with accessory apatite, zircon, and iron oxide and secondary chlorite, epidote, mica, and kaolin. Abundant quartz-feldspar intergrowths (micropegmatite) occur. A partial peripheral granulation of the quartz and feldspar is shown and a rude orientation of the biotite is noticeable.

In one opening the rock is a typical granite gneiss of gray color and fine grain. It is identical in mineral composition with the granite, except that some muscovite is present. A chemical analysis of the gneiss is given on page 175 (No. 19). The specific gravity is 2.64.

The *Whittle quarry* includes several small openings on the south side of Moores Creek, about 4 miles northwest of Batesburg. The rock is a porphyritic biotite granite of dark-gray color and coarse grain. The quartz has a decided bluish opalescent cast and the groundmass feldspars are dark gray. As a rule the feldspar phenocrysts are of irregular outline, roughly rounded, the largest measuring about 2¼ by 1¾ inches. They inclose biotite and are of white to gray color. The minerals are potash feldspar (microcline and orthoclase), soda-lime feldspar (oligoclase), quartz, and biotite, with secondary colorless mica, chlorite, iron oxide, and kaolin. The feldspar and biotite show some alteration, the former to mica and kaolin, the latter to chlorite and iron oxide. The orthoclase is partly intergrown with plagioclase. Carlsbad twins are common. The feldspar and quartz are crossed by fractures which are filled with mineral matter.

A chemical analysis of a similar granite on Milton Prater's place on Clouds Creek, 4.7 miles north of Batesburg, taken from Sloan's report,[a] is given below and serves to show the general composition of the rock.

Analysis of porphyritic granite from Prater's place, north of Batesburg, S. C.

Silica (SiO_2)	68.70
Alumina (Al_2O_3)	15.49
Ferric oxide (Fe_2O_3)	1.10
Ferrous oxide (FeO)	3.73
Magnesia (MgO)	.86
Lime (CaO)	1.70
Soda (Na_2O)	3.09
Potash (K_2O)	3.36
Ignition	.81
Manganese oxide (MnO)	Trace.
Titanic oxide (TiO_2)	.84
Phosphoric oxide (P_2O_5)	Trace.
Sulphuric oxide (SO_3)	.13
	99.51

The specific gravity is 2.73.

The dark-gray, coarse-grained porphyritic granite occupies an extensive area, the width of which is not less than 3 miles. Large bowlder outcrops are abundant near Moores and Clouds creeks. Numerous small openings have been made in the vicinity of both streams and some of these date back many years. The product was formerly used for millstones.

SPARTANBURG COUNTY.

The quarries in Spartanburg County are near Pacolet, about 12 miles southeast of the city of Spartanburg.

The *Pacolet Granite Company's (Johnson) quarry* is located about 0.75 mile northwest of Pacolet station. The dominant facies of the rock is a biotite granite of medium-gray color and fine grain. A second facies is a pronounced biotite granite gneiss of light-gray color and fine grain. The banding of the gneissic phase is in places highly contorted. Mineralogically there is no difference in the two facies. The minerals are potash feldspar (orthoclase and microcline), soda-lime feldspar (oligoclase), quartz, biotite, and a little muscovite, together with accessory apatite, zircon, and iron oxide and secondary chlorite, much epidote, light mica, and kaolin. The orthoclase is intergrown with plagioclase as microperthite. The feldspars are partly altered to kaolin and light mica. A partial granulation of the quartz and feldspar is apparent in small areas of fine-grained mosaics. Some of the larger feldspar individuals inclose irregular rounded grains of quartz and feldspar.

[a] Sloan, Earle, op. cit., p. 192.

The quarry had not been worked for some time prior to the writer's visit in July, 1908. It is roughly circular in outline, about 250 by 300 feet and 15 to 20 feet deep. The sheets range from 4 inches to 2 feet in thickness and are approximately horizontal. The vertical joints strike east and west and are spaced at intervals of 1 inch to 3 feet. The faces of some of the joints are slickensided. Pegmatite dikes up to 12 inches thick are abundant. Besides the usual minerals—feldspar, quartz, and mica (biotite and muscovite)—some of the pegmatite dikes carry black tourmaline. There are some knots in the granite. Several feet of stripping is necessary.

The *Keystone Granite Company's quarry*, comprising two openings half a mile apart, is 2½ miles N. 20° W. from Pacolet station. The rock is a biotite granite of medium-gray color and fine grain. It is identical with the dominant facies of granite at the Pacolet Granite Company's quarry, described above. The minerals are potash feldspar (orthoclase and a little microcline), soda-lime feldspar (oligoclase), quartz, biotite, and some muscovite, together with accessory apatite, zircon, and magnetite and secondary chlorite, epidote, kaolin, and much light-colored mica. The orthoclase is partly intergrown with plagioclase as microperthite. Twinning on the Carlsbad law occurs. Rutile is present as threadlike inclusions in the quartz. Some of the feldspar shows partial alteration into kaolin and light-colored mica.

A chemical analysis of the granite made by the Pittsburg Testing Laboratory, Pittsburg, Pa., is given on page 175 (No. 12). Sloan[a] gives the compressive or crushing strength as 21,420 pounds to the square inch.

The largest opening is about 300 by 350 feet and 30 feet deep. The sheets average several feet in thickness. The vertical joints strike east and west and are widely spaced; their faces are locally slickensided. Pegmatite dikes up to 18 inches thick are observed. A large cutting and polishing plant was formerly operated at the quarry, but it has been almost dismantled. A spur track, now unused, runs between the quarry and Pacolet station.

The working qualities of this granite are very good. It is susceptible of a high degree of polish and of carved work, as shown in large pieces of the granite at the old dressing plant. It was extensively used for monumental stock.

UNION COUNTY.

Granite has been quarried at two localities in Union County—in the extreme southeast corner, northwest of Carlisle, and near the center, within several miles on the south and west sides of Union, the county seat. The product from the quarries near Union was used

[a] Sloan, Earle, op. cit., p. 198.

for macadamizing the streets of Union and the county highways. The granite formerly quarried northwest of Carlisle merits description.

Flatrock quarry is about 2½ miles north-northwest of Carlisle. It consists of one fairly large opening last worked about fourteen years ago. The rock is a biotite granite of medium-gray color and fine grain, both color and texture being very uniform. The feldspars are white and highly lustrous. The minerals are potash feldspar (orthoclase, partly microperthite, and microcline), soda-lime feldspar (oligoclase), quartz, biotite, and a few shreds of muscovite, together with accessory apatite, zircon, and magnetite and secondary chlorite, epidote, and light-colored mica. A part of the feldspar is considerably altered. Zonal and micropoikilitic structures and Carlsbad twinning are indicated in some of the feldspars. Micropegmatite (intergrowths of quartz and feldspar) occurs in small, irregularly rounded areas.

A chemical analysis of this granite is given on page 174 (No. 8). The specific gravity is 2.63.

There are several sets of vertical joints having directions of N. 30° E., N. 35° W., N. 60° W., N. 70° W., and east-west. Slickensides are developed on some of the joint faces. There are a few small knots and pegmatites.

The product from this quarry was used for bridge piers along the Seaboard Air Line Railway and to some extent in the neighborhood for buildings.

YORK COUNTY.

The granites of York County which have thus far attracted attention and are of economic importance are limited to the north-central portion of the county. Beginning near Bowling Green, at the state line on the north, the area extends southward to Yorkville and probably beyond and is traversed in a nearly north-south direction by the Yorkville-Gastonia Railway. The granites are biotite granites, but vary in color and texture, as indicated in the individual descriptions of the two areas below. Systematic quarrying has not been attempted, but a little stone has been quarried from time to time in different places to meet the local demand.

Clover area.—The Clover area, containing a single type of biotite granite, extends southward from a point near Bowling Green to Yorkville. The granite is exposed at the surface in many places over the area in nearly flat-lying (locally called "flat-rock") and sloping surface masses of considerable areal extent. Exposures of this character are especially noted within a radius of 2 miles to the north, northwest, east, and southeast of Clover station. The exposures of the granite near Filbert station (west side) are in the form of huge isolated bowlders 10 to 15 feet high and proportionately large otherwise. A small amount of the granite has been quarried from surface "raises" at a number of places in the vicinity of Clover.

The rock is a biotite granite of light-gray color and medium-coarse, even-granular to porphyritic texture. Both feldspar and biotite show some alteration in the surface portions of the granite, the former appearing white, opaque, and chalky from partial kaolinization, the latter showing irregular areas of reddish-brown staining from partial leaching of the iron oxide immediately adjacent. The minerals are potash feldspar (orthoclase and microcline), soda-lime feldspar (oligoclase), quartz, biotite, and occasional muscovite, together with accessory apatite, zircon, and iron oxide and secondary chlorite, epidote, colorless mica, and kaolin. Intergrowths of orthoclase with plagioclase feldspar, as microperthite, and of feldspar with quartz, as micropegmatite, are abundant. The larger feldspar individuals carry many inclosures of feldspar, chiefly quartz and feldspar-quartz intergrowths (micropegmatite). Microcline exceeds orthoclase in some sections and is much less in others. Plagioclase, likewise, may be greater or less in amount than potash feldspar. The feldspars are in part much altered and some of them show peripheral granulation from pressure effects.

In the porphyritic facies of this granite the feldspar phenocrysts are of both regular (idiomorphic) and irregular (allotriomorphic) outline and of white color and contain inclosures of groundmass biotite. In size they range up to 2 inches by half an inch. The ratio of phenocrysts to groundmass is very variable.

A chemical analysis of the granite from Jackson's quarry, half a mile north of Clover, reported by Sloan,[a] is given below and shows the general composition of the rock in the York County area. The specific gravity is 2.66.

Analysis of granite from the Jackson quarry, York County.

Silica (SiO_2)	68.90
Alumina (Al_2O_3)	15.75
Ferric oxide (Fe_2O_3)	1.16
Ferrous oxide (FeO)	1.49
Magnesia (MgO)	.74
Lime (CaO)	2.66
Soda (Na_2O)	4.76
Potash (K_2O)	3.49
Ignition	.18
Manganese oxide (MnO)	Trace.
Titanic oxide (TiO_2)	.36
Phosphoric oxide (P_2O_5)	Trace.
Sulphuric oxide (SO_3)	Trace.
	99.49

[a] Sloan, Earle, op. cit., p. 216.

Filbert area.—The Filbert area lies several miles west of Filbert station. The granite quarried on the Whiteside place, on Buckhorn Creek, 2 miles west of Filbert, may be taken as the type. It is a biotite granite of medium-gray color and fine grain, with a pronounced porphyritic tendency in places. The scattered feldspar phenocrysts are usually of irregular (allotriomorphic) outline, locally flat-tabular (idiomorphic), measuring up to 1 inch by half an inch, and twinned on the Carlsbad law. They are of white color. The minerals composing the granite at the Whiteside quarry are potash feldspar (orthoclase and microcline), soda-lime feldspar (oligoclase), quartz, biotite, and scant muscovite, together with accessory apatite and zircon and secondary chlorite, epidote, and light mica. Feldspar intergrowths as microperthite and feldspar-quartz intergrowths as micropegmatite are abundant.

A chemical analysis of this granite is given on page 174 (No. 10). The specific gravity is 2.65.

The sheets are from 6 inches to 2 feet thick and the vertical joints recur at wide intervals. There are a few pegmatite dikes not exceeding 2 inches in thickness and some scattered small knots.

Quarrying operations were suspended in the spring of 1908. The product was used for building purposes in Yorkville.

CHAPTER VII.

THE GRANITES OF GEORGIA.

THE GEORGIA PIEDMONT REGION.[a]

TOPOGRAPHY.

The Georgia Piedmont region occupies the middle northern portion of the State. It is a belt of undulating country having a northeast-southwest extension along the eastern base of the Appalachian Mountains and disappearing beneath the Coastal Plain sediments on the southeast. It has an altitude along its western edge of about 1,000 feet and slopes gradually seaward, with an elevation along the fall line, its southeastern limit, of 250 to 300 feet. Residual masses of partly reduced areas, such as Kenesaw, Lost, and Stone mountains, rise several hundred feet above the general level of the upland surface.

The major streams preserve a general parallelism in their courses across the Piedmont region. With the exception of the upper course of Chattahoochee River, the major streams trend in general to the southeast, approximately at right angles to the northeast-southwest course of the plateau. The streams have apparently maintained their courses across the plateau regardless of the structure and hardness of the rocks. They have cut through the deep mantle of decayed rock into the fresh, hard rock beneath. The resulting valleys are deep and narrow, and the interstream areas are as a rule marked by low, rounded hills and ridges of slight and gentle curvature.

All the large streams except Savannah and Chattahoochee rivers head within the limits of the plateau. The Chattahoochee rises near the South Carolina line and flows across the plateau in a nearly southwest course, changes to a southward course near the middle southern portion of the plateau, at the Alabama line, and continues so to the Gulf. This stream presents an unsymmetrical aspect with reference to its tributaries.[b] Since the establishment of the minor drainage ways on the plateau some of them, by means of more favorable conditions, have encroached on the northeast drainage area of the Chatta-

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[a] Watson, T. L., Bull. Geol. Survey Georgia, No. 9-A, 1902, pp. 60-65.

[b] Campbell, M. R., Drainage modifications and their interpretation: Jour. Geology, vol. 4, 1896, pp. 672-673.

hoochee. A strong southeast slope has been acquired by the plateau since its elevation in middle Mesozoic time, which has enabled the minor drainage lines to establish straight and regular courses at right angles to that of the Chattahoochee, while forming in the basins of the other major streams a symmetrical drainage of dendritic pattern.

The western portion of the plateau in the vicinity of Cartersville lies wholly within the drainage basin of the Etowah. The conditions in the Georgia Piedmont are similar to those in the same province through the Carolinas, Virginia, and Maryland; the streams are not navigable within the limits of the area, a fact which precludes the shipment of stone by water.

GEOLOGY.

ROCKS OF THE PLATEAU.

The Piedmont region is composed of crystalline rocks, which in places afford at present but little evidence of having been deposited as sediments. Whatever may have been their origin, they have been subjected to such profound metamorphism, mainly pressure and recrystallization, that proof of sedimentation is scant. This metamorphism has induced a secondary foliation in the rocks, by arranging the mineral constituents along parallel lines that evidently bear little or no relation to the possible original bedding planes in many of the sedimentary rocks.

The rocks consist principally of granites, gneisses, and schists, invaded by dikes of basic eruptive rocks belonging mainly to the gabbroic, dioritic, and diabasic types. Along the northwestern margin and in other parts of the plateau a belt of basic ferromagnesian silicate rocks, containing deposits of corundum, crosses the State in an approximately northeast-southwest direction. In the eastern, middle, northern, and southwestern parts of the plateau are belts of quartzite and in some places limestone. The rocks usually dip to the southeast at variable angles, and strike from 20° to 30° east of north. Local variations in both dip and strike are shown in all parts of the region.

AGE RELATIONS OF THE ROCKS.

Very little has yet been done toward deciphering the age and structural relations of the rocks of the Georgia Piedmont region. According to Hayes[a] the southeastern portion of Bartow County in northwestern Georgia is about equally divided between the older crystalline and metamorphic rocks of the Piedmont Plateau and Appalachian Mountains on the east and the Paleozoic sediments of the Appalachian Valley on the west. The Paleozoic sediments are

[a] Hayes, C. W., Geological relations of the iron ores in the Cartersville district, Georgia: Trans. Am. Inst. Min. Eng., vol. 30, 1901, pp. 403-408.

Cambrian to Silurian in age. To the south and east of them lie the metamorphic crystalline rocks of the Piedmont area, comprising slates, schists, conglomerates, gneiss, and granite. The oldest of these rocks is the granite at Corbin, Ga., which is mapped as pre-Cambrian. The conglomerate, slate, and schist were mapped as Ocoee and provisionally assigned to the Algonkian because no fossils were found in the rocks and because they have every appearance of extreme age.

The rocks of the Ocoee group generally show an increasing degree of metamorphism toward the southeast; within a few miles of this region they pass into schists and gneisses, the original form of which, whether igneous or sedimentary, can not be determined. This increased metamorphism toward the southeast is due in part to the greater compression which that region has suffered and in part to the intrusion of considerable bodies of igneous rocks into the sedimentary beds.

The intrusive rocks present a considerable variety in composition, varying from extremely basic diabase to acidic granite. Diorite is the most common type and was among the earlier intrusions. It has been metamorphosed for the most part into amphibolite schist. An area near Acworth, Ga., is occupied by gneiss which, like the granite at Corbin, is probably Archean in age and formed the foundation on which the oldest sediments of the region were deposited.

Several thin bands of magnesian limestone and larger areas of sandstone or quartzite occur in the Georgia Piedmont area, intimately associated with other probably older metamorphic crystalline rocks. It is not unlikely that careful study will reveal a post-Algonkian age for at least the limestones and the quartzite of this area.

In his study of the granites and gneisses of the Georgia Piedmont region,[a] the present writer mapped and described most of them as pre-Cambrian. Several periods of intrusion of closely similar acidic material are represented, the earliest being schistose in structure, the later massive. The granite gneisses, regarded as belonging to the earlier intrusion, are pre-Cambrian, and the massive granites representing the later period of intrusion are very probably Paleozoic in age.

THE GRANITES.

FIELD RELATIONS.

The Piedmont region in Georgia is occupied chiefly by mica schists and gneisses, cut in places by dikes of basic eruptive rocks. The schist-gneiss complex is invaded by large masses of granite. From many of the larger granite masses well-defined granite dikes or tongues project and cut abruptly into the adjacent rocks. The line of contact between the granites and the contiguous fresh rocks can be

[a] Watson, T. L., Granites and gneisses of Georgia: Bull. Geol. Survey Georgia, No. 9-A, 1902, 367 pp.

observed in few places, because of the extreme depth of residual decayed material, but here and there the contact is shown in the partial decay of the rocks and the relations of the granites to the surrounding schists are apparent.

Mica-quartz schist forms a considerable part of the crystalline complex. It is a thinly foliated rock with somewhat variable mineral composition, ranging from a rock containing dominant quartz to one containing dominant mica. Feldspar is in many places nearly or entirely absent, but locally it forms an important constituent. Fresh exposures of this rock are rare in the Georgia area.

The dikes of basic eruptive rocks are less common in the Georgia granites than in those of North Carolina. They vary from a few inches to a few hundred feet in width and some of them can be traced for many miles on the surface. They present the usual characteristics of gabbros, diabases, and diorites, and range from gray to almost black in color. In mineral composition they vary from olivine-free rocks to those in which olivine is an important constituent, and in texture from fine to coarse granular. The final product of weathering of the basic eruptive rocks is a stiff, highly ferruginous deep-red to yellow clay.

No definitely identified inclusions of foreign rocks have been observed in the exposed granite masses, but many of the granites contain areas of an irregular character, which can doubtless be ascribed to such origin. In some respects these bodies differ strongly from the inclosing granites and many of them probably represent inclusions of foreign rock. Basic segregations (schlieren) of various sizes and shapes, such as form so common a feature of slowly solidifying granite magmas, are present in many of the granite stocks. They are abundant in the porphyritic granite area of Fayette County and in the granite worked by the Greenville Granite Company in Meriwether County. The segregations are darker in color and finer grained in texture than the inclosing granites, are more or less rounded in outline, and in places display a decided porphyritic tendency. Irregular dark bodies of variable size, composed almost entirely of biotite, are common in some of the Lithonia quarries.

DISTRIBUTION.

The granites and granite gneisses of workable grade in Georgia are limited to the Piedmont region, described on pages 217–267. That the granitic rocks are very generally distributed over the Georgia crystalline area is indicated by the fact that of the sixty-one counties composing the area, few, if any, are without such rocks. The quarrying industry, however, is confined to ten of the sixty-one, and, in fact, the total output of quarried granite shipped beyond the limits of the State comes from only four counties, of which Dekalb County is vastly the largest producer.

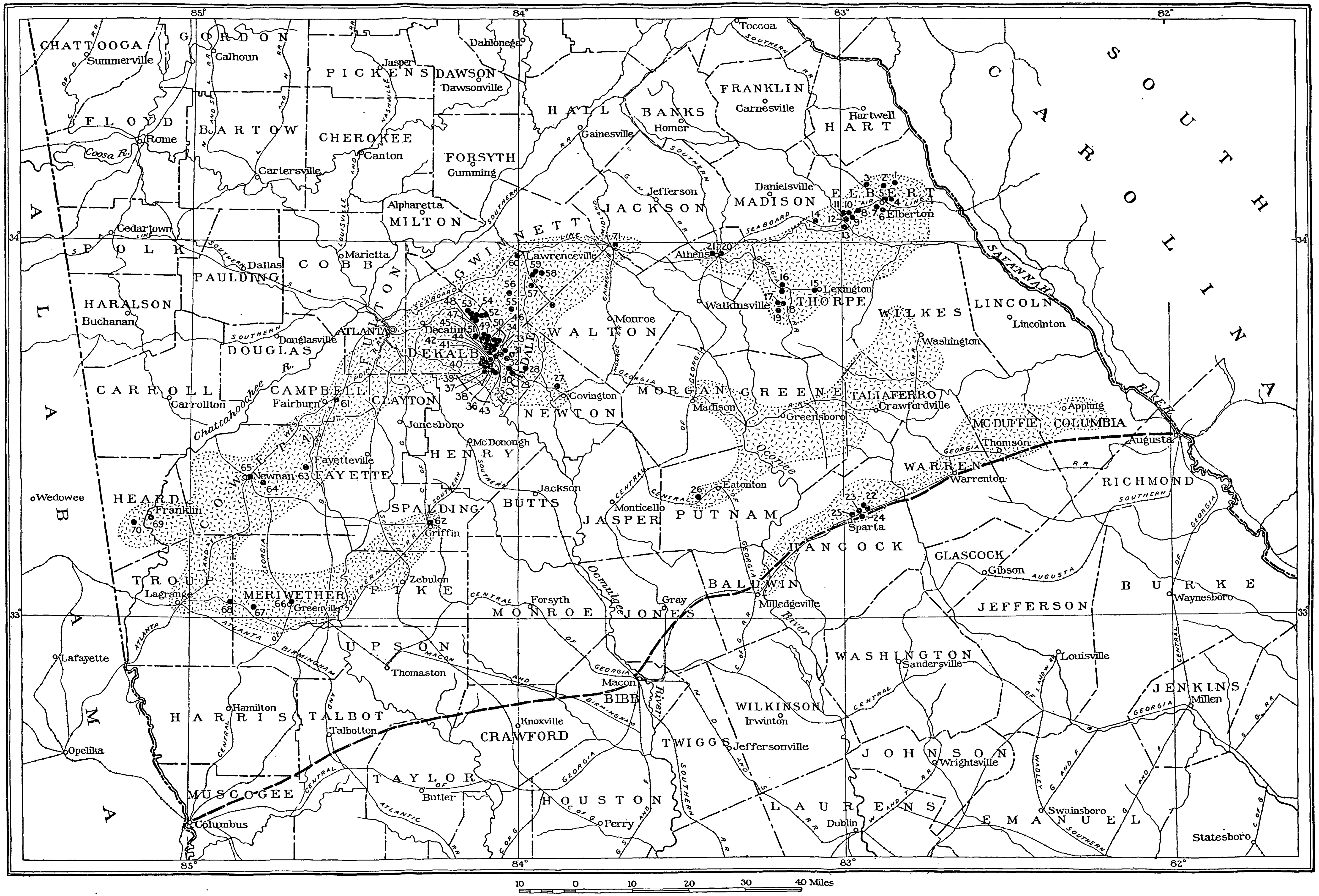
The map (Pl. XXIV) shows the distribution of the granites and gneisses that are quarried in Georgia. They occur in five principal areas—(1) the Elberton-Oglesby-Lexington area, (2) the Lithonia-Conyers-Lawrenceville area, (3) the Fairburn-Newnan-Greenville area, (4) the Stone Mountain area, and (5) the Sparta area. The most important of these at present, commercially, are the Lithonia and Stone Mountain areas, in Dekalb County, the stone from which is used principally for building and street purposes and is not desirable for monumental stock. For the latter purpose the stone from the Oglesby-Lexington area is the most desirable in the State. Besides the five principal areas named above, there are numerous minor ones in which more or less stone has been quarried at times for strictly local purposes.

GENERAL CHARACTER OF OUTCROPS.

The Georgia granites are exposed at the surface in the form of large horizontal masses, as dome-shaped areas of steep and gentle slopes, as large well-rounded bowlders scattered over the surface and partly buried in the residual clay, and as ledges exposed along the streams. The outcrops of the horizontal masses vary in extent from 1 acre to 50 acres or more; the dome-shaped areas contain from 50 to many hundred acres of exposed rock.

The best illustrations of the horizontal masses occur in Hancock, Heard, Meriwether, and Pike counties. Stone Mountain, in Dekalb County, which rises to an elevation of 686 feet above the surrounding lowland plain and has a basal circumference of approximately 7 miles, is the most extensive of the dome-shaped masses. Pine, Arabia, Collinsville, McDaniel, and Rock Chapel mountains, belonging to the Lithonia-Conyers-Lawrenceville area of contorted granite gneiss, are some of the other dome-shaped areas which vary in elevation from 75 to 200 feet. Similar exposures of porphyritic granites include the Heggie (Cedar rock) area in Columbia County and the porphyritic area 10 miles south of Greensboro, in Greene County. Outcrops of the kinds described above are numerous throughout the Georgia Piedmont region.

The large exposures require no stripping prior to opening quarries, but in many of the smaller areas, if extensive quarrying is contemplated, it is necessary to remove a variable depth, up to 12 feet or more, of loose residual material before hard rock can be reached. For a slight depth below the surface the bared and hard rock surfaces in the natural outcrops invariably show a partial decay and discoloration termed "sap," which must be removed before fresh rock can be quarried. The first or surface "raise" usually removes all the sap portion of the rock so that the second and succeeding raises include fresh granite.



MAP OF GEORGIA SHOWING DISTRIBUTION OF GRANITE AREAS AND LOCATION OF GRANITE QUARRIES.

Based on map of Georgia Geological Survey, Bulletin 9–A, 1902.

LEGEND

Granite quarries (*numbers refer to list*)

Granite and gneiss

Fall line

QUARRIES

1 Adams
2 Brewer
3 Fortson (Swift & Etheridge)
4 Carlton
5 Tate & Oliver
6 Swift & Wilcox
7 Heard
8 Etheridge (Long Blue Granite Co.)
9 Seabord Air Line Railway
10 Deadwyler, or Collins & Venable (Long Blue Granite Co.)
11 Coggins (Long Blue Granite Co.)
12 Hill (Long Blue Granite Co.)
13 Brown & Deadwyler
14 David
15 Lexington Blue Granite Co.
16 Willingham & Wilkins
17 Heath
18 Arnold
19 Diamond Blue Granite Co.
20, 21 Athens
22 Charley Rocker
23 Georgia Quincy Granite Co. (new)
24 Georgia Quincy Granite Co.
25 Mallally
26 Linch
27 Freeman
28 Powell
29 Whittaker
30 Redwine & James
31 Paper Mill
32 Tilly
33 Pierce
34 Turner
35 Mary Reagin and Georgia Railroad
36 McDaniel Mountain
37, 38 Arabia Mountain
39 Jenkins
40 Cooper
41 Johnson
42, 43 No name
44 Walker
45 Collinsville Mountain
46 Pine (Little Stone) Mountain
47 Southern Granite Co
48 Chupp
49 Wilson, Whitley
50 Rock Chapel Mountain
51 Floyd
52 Nash & McCurdy, Veal
53, 54 Stone Mountain
55 Snell
56 Sawyer
57 Langley
58 Turner
59 Trip (Cates, Tribble & Bennett)
60 Lawrenceville
61 Carmichael
62 Turner
63 Overby
64 Sam Hill
65 Cole
66 Greenville Granite Co.
67 Odessa
68 Mountville
69 Wynn
70 Flat Rock
71 Saunders

Note.—The Brand, Brantley, Chupp, J. L., Crossley, Goddard, Johnson, and Lee Bros. quarries are opened near to and may be considered parts of Arabia, Collinsville, Pine (Little Stone), and Rock Chapel mountains

CHEMICAL COMPOSITION.

The Georgia granites show more or less variation in texture and structure and are grouped accordingly as even-granular granites, porphyritic granites, and granite gneisses. In chemical composition the three groups show remarkably close agreement and are similar to the granites from the other States described in this bulletin. The analyses of the Georgia granites show their most characteristic feature to be a high soda content, which is above the average for normal granites. The soda and potash show nearly equal percentages in most of the analyses, but in some the potash exceeds the soda and in others the soda is in considerable excess over the potash. The high soda content is due principally to the presence of large amounts of plagioclase feldspar, which places the rocks with the quartz monzonites. Analyses were made of the potash feldspar phenocrysts from two of the widely separated porphyritic areas, with the result that approximately one-third of the potassium was found to have been replaced by sodium in the orthoclase (analyses 4 and 5 below).

Analyses of Georgia granites.[a]

Constituents.	1.	2.	3.	4.	5.
Silica (SiO_2)	69.67	69.28	73.76	64.64	64.40
Alumina (Al_2O_3)	16.63	16.73	14.52	19.64	18.97
Iron oxide (Fe_2O_3)	1.28	1.75	1.03	.37	.37
Magnesia (MgO)	.55	.72	.29	Trace.	Trace.
Lime (CaO)	2.13	2.16	1.14	.67	.59
Soda (Na_2O)	4.73	4.33	4.16	3.06	3.60
Potash (K_2O)	4.71	4.59	4.63	10.00	11.40

[a] Watson, T. L., Granites and gneisses of Georgia: Bull. Geol. Survey Georgia No. 9-A, 1902, pp. 239, 241.

1. Average of 21 analyses of Georgia even-granular granites.
2. Average of 10 analyses of Georgia porphyritic granites.
3. Average of 12 analyses of Georgia granite gneisses.
4. Porphyritic feldspars (phenocrysts) from Heggie Rock, Columbia County, Ga.
5. Porphyritic feldspars (phenocrysts) from McCollum place, Coweta County, Ga.

Averages of 21, 10, and 12 analyses of the even-granular granites, porphyritic granites, and granite gneisses, respectively (1, 2, and 3 in the table), show remarkable uniformity in the soda and potash contents for these groups of granite rocks; but many of the individual analyses exhibit a greater variation. The high range in total alkalies ($Na_2O + K_2O$) is also a very noteworthy feature in these analyses. The general average for the total alkalies is from 8.79 per cent in the granite gneisses to 9.44 per cent in the granites.

The Georgia granites contain an average of approximately 70 per cent of silica, as shown in the table. The normal granites and their porphyritic facies show no appreciable difference in silica content, as would be expected; but the granite gneisses are slightly more acidic and range from 3 to 4 per cent higher in this constituent. This relationship in the silica content is almost equally well shown when a comparison of individual analyses of the several groups is made.

MINERAL COMPOSITION.

The close similarity in mineral composition between the three types of granitic rocks here distinguished can not be emphasized too strongly. They are as nearly identical in mineral composition as different rocks could well be. The minerals found in one are invariably present in the others, and those most abundant in one also predominate in the others.

The granitic rocks of Georgia are made up of mixtures of the essential minerals feldspar, quartz, and biotite, with varying proportions of muscovite intimately associated with the biotite. Plagioclase is invariably present in large amount and in many rocks exceeds the orthoclase. Biotite is subordinated to muscovite in only two of the specimens examined. The absence of hornblende is a marked feature. Other minerals that are common to most granites occur as microscopic accessories, but do not exert any influence on the properties of the rock. A number of other minerals, such as calcite, garnet, tourmaline, hornblende, hyalite, molybdenite, and uranophane, occur sporadically in several localities, but are only of local interest.

PHYSICAL TESTS.

The following table gives some properties of the even-granular granites of Georgia:

Properties of Georgia even-granular granites.

Quarry.	Specific gravity.	Ratio of absorption.	Weight per cubic foot (pounds).	Cubic feet of stone in 2,000 pounds.
Lexington Blue Granite Co	2.666	0.092	166.25	12.0
Diamond Blue Granite Co	2.666	.088	166.62	12.0
Echols Mill	2.657		166.06	12.0
Sam Hill	2.689		168.06	11.9
R. D. Cole	2.700		168.75	11.8
A. M. Hill	2.731		170.68	11.7
T. B. Tigner	2.739		171.18	11.6
Greenville Granite Co	2.662	.086	166.37	12.0
Swift & Wilcox	2.652	.090	165.75	12.0
Swift & Wilcox "flat rock"	2.645	.092	165.31	12.0
Tate & Oliver	2.670	.093	166.87	11.9
Coggins	2.840	.090	177.50	10.7
Bisson	2.664		166.50	12.0
Deadwyler (Collins & Venable)	2.662		166.37	12.0
Childs	2.665	.092	166.56	12.0
Carmichael	2.658		166.12	12.0
Linch	2.701	.060	168.81	11.8
Stone Mountain	2.686	.067	167.90	11.9

The following table shows the results of tests on specimens of granite from Stone Mountain and contorted granite gneiss from Lithonia, Ga.:

Crushing tests of Georgia even-granular granite and granite gneiss.[a]

AT WASHINGTON NAVY-YARD, 1887.

Locality.	Dimensions (inches).	Crushed at—	
		Pounds.	Pounds per square inch.
Lithonia	2.00 x 2.00 x 2.02	76,000	....
Do	2.00 x 2.01 x 2.00	83,400	....
Lithonia (No. 3)	2.06 x 2.06 x 2.09	52,650	....
Lithonia	2.01 x 2.01 x 2.01	(a)	....
Do	2.00 x 1.98 x 1.98	(a)	....
Stone Mountain	2.05 x 2.00 x 2.01	(a)	....
Do	1.99 x 1.99 x 2.00	50,325	....
Do	1.99 x 1.99 x 2.00	48,760	....
Do	2.02 x 2.02 x 2.03	65,610	....

[a] Did not crush at 85,000 pounds pressure.

AT PURDUE UNIVERSITY, LAFAYETTE, IND.

Locality.	Dimensions (inches).	Pounds.	Pounds per square inch.
Lithonia	2.02 x 2.04 x 2.07	80,000	....
Do	2.02 x 2.01 x 2.06	61,000	15,024
Do	2.01 x 2.01 x 2.01	80,000	19,801
Do	2.01 x 2.00 x 2.00	80,700	....
Do	2.02 x 2.08 x 2.02	75,700	18,017
Do	2.02 x 2.05 x 2.02	64,000	15,455
Do	2.06 x 2.02 x 2.02	78,700	18,913
Do	2.04 x 2.04 x 2.06	71,700	17,229
Do	2.04 x 2.03 x 2.03	79,700	19,246
Do	2.04 x 2.04 x 2.05	79,700	19,151
Do	2.02 x 2.02 x 2.01	74,700	18,307
Do	2.01 x 2.02 x 2.04	70,700	17,413
Stone Mountain	2.00 x 2.01 x 2.02	50,000	12,438
Do	1.99 x 2.01 x 1.99	57,700	14,425
Do	2.04 x 2.04 x 2.05	53,700	12,904
Do	2.04 x 2.07 x 2.05	55,700	13,190
Do	2.01 x 2.03 x 2.02	54,700	13,406
Do	2.02 x 2.05 x 2.01	52,700	12,726

[a] Granite pavements, compiled by Venable Brothers, Atlanta, Ga., 1893.

STRUCTURAL FEATURES OF THE GRANITES.

JOINTS.

The principal granite masses in Georgia are cut by joints, but as a rule these are by no means so conspicuously developed as in many granite areas elsewhere in the United States. The large residual masses of the granite gneiss of Lithonia and the granite of Stone Mountain are cut by joints that are in the main widely spaced and not very conspicuous. In most places there are two sets of joints which intersect each other approximately at right angles, the best-developed ones having nearly due east-west and north-south courses. In many of the quarries the major set of joints approximates a true northeast-southwest direction.

In the Oglesby-Lexington area of dark blue-gray granite many of the outcrops are in the form of large and small rounded bowlders strewn loosely over the surface or partly buried in the residual clay. These bowlders have been derived from weathering along the joint planes which intersect the granite. Decay progressed more rapidly on the edges and corners than along the flat sides of the blocks, thus giving them their present form. In these bowlder areas the surface rock is as a rule partly weathered for some distance down, and care should be used in selecting rock for dimension work. Beneath the weathered material the quarries exhibit solid rock of excellent quality and furnish highly satisfactory dimension stone. Jointing in the Oglesby-Lexington area is sufficiently developed to aid materially in quarrying the stone.

SLICKENSIDES.

Subsequent movement in many of the quarries is indicated in the slickensided surfaces of the joints. Slickensides are conspicuously developed in the Stone Mountain, Lithonia, and Hancock-Putnam counties granite areas, where the surfaces of the joints are coated with smooth yellowish damourite, in many places grooved and striated from the movement.

DIKES AND VEINS.

Two sets of intersecting material, differing in texture and origin and to some degree in mineral composition, are common to the granitic rocks. On the basis of texture and composition these are divisible into true dikes and veins. They are not so conspicuous in the Georgia granites as in areas of similar rocks over other parts of the continent, and only very rarely do they interfere with the quarrying of dimension stone.

GRANITE DIKES.

Nearly vertical granite dikes, varying in width from a few inches to 40 feet, cut the rocks in places. They are dark blue-gray in color and of fine and even grain, and are composed of quartz, orthoclase, and plagioclase feldspars, and biotite as the principal minerals. Except for their finer-grained texture they can not be distinguished in hand specimens from granites of the Oglesby and other areas of blue-gray granite in the State. They are common to some of the porphyritic granites and gneisses, but have not been observed penetrating any of the even-granular granites. They cut the porphyritic granite of Hancock and Warren counties and the contorted granite gneiss of Meriwether County.

A chemical analysis of the specimens collected from a 40-foot dike cutting the porphyritic granite gneiss in Warren County gave the following results:

Analysis of granite dike in Warren County, Ga.

[T. L. Watson, analyst.]

SiO_2	68.76
Al_2O_3	16.80
Fe_2O_3	.99
CaO	2.72
MgO	1.00
Na_2O	4.82
K_2O	3.70
Ignition	.29
	99.08

This analysis should be compared with the analyses of the granites from the Elberton-Oglesby-Lexington and Fairburn-Newnan-Greenville areas (pp. 220, 225, 229).

APLITE DIKES.

Aplites have been observed in association with the granite masses only at Stone Mountain, on the northwest side of which several less than 6 inches in width are exposed in the quarries. The aplite is banded with pegmatite. Apart from its being more compact and of much finer grain, the aplite is readily distinguished in the hand specimen from the inclosing granite by its lighter color and by its small content of mica. Biotite is entirely absent and muscovite is only sparingly distributed through the rock. Here and there small crystals of red garnet are present.

The aplite is composed chiefly of the potash and soda feldspars and quartz. Stout laths of striated acidic plagioclase are numerous. The small percentage of lime (less than 1 per cent) and the large percentage of soda shown in the analysis below indicate the preponderance of the soda molecule (albite).

Analysis of aplite from Stone Mountain, Georgia.

[T. L. Watson, analyst.]

SiO_2	74.30
TiO_2	None.
Al_2O_3	14.73
Fe_2O_3	.78
MnO	Trace.
CaO	.90
BaO	None.
SrO	None.
MgO	Strong trace.
Na_2O	4.61
K_2O	4.52
H_2O	.21
P_2O_5	Trace.
	100.05

The mineral composition of the aplite computed from the above analysis is as follows:

Potash feldspar	26.69
Soda molecules	38.77
Lime molecules	4.45
Quartz	28.30

From the above calculations the ratio of soda molecules to lime molecules is 9 to 1, which corresponds to a lime-bearing albite of the composition Ab_9An_1.

PEGMATITE DIKES AND VEINS.

The pegmatite dikes of this region differ from the true granite dikes described above principally in texture. Some of them are true pegmatite intrusions of aqueo-igneous origin; others are as certainly true veins of segregation. They are common to the porphyritic and nonporphyritic granites and granite gneisses, and are characterized by the usual coarse-grained texture, being composed almost exclusively of large cleavable pink and white feldspar and quartz with some biotite and here and there a little muscovite. Some of the dikes are very extensive and are apparently deep seated; others are minute and are entirely inclosed by the granite. They are of irregular outline and cut the granite without regard to direction. Thin sections show the feldspar to be microcline, orthoclase, and plagioclase, with local microperthite. Nearly all degrees of variation in the proportion of feldspar to quartz are indicated.

ORIGIN OF PHENOCRYSTS IN THE PORPHYRITIC GRANITES.

The porphyritic feldspars in the Georgia granites are believed to have crystallized contemporaneously with that of the groundmass minerals after the magma had come to rest. The evidence favoring this belief consists in (1) the absence of definite arrangement among the phenocrysts; (2) the absence of phenocrysts from the border zones of the granite areas—that is, gradation from an interior porphyritic facies peripherally into an even-granular granite of coarse texture and the same mineral and chemical composition; (3) the absence of evidence of magmatic resorption or corrosion of the phenocrysts; and (4) the presence of abundant inclusions of the groundmass constituents in the phenocrysts. These facts are regarded by the writer to indicate that the phenocrysts of these granites were developed in place and are not, according to the old belief, of intratelluric origin.

RELATIONS OF THE GRANITES AND THE GRANITE GNEISSES.

The granites and granite gneisses of the Georgia Piedmont are genetically very closely related. Both are light to dark gray in color and even granular to porphyritic in texture, and both have suffered more or less the effects of pressure. The granite gneisses differ from the granites only in the banded structure induced in them through pressure metamorphism. As has been pointed out elsewhere, the granite gneisses represent unquestionable foliated phases of massive granites similar to those of the present areas but of an earlier period of intrusion.

VARIETIES OF GRANITE.

Mineralogically the granites of Georgia are divisible into three leading types—(1) biotite granite or granitite, under which most of the granites of the State are grouped; (2) muscovite-biotite granite; and (3) biotite-bearing muscovite granite, of which the granite of Stone Mountain is the best representative. Texturally and structurally the granites are grouped as even-granular massive granites, porphyritic granites, and granite gneisses.[a] The relationships of these three phases of the granitic rocks are established below.

EVEN-GRANULAR MASSIVE GRANITES.

GENERAL STATEMENT.

Granites of superior quality and variety, well suited for general building and monumental work, have long been known in Georgia. For many years the famous light-gray muscovite granite from Stone Mountain was the only type of Georgia granite generally known beyond the limits of the State. Within the past few years, however, several areas yielding a high-grade monumental granite have come somewhat prominently into favor. Developments have recently been made in other areas of the Georgia Piedmont region, and the local granite industry has steadily grown until Georgia now ranks as the first granite producer among the Southern States.

With two exceptions all the granites are biotite granites. Muscovite is usually present in variable amount and is very prominent as an accessory in several localities. Hornblende is entirely lacking. In color the even-grained granites vary from light gray through intermediate gray to a dark blue gray, and in texture from fine to medium grained. Both color and texture are fairly uniform for each type.

There are four principal areas of even-granular granites in Georgia that are commercially important at present, or will become so in the near future. These are the Oglesby-Lexington blue-gray granite

[a] The term granite gneiss is here used to denote those gneisses that have been derived from original granites by metamorphism and that are, therefore, of igneous origin.

area, comprising the counties of Elbert, Madison, and Oglethorpe; the Elberton-Echols Mill light-gray granite area, in Elbert and Oglethorpe counties; the Fairburn-Newnan-Greenville medium blue-gray granite area, comprising the counties of Campbell, Coweta, and Meriwether; and the Stone Mountain light-gray granite area in Dekalb County. Besides these there are numerous smaller areas widely distributed over the Piedmont region, the granite of which belongs to one or the other of the types of the four areas named above.

BLUE-GRAY GRANITE OF THE OGLESBY-LEXINGTON AREA.

GENERAL DESCRIPTION.

The Oglesby-Lexington belt of dark blue-gray granite has a northeast-southwest direction through parts of Oglethorpe, Madison, and Elbert counties for about 30 miles, with an average width of 4 to 6 miles. The accompanying map (fig. 18) shows the Oglesby-Lexington area of blue-gray granite and the Elberton–Echols Mill area of light-gray granite as a single area. A variable thickness of residual decayed granite mantles the fresh rock, but outcrops of the granite are rather common, as flat-surfaced areas along the stream courses and as large bowlder outcrops on the interstream areas. Both forms of outcrops usually afford good quarry sites, and numerous quarries have been opened, grouped chiefly about two principal centers—Lexington and Huching, in Oglethorpe County, and Oglesby, in Elbert County. A list of the principal quarries opened in this belt is given below.

The rock is a biotite granite of dark blue-gray color and fine, even grain. It is fairly uniform in texture and color throughout the area; local variation in color is noted here and there, but not to such an extent as to injure the stone. The granite works well under the hammer and takes an excellent polish, with a striking contrast between the cut and polished surfaces. Its uniformity in color and texture, fineness of grain, freedom from imperfections and blemishes, and great strength and durability give it first rank as a monumental stone. It is used almost entirely for monumental stock, and for this purpose is commercially the most important in Georgia. The area is traversed by several lines of railroad, which afford abundant transportation facilities.

The large number of openings made over the area from which the granite has been quarried show the vertical joints to be widely spaced, thus affording abundant opportunity for the quarrying of dimension stone. Only in one opening—the Hill quarry, near Oglesby—are the joints so closely spaced as to prevent the quarrying of dimension stone, and here in only a single zone of about 10 feet in width. Small pegmatite veins from a fraction of an inch to several inches wide intersect the granite in nearly every opening, but only in one quarry are they so abundant as to interfere seriously with quarrying. These veins consist of coarse crystallizations of quartz and feldspar with scant muscovite and biotite.

MICROSCOPIC CHARACTERS.

This granite consists of anhedra of an average size of 0.5 to 1.5 millimeters. The principal minerals are orthoclase, microcline, plagioclase near oligoclase, quartz, biotite, some muscovite, a little

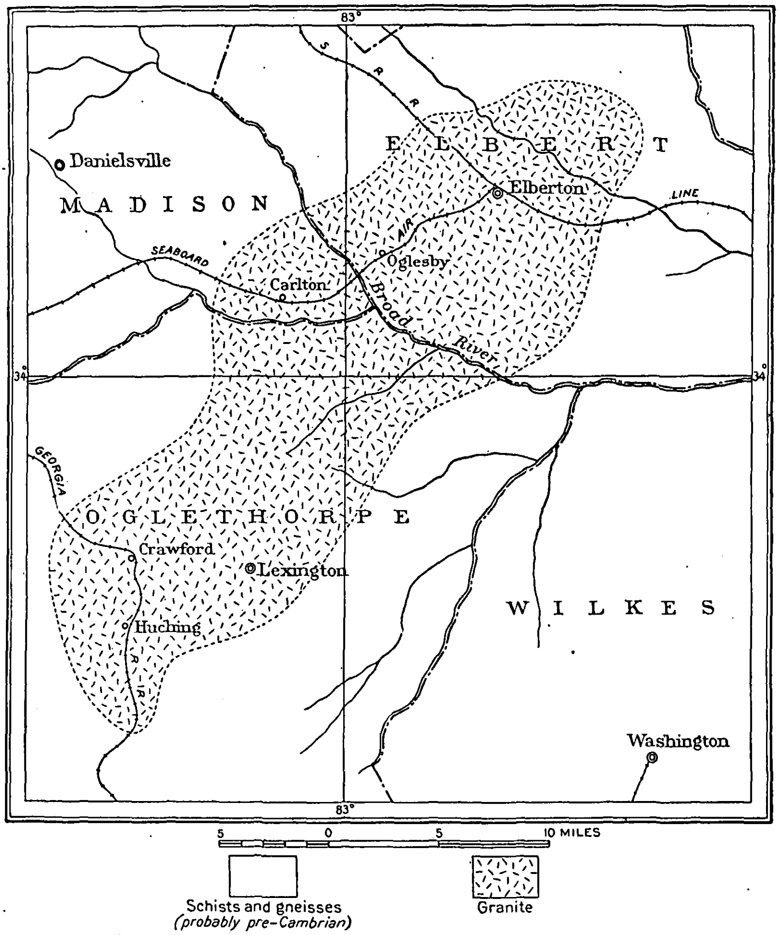


FIGURE 18.—Map of Oglesby-Lexington and Elberton-Echols Mill granite areas, Georgia.

included apatite and zircon, and occasional grains of magnetite and pyrite. The secondary constituents are chlorite, epidote, muscovite, and kaolin. Much of the quartz occurs as droplike inclusions in the large feldspar individuals; and locally it is intergrown with a part of the feldspar in the form of ovals or rounded disks of granophyric structure. Orthoclase is the dominant feldspar and exhibits in places microperthitic intergrowths with a triclinic feldspar. Microcline varies in quantity, but may equal the orthoclase. Twinning on the

Carlsbad law is common to the potash feldspars. Plagioclase is present in large amount and in most sections equals or exceeds orthoclase. As a rule, low extinction angles in basal sections characterize the plagioclase—a fact which, with the percentage of lime given in the analyses, indicates oligoclase. Biotite is regularly distributed through the rock in single shreds of deep-brown color and strong pleochroism. It is intimately associated with muscovite, which is usually present in smaller amount but here and there may equal the biotite. The biotite is partly altered to chlorite.

CHEMICAL COMPOSITION.

The following chemical analyses of the dark blue-gray granite from the Oglesby-Lexington area were made by the writer in the chemical laboratory of the Georgia Survey:

Analyses of dark blue-gray granite from the Oglesby-Lexington area, Georgia.

	1.	2.	3.	4.	5.	6.	7.
Silica (SiO_2)	70.30	70.18	70.03	69.53	69.36	69.64	70.38
Alumina (Al_2O_3)	16.17	17.30	15.62	16.46	17.23	17.21	16.47
Iron oxide (Fe_2O_3)	1.19	1.20	1.31	1.15	1.43	1.32	1.17
Magnesia (MgO)	.31	.64	.52	.85	.59	.66	.31
Lime (CaO)	2.61	2.03	2.45	2.10	2.14	2.14	1.72
Soda (Na_2O)	4.72	4.36	4.82	5.00	5.17	4.53	4.98
Potash (K_2O)	4.88	4.77	5.42	4.91	4.57	4.95	5.62
Ignition	.63	.35	.77	.91	.33	.35	.31
Specific gravity	2.666	....	2.666	....	2.665	....	....

1. Diamond Blue Granite Company's quarry, near Huching, Oglethorpe County.
2. Brown & Deadwyler quarry, Madison County.
3. Lexington Blue Granite Company's quarry, Lexington, Oglethorpe County.
4. Huching quarry, Oglethorpe County.
5. Childs quarry, near Oglesby, Elbert County.
6. Hill quarry, near Oglesby, Elbert County.
7. Etheridge quarry, 3 miles east of Oglesby, Elbert County.

According to the definition given by Brögger the above analyses show the rock of this belt to be quartz monzonite.

PHYSICAL TESTS.

The ratio of absorption of these granites was determined by the writer in the Georgia Survey laboratory on carefully selected specimens from a number of quarries in this belt, with the following results:

Absorption of granite from Oglesby-Lexington area, Georgia.

	Percentage of absorption.
Lexington blue-granite quarry, Oglethorpe County	0.092
Diamond blue-granite quarry, Oglethorpe County	.088
Coggins quarry, Elbert County	.090
Childs quarry, Elbert County	.092

The above figures indicate a compact, close-grained rock that will not be appreciably affected by frost action.

Tests made on specimens of the Diamond Blue Granite Company's granite at the Watertown Arsenal January 17, 1894, illustrate the compressive crushing strength of the dark blue-gray granite of the Oglesby-Lexington granite area.

Compressive strength of granite from Diamond Blue Granite Company's quarry, Oglethorpe County, Ga.

Test No.	How tested.	Size (inches).	Pressure (pounds per square inch).
7304	On bed......	3.07 x 3.06 x 3.04	26,340
7307	On grain....	3.16 x 2.99 x 3.10	23,860

DESCRIPTIONS OF QUARRIES.

INTRODUCTORY STATEMENT.

A list of the quarries, both large and small, opened in the belt of dark blue-gray granite follows. Some of the openings listed are small and the production from them has been very meager. Only two were operating during the summer of 1908, namely, the Deadwyler (Collins & Venable) and the Etheridge.

Quarries in the Oglesby-Lexington belt of dark blue-gray granite.

Oglethorpe County:
- Arnold..................................1½ miles west of Huching.
- Diamond Blue Granite Company.....2 miles southwest of Huching.
- Heath....................................2 miles west of Huching.
- Lexington Blue Granite Company...One-half mile west of Lexington.
- Willingham........................1½ miles northwest of Crawford.

Madison County:
- Brown & Deadwyler.....................2½ miles south of Carlton.
- David......................................2 miles west of Carlton.

Elbert County:
- Long Granite Company's quarries—
  - Coggins.........................1½ miles southwest of Oglesby.
  - Deadwyler (Collins & Venable)...1½ miles southwest of Oglesby.
  - Hill..............................1 mile southwest of Oglesby.
  - Etheridge...........................3 miles east of Oglesby.
  - Bisson...........................1½ miles southwest of Oglesby.
- Childs..............................1 mile southwest of Oglesby.
- Seaboard.....................One-half mile northeast of Oglesby.

ELBERT COUNTY.

The *Coggins quarry*, opened in 1882 in a bowldery outcrop of the granite, is about 1½ miles southwest of Oglesby. It has been operated at intervals since its opening. The rock is a biotite granite of dark blue-gray color and fine, even grain. Its minerals are potash feldspar (orthoclase and microcline), soda-lime feldspar (oligoclase), quartz, black mica (biotite), and a little white mica (muscovite), together with accessory apatite and zircon and secondary chlorite.

Chemical analyses of the fresh and decayed granite gave the following results:

Analyses of granite from Coggins quarry, near Oglesby, Ga.

[T. L. Watson, analyst.]

	Fresh.	Decayed.
Silica (SiO_2)	69.74	60.94
Alumina (Al_2O_3)	16.72	23.29
Iron oxide (Fe_2O_3)	1.45	2.44
Lime (CaO)	1.93	.04
Magnesia (MgO)	.36	.43
Soda (Na_2O)	4.84	2.18
Potash (K_2O)	4.33	3.57
Ignition	.47	8.03

The specific gravity is 2.84 and the percentage of absorption is 0.090.

This granite does not contain any blemishes; it takes a high polish, works well under the hammer, and shows strong contrast between the hammered and polished surfaces.

The *Deadwyler* (*Collins & Venable*) *quarry* is near the Coggins quarry, about 1,900 feet north of the Seaboard Air Line Railway. It is opened in a bowldery outcrop, and in some places decayed material is visible along the joint surfaces to the entire depth of 40 feet. (See Pl. V, *B*.) The stone is identical in mineral composition, color, and texture with the granite of the Coggins quarry. About 568 cubic yards of it was quarried in 1891 for bridge piers along the Seaboard Air Line. The quarry was operating during 1908 to supply monumental stock exclusively.

The *Hill quarry* is a mile southwest of Oglesby, directly south of the Seaboard Air Line Railway. It has been worked to a depth of 40 feet and during its period of activity it was probably the most extensive quarry in the Oglesby portion of the area. It has been idle for some years. The rock is a biotite granite of the same color, texture, and mineralogy as the granite of the Coggins quarry. Magnetite is sparingly present in some of the thin sections. Vertical joints strike east-west and north-south, and except in a 10-foot zone at the south end of the quarry, the joints are sufficiently far apart to permit the quarrying of dimension stone. Weathering along some of the joints extends to the depth of working—40 feet. A chemical analysis of the granite, made by the writer, is given on page 220 (No. 6).

The *Etheridge quarry* is about 3 miles east of Oglesby, directly southeast of the Seaboard Air Line Railway. It was opened in 1893, in a sloping surface exposure of the granite, and in places is worked to a depth of 20 feet or more. It was one of the two quarries in the Oglesby area operating during the summer of 1908. The rock is biotite granite of medium-gray color and fine, even grain. It is somewhat lighter in color than the granite quarried in the immediate vicinity of Oglesby. On account of this difference the company designates the two granites "Oglesby dark-blue" and "Oglesby light-blue" granite. It differs in mineral composition from the granite nearer Oglesby only in possessing slightly more muscovite. A chemical analysis of the granite is given on page 220 (No. 7).

The *Childs quarry*, 800 yards east of the Hill quarry, is in an excellent body of the fine even-grained dark blue-gray granite. Quarrying was discontinued many years ago because of the large waste occasioned by the numerous dikes of pegmatite. These vary in thickness from a fraction of an inch to many inches and cut the granite indiscriminately. A chemical analysis of the granite is given on page 220.

The *Seaboard quarry* is immediately south of the Seaboard Air Line Railway about half a mile northeast of Oglesby. The rock is a biotite granite of dark blue-gray color and fine grain, similar in all respects to the granite quarried by the Long Granite Company near by. The quarry is operated at intervals by the Seaboard Air Line Railway to supply crushed stone for ballast. It was idle at the time of the writer's visit in July, 1908, and was reported to have suspended work in September, 1907.

MADISON COUNTY.

The *Brown & Deadwyler quarry* is near the confluence of the north and south forks of Broad River, about 2½ miles south of Carlton. The opening, made about fifteen years ago, is a small one in large bowlder outcrops. In mineral content, color, and texture the granite is identical with that quarried near Oglesby. A chemical analysis of it is given on page 220 (No. 2).

OGLETHORPE COUNTY.

The *Diamond Blue Granite Company's quarry* comprises four openings some distance apart, about 2 miles southwest of Huching. The openings are on both sides of a small stream, and the principal one is in a 20° to 30° slope of exposed granite. The product, which was used almost exclusively for monuments, was shipped to various points outside of the State.

The rock is a biotite-muscovite granite of dark blue-gray color and fine, even grain. The feldspars have a decided bluish-gray tone and in descending order of abundance, comprise microperthitic orthoclase, microcline, and a soda-lime feldspar near oligoclase. Muscovite nearly equals the biotite in amount. A few pegmatite dikes of slight thickness cut the granite. Two chemical analyses made by the writer from specimens collected from the four openings averaged as follows:

Average analysis of granite from Diamond Blue Granite Company's quarry, near Huching, Ga.

Silica (SiO_2)	69.915
Alumina (Al_2O_3)	16.315
Iron oxide (Fe_2O_3)	1.170
Lime (CaO)	2.355
Magnesia (MgO)	.580
Soda (Na_2O)	4.860
Potash (K_2O)	4.895
Ignition	.770

Results of tests of the compressive crushing strength and the percentage of absorption of the granite are given on pages 220, 221.

The *Lexington Blue Granite Company's quarry* is half a mile west of the court-house at Lexington. The granite outcrops as flat masses and bowlders over a considerable area over the south slope of Town Creek. Half a dozen openings have been made. The rock is a biotite granite of dark blue-gray color and fine, even grain. The minerals are potash feldspar (orthoclase and microcline), soda-lime feldspar (oligoclase), quartz, and black mica (biotite), with considerable white mica (muscovite) and the usual accessory and secondary minerals. Micrographic intergrowths of quartz and feldspar are abundant. Pegmatite dikes varying from a fraction to several inches in thickness cut the granite in many places. A chemical analysis of the granite is given on page 220 (No. 3). The ratio of absorption is 0.092.

LIGHT-GRAY GRANITE OF THE ELBERTON–ECHOLS MILL AREA.

GENERAL DESCRIPTION.

The light-gray granite of the Elberton–Echols Mill area is represented by a belt of approximately the same dimensions and general direction as the dark blue-gray granite of the Oglesby-Lexington area, which lies immediately adjacent on the southeast. The two areas are well differentiated as to color, and in a less degree as to texture, in their extreme portions, but they undoubtedly form parts of the same general area, as the gradation is well shown near Elberton and Carlton. The two areas are mapped together in figure 18.

The rock is a biotite granite of light-gray color and medium even-grained texture. Slight local variation in color and texture is noted. The granite is well suited to all grades of constructional work. Dimension stone is readily obtained and the rock works well under the hammer. Pegmatite veins and dark segregations, chiefly of biotite, are observed here and there in some of the openings, but these can readily be avoided without waste in working. The principal openings in this belt of granite are grouped about Elberton, in Elbert County. The rock has been used chiefly for building purposes to supply the local market.

The light-gray granite of the Elberton–Echols Mill area does not differ essentially in mineral composition from the dark blue-gray granite of the Oglesby-Lexington area, although the two contrast strongly in hand specimens. The difference is essentially one of color, the biotite being distributed at greater intervals and in somewhat shorter aggregated shreds in the light-gray granite. As a rule, the light-gray rock is a little more coarsely crystalline in texture than the dark blue-gray rock. The same minerals are present in nearly the same proportions and they show the same characteristics in the two types. Orthoclase, microcline, acidic plagioclase (oligoclase), quartz, biotite, a little muscovite, apatite, and zircon are the primary minerals.

CHEMICAL COMPOSITION.

The following analyses, made in the Georgia Survey laboratory by the writer, serve to illustrate the composition of the light-gray granite of the Elberton–Echols Mill area. Analyses 1, 2, and 3 represent the typical light-gray granite; analysis 4, the rock intermediate between the Oglesby dark blue-gray and the Elberton light-gray types.

Analyses of granite from Elberton–Echols Mill area.

	1.	2.	3.	4.
Silica (SiO_2)	68.81	69.45	69.25	71.00
Alumina (Al_2O_3)[a]	17.67	15.93	16.04	16.33
Iron oxide (Fe_2O_3)[b]	1.13	1.31	1.72	1.12
Magnesia (MgO)	.50	.55	.31	.35
Lime (CaO)	2.17	1.91	1.89	1.83
Soda (Na_2O)	4.97	4.33	4.52	4.80
Potash (K_2O)	3.90	5.16	4.49	4.65
Ignition	.30	.50	.43	.87
	99.45	99.14	99.10	100.95
Specific gravity	2.657	2.652	2.670	....

[a] Contains traces of P_2O_5, TiO_2, and ZrO_2 when present. [b] All iron estimated as Fe_2O_3.

1. Echols Mill, Oglethorpe County.
2. Swift & Wilcox, Elbert County.
3. Tate & Oliver, Elbert County.
4. Fortson, Elbert County.

ABSORPTION TESTS.

The percentage of absorption of the light-gray granite of the Elberton-Echols Mill area is from 0.090 to 0.092 at the Swift & Wilcox quarry, near Elberton, and 0.093 at the Tate & Oliver quarry at Elberton.

DESCRIPTIONS OF QUARRIES.

INTRODUCTORY STATEMENT.

The principal openings made in the light-gray granite are in the vicinity of Elberton, Elbert County. Most of these are very small. About half of them are in granite intermediate in color and texture between the dark blue-gray of Oglesby and the light-gray of Elberton, and mark the passage of one type into the other. In the Echols Mill portion of the area, in Oglethorpe County, extensive exposures of the light-gray granite are numerous and good quarry sites are readily obtained, but the distance from transportation lines is a barrier to development. No openings of sufficient size to be called quarries have been made in the Echols Mill area. The quarries and openings worked in the light-gray granite are listed below:

Quarries and openings in the light-gray granite of the Elberton–Echols Mill area.

Elbert County:	
Adams [a]	4½ miles northeast of Elberton.
Carlton [a]	1¼ miles northeast of Elberton.
Fambrough	¾ mile south of Elberton.
Fortson [a]	½ mile northeast of Goss.
Heard	1 mile southwest of Elberton.
Hester [a]	1½ miles northwest of Elberton.
Swift & Wilcox	1 mile south of Elberton.
Tate & Oliver	½ mile northeast of Elberton.
Oglethorpe County:	
Andrew	2 miles southeast of Carlton.
Arnold	10 miles northeast of Lexington.
Echols Mill	11 miles northeast of Lexington.

ELBERT COUNTY.

The *Adams quarry*, comprising two openings 150 feet apart, is 4½ miles northeast of Elberton. The granite outcrops as large bowlders over approximately 5 acres of surface. Several bowlders were worked up in 1885 and 1886 for local purposes. In 1890 a large quantity of stone was quarried for bridge piers in the construction of the Seaboard Air Line Railway bridge over Savannah River. The rock is a biotite granite of medium blue-gray color and medium-fine grain. It is intermediate in color and texture between the Oglesby dark blue-gray and the Elberton–Echols Mill light-gray types. The minerals are potash feldspar (orthoclase and microcline), soda-lime feldspar (oligoclase), quartz, and black mica (biotite), with a little white mica (muscovite), and the accessories apatite, zircon, and magnetite. Secondary chlorite and epidote occur. A chemical determination of silica gave 69.41 per cent. The sap (partly weathered granite) is

[a] Granite intermediate in color and texture between the dark blue-gray of Oglesby and the light-gray of Elberton, and marking the transition of one type into the other.

very thin. The granite takes a good polish, works well under the hammer, and is desirable for either monumental or general architectural purposes.

The *Swift & Wilcox quarry*, opened in 1888 and worked at intervals since, comprises two openings close together, a mile south of Elberton. A stripping of 3 to 6 feet is necessary in the larger opening. Flat-surfaced and bowlder exposures of the granite are abundant in the vicinity of the quarry. The rock is a biotite granite of light-gray color and even, medium grain. It is entirely massive and uniform in color and texture. It has been regarded by the writer as the typical light-gray granite of the Elberton–Echols Mill area. Its minerals are potash feldspar (orthoclase and microcline), soda-lime feldspar (oligoclase), quartz, and black mica (biotite), with a little white mica (muscovite); accessory apatite and zircon are sparingly present. The biotite is partly altered to chlorite. The potash feldspar exceeds plagioclase. Micropegmatitic intergrowths of quartz and feldspar are common. Chemical analyses of the fresh and partly decayed granite from this quarry gave the following results:

Analyses of granite from Swift & Wilcox quarry, near Elberton, Ga.

[T. L. Watson, analyst.]

	Fresh.	Partly decayed.
Silica (SiO_2)	64.45	69.00
Alumina (Al_2O_3)	15.93	17.31
Iron oxide (Fe_2O_3)	1.31	1.31
Lime (CaO)	1.91	1.18
Magnesia (MgO)	.55	.42
Soda (Na_2O)	4.33	4.00
Potash (K_2O)	5.16	4.74
Ignition	.50	1.79

Small dikes of pegmatite, and a few small dark areas (knots) occur here and there. Results of physical tests made on specimens of the granite are given on page 225.

The *Tate & Oliver quarry* is located in Pinetown, a district of Elberton, about half a mile northeast of the court-house. The larger part of a 2-acre flat-surfaced exposure has been worked to a depth of less than 15 feet. The rock is a biotite granite of the same color, texture, and mineral composition as the light-gray type from the Swift & Wilcox quarry, described above. A chemical analysis of this granite made by the writer is given on page 225. The percentage of absorption is 0.093.

OGLETHORPE COUNTY.

The light-gray granite is abundantly exposed in the north-central portion of Oglethorpe County at and near Echols Mill, 12 miles northeast of Lexington. Extensive outcrops occur at Echols Mill and are in every respect identical in color, texture, and mineral composition with the granite of the Swift & Wilcox quarry, near Elberton, in Elbert County. The light-gray type has not been quarried in Oglethorpe County.

Thin sections of the Echols Mill light-gray granite show the minerals to be potash feldspars (orthoclase and microcline), soda-lime feldspar (oligoclase), quartz, black mica (biotite), and a little white mica (muscovite), together with accessory apatite, zircon, and magnetite The biotite is partly altered to chlorite. A chemical analysis of this granite is given on page 225 (No. 1).

MEDIUM-GRAY GRANITE OF THE FAIRBURN-NEWNAN-GREENVILLE AREA.

GENERAL DESCRIPTION.

The medium-gray type of the Fairburn-Newnan-Greenville area traverses Campbell, Coweta, and Meriwether counties in a nearly north-south course, quarries being opened near Fairburn, Newnan, and Greenville, the respective county seats. A similar granite has been quarried in the vicinity of Griffin, Spaulding County, for strictly local use. Coarsely crystalline porphyritic granites and gneisses of essentially the same mineral and chemical composition as the even-granular type are found in intimate association with it over parts of Campbell, Coweta, and Meriwether counties.

The even-granular massive biotite granite of this area comprises two varieties. One, a medium-gray, is an average fine-textured rock; the other, a dark blue-gray granite occurring in the southwest part of Meriwether County, is more coarsely crystalline and darker in color and contains a larger proportion of biotite than the medium-gray type. Variation in color and texture of the even-grained granites in general is very slight over the area. In the northern part of the area, near Fairburn, the granite is somewhat lighter in color, and in the middle and southern parts, near Newnan and Greenville, it is correspondingly darker. This type is closely similar in mineral and chemical composition to the dark blue-gray of the Oglesby-Lexington area and the light gray of the Elberton–Echols Mill area described above, and is intermediate between the two in color and texture.

MICROSCOPIC CHARACTERS.

The primary constituents are orthoclase, microcline, plagioclase near oligoclase, quartz, biotite, a little muscovite, apatite, and zircon. Secondary epidote and chlorite from the alteration of feldspars and biotite are usually present. A few garnets have been noted in several places in the northern part of the area. The orthoclase is intergrown in part with a second feldspar, acidic plagioclase, as microperthite. Microcline is nearly absent in some places and is very abundant in others. Acidic plagioclase is a constant constituent and in some thin sections it equals or exceeds in amount the potash feldspars. Biotite is variable in amount and is everywhere the principal accessory. Muscovite, usually present in small quantity, is intimately associated with the biotite. Epidote occurs in irregular grains and is rather common as large idiomorphic crystals in thin sections of the granite from the Cole quarry, near Newnan.

CHEMICAL COMPOSITION.

The chemical composition of the granite from the Fairburn-Newnan-Greenville area is shown in the analyses below, which were made by the writer in the laboratory of the Georgia Survey:

Analysis of granite from the Fairburn-Newnan-Greenville area, Georgia.

	Carmichael.	Greenville Granite Co.	Cole.	Overby.	Hill.
Silica (SiO_2)	69.55	69.88	69.08	69.07	68.38
Alumina (Al_2O_3)	16.72	16.42	17.67	16.56	17.79
Iron oxide (Fe_2O_3)	.99	1.96	1.41	1.37	1.21
Magnesia (MgO)	.27	.36	.64	.76	.72
Lime (CaO)	1.69	1.78	3.27	1.83	1.76
Soda (Na_2O)	5.88	4.46	4.56	4.65	4.36
Potash (K_2O)	3.94	5.63	3.29	5.02	3.57
Ignition	.27	.36	.56	.92	.78
	99.31	100.85	100.48	100.18	99.66
Specific gravity	2.658	2.662	2.700	....	2.689

Considered singly, three of the analyses (Carmichael, Cole, and Hill quarries) show an excess of soda over potash, and the rock from these quarries is more properly designated quartz monzonite. In the two remaining analyses (Greenville Granite Company and Overby quarries) the soda content is quite large, but is inferior in amount to the potash. An average of the alkalies for the five analyses shows an excess of soda over potash of about 0.5 per cent, a fact which would group the even-granular acidic plutonic rocks of this area with the quartz monzonites. The high soda content in each of the analyses is a noteworthy feature.

ABSORPTION TEST.

The percentage of absorption of the granite of this area corresponds closely with that of the dark blue-gray and light-gray belt of Oglethorpe and Elbert counties described above. The percentage of absorption of the granite from the Greenville Granite Company's quarry in Meriwether County was found to be 0.086.

DESCRIPTIONS OF QUARRIES.

INTRODUCTORY STATEMENT.

Practically no systematic quarrying has been carried on in any part of the area. Five quarries have been worked as follows:

Quarries in the Fairburn-Newnan-Greenville area, Georgia.

Meriwether County:	
Greenville Granite Company	1 mile northeast of Greenville.
Coweta County:	
Hill	3¼ miles east of Newnan.
Cole	One-half mile east of Newnan.
Overby	10 miles east of Newnan.
Campbell County:	
Carmichael	2¼ miles N. 25° E. of Fairburn.

Practically none of the stone from this area has been marketed outside of the State. The granite is of homogenous color and texture, and is admirably adapted for general building and constructional work, and in places for monumental stock. It has been used locally for nearly all grades of work, such as buildings, monuments, cemetery coping and retaining walls, and railroad construction.

The openings are in bowlder and flat-surfaced exposures, the common form of outcrops. Most of the outcrops are of large dimensions and practically free from soil covering. The quarries are well located with reference to transportation by rail and admit of easy working. The most extensive areas of the granite and the largest quarries are mainly in Coweta and Meriwether counties. Jointing is not very conspicuously developed and the planes are always widely spaced, permitting the quarrying of dimension stone. Dikes of pegmatite and fine granite are rare, and the rock is generally free from deleterious minerals.

CAMPBELL COUNTY.

The *Carmichael quarry*, opened in an area of bowlder outcrops covering 10 to 15 acres, lies on the east side of the Altanta and West Point Railroad, about 2¼ miles N. 25° E. of Fairburn. It was opened in 1898 to supply stone for coping and monuments for the cemetery in Jacksonville, Fla. Thirty-five cars of the stone were shipped by June, 1899. The rock is a biotite granite of medium-gray color and even, fine grain. Its minerals are potash feldspar (orthoclase and microcline), soda-lime feldspar (oligoclase), quartz, black mica (biotite), and a little white mica (muscovite), with secondary chlorite, epidote, and a light-colored mica. A chemical analysis of this granite is given on page 229. A few pegmatite dikes of slight thickness cut the rock. The vertical joints strike northwest-southeast and their surfaces are slickensided, indicating some movement in the mass. The rock is susceptible of a high polish.

COWETA COUNTY.

The *Cole quarry* is opened in a flat-surfaced exposure of granite less than 1 acre in extent half a mile east of Newnan. It was opened about eighteen years ago and is worked to a depth of about 30 feet. The product has been used mostly for building purposes in the town of Newnan. The rock is a biotite granite of dark-gray color and medium-fine, even grain. Scattered folia of muscovite are visible to the naked eye. In the hand specimens the rocks resemble somewhat closely the dark-gray granite of Oglesby. The minerals are potash feldspar (orthoclase and microcline), soda-lime feldspar (oligoclase), quartz, black mica (biotite), and a little white mica (muscovite), with accessory apatite and zircon. The secondary minerals are chlorite, epidote, and a light-colored mica. Epidote occurs both in irregular grains and in platy form with partial crystal outline. Chemical analyses of the fresh and decayed granite gave the following results:

Analyses of granite from Cole quarry, Coweta County, Ga.

[T. L. Watson, analyst.]

Constituents.	Fresh.	Decayed.
Silica (SiO_2)	69.08	56.99
Alumina (Al_2O_3)	17.67	26.02
Iron oxide (Fe_2O_3)	1.41	1.91
Magnesia (MgO)	.64	.17
Lime (CaO)	3.27	.75
Soda (Na_2O)	4.56	1.91
Potash (K_2O)	3.29	2.40
Ignition	.56	9.76

The decayed rock extends to a depth of 15 feet below the surface. Within this zone the granite is sheeted, the sheets being thinnest near the surface and merging below into perfectly massive rock. The vertical joints strike east-west and north-south, the two sets having about equal development. There are numerous dikes of pegmatite, most of which strike north and south. Small areas of biotite chiefly (knots) occur.

The *Hill quarry*, opened in a ledge on the east side of White Oak Creek, is 3¼ miles nearly east of Newnan. It was first opened about 1888 to supply stone for the Central of Georgia Railway. The opening is only a few feet above stream level. The rock is a biotite granite of medium dark-gray color and medium-fine, even grain. Scattered shreds of muscovite are visible to the unaided eye. The minerals are potash feldspar (orthoclase and microcline), soda-lime feldspar (oligoclase), quartz, black mica (biotite), and a little white mica (muscovite), with accessory apatite and zircon. Chlorite and epidote occur as secondary minerals. A chemical analysis of this granite is given on page 229.

The vertical joints strike S. 35° E. Numerous thin dikes of a fine-grained biotite granite, striking approximately northwest to southeast, cut the main mass. The stone takes a good polish.

The *Overby quarry* is opened in a 2-acre flat-surfaced exposure 10 miles east of Newnan. Its long distance from the railroad has hindered its development. The small quantity of stone quarried was used for monument bases, sills to windows and doors, and retaining walls in cemeteries. The rock is a biotite granite of medium-gray color and medium-fine, even grain. It resembles very closely that from the Carmichael quarry in Campbell County (p. 230). It is a shade coarser in texture and lighter in color than that from the Cole and Hill quarries, described above. In mineral composition it is identical with these granites. A chemical analysis, made by the writer, is given on page 229.

MERIWETHER COUNTY.

The *Greenville Granite Company's quarry,* 1 mile northeast of the court-house at Greenville, is opened in a bowlder outcrop of granite. Similar outcrops extend over a considerable area. The product was used chiefly for cemetery and building purposes in Columbus, Ga. The rock is a biotite granite of dark blue-gray color and medium-fine, even grain. Scattered shreds of muscovite and Carlsbad twins of orthoclase are visible in the hand specimens. The minerals are potash feldspar (orthoclase and microcline), soda-lime feldspar (oligoclase), quartz, black mica (biotite), and a little white mica (muscovite), with accessory apatite, zircon, and rutile. The biotite is partly altered to chlorite. The orthoclase is intergrown with a second feldspar. Rounded areas of quartz and feldspar are inclosed in the larger grains of the two minerals. Chemical analyses of the fresh and decayed granite from this quarry gave the following results:

Analyses of granite from Greenville Granite Company's quarry, near Greenville, Ga.

[T. L. Watson, analyst.]

Constituents.	Fresh.	Decayed.
Silica (SiO_2)	69.88	51.29
Alumina (Al_2O_3)	16.42	29.69
Iron oxide (Fe_2O_3)	1.96	6.33
Magnesia (MgO)	.36	.14
Lime (CaO)	1.78	.07
Soda (Na_2O)	4.46	1.12
Potash (K_2O)	5.63	1.50
Ignition	.36	10.36

The specific gravity is 2.662 and the percentage of absorption is 0.086. This granite resembles very closely that quarried in the Oglesby area in Elbert County, described on pages 221–223, except that the latter is a shade darker in color and slightly finer grained. Both are susceptible of a high polish.

LIGHT-GRAY GRANITE OF STONE MOUNTAIN.

GENERAL DESCRIPTION.

The light-gray granite of Stone Mountain (map, fig. 19) is strongly contrasted with all other types of granite in Georgia. It differs from them in mineral composition in its large preponderance of muscovite over biotite, which, though invariably present, occurs in

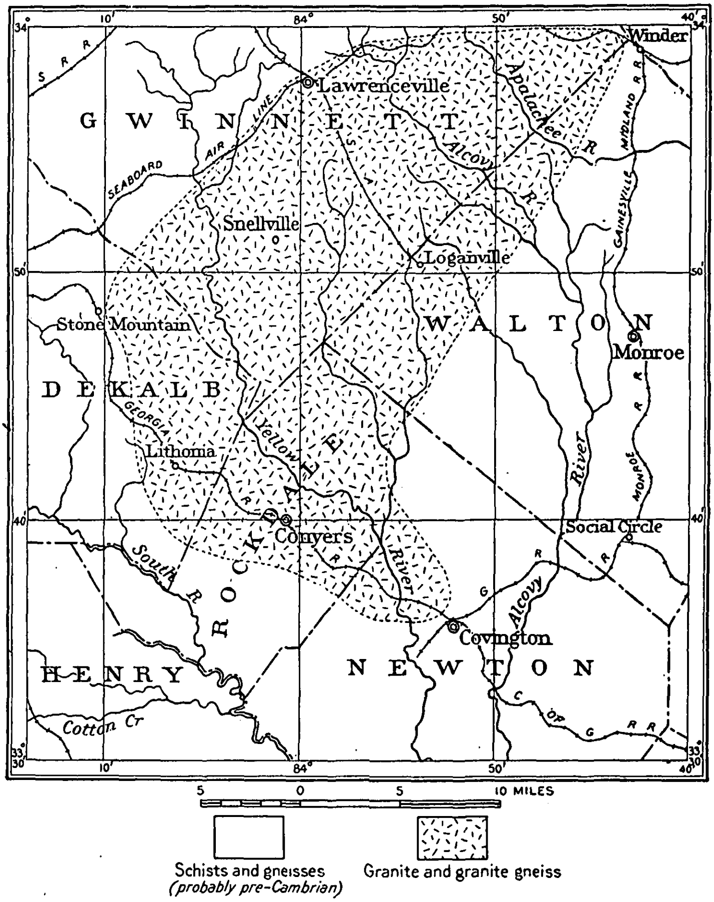


FIGURE 19.—Map of Stone Mountain and Lithonia-Conyers-Lawrenceville granite and gneiss area, Georgia.

very small quantity. The rock is therefore a biotite-bearing muscovite granite. It is uniformly light gray in color over the entire area, but in places shows slight variation in texture. It is intermediate between the other types of even-granular granites on the one hand and the coarsely crystalline matrix of the porphyritic granites on the other. The potash feldspars predominate, with orthoclase usually in excess of microcline. The orthoclase is locally intergrown with a second feldspar in micropeıthitic structure.

The microcline is subject to considerable variation in amount, equaling orthoclase in some sections and sinking to a minimum in others. Plagioclase is present in large amount as stout laths twinned on the albite law; the lamellæ usually give low extinction angles in basal sections. Micropoikilitic structure is developed in the larger feldspar individuals. The small quantity of biotite is intimately associated with the muscovite. Accessory apatite and zircon and some secondary chlorite occur.

Several minerals not usually seen in the sections of the granite from Stone Mountain are common constituents of the rock. The most abundant of these is black tourmaline, which is present in nearly every large block of the stone quarried. The tourmaline occurs rarely as single crystals distributed through the granite, but mostly as radiating and roughly parallel groups that occupy white areas of quartz and feldspar from which the two micas, muscovite and biotite, have been excluded. These quartz-feldspar areas vary from a fraction of an inch to several inches in diameter and from oblong to circular outlines. The tourmaline individuals are of slender prismatic form, varying from a fraction of a millimeter to several millimeters in cross section without terminal faces; they are jet black in color and are as a rule considerably fractured. These tourmaline areas are not sufficiently numerous in the granite nor large enough to affect the color of the rock, and, though clearly visible, they do not in any measure detract from the good qualities of the stone for general building purposes. Small crystals of red garnet are not uncommon. The surfaces of some of the joints are thinly incrusted with a mixture of uranophane and hyalite.

At Constitution, about 6 miles southeast of Atlanta and about 12 miles southwest of Stone Mountain, is a second exposure of a biotite-bearing muscovite granite of light-gray color and fine grain. A small quantity of the rock has been quarried and used chiefly for monuments. It consists of the same minerals in the same proportions as at Stone Mountain. Intergrowths of quartz and feldspar are common. The prismatic inclusions of apatite are in places bent and broken, indicating pressure effects on the granite mass.

CHEMICAL COMPOSITION.

The composition of the granite of Stone Mountain is shown in analyses 1 and 2, below; analysis 3 is that of an aplite which intersects the granite.

Analyses of granite from Stone Mountain, Georgia.

Constituents.	1.	2.	3.
Silica (SiO_2)	72.56	71.66	74.30
Alumina (Al_2O_3)	14.81	16.05	14.73
Iron oxide (Fe_2O_3)	.94	.86	.78
Magnesia (MgO)	.20	.17	Trace.
Lime (CaO)	1.19	1.07	.90
Soda (Na_2O)	4.94	4.66	4.61
Potash (K_2O)	5.30	4.92	4.52
Ignition	.70	1.00	.21
Phosphoric oxide (P_2O_5)	Not det.	Not det.	Trace.
	100.64	100.39	100.05

1. Fresh granite, Stone Mountain, Georgia. R. L. Packard, analyst.
2. Granite spall exposed for three or four years, Stone Mountain, Georgia. R. L. Packard, analyst.
3. Aplite, Stone Mountain, Georgia. T. L. Watson, analyst.

PHYSICAL TESTS.

Four crushing-strength tests of 2-inch cubes of granite from Stone Mountain gave 85,000, 50,325, 48,760, and 65,610 pounds, equivalent to 21,250, 12,581, 12,190, and 16,402 pounds per square inch. A similar series of strength tests made in 1890 at Purdue University, Lafayette, Ind., gave 12,438, 14,425, 12,904, 13,190, 13,406, and 12,726 pounds per square inch. Another series of tests made at the Watertown Arsenal gave 25,630 and 28,130 pounds per square inch, on bed.

DESCRIPTION OF QUARRIES.

In addition to the Stone Mountain quarries, which are the most extensive in the State, about half a dozen small quarries have been worked nearby in the adjacent lowland belt of the same granite. All the quarries opened in the Stone Mountain type of granite are located in Dekalb County. The quarries in this area are listed below.

Dekalb County, Ga., quarries in the light-gray granite near Stone Mountain.

Constitution[a]	6 miles south of Atlanta.
Nash & McCurdy	3 miles east of Stone Mountain.
Shepard	2½ miles south of Stone Mountain.
Stone Mountain	1 mile east of Stone Mountain.
Thomas	6 miles southeast of Stone Mountain.
Thompson	2 miles northeast of Stone Mountain.
Veal	3 miles east of Stone Mountain.
Wiggins	1 mile north of Redan.

Stone Mountain, which is a huge doming ridge of granite (Pl. XXV, *A*), is situated about 16 miles east of Atlanta in Dekalb County. It is an elliptical boss, with its longer axis trending northeast and southwest and its steepest side facing northward. It rises 686 feet above the adjacent lowland plain of crystalline rocks, and measures 7 miles in circumference around its base. The present ridge is the

[a] The Constitution granite quarry is not in the Stone Mountain area, but is listed here because it is located in Dekalb County.

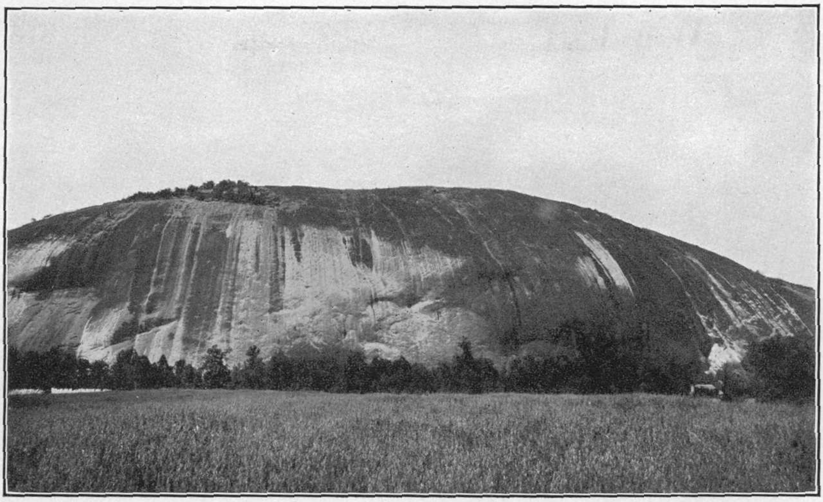
unreduced remnant of a much larger granite mass. The evidence favoring this conclusion is the fact that a belt of the same granite reduced to the general level of the surrounding Tertiary Piedmont plain skirts the north, west, and south sides of the ridge with a width varying from a quarter of a mile to more than a mile.

The granite of Stone Mountain and the granite gneiss of the adjacent Lithonia area in the same county have had the widest distribution and are the best known of the Georgia granites outside of the State. From the time of their first opening, prior to the civil war, to within the last few years the quarrying of stone in these two areas formed practically the whole granite industry in Georgia. These are the largest granite quarries in Georgia and they yield a much larger output than any other areas in the State.

Numerous quarries yielding an excellent light-gray granite are worked along the western and southern flanks of the ridge. (See Pl. XXV, *B*.) The stone has been used most extensively for general building purposes, and almost as largely for street material in the form of blocks and curbing. Its very light color makes it undesirable for monument stock. It has been marketed in the principal towns and cities in the South and West.

The doming mass is apparently formed of sheets of varying thicknesses, with no visible lines of separation except at the surface, where the granite has been subjected to weathering. The sheets conform in general to the present surface of the boss. They are cut by two sets of vertical joints, which, in connection with the slope, afford superior facilities for easy quarrying. The vertical joints are widely spaced and intersect at approximately right angles, but jointing is not a conspicuous feature. Slickensides on the joint surfaces indicate subsequent movement. The rock is further cut by pegmatite dikes, which vary in width from a fraction of an inch to 18 inches. In addition to the coarsely crystallized feldspar and quartz composing these dikes, mica, tourmaline, and garnet occur, in places concentrated along the central portion of the dike rather than distributed through the light-colored quartz-feldspar portions. Several aplite dikes less than 6 inches in width, banded with pegmatite, are exposed in the quarries on the northwest side of the mountain. The table of analyses (p. 235) shows that the aplite of the Stone Mountain boss contains equal potash and soda.

Every facility in the way of modern equipment for work, such as engines, boilers, steam drills, and other appliances and machinery, is in use at Stone Mountain. About 8 miles of railway are operated from the main line of the Georgia Railroad at Stone Mountain station to and around the base of the ridge. The equipment is probably equal in all essentials to that of the larger quarries in the East, and renders the company abundantly able to handle stone of any desired



A. STONE MOUNTAIN, A GRANITE DOME, DEKALB COUNTY, GA.

B. STONE MOUNTAIN QUARRIES, STONE MOUNTAIN, DEKALB COUNTY, GA.

dimensions and shape. As opened in 1893, the Stone Mountain quarries were capable of yielding 25,000 paving blocks a day. At present this can be increased to any desired output.

ISOLATED AREAS OF EVEN-GRAINED GRANITE.

Putnam, Spaulding, Warren, and Wilkes counties contain even-granular granites which belong to one or the other type of biotite granites described above. These are of future commercial importance and should therefore be noted. In each place a little of the stone has been quarried for local purposes. The granites are closely similar in mineral and chemical composition and range from light to dark blue-gray in color and from medium-coarse to fine grained in texture. Muscovite is sparingly present in the granite of Spaulding and Putnam counties. The location and general properties of these granites may be briefly summarized as follows:

Just beyond the northern limits of Griffin, Spaulding County, several very small openings are made in a biotite granite of light-gray color and medium-coarse grain. A little muscovite occurs in the rock, a chemical analysis of which is given below.

The *Linch quarry*, 4 miles west of Eatonton, Putnam County, is opened in a biotite granite of dark blue-gray color and even, fine grain. Scant muscovite is associated with the biotite. The granite is susceptible of a high polish and is entirely suited for monumental stock. It resembles the dark blue-gray granite of the Oglesby-Lexington area. A chemical analysis of the stone is given below.

Analyses of granite from Putnam and Spaulding counties, Ga.

Constituents.	Putnam County.	Spaulding County.
Silica (SiO_2)	69.34	69.07
Alumina (Al_2O_3)	17.01	16.56
Iron oxide (Fe_2O_3)	1.74	1.37
Magnesia (MgO)	.61	.76
Lime (CaO)	2.77	1.83
Soda (Na_2O)	4.69	4.66
Potash (K_2O)	4.54	5.02
Ignition	.26	.92

The specific gravity is 2.701 and the percentage of absorption is 0.060.

In Warren County, 2 miles southeast and 7½ miles east of Warrenton, are large areas of biotite granite of light-gray to dark blue-gray color and fine grain. This area extends eastward into McDuffie County.

Two miles south of Washington, Wilkes County, a biotite granite of medium-gray color and medium-coarse grain has been opened. A schistose structure is indicated in places.

PORPHYRITIC GRANITES.

GENERAL STATEMENT.

Associated with the even-granular granites within the Georgia Piedmont region are a number of coarse-textured porphyritic granites. The distribution of the principal areas of porphyritic granite is shown on the accompanying map (fig. 20.) These are (A) the area in Campbell, Coweta, and Fayette counties; (B) the Pike County area; (C) the Fulton County area; (D) the Brinkley Place–Holders Mill area; (E) the Sparta area; (F) the Milledgeville area; (G) the Greene County area; and (H) the Columbia County area.

Except in the Sparta area, the porphyritic granite has been only sparingly quarried, and then to supply a strictly local demand. The

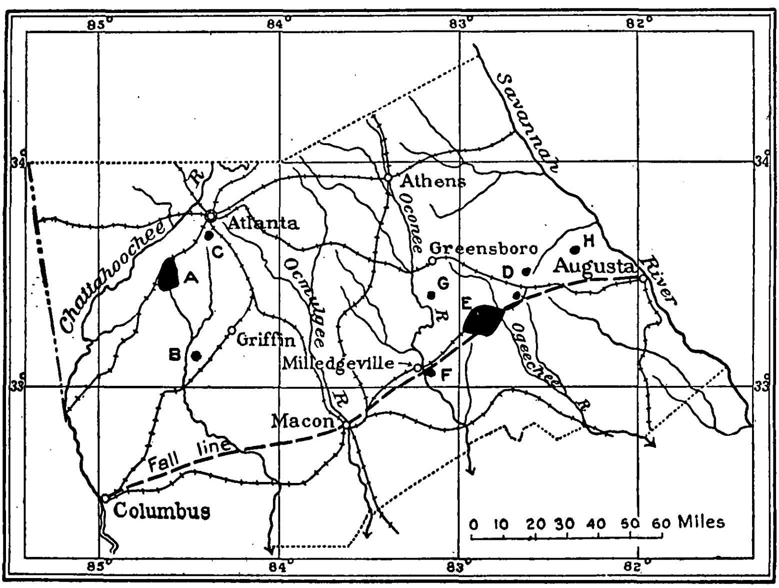


FIGURE 20.—Map of Piedmont Georgia, showing areas of porphyritic granite.

areas in Greene and Columbia counties are too remote from lines of transportation to be of commercial importance. The granite exposures are in the nature of bowlders and flat-surfaced or low doming masses, usually of large size.

Certain general features are common to all the porphyritic granites, although the rocks are strongly contrasted in some of the areas. With one exception they are massive, without, as a rule, visible evidence of primary or secondary foliated structure. The exception is in the Brinkley Place–Holders Mill area, where the rock has a pronounced schistose structure, induced by pressure metamorphism. The porphyritic granites are prevailingly of light to dark gray color, according to the amount of biotite present, and of coarse grain.

The same textural and structural characteristics and relationships are generally developed in each of the areas of porphyritic granite. Gradation from one rock facies (porphyritic) into the other (even granular) was not sharply defined in every area, owing, perhaps, to a lack of sufficient exposures, but it could be easily traced in many of them.

MICROSCOPIC CHARACTERS.

Microscopically, the rocks are as nearly identical as it is possible for rocks of separate areas to be. They all contain the same minerals, both essential and accessory, in nearly the same proportions. They are composed of admixtures of the feldspars and quartz, in which lie stout plates of biotite.

The groundmass is a coarse-grained biotite granite, the essential constituents of which measure 3 to 8 millimeters. Microcline is subject to more variation in amount than in the even-granular granites described above, and plagioclase is slightly increased. The plagioclase shows roughly lath-shaped outlines and as a rule the extinction angles indicate an acidic feldspar near oligoclase. The ratio of lime to soda in the analyses given on page 240 corroborates the inference. Orthoclase shows microperthitic intergrowths with a second feldspar, probably albite. Intergrowths of quartz and feldspar, present in all the thin sections, afford evidence of simultaneous crystallization of a part of the feldspar and quartz. Micropoikilitic feldspars, from inclusions of quartz principally, are abundant. Biotite, intergrown with occasional foils of muscovite, is the chief accessory and varies somewhat in quantity for the individual areas. Apatite, zircon, and magnetite occur as accessories. A little chlorite, epidote, and light-colored mica are present as constant secondary products from the alteration of the biotite and feldspars. Many of the thin sections show the effects of pressure metamorphism in the nature of crushing, lines of fracture, and undulatory extinction common to some of the larger quartz-feldspar individuals.

The potash feldspars are the only porphyritically developed minerals. They are usually opaque and white in color, but pink tints are common. They vary from 10 to 15 millimeters in length and from 5 to 10 millimeters in width, and show further variation from allotriomorphic (without crystal faces) to idiomorphic (with crystal faces) individuals. The idiomorphic type prevails and is flat tabular, parallel to the clinopinacoid, with (001) and (101) cleavages well developed. The feldspars display the usual habit of simple Carlsbad twins. As a rule the phenocrysts are very conspicuous and are readily differentiated from the groundmass feldspar; although in Campbell, Coweta, and Fayette counties the phenocrysts and a portion of the groundmass feldspars seemingly grade into each other. The phenocrysts invariably contain inclusions of all the groundmass minerals, and this, with other evidence, indicates simultaneous growth with the interstitial components. The included biotite plates are macroscopic in size and in many places the included mica is as large as the same groundmass mineral. The inclusions are distributed through the phenocrysts without regard to definite arrangement. Analyses of feldspar phenocrysts from two of the Georgia areas are given below (Nos. 9 and 10).

CHEMICAL COMPOSITION.

The marked uniformity in the mineral composition of the various porphyritic granites from the widely separated areas suggests similar uniformity in chemical composition. The usual amount of free quartz common to this class of rocks and the abundance of potash feldspar, with increased amounts of plagioclase and proportionally small amounts of accessory minerals, indicate a normal percentage of silica and lime, an increased percentage of alkalies, and comparatively small amounts of iron and magnesium oxides. These inferences are well shown in the analyses given below. Attention is called to the prevailingly high percentage of soda shown. In nearly half of the analyses the soda is slightly in excess of the potash and in the remainder it nearly equals or is but slightly less than the potash, a proportion which allies these rocks, like the even-granular granites, with quartz monzonites. This high range in soda is traceable primarily to the large amount of acidic plagioclase; second, to the microperthitic intergrowths of acidic plagioclase with the potash feldspars present in the rocks; and last, to the partial replacement of potash by soda in the straight potash feldspar (analyses 9 and 10). A comparison of these analyses with those of the even-granular granites (pp. 220, 225, 229, 235, 237) shows very close agreement.

Analyses of the Georgia porphyritic granites.

	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.
SiO_2	70.90	70.88	70.24	69.77	69.48	69.37	69.17	69.13	64.64	64.40
Al_2O_3[a]	15.86	15.86	16.78	17.05	16.64	16.99	16.47	17.14	19.64	18.97
Fe_2O_3[b]	1.37	1.77	1.46	1.60	1.84	1.99	1.23	1.52	.37	.37
MgO	.02	.93	.76	.99	.29	.84	.61	.79	Tr.	Tr.
CaO	2.15	1.79	2.00	2.21	2.32	2.93	2.02	1.85	.67	.59
K_2O	4.62	4.64	5.03	4.08	4.49	4.54	4.41	5.49	10.00	11.40
Na_2O	5.05	3.94	3.70	3.97	4.74	3.44	4.89	4.06	3.06	3.60
Ignition	.50	.49	.50	.44	.46	.55	1.06	.52	.22	.19
	100.47	100.30	100.47	100.11	100.26	99.75	99.85	100.50	98.60	99.52

[a] Contains traces of P_2O_5 and ZrO_2. [b] All iron was determined as Fe_2O_3.

1. Georgia Quincy Granite Company's quarry, near Sparta, Hancock County.
2. McElwaney place, near Line Creek, Fayette County.
3. Flat (Cedar) Rock, 9 miles west of Zebulon, Pike County.
4. Heggie Rock, 3 miles east of Appling, Columbia County.
5. Sparta quarry, Hancock County.
6. Calloway place, 3 miles southeast of Milledgeville, Baldwin County.
7. Moseley quarry, 6 miles south of Atlanta, Fulton County.
8. Porphyritic granite area, 10 miles south of Greensboro, Greene County.
9. Feldspar phenocrysts from Heggie Rock, Columbia County.
10. Feldspar phenocrysts from McCollum place, Coweta County.

PHYSICAL TESTS.

Tests to determine specific gravity, ratio of absorption, weight per cubic foot, and number of cubic feet of stone contained in 2,000 pounds were made on the porphyritic granites as follows:

Physical tests of porphyritic granites.

Quarry.	Specific gravity.	Ratio of absorption.	Weight per cubic foot (pounds).	Cubic feet of stone in 2,000 pounds.
Charley Rocker, Hancock County	2.687	0.037	167.93	11.9
Georgia Quincy Granite Company	2.664		166.50	12.0
Mallally, Hancock County		.049		
Heggie Rock, Columbia County	2.674		166.87	11.9
McElwaney, Fayette County	2.659		166.18	12.0

DESCRIPTION OF INDIVIDUAL AREAS.

CAMPBELL, COWETA, AND FAYETTE COUNTIES.

The area occupying contiguous portions of Campbell, Coweta, and Fayette counties, marked A on the accompanying map (fig. 20), lies 30 miles southwest of Atlanta. The outcrops are usually small and in the nature of bowlder and flat-surfaced masses. The exposures are most numerous in the vicinity of Palmetto and Coweta, stations on the Atlanta and West Point Railroad, and near Line Creek, in Fayette County. Specimens of the porphyritic granite collected from the outcrop near Line Creek are somewhat lighter in color than similar ones from the Palmetto and Coweta areas. The ratio of quartz to biotite in the Line Creek outcrop is visibly greater than in the exposures in Campbell and Coweta counties. The rock, however, is generally rather uniform over the entire area. Several good contacts of the partly decayed porphyritic granite and mica schist are exposed along the wagon roads and in the cuts of the railroad traversing the area. The field relations of the two rocks indicate that the porphyritic granite is the younger rock, intruded into the overlying schist and exposed subsequently by erosion.

The granite is a porphyritic granite of medium-light to dark gray color and coarse grain. Its extreme coarseness renders the porphyritic texture less pronounced in this than in the finer-grained porphyritic granites. The porphyritically developed mineral (feldspar) grades imperceptibly from very large, irregular, locally stout, tabular phenocrysts into the smaller feldspars of the groundmass, making it difficult usually to distinguish between groundmass and phenocryst feldspar.

The feldspar phenocrysts vary from extremely irregular cleavable grains, anhedra 30 by 30 millimeters in size, to roughly idiomorphic crystals, tabular, parallel to the clinopinacoid (010), and twinned on the Carlsbad law. Abundant inclusions of large irregular plates of biotite are readily visible to the unaided eye, in all the phenocrysts. The phenocrysts are prevailingly allotriomorphic and differ in this respect from those of the other areas described below. The feldspars are white in color, as a rule partly cloudy or opaque rather than limpid in appearance. The porphyritically developed minerals are composed of both orthoclase, with microperthitic structure, and microcline usually inclosing inequidimensional grains of quartz, feldspar, and biotite, without orientation. The more basic inclusions, accessory apatite and zircon, are also contained in the phenocrysts.

A thin section of one of the feldspar phenocrysts from the Coweta portion of the area shows the characteristic microcline structure and contains abundant inclusions of irregularly bounded crystals of feldspar, quartz, and biotite; several rounded disks or ovals of intergrowths of quartz and feldspar; and prismatic needle-like inclusions of apatite and zircon. A chemical analysis of fragments of carefully selected phenocrysts from hand specimens of the Coweta outcrops of the rock is given on page 240 (No. 10).

The porphyritic granites from Anson and Richmond counties and those from Mount Monroe, Iredell County, N. C., closely resemble in color and texture the porphyritic granite of Campbell, Coweta, and Fayette counties in Georgia. The phenocrysts in the North Carolina granite are usually without crystal boundaries (allotriomorphic) and as a rule are large and contain numerous plates of included biotite. A similar rock, though darker colored because of the larger amount of biotite present, occurs in Aiken County, S. C. The porphyritic feldspars in the Aiken County granite present the same characteristics as the phenocrysts of the Georgia and North Carolina porphyritic granites.

The granite of the Georgia locality has been opened in a number of places where a little stone has been quarried to supply a purely local demand.

PIKE COUNTY.

The Pike County granite area, marked B on the map (fig. 20), includes 50 acres or more of exposed flat-surfaced rock in the northwestern part of the county. The porphyritic facies of the rock gradually passes into the even-textured granite. Only a small proportion of this area, however, shows the porphyritic texture. The rock is a biotite granite of medium-gray color and medium grain. It varies from even granular to porphyritic in texture, and shows in places a partial gneissoid structure. The phenocrysts consist of the potash feldspars, orthoclase and microcline, measuring 10 to 30 millimeters long and 5 to 10 millimeters broad, flat tabular, and parallel to the clinopinacoid (010). Carlsbad twinning is common. Inclusions of biotite as large as that occurring in the groundmass are very abundant in the phenocrysts, which contain, in addition to the biotite, microscopic inclusions of irregularly bounded crystals of the interstitial quartz and feldspar.

The granite has not been quarried, except that now and then a surface "raise" is made, and some stone is obtained for chimneys and foundations for houses in the immediate neighborhood. The stone can be easily quarried, and is of good quality.

FULTON COUNTY.

The porphyritic granite of the Fulton County area, marked C on the map (fig. 20), is exposed in bowlder form over a large territory 6 miles south of Atlanta, in the extreme southern part of the county. The gradation from the interior porphyritic facies, peripherally, into an even-textured granite of the same color and texture and having the same mineral and chemical composition is more gradual and more strikingly shown in this than in any of the areas previously described.

Near the center of the granite mass the phenocrysts compose more than 50 per cent of the rock and near the center the phenocrysts usually show crystal outline (idiomorphic), but in the transition zone of the granite mass they are allotriomorphic (without crystal outline).

The granite consists of a medium-coarse groundmass of quartz, the potash feldspars (orthoclase and microcline), numerous laths of twinned plagioclase, biotite, and some muscovite, in which are embedded large potash-feldspar phenocrysts. Accessory apatite, magnetite, and zircon and the alteration products chlorite, kaolin, and light-colored mica are noted. Some of the feldspars and biotite are considerably altered. Microcline and orthoclase are porphyritically developed and measure 15 to 50 millimeters in length. The phenocrysts possessing idiomorphism (crystal outline) usually display the Carlsbad twinning and are elongated in the clinopinacoidal direction.

A thin section of one of the phenocrysts showed the characteristic microcline structure and numerous inclusions of quartz, biotite, and the groundmass feldspars, which measure as much as 1 millimeter. Prismatic crystals of apatite and zircon, as inclusions in both the phenocrysts and the included groundmass feldspars of the porphyritic crystals, are numerous. The zircon crystals are in places grouped in threes, much after the manner of penetration twins.

Quarrying in this area has been confined to the working up of a few large bowlders, but the accessibility and good qualities of the stone should give it future importance.

WARREN COUNTY.

Two somewhat extensive outcrops of foliated porphyritic biotite granite occur in the middle portion of Warren County, approximately 10 miles from each other in an almost east-west direction. These are known as the Holders Mill and Brinkley Place granite masses, and are marked D on the map (fig. 20).

The rock has a pronounced secondary foliated structure. The quartz and feldspar crystals are drawn out and inclosed between the biotite layers, forming in places distinct augen of the two light-colored minerals. The rock contains abundant black biotite plates arranged along somewhat parallel lines. The quartz and feldspar grains are greatly squeezed and mashed, and are more or less drawn out in directions parallel with the biotite layers, as a result of pressure metamorphism. The foliated structure is derived or secondary and not primary.

The feldspar phenocrysts are composed principally of microperthitic orthoclase, with some microcline 15 to 20 millimeters long, are opaque white to pink in color, contain numerous inclusions of biotite plates, and exhibit the usual habit of Carlsbad twins. They are prevailingly irregular in crystal outline and badly fractured from subsequent intense metamorphism. They are embedded in a coarse-grained groundmass of quartz, feldspar, and biotite. The groundmass feldspathic constituent consists of the potash feldspars, with microperthitic structure, and some laths of plagioclase near oligoclase. The large feldspar individuals (phenocrysts) contain inclusions of irregularly bounded crystals of quartz, biotite, and other feldspar species. These inclusions are usually round or oval in outline. Peripheral shattering from pressure effects of the larger feldspar and quartz crystals is pronounced. Intergrowths of quartz and feldspar are common. Biotite occurs as grouped shreds and plates altered to chlorite and here and there to epidote. A few scattered grains of magnetite are observed.

Still a third exposure of granitoid rock showing a pronounced porphyritic texture in places lies 6 to 8 miles south of the Brinkley Place–Holders Mill area. It differs greatly from the granite of that area in having a less strongly marked and finer-grained porphyritic texture, in containing less biotite, and in being massive instead of foliated in structure; it also contains a larger proportion of plagioclase and a smaller percentage of microcline. This area is entirely undeveloped.

HANCOCK COUNTY.

A coarse-grained porphyritic granite outcrops a quarter of a mile east of Sparta depot, Hancock County, and the exposures are more or less continuous from this point for 11 miles in a northeast direction along the Georgia Railroad, extending from Sparta to Mayfield station. This area, marked E on the map (fig. 20), lies near the passage of the crystalline rocks beneath the Coastal Plain sands and clays (the "fall line") and is the only producing area of porphyritic granite in Georgia. It is elliptical in shape, with its longer diameter trending northeast and southwest for 11 miles. The granite outcrops as bowlder and flat-surfaced masses, covering as much as 4 to 5 acres in a single exposure. The area is traversed by the Macon branch of the Georgia Railroad, which affords ample facilities for shipping.

The rock is generally porphyritic, grading in many localities into a nonporphyritic, even-grained granite of the same mineral and chemical composition. In several places the porphyritic texture almost wholly disappears and the rock grades into a coarse-grained biotite granite. In a number of quarries the rock shows in places a somewhat pronounced gneissoid structure. Joints are not conspicuous in any of the quarries and are everywhere widely spaced. Pegmatites cut the granite in several of the quarries.

The rock is prevailingly a coarse-grained, medium-gray porphyritic biotite granite. The phenocrysts are composed of the potash feldspars, having a pronounced pinkish cast, which appears in the thin sections. They are flat tabular in crystal form, averaging 20 millimeters in length parallel to the clinopinacoid (010). Carlsbad twins are common. The phenocrysts are further characterized by numerous inclusions of the principal groundmass minerals.

The porphyritic feldspars are embedded in a coarse-grained groundmass of quartz, potash and soda-lime feldspars, and biotite, with some accessory muscovite, chlorite, apatite, zircon, epidote, and scattered grains of magnetite. Microperthitic structures are common to the potash feldspars. Intergrowths of quartz and feldspar are less frequently observed than in some other areas. The rock of the Hancock County area differs from that of Campbell, Coweta, and Fayette counties in containing less biotite and hence being lighter in color, and in that the phenocrysts are idiomorphic instead of allotriomorphic and are usually of a pinkish cast rather than white. Microcline is likewise variable for the two areas in thin sections of the rock examined from various places.

Like the rock in the Campbell-Fayette area, the porphyritic granite of Sparta is surrounded on all sides by mica schist; but the great depth of residual decay of the granite and schist prevents exposures of the contact between the two. The field relations indicate, as in the other area, that the granite is the younger rock, intrusive into the then overlying schist.

The chemical composition of the granite from this area is shown in analyses 1 and 5, page 240. The percentage of absorption is small, as indicated on page 241. The granite has had an extensive use in Georgia and several of the adjoining States, principally for street purposes, as in Belgian blocks and curbing. It has been used to some extent as a building stone and occasionally for monuments.

A number of quarries have been worked somewhat extensively within several miles northeast of Sparta. These are listed below.

Quarries in the Sparta area, Hancock County, Ga.

	Miles northeast of Sparta.
Charley Rocker	3½
Georgia Quincy Granite Company	2
Mackin	1¾
Mallally	¾
Old Rocker	3¼

The *Charley Rocker quarry*, about 3½ miles northeast of Sparta and three-quarters of a mile north of the Georgia Railroad, is opened in a flat-surfaced exposure of the granite. It has been worked to a depth of less than 20 feet. The product is used principally in the form of blocks for street paving. The rock is a porphyritic biotite granite of light gray color and coarse grain. A chemical analysis of the granite is here given for reference:

Analysis of granite from Charley Rocker quarry, near Sparta, Ga.

Silica (SiO_2)	67.62
Alumina (Al_2O_3)	16.29
Iron oxide (Fe_2O_3)	2.31
Magnesia (MgO)	.78
Lime (CaO)	2.37
Soda (Na_2O)	5.42
Potash (K_2O)	4.58
Ignition	.32

The specific gravity is 2.687, and the percentage of absorption is 0.037.

The *Georgia Quincy Granite Company's quarry* is half a mile south of the Georgia Railroad and about 2 miles northeast of Sparta, in a large flat-surfaced exposure of granite. Three acres or more have been stripped. The product is used principally for street work in the form of blocks and curbing and to a minor extent in buildings. The rock is a porphyritic biotite granite of medium-gray color and coarse grain. A gneissoid structure is discernible in places. Vertical joints of wide spacing and a few pegmatite dikes several inches wide intersect the granite. The joint surfaces are slickensided from subsequent movement in the granite mass. A chemical analysis of the granite is given on page 240 (No. 1); and the results of physical tests on page 241.

The *Mackin (Sparta) quarry*, a quarter of a mile north of the Georgia Railroad and about 1¾ miles northeast of Sparta, is a small opening. The rock is a porphyritic biotite granite of medium-gray color and coarse grain. The opening exposes a 9-foot dike of dark-gray, fine, even-grained granite penetrating the porphyritic granite.

The *Mallally* (*Sparta*) *quarry*, a quarter of a mile north of the Georgia Railroad and about three-quarters of a mile northeast of Sparta, is opened in a flat-surfaced outcrop. It has been worked to a depth of 25 feet in places. The rock is a porphyritic biotite granite of medium-gray color and coarse grain. It is difficult to distinguish in hand specimens from the Georgia Quincy Granite Company's rock. A chemical analysis of the granite is given on page 240 (No. 5); and the results of physical tests on page 241. The rock is cut by an east-west set of vertical joints, and by a dike several feet wide of very fine textured, dark blue-gray biotite granite. It contains a few dark-colored segregations (knots).

The *Old Rocker quarry*, one of the first quarries opened in the area, is about a quarter of a mile northwest of the Charley Rocker quarry, described above. The granite is exposed in ledge form over several acres of ground. Considerable quarrying has been done and the product was used as blocks and curbing for street work. The rock is a biotite granite of light-gray color and even, coarse grain. It differs in texture from the granite of the other quarries in the area in being even granular instead of porphyritic and in containing less of the black mica (biotite).

BALDWIN COUNTY.

Large bowlder outcrops of coarse-grained porphyritic granite occur 3 miles southeast of Milledgeville, the county seat of Baldwin County. Like the rock of the Hancock County area, the Baldwin County porphyritic granite mass is located near the line of contact between the Piedmont crystalline rocks and the Coastal Plain sediments (area marked F on the map, fig. 20).

A part of the granite used in the construction of the old state capitol at Milledgeville, now the State Normal and Industrial College, was quarried from this area. No regular quarries have been opened and no recent quarrying has been done.

Hand specimens of the granite from Baldwin County are indistinguishable from similar specimens of the Columbia County porphyritic mass, described below. The rock is a very coarse grained porphyritic granite, composed of an aggregate of interlocking quartz and feldspar—orthoclase with microperthitic structure, microcline, and plagioclase—with intergrown shreds of biotite. It varies in color from medium to dark gray. Both microcline and orthoclase occur in the groundmass and as porphyritically developed minerals. The larger phenocrysts are 30 to 40 millimeters long and 5 to 10 millimeters broad. They are prevailingly idiomorphic (with crystal faces) in form, flat tabular parallel to the clinopinacoid (010), and commonly twinned on the Carlsbad law. Abundant inclusions of black biotite folia are plainly visible to the unaided eye in the feldspar phenocrysts, and numerous additional irregularly bounded quartz and feldspar grains without definite orientation are shown by the microscope.

The groundmass is composed of an abundance of white, opaque feldspars, dark-colored smoky quartz, and biotite plates measuring 2 to 5 millimeters in diameter. The accessories are apatite, zircon, and scattered grains of magnetite, with some secondary light-colored mica, chlorite, and epidote derived from the alteration of the feldspars and biotite. Bent and curved filaments of rutile are abundant in the larger quartz grains. The effects of slight pressure metamorphism are evident in the lines of fracture and undulous extinction common to the larger quartz and feldspar individuals.

GREENE COUNTY.

The Greene County porphyritic granite area, marked G in figure 20, includes at least 100 acres in the main outcrop, located 10 miles south of Greensboro, in the southern part of the county. The main central exposure is in the form of a low, flat-doming mass with a roughened and irregular surface, partly covered with a thick growth of cedars.

An even-granular granite of medium-coarse grain outcrops in bowlder form 3 miles south of Greensboro, and is continuous along the public highway from this point to the main porphyritic mass. The even-granular texture grades interiorly into the typical porphyritic texture. The even-granular granite apparently varies in mineral composition from place to place along the north-south section. A zone 2½ miles north of the porphyritic area shows absence of all trace of porphyritic texture, but is a medium-grained biotite granite agreeing, microscopically, in mineral and in chemical composition with the porphyritic granite. Five miles north of the central porphyritic mass are outcrops of a coarse but close, compact-grained granite, containing only a very small amount of biotite. The feldspars show pronounced pink and greenish tints. About 4 miles south of Greensboro, on the north side of Beaver Dam Creek, is an outcrop of practically the same granite. The quartz is decidedly dark in color and of the smoky variety; the feldspars are flesh colored, and the rock contains but little mica.

The porphyritic facies of the rock consists of a coarse-grained light-gray groundmass of quartz, feldspar, and biotite, in which are embedded large, flat-tabular feldspar phenocrysts. The porphyritic feldspars average 30 to 50 millimeters in length and 10 to 15 millimeters in breadth, and indicate the usual elongation parallel to the clinopinacoid (010) and Carlsbad twinning. The phenocrysts are deep pink to perfectly white in color and are mostly cloudy and opaque in appearance.

A thin section of one of the phenocrysts under the microscope showed the feldspar variety microperthitic orthoclase. The microscope further revealed abundant inclusions of fairly large grains of feldspar, twinned in several places after the albite and Carlsbad laws, and of quartz and biotite having partial orientation with the (010) cleavage. As a rule, however, the inclusions are not oriented. The biotite inclusions are sufficiently large to be visible to the unaided eye.

The ratio of phenocrysts to groundmass is variable, the probable extremes being 1 to 1 and 2 to 1, with all gradations between. The individual mineral grains range from a few millimeters to 5 or 6 millimeters in size. The arrangement of phenocrysts in some small portions of the mass is suggestive of fluxion structure.

The potash feldspars, orthoclase, and microcline are the porphyritically developed minerals. The orthoclase contains numerous microperthitic structures. Plagioclase is abundant. Small rounded disks or ovals of intergrown quartz and feldspar are common. The larger feldspar and quartz crystals indicate slight peripheral shattering in some of the thin sections.

The biotite is considerably altered to chlorite and some epidote, and some of it carries inclusions. Scattered grains of magnetite and prismatic inclusions of apatite and zircon are present.

Remoteness from lines of transportation has precluded development of this area. A few stones have been stripped from time to time from several of the surface ledges and used in the construction of some of the county homes.

COLUMBIA COUNTY.

The Columbia County area, marked H on figure 20, lies near the fall line (the contact between the Piedmont crystalline rocks and the Coastal Plain sediments), a short distance west of the South Carolina boundary.

About 1¾ miles east of Appling, the county seat of Columbia County is an outcrop of coarse-grained porphyritic granite. The feldspars are slightly pink in color, with a somewhat greenish cast in places. The phenocrysts measure 20 to 35 millimeters in length and 5 to 15 millimeters in breadth, and commonly show the contact type of Carlsbad twins. The rock is composed of a coarse-grained groundmass of potash and plagioclase feldspars (orthoclase predominating) and quartz, with biotite and scattered large plates of muscovite. The phenocrysts consist of large tabular microperthitic orthoclase. The quartz grains are badly fractured. Plagioclase feldspar is more abundant in this than in many of the other granite areas. Intergrowths of quartz and feldspar are sparingly present. The large feldspar phenocrysts contain abundant inclusions of the groundmass minerals, especially biotite and plagioclase.

The main porphyritic granite body is 1¼ miles farther east, outcropping as a large doming mass. The porphyritic facies is readily traceable peripherally into an even-granular granite of medium-coarse texture. The even-granular facies of the rock is best exposed along the public highway 3 miles slightly east of south from Appling. Hand specimens of the rock from the two exposures can not be distinguished from each other. The porphyritic feldspars in the principal exposure show the same microscopic tendencies as in the other areas.

A thin section of one of the phenocrysts from the main outcrop showed the characteristic microcline structure, with numerous inclusions of irregular grains of all the groundmass minerals. A chemical analysis of carefully selected fragments of phenocrysts from this rock yielded the results given on page 240 (No. 10).

The phenocrysts are embedded in a coarse-grained groundmass of flesh-colored feldspars having a slight greenish cast, somewhat dark, smoky quartz, and biotite. The porphyritic feldspar crystals make up nearly half of the rock. The feldspars are white and opaque rather than pink in color over the greater part of the exposure. In the hand specimens this rock very closely resembles that from Greene County. Here, as in the areas described above, the feldspathic constituent consists of potash and plagioclase feldspars in nearly equal amounts. The porphyritic feldspars are chiefly orthoclase with some microcline, carrying inclusions of all the groundmass minerals. The included biotite shreds are visible microscopically. Some of the largest plagioclase inclusions in the orthoclase phenocrysts carry, in turn, microscopic inclusions of quartz and other groundmass minerals. Twinning according to the Carlsbad and albite laws among the included feldspar species is commonly observed. The biotite is partly altered to chlorite and epidote. Muscovite is sparingly present, intergrown with biotite. Accessory magnetite and apatite occur.

Like that of Greene County, the Columbia County area is entirely undeveloped, because of its remoteness from lines of railroad.

GRANITE GNEISSES.

INTRODUCTORY STATEMENT.

A major part of the granitic rocks in the Piedmont region of Georgia are gneisses, both light-colored (acidic) and dark-colored (basic) rocks. The light-colored or acidic gneisses closely resemble the massive granites; the dark-colored or basic gneisses usually carry much hornblende in place of biotite and a preponderance of plagioclase over the potash feldspars. These features suggest that the basic gneisses are the banded equivalents of the eruptive basic rocks, gabbro and diorite, from which they have probably been derived. They assume a porphyritic facies in some localities.

Extensive areas of light-colored gneiss of granitic composition occur in the Georgia Piedmont region, this type being one of the most important in the plateau complex. The granitic gneisses vary from medium to coarse textured rocks, having a pronounced banded or schistose structure. The planes of schistosity vary from moderately irregular to highly contorted lines and the banding is exceedingly irregular, ranging from very thin to relatively thick layers.

The granite gneisses are closely related, genetically, to the massive granites, from which they differ only in the banded structure, secondarily induced by pressure metamorphism. The two types are essentially alike in mineral and chemical composition. The minerals occurring in one are invariably present in the other. Moreover, the minerals most abundant in one are predominant in the other. Like the massive granites the acidic gneisses are biotite-bearing rocks. Muscovite is a general associate of the biotite but is subordinate in amount. Hornblende does not occur. For these reasons the acidic gneisses are believed to have been derived from the massive granites, and are therefore designated granite gneisses. Probably there are gneisses of sedimentary origin in the Georgia Piedmont region, but the areas of gneiss studied and described in this report afford no evidence of such rocks.

There are in Georgia two principal areas of granite gneiss, which, though widely separated, are essentially identical in all respects. These are the Lithonia-Conyers-Lawrenceville area (fig. 19) and the Odessa-Mountville area. Of these only the first has been extensively developed. The stone from it has been extensively quarried and shipped beyond the limits of the State and is probably as well known both in and out of the State as the famous granite of Stone Mountain.

Among the larger and more important areas of undeveloped granite gneiss are Flat Rock, in Heard County; Flat Shoals, in Meriwether County; Flat Rock, in Coweta County; the Covington area, in Newton County; and the Athens area, in Clarke County.

CHEMICAL COMPOSITION.

The chemical composition of the granite gneisses is well brought out in the analyses below, which were made by the writer in the Georgia Survey laboratory. A comparison of these analyses with those of the massive even-granular granites on page 211 will indicate strikingly close similarity. The gneisses average slightly higher in silica and somewhat lower in alumina and lime than the granites.

Analyses of granite gneisses from Georgia.

	1.	2.	3.	4.	5.	6.	7.	8.
Silica (SiO_2)	76.37	76.00	75.89	75.45	74.06	71.20	69.51	68.89
Alumina (Al_2O_3)	13.31	13.11	14.02	13.71	14.22	15.46	16.32	16.47
Iron oxide (Fe_2O_3)	1.21	.92	.71	.92	1.09	1.17	2.38	2.34
Magnesia (MgO)	.10	.27	.12	.18	.12	.38	1.28	.40
Lime (CaO)	1.13	1.06	.70	.94	1.09	1.36	1.84	1.63
Soda (Na_2O)	4.02	3.88	3.64	3.87	3.97	4.96	3.82	4.38
Potash (K_2O)	3.68	4.69	5.56	4.30	4.89	5.30	3.47	4.15
Ignition	.20	.31	.28	.40	.27	.52	1.11	.32
Specific gravity	2.642	2.686	2.642	2.643	....	....	....	....

1. Contorted biotite granite gneiss, Odessa quarry, Meriwether County.
2. Contorted biotite granite gneiss, Crossley quarry, near Lithonia, Dekalb County.
3. Contorted biotite granite gneiss, Snell quarry, Snellville, Gwinnett County.
4. Contorted biotite granite gneiss, Tilly quarry, Rockdale County.
5. Contorted biotite granite gneiss, average of quarries near Lithonia, Dekalb County.
6. Biotite granite gneiss, Freeman quarry, near Covington, Newton County.
7. Biotite granite gneiss, Athens, Clarke County.
8. Biotite granite gneiss, McElvaney Shoals, Gwinnett County.

PHYSICAL TESTS.

The results of tests made on the Georgia gneisses to determine specific gravity, ratio of absorption, weight per cubic foot, and number of cubic feet of stone in 2,000 pounds are tabulated below:

Physical tests of granite gneisses from Georgia.

Quarry.	Specific gravity.	Ratio of absorption.	Weight per cubic foot (pounds).	Cubic feet of stone in 2,000 pounds.
Odessa, Meriwether County	2.642	0.056	165.12	12.1
Snell, Gwinnett County	2.642	.075	165.12	12.1
Tilly, Rockdale County	2.643	....	165.18	12.1
Lithonia, Dekalb County	2.686	.052	167.90	11.9
Flat Rock, Heard County	2.648	....	165.50	12.0
Arabia Mountain, Lithonia	....	.050	....	....

The following crushing tests were made on specimens of Lithonia contorted granite gneiss.

Crushing tests of granite gneiss from Lithonia, Ga.[a]

AT WASHINGTON NAVY-YARD, 1887.

Dimensions (inches).	Crushed at—	
	Pounds.	Pounds per square inch.
2.00 x 2.00 x 2.02	76,000	....
2.00 x 2.01 x 2.00	83,400	....
2.06 x 2.06 x 2.09	52,650	....
2.01 x 2.01 x 2.01	(b)	....
2.00 x 1.98 x 1.98	(b)	....
2.02 x 2.04 x 2.07	80,000	....
2.02 x 2.01 x 2.06	61,000	15,024
2.01 x 2.01 x 2.01	80,000	19,801
2.01 x 2.00 x 2.00	80,700	....
2.02 x 2.08 x 2.02	75,700	18,017
2.02 x 2.05 x 2.02	64,000	15,455

[a] Granite pavements, compiled by Venable Brothers, Atlanta, Ga., 1893.
[b] Did not crush at 85,000 pounds.

SURFACE OF GRANITE GNEISS, LITHONIA, DEKALB COUNTY, GA.

Crushing tests of granite gneiss from Lithonia, Ga.—Continued.

AT PURDUE UNIVERSITY, LAFAYETTE, IND.

Dimensions (inches).	Crushed at—	
	Pounds.	Pounds per square inch.
2.06 x 2.02 x 2.02	78,700	18,913
2.04 x 2.04 x 2.06	71,700	17,229
2.04 x 2.03 x 2.03	79,700	19,246
2.04 x 2.04 x 2.05	79,700	19,151
2.02 x 2.02 x 2.01	74,700	18,307
2.01 x 2.02 x 2.04	70,700	17,413

LITHONIA-CONYERS-LAWRENCEVILLE AREA.

GENERAL DESCRIPTION.

The Lithonia-Conyers-Lawrenceville area covers parts of five counties and lies immediately adjacent on its north and west sides to the famous Stone Mountain. (See map, fig. 19.) The area includes the extreme eastern part of Dekalb County and extends in a northeasterly direction through the northern and middle portions of Rockdale County, the western part of Walton County, and the southern half of Gwinnett County, into Jackson County, in the vicinity of Winder. The principal quarrying center is Lithonia, a station on the Georgia Railroad, in Dekalb County. Quarries have been worked in the vicinity of Conyers, Rockdale County, and a few scattered small openings have been operated near Snellville and Lawrenceville, Gwinnett County.

In the immediate vicinity of Lithonia and to the north and east the granite gneiss is exposed as flat-surfaced masses and in residual domelike bosses (Pl. XXVI), some of the latter rising several hundred feet above the surrounding plain. Pine (Little Stone), Arabia, Collinsville, and Rock Chapel mountains, in Dekalb County, and McDaniel Mountain, in Rockdale County, are the most conspicuous of the dome-shaped masses of granite gneiss in this area. Pine Mountain is the largest, and is second in size and importance as a producer of stone only to Stone Mountain, about 8 miles distant.

The readiness with which sheets of the stone of large size and of any desirable thickness can be raised over the slopes of the doming masses makes them important quarrying areas. The most extensive quarries in the Lithonia portion of the area are to be found on some of the domes of granite gneiss.

LITHOLOGIC CHARACTERS.

The rock is a hard, firm, close-textured, fine-grained biotite granite gneiss of medium-gray color. It is in the main highly contorted and usually thin banded, the black biotite and light-colored feldspars and quartz being more or less differentiated into layers. As compared with the bands of light-colored minerals those of biotite are very thin. In addition to forming distinct bands, the biotite is more sparingly distributed through the quartz-feldspar layers.

The principal minerals are orthoclase, microcline, plagioclase (oligoclase), quartz, biotite, a little muscovite, apatite, zircon, and magnetite. Some secondary chlorite, epidote, kaolin, and a light mica occur. Crystals of red garnet are very common in some of the quarries. The garnet forms in places thick lenses of considerable length, alternating with bands of the principal minerals, and is distributed through the rock as single crystals. Small bunches of black tourmaline, similar to those in the granite of Stone Mountain, in well-rounded areas of quartz and feldspar, are distributed through the gneiss, but are by no means so abundant as at Stone Mountain.

Orthoclase is the dominant feldspar and in part is intergrown with a plagioclase feldspar as microperthite. Microcline is subject to much variation, its general average being probably somewhat larger for the gneiss than for the even-grained granites. This increase in microcline in the gneiss can probably be accounted for as a result of pressure metamorphism, for numerous pieces of the mineral show some indications of a possible induced structure, such as might result from excessive strain. Plagioclase is likewise variable in amount, but, as indicated in the analyses on page 252, its general average is high, as shown by the N_2O being approximately equal to or greater molecularly than K_2O. Some muscovite is associated with the biotite. Rounded inclusions of quartz and feldspar are common to the larger feldspar individuals. Intergrowths of quartz with feldspar occur, but are less common than in the massive granites.

Pegmatite dikes in which black tourmaline is one of the minerals are present. Vertical joints are by no means conspicuously developed. They are widely spaced and their surfaces are in many places coated with damourite, which is slickensided, grooved, and striated, affording evidence of subsequent movement.

DESCRIPTIONS OF QUARRIES.

GENERAL STATEMENT.

Forty-six quarries have been worked in the Lithonia-Conyers-Lawrenceville granite gneiss area. These are distributed among five counties—Dekalb, Rockdale, Gwinnett, Jackson, and Walton. Dekalb County contains most of the quarries and all the larger ones; they are grouped about and near Lithonia, 20 miles east of Atlanta, as the quarrying center and shipping point on the Georgia Railroad.

All quarries within the area, both large and small, that are now operating or have been operated are listed below. Numerous small openings are not included in the list. Of the 46 quarries listed only a few were operating during the summer of 1908.

The description of the quarries will be limited to some of the larger and more important ones in each county. The stone from the numerous quarries over the area shows only slight if any variation in color, texture, and structure, so that description of each quarry would entail a useless amount of repetition. Moreover, the fresh rock from the several quarries, both large and small, seems equally well adapted to the uses made of it. Joints and pegmatite dikes are not so pronounced as in many granite areas, and in none of the quarries do they involve waste in operating.

Quarries in the Lithonia-Conyers-Lawrenceville granite gneiss area.

Quarry.	Location.	
	Post-office.	County.
Almond	Conyers	Rockdale.
Arabia Mountain	Lithonia	Dekalb.
Bosier	do	Do.
Brand	do	Do.
Braswell	do	Do.
Brantley	do	Do.
Bush	Winder	Gwinnett and Walton.
Cates	Grayson	Gwinnett.
Chupp, Jake	Lithonia	Dekalb.
Chupp, J. H	do	Do.
Chupp, J. L	do	Do.
Collinsville Mountain	do	Do.
Cooper	do	Do.
Crossley	do	Do.
Duncan	do	Do.
Ewing	Lawrenceville	Gwinnett.
Floyd	Redan	Dekalb.
Georgia Railroad	Lithonia	Do.
Goddard	do	Do.
Henderson	do	Do.
Jenkins	do	Do.
Johnson	do	Do.
Langley	Grayson	Gwinnett.
Lawrenceville	Lawrenceville	Do.
Lee Brothers	Lithonia	Dekalb.
McDaniel Mountain	do	Rockdale.
Pierce	Conyers	Do.
Pine (Little Stone) Mountain	Lithonia	Dekalb.
Powell	Conyers	Rockdale.
Reagin and Georgia Railroad	Lithonia	Dekalb.
Redwine & James	Conyers	Rockdale.
Rock Chapel Mountain	Lithonia	Dekalb.
Rockmore	Loganville	Walton.
Saunders	Winder	Jackson.
Sawyer	Snellville	Gwinnett.
Snell	do	Do.
Southern Granite Company	Lithonia	Dekalb.
Tilly	Conyers	Rockdale.
Tribble & Bennett	Grayson	Gwinnett.
Turner	Lawrenceville	Do.
Wade	Lithonia	Dekalb.
Walker	do	Do.
Weeks	do	Do.
Whitley	do	Do.
Whittaker	Conyers	Rockdale.
Wilson	Lithonia	Dekalb.

DEKALB COUNTY.

The *Arabia Mountain quarries* are opened on Arabia Mountain, which consists of two large dome-shaped granite gneiss masses, 3 miles south of Lithonia. The peaks are close together, having a northeast-southwest alignment and averaging about 85 feet high. The southwest peak is the higher and larger of the two. Quarries of large dimensions have been worked over the basal slopes and edges of the northeast peak, and less extensively on the east side. (See Pl. XXVII, *B*.) Development has not been so extensive on the southwest peak, but the stone has been "raised" over approximately half of its slope, preparatory to opening quarries. The south and southwest sides of the peak have not been touched. The rock is a contorted biotite granite gneiss of light-gray color, medium grain, and irregular banding. Garnet and magnetite are visible in the rock. Segregation veins of pegmatite and small dark areas of black tourmaline occur. The joint surfaces are mostly slickensided and are coated in some places with damourite, indicating movement in the rock mass. A chemical analysis of the rock from these quarries is given on page 252 (No. 5). The percentage of absorption for the rock is 0.050. A spur track is operated between the Georgia Railroad at Lithonia and the northeast peak.

The *J. L. Chupp quarries* comprise six large openings in a 10-acre flat-surfaced exposure about a mile from Lithonia. Work was first begun in 1882 and has been more or less continuous to the present time. An approximate estimate showed that about 50,000 feet of stone had been quarried annually for the ten years prior to 1900. The product was shipped to various cities in and outside of the State, and used principally for street purposes and to some extent in building. The rock is a contorted biotite granite gneiss of light-gray color and medium grain. It carries local thin bands of red garnet and is cut in places by thin pegmatite dikes.

The *Collinsville Mountain quarries* are about a mile east of south from Lithonia, on Collinsville Mountain, one of the smaller dome-shaped masses. The peak lies south of and adjacent to Little Pine Mountain. Its greatest elevation is less than 100 feet and its slopes are gentle, with partly rough and uneven surfaces. The main line of the Georgia Railroad passes directly over the south slope of the dome. Quarries have been worked over nearly the entire rock mass. The rock is a contorted biotite granite gneiss of light-gray color and irregular banding and is in places highly garnetiferous. Many of the garnets are of large size and are partly altered to brownish epidote. Crystals of magnetite and black tourmaline are distributed through the rock in the usual quantity. The product was shipped to different parts of the South for paving and general street work. During the summer of 1901 work was resumed on rather an extensive scale to supply orders from Washington, D. C., and St. Louis, Mo., for curbing. A crusher was operated on the property in order to work up the quarry waste.

A. EAST SLOPE OF PINE MOUNTAIN, A GRANITE GNEISS DOME, LITHONIA, DEKALB COUNTY, GA.

B. QUARRY FACE OF GRANITE GNEISS, ARABIA MOUNTAIN QUARRIES, NEAR LITHONIA, DEKALB COUNTY, GA.

The *Cooper quarry*, 2½ miles south of Lithonia, comprises several openings in an 8-acre flat-surfaced outcrop. The rock is a contorted biotite granite gneiss of excellent grade and of somewhat darker color than is common because of the slightly increased amount of the dark mineral biotite. Segregation veins of pegmatite and dark areas of black tourmaline are exhibited in places in the rock. The production has been large.

The *Crossley quarry*, comprising six openings, is 3½ miles southeast of Lithonia. The openings are in a 40-acre tract of exposed rock forming a part of the extended basal slope of Arabia Mountain, cut off by stream erosion. The first quarrying was done more than twenty years ago. The rock is a contorted biotite granite gneiss of light-gray color and irregular banding. Many small segregation veins of pegmatite penetrate the gneiss. Garnets of red color, in the form of thin bands and as single individuals disseminated through the rock, are common. Scattered small groups of black tourmaline also occur.

The following analyses of the fresh and partly decayed rock were made by the writer:

Analyses of fresh and decayed granite gneiss from Crossley quarry, Dekalb County, Ga.

	Fresh.	Decayed.
Silica (SiO_2)	76.00	71.67
Alumina (Al_2O_3)	13.11	16.14
Iron Oxide (Fe_2O_3)	.92	1.22
Magnesia (MgO)	.27	.10
Lime (CaO)	1.06	.29
Soda (Na_2O)	3.88	2.80
Potash (K_2O)	4.69	4.52
Ignition	.31	4.03

The product from this quarry has been used almost entirely for street work and has had a good market in St. Louis, Birmingham, and Montgomery, and in the principal towns in Georgia.

The *Georgia Railroad quarry* is located near the southeast limits of the town of Lithonia. The rock is exposed as flat-surfaced masses and most of the exposed surface has been worked to considerable depth. Much stone has been quarried, worked into blocks for curbing for street paving, and shipped to various points in Alabama, Florida, Georgia, and Tennessee, with smaller shipments to Chicago and Washington. The rock is a contorted biotite granite gneiss of light-gray color, medium grain, and irregular banding. It is of good grade.

The *Johnson quarry*, half a mile north of Little Pine Mountain, was first opened in 1886. It is very extensive and a large amount of stone has been quarried. The rock, which is of excellent grade, is a contorted biotite granite gneiss carrying in places large quantities of small red garnets in bands and also irregularly distributed through the rock as single grains and crystals. Some magnetite and black tourmaline crystals are disseminated through the rock. The product was worked into blocks, curbing, and flagging, and used for street purposes.

The *Pine Mountain quarries,* on Pine Mountain (Little Stone Mountain) 1 mile east of Lithonia, are the most extensive quarries in the granite gneiss area. Pine Mountain is the largest of the doming masses of granite gneiss in the area and is second in size only to Stone Mountain. Its height is about 150 feet. Its slopes are rounded and have easy gradients and for the most part are bare of plant growth. The worked quarries are limited to the north and southwest slopes of the mountain, which have been "raised" and worked from the base nearly to the top. The southwest slope has been worked to a greater depth than the north slope. (See Pl. XXVII, *A*.)

The rock is the typical contorted biotite granite gneiss, of light-gray color, medium grain, and irregular banding. Scattered folia of muscovite are visible in the hand specimens. Here and there small segregation veins of pegmatite and dark areas of biotite occur. Scattered grains of magnetite and garnet and rarely areas of tourmaline have been noted in places. The general absence of visible jointing in this mass is a very noticeable feature.

The chemical composition of the rock is shown in an analysis on page 252, and the results of strength tests on 2-inch cubes are given on page 252. A test to determine the capacity of the rock to absorb water, made by F. W. Clarke, showed a gain in weight of 0.2 gram (from 381.5 to 381.7 grams) after soaking for forty-eight hours.

The Pine Mountain quarries were the first to be opened and worked in the Lithonia area. They are among the largest and most productive in the area, the product being shipped to many of the principal towns and cities in the South and West. The ease with which the stone can be quarried is of considerable economic importance. Beginning at the bottom of the slope, one raise, ranging from 7 to 11 feet in thickness, is readily effected, extending nearly or quite to the top. This method of quarrying the stone is equally available for each of the doming masses in the area. It is very similar to that in use in the Mount Airy quarries in North Carolina, described on pages 150–151.

The shipments from these quarries have amounted to as much as 30 carloads of stone a day in some years. The product is extensively used in the form of blocks and curbing for street work.

The *Southern Granite Company's quarry,* three-quarters of a mile north of Lithonia, includes about 5 acres of a flat-surfaced exposure worked to a depth of 20 feet. The product, worked into blocks and curbing, is shipped to the principal towns in the South. The rock is a contorted biotite granite gneiss of good grade. A considerable sprinkling of magnetite grains and several small areas of molybdenite occur. The following analyses of the fresh and partly decayed rock were made by the writer:

Analyses of granite from Southern Granite Company's quarry, near Lithonia, Ga.

	Fresh.	Partly decayed.
Silica (SiO_2)	72.96	74.53
Alumina (Al_2O_3)	14.70	13.70
Iron oxide (Fe_2O_3)	1.28	1.15
Magnesia (MgO)	.07	Trace.
Lime (CaO)	1.28	.95
Soda (Na_2O)	4.18	4.41
Potash (K_2O)	4.73	5.20
Ignition	.23	.81

The *Rock Chapel Mountain quarries* are opened on the doming mass known as Rock Chapel Mountain, 3 miles northeast of Lithonia. This is one of the smaller domes in the Lithonia area. Fourteen quarries have been raised over the peak, but no stone has been removed except from the west-side quarry. The raised quarries extend from the top down to the base of the north and northwest sides. The rock is a contorted biotite granite gneiss of light-gray color and medium grain. The sap (partly decayed rock) is very thin and consists of the usual hard, firm, reddish material.

The *Wilson quarry*, 2½ miles northeast of Lithonia, consists of five large openings close together in flat-surfaced outcrops. Systematic quarrying was first begun in 1891. In 1898, between January and August, 150 carloads of the stone were shipped. The rock is the contorted biotite granite gneiss, containing a goodly sprinkle of large magnetite grains. The partly decayed rock (sap) is very thin and usually of a reddish color, due to the iron stain derived from the partial decay of the biotite.

The *Whitley quarry*, a quarter mile southwest of the Wilson quarry, includes six openings almost joining one another. The product is used for paving and curbing in street work. The rock is a contorted biotite granite gneiss of excellent grade, containing the usual sprinkle of magnetite grains. There are a few thin veins of pegmatite in it.

GWINNETT COUNTY.

The *Bush quarry*, a quarter of a mile south of Winder, includes a number of openings in flat-surfaced exposures of the rock. The Gwinnett-Walton county line divides the property, placing the openings partly in one county and partly in the other. The rock is a contorted biotite granite gneiss of variable color and texture, cut by many pegmatite dikes. It is not so highly contorted as the gneiss in the vicinity of Lithonia, described above. When broken across the schistosity the fractured surface presents roughly an augen-gneiss appearance, the quartz-feldspar grains being partly lens-shaped and irregularly wrapped by the layers of biotite.

The *Lawrenceville quarry* lies near the limits of the town of Lawrenceville, 460 yards from the Seaboard Air Line Railway. The opening is made in a 3-acre flat-surfaced exposure of the rock and has been worked to a depth of 10 feet. The rock is a contorted biotite granite gneiss of light-gray color and medium grain. Its minerals are orthoclase, microcline, plagioclase, quartz, and biotite, with accessory zircon and secondary chlorite, epidote, and a light-colored mica. The larger feldspar and quartz individuals inclose smaller grains of the two minerals, of irregular outline.

The *Snell quarry* includes four large openings in a flat-doming mass 2 miles south of Snellville. Quarrying was begun here in 1883. The rock is a contorted biotite granite gneiss of light-gray color and medium grain, cut by numerous pegmatite dikes several inches thick. The minerals are orthoclase, microcline, plagioclase near oligoclase, quartz, biotite, and a little muscovite, with secondary chlorite, garnet, epidote, and a light-colored mica. Microcline and orthoclase are about equal in amount. The large feldspar individuals contain rounded grains of quartz and feldspar. A chemical analysis of this rock (No. 3) and an absorption test are given on page 252.

The *Turner quarry* comprises three large openings in a 6-acre exposure of gneiss 5 miles southeast of Lawrenceville. The product has been used principally in railroad construction. The rock is a biotite granite gneiss of light-gray color and medium grain. The bands are less contorted than in the rock near Lithonia. There are very few pegmatite dikes. The principal minerals are orthoclase, microcline, plagioclase near oligoclase, quartz, and biotite. Slender foils of muscovite are developed along the roughly parallel lines of fracture.

JACKSON COUNTY.

For several miles on the north and west sides of Winder, in the southeastern part of Jackson County, the Lithonia belt of contorted biotite granite gneiss outcrops as flat-surfaced masses. So far as the writer has been able to trace it, the Jackson County outcrops mark the northernmost extension of the Lithonia-Conyers-Lawrenceville granite gneiss area. Several openings have been made just beyond the north and west limits of the town of Winder, and some of the stone has been quarried for local purposes.

The rock exposed in the openings is fairly uniform and somewhat highly contorted and is composed of an admixture of feldspar, quartz, and biotite. It can hardly be distinguished in the hand specimens from the similar rock quarried at Lithonia, although on close inspection slight differences are discernible between the rocks of the two localities. The Jackson County rock contains an increased amount of biotite in larger flecks and perhaps a little less quartz and more feldspar than that at Lithonia. It is also somewhat coarser in grain and as a rule less highly contorted than the typical granite gneiss at Lithonia. The variations are regarded as very slight indeed, for the extreme portions of so extensive a granite area.

ROCKDALE COUNTY.

The *McDaniel Mountain quarries* are opened on McDaniel Mountain, a doming mass of granite gneiss located near the DeKalb County line, about three-fourths of a mile east of the north peak of Arabia Mountain. Its height will not exceed 100 feet and its slopes are gentle. The quarries are confined to the west and southwest slopes of the peak. On the south and northwest slopes surface raises have been made but the stone has not been worked up. The rock is a contorted biotite granite gneiss of light-gray color, medium grain, and irregular banding. It is cut in places by a few veins of pegmatite and locally contains a sprinkle of magnetite grains.

The *Pierce quarry*, on Yellow River, 3 miles north of Conyers, is a large one and much stone has been taken from it, but it has been idle for more than twelve years. The rock is a contorted biotite granite gneiss of light-gray color and medium grain, containing many magnetite grains distributed through it. The principal minerals are orthoclase, microcline, plagioclase near oligoclase, quartz, and biotite, with some secondary chlorite and epidote.

The *Powell quarry* comprises four openings in a 4-acre exposure about 2 miles east of Conyers. It was last worked in 1896. The rock is a highly contorted biotite granite gneiss of the usual color and texture, containing numerous garnets in places. The principal minerals are orthoclase, microcline, plagioclase near oligoclase, quartz, biotite, and a little muscovite, with secondary chlorite, epidote, and a light-colored mica. Roughly rounded grains of quartz and feldspar are common as inclosures in the larger individuals of these two minerals. Intergrowths of the quartz and feldspar occur.

The *Tilly quarry* includes three large openings close together in a 5-acre flat-surfaced exposure of the rock, 2 miles northwest of Conyers. The rock is of the same grade of contorted biotite granite gneiss as that of the Powell quarry, described above, and consists of the same minerals in the same order of abundance. A chemical analysis of this rock is given on page 252 (No. 4).

The *Turner quarry*, in a 6-acre exposure near Conyers, about a mile from the Georgia Railroad, was opened in 1890. A large quantity of the stone has been quarried and used principally for Belgian blocks. The rock is a highly contorted biotite granite gneiss of light-gray color, containing considerable magnetite grains in places. Some bands of garnet occur and the rock is cut by a few thin veins of pegmatite. The principal minerals are the same as for the similar rock described above.

WALTON COUNTY.

The Lithonia-Conyers-Lawrenceville granite gneiss area includes a portion of eastern Walton County. Less than half a dozen small openings, from which granite gneiss has been quarried, have been made in the county, most of them near the village of Loganville. No stone has been shipped. Some variation in the color and texture of the rock is observed, although many of the hand specimens can not be distinguished from those of the typical granite gneiss of the Lithonia area.

ODESSA-MOUNTVILLE AREA.

INTRODUCTORY STATEMENT.

The Odessa-Mountville area extends in a general east-west direction through parts of Troup and Meriwether counties, in middle southwestern Georgia, near the Alabama line. Hand specimens of the rock from this area are indistinguishable from those of the Lithonia-Conyers-Lawrenceville area, and the two rocks are identical in mineral and chemical composition. The results of physical tests and chemical analysis of specimens of the Odessa rock are given on page 252. The granite gneiss is exposed along the streams and on the inter-stream areas as flat-surfaced masses, some of which are of considerable extent. Only a few quarries are opened in the area.

LITHOLOGIC CHARACTERS.

The gneiss is an irregularly banded, highly contorted biotite granite gneiss of medium light-gray color and fine to medium grain. Its minerals are orthoclase, microcline, plagioclase near oligoclase, quartz, and biotite, with accessory magnetite, zircon, and apatite. Secondary chlorite and epidote occur. The potash feldspar is intergrown with a second feldspar in microperthitic fashion. Microcline and plagioclase usually average high in quantity but are rather variable. The larger feldspar and quartz individuals contain rounded inclosures of the same minerals. Magnetite crystals, mostly visible to the naked eye, are disseminated through the gneiss of this area, as through that of the Lithonia-Conyers-Lawrenceville area.

The granite gneiss is intersected in places by dikes of pegmatite and of biotite granite of dark-gray color and fine grain. Dark segregated areas (knots) of black mica (biotite) occur to a minor extent.

DESCRIPTIONS OF QUARRIES.

Although large outcrops of biotite granite gneiss are numerous over the Odessa-Mountville area, very few quarries have been opened. The two principal ones are the Odessa quarry, in Meriwether County, and the Mountville quarry, in Troup County.

The *Odessa quarry*, 6 miles west of Greenville and half a mile north of Odessadale, in Meriwether County, lies in a 15-acre exposure of the rock and comprises about 2 acres worked to a depth of 10 feet. It was worked for a period of three years after being first opened about fourteen years ago, the product being used principally for river work by the United States Government on St. Johns River in Florida.

The rock is a highly contorted biotite granite gneiss of light-gray color, medium grain, and irregular banding. It is entirely similar to the granite gneiss quarried near Lithonia, Dekalb County, and hand specimens of the rock from the two localities can not be distinguished. Its principal minerals are orthoclase, microcline, plagioclase near oligoclase, quartz, and biotite. Rounded inclusions of quartz and feldspar are contained in the larger feldspar individuals. The biotite is partly altered to chlorite. Pressure effects are indicated in peripheral shattering, wavy extinction, and lines of fracture in the larger grains of quartz and feldspar. Dikes of pegmatite and of biotite granite of dark-gray color and fine grain cut the granite gneiss and in places the rock contains segregated areas (knots) of black mica (biotite) and scattered grains of magnetite.

A chemical analysis of this rock is given on page 252 (No. 1); the results of physical tests are given on page 252.

The *Mountville quarry*, 8 miles east of Lagrange and 1 mile west of Mountville, is opened in a 4-acre flat-surfaced outcrop. The small quantity of stone quarried here has been used for street purposes.

The rock is a highly contorted biotite granite gneiss of light-gray color, medium grain, and irregular banding, carrying a few scattered grains of magnetite in places. Its minerals are orthoclase, microcline, plagioclase (oligoclase), quartz, and biotite, with accessory zircon, apatite, and magnetite. The secondary minerals are chlorite and epidote. Orthoclase is intergrown with a second feldspar and is largely microperthitic. Inclosures of quartz and feldspar are contained in the larger feldspar grains. The thin sections exhibit evidences of pressure effects similar to those in the Odessa quarry described above. A comparative study of the thin sections of the rock with those of the granite gneiss from Lithonia reveals their practical identity.

MERIWETHER COUNTY.

The Flat Shoals area of foliated granite is 12 miles east of Greenville and about the same distance west of Zebulon. Extensive exposures of the rock can be traced along Flint River for some distance in Meriwether and Pike counties. The outcrops extend back from the river for some distance on the Meriwether County side. The area is somewhat remote from the railroad, and except for a small opening made some years ago at Freeman's mill it is wholly undeveloped.

The rock is a foliated biotite granite of light-gray color and medium grain. Its minerals are microperthitic orthoclase, microcline, plagioclase (albite), quartz, and biotite, with accessory apatite and zircon. The secondary minerals are chlorite, epidote, and a light-colored mica. Finely crushed grains of the quartz and feldspar are abundant about the borders of the larger individuals of the two minerals. The following chemical analysis was made by the writer:

Analysis of foliated granite from Flat Shoals, Meriwether County, Ga.

Silica (SiO_2)	74.80
Alumina (Al_2O_3)	15.46
Iron oxide (Fe_2O_3)	1.04
Magnesia (MgO)	.11
Lime (CaO)	.82
Soda (Na_2O)	4.80
Potash (K_2O)	2.52
Ignition	.31

COWETA COUNTY.

About 11 miles northwest of Newnan, the county seat of Coweta County, are large areas of foliated granite (granite gneiss) bordering Chattahoochee River and extending across the river into Carroll and Heard counties on the north and west, respectively. The rock outcrops as flat-surfaced and low dome-shaped masses, forming the prominent hills and ridges in the area. The topography is less subdued here than in other portions of the county. The most extensive outcrop of the gneiss is that known as Flat Rock, which derives its name from the character of the exposure at the surface. No quarries have been opened in it. The main body of the rock in Coweta County is 6 miles from Sargent, the nearest railroad station.

The rock is a thinly banded biotite granite gneiss of light-gray color and medium grain. Its minerals are microperthitic orthoclase and microcline in nearly equal amounts, plagioclase, quartz, biotite, and muscovite, with accessory zircon and apatite and secondary epidote, garnet, chlorite, and light-colored mica. Pressure effects are manifested in the peripheral shattering of the larger quartz and feldspar individuals. Inclusions are common to the quartz, feldspar, and biotite. Pegmatite dikes an inch or more in thickness cut the rock in places. A comparison of the following chemical analysis, made by the writer, with that of the Flat Shoals rock, in Meriwether County (p. 264), and that of Flat Rock, in Heard County (p. 265), establishes their practical chemical identity.

Analysis of granite gneiss from Flat Rock, Coweta County, Ga.

Silica (SiO_2)	73.95
Alumina (Al_2O_3)	14.23
Iron oxide (Fe_2O_3)	1.29
Magnesia (MgO)	.23
Lime (CaO)	1.07
Soda (Na_2O)	4.61
Potash (K_2O)	5.29
Ignition	.25

HEARD COUNTY.

An extensive body of foliated granite occurs 3 miles southwest of Franklin, the county seat of Heard County. There are at least 400 acres of the rock exposed in one continuous flat-surfaced outcrop, broken here and there by knolls of slight elevation. Parts of the exposure are timbered. Small amounts of the stone have been quarried from time to time during the last fifty years for strictly local use. Seven openings have been made in all.

The rock is a thinly foliated biotite granite, of light-gray color and fine grain. Biotite is distributed along roughly parallel lines through the rock in flattened areas of grouped shreds, which vary from 2 to 20 millimeters in diameter. When the rock is broken at angles to the foliation the parallel arrangement of the mica (biotite) is very noticeable. The rock is composed of orthoclase, microcline, and plagioclase (oligoclase) in about equal amounts, quartz, biotite, and scattered intergrown shreds of muscovite. Here and there grains of reddish garnet occur. The biotite is partly altered to chlorite. Rounded areas of quartz are inclosed in the larger feldspar grains. The orthoclase is partly intergrown with a second feldspar as microperthite. Partial peripheral shattering of the quartz and feldspar is shown in the thin sections.

The following chemical analysis of the rock, made by the writer in the Georgia Survey laboratory, will show its composition:

Analysis of foliated granite from Flat Rock, Heard County, Ga.

Silica (SiO_2)	74.96
Alumina (Al_2O_3)	13.71
Iron oxide (Fe_2O_3)	.90
Magnesia (MgO)	.24
Lime (CaO)	1.02
Soda (Na_2O)	4.68
Potash (K_2O)	4.79
Ignition	.44

The specific gravity is 2.648.

NEWTON COUNTY.

Newton County contains a number of areas of irregularly banded biotite gneiss of coarse grain and medium to dark gray color. Among these are two rather large flat-surfaced exposures, which may be of commercial importance—one 2 miles northwest and the other 1½ miles southeast of Covington, the county seat. Considerable stone has been quarried from the mass exposed 2 miles northwest of Covington.

The rock is a biotite granite gneiss of dark-gray color and coarse grain, and is very irregularly banded. When compared with the granite gneiss of the Lithonia area in Dekalb County, it shows a striking contrast in color and texture. In addition to its coarser grain and darker color, it lacks the hardness, compactness, and lively appearance of grain so characteristic of the Lithonia rock. Thin sections of the gneiss show the principal minerals to be microcline, orthoclase, plagioclase, quartz, and biotite, and the secondary minerals chlorite, kaolin, and a light-colored mica. Intergrowths of the feldspar with quartz are somewhat common. The larger grains of microcline contain rounded inclosures of both quartz and feldspar.

A chemical analysis of the gneiss, made by the writer, shows the following composition:

Analysis of gneiss from Newton County, Ga.

Silica (SiO_2)	71.20
Alumina (Al_2O_3)	15.46
Iron oxide (Fe_2O_3)	1.17
Magnesia (MgO)	.33
Lime (CaO)	1.36
Soda (Na_2O)	4.96
Potash (K_2O)	5.30
Ignition	.52

CLARKE COUNTY.

An irregularly banded gneiss of dark-gray color and coarse grain is extensively exposed along Oconee River within and beyond the limits of Athens, and considerable of the stone has been quarried and used in that city.

The rock is a biotite gneiss of dark-gray color and coarse grain. It is of porphyritic texture in places, the feldspar phenocrysts measuring from 30 to 40 millimeters in length. Thin sections of the gneiss show the principal minerals to be orthoclase, microcline, plagioclase, quartz, and biotite, with some muscovite. The biotite is partly altered to chlorite and the feldspars to kaolin and a light-colored mica. The plagioclase is more altered than the potash feldspars. Intergrowths of quartz with feldspar are noted here and there.

A chemical analysis of the gneiss, made by the writer, is given below:

Analysis of gneiss from Clarke County, Ga.

Silica (SiO_2)	69.51
Alumina (Al_2O_3)	16.32
Iron oxide (Fe_2O_3)	2.38
Magnesia (MgO)	1.28
Lime (CaO)	1.84
Soda (Na_2O)	3.82
Potash (K_2O)	3.47
Ignition	1.11

CHAPTER VIII.

THE GRANITES OF ALABAMA.

THE CRYSTALLINE AREA.

The crystalline area in Alabama, representing the extreme southwestern extension of the Piedmont Plateau in the southeastern Atlantic States, is roughly triangular in shape and has an estimated area of less than 5,000 square miles. Its greatest dimension is along the Georgia-Alabama boundary, where it extends from Columbus, Ga., northward for an approximate distance of 100 miles. From this boundary it narrows toward the west, and near the central portion of Alabama it passes beneath and is concealed by the cover of younger sediments. On the south and southwest the rocks of the crystalline area pass beneath the coastal plain sediments and on the northwest they are covered by the Paleozoic sediments.

The crystalline area occupies the eastern north-central portion of the State, and comprises the whole or a part of Chambers, Chilton, Clay, Cleburne, Coosa, Elmore, Lee, Macon, Randolph, Talladega, and Tallapoosa counties. Both granites and gneisses occur within this area, and not, so far as known, elsewhere in the State, but no quarrying industry has been established and these rocks are commercially almost wholly undeveloped.

According to the geologic map of the State and the accompanying chart, published by the State survey in 1894, the rocks of the area are grouped into those "fully crystalline" (Archean) and those "imperfectly crystalline," which are of uncertain age, but are referred partly to the Algonkian and partly to the Cambrian or later. Of the "fully crystalline" rocks, mica-schist is the prevailing type, with some gneiss and granite. Hornblendic, pyroxenic, and chrysolitic rocks are reported. The "imperfectly crystalline" rocks comprise an unknown thickness of quartzites, conglomerates, and clayey and sandy shales.

THE GRANITES.

Granite in considerable quantity and of good quality occurs in a few localities in the crystalline area of Alabama, but no regular quarries have been opened. It is reported in a position favorable for quarrying at different points in Lee, Tallapoosa, Chambers, Randolph, Elmore, Chilton, Coosa, Cleburne, and Clay counties.

The granite outcrops in low domelike masses of naked rock, some of them 200 acres or more in extent, locally called "flat rocks." According to Smith and McCalley,[a] the largest of these flat-rock areas lie near Almond, Blakes Ferry, Rock Mills, and Wedowee, in Randolph County; near Milltown, in Chambers County; and southwest of Roxana and along Sougahatchee Creek, in Lee County. Smaller exposures of granite are reported from each of the other counties in the crystalline area.

Gneisses are associated with the massive granites and in places both rocks yield desirable stone for building and other purposes. The factories, dams, and bridge piers at Tallassee and vicinity were constructed of the gneissoid granite, which is exposed along Tallapoosa River in this locality. Smith and McCalley[b] say that some granite has been quarried and used locally about Wedowee, in Randolph County, and at Rockford and other places in Coosa County. Rough stone was quarried in many of the counties in the crystalline area traversed by the Central of Georgia Railroad, and used in the construction of the culverts and bridge foundations along the road.

The small amount of granite and gneiss thus far quarried in Alabama has been consumed entirely by the local trade, which has been very slight. Should a demand arise for this kind of stone favorable quarry sites could be obtained and the stone developed. The most promising areas of granite in Alabama are remote from lines of transportation, a fact which, taken in connection with the meager demand for granite, which is readily supplied from Georgia, is unfavorable to development of the areas.

[a] Smith, E. A., and McCalley, Henry, Index to the Mineral Resources of Alabama: Alabama Geol. Survey, 1904, p. 67.

[b] Idem, p. 67.

APPENDIX.

STATISTICS OF PRODUCTION.

The following tables show the production of granite in the area covered by this report, by States and uses, for the years 1905, 1906, 1907, and 1908:[a]

Production of granite in southeastern Atlantic States, 1905–1908.

1905.

State.	Building stone.		Monumental stone.		Paving blocks.		Curbing.	Flagging.
	Rough.	Dressed.	Rough.	Dressed.	Number.	Value.		
Georgia	$89,350	$101,375	$50,038	$25	7,946,000	$296,750	$246,543	$2,310
Maryland	233,716	125,177	38,860	4,600	869,000	38,900	21,742	7,419
North Carolina	75,125	228,726	5,969	3,142	1,139,675	48,234	70,535	3,773
South Carolina	18,989	40,670	29,740	14,250	348,500	9,604	14,197	1,178
Virginia	31,224	28,950	10,415	37,180	913,440	19,220	8,948	2,550
	448,404	524,898	135,022	59,197	11,216,615	412,708	361,965	17,230

State.	Crushed stone.			Rubble.	Riprap.	Other.	Total.
	Road making.	Railway ballast.	Concrete.				
Georgia	$7,300	$77,717	$62,723	$29,314	....	$7,722	$971,207
Maryland	133,599	8,046	212,592	102,733	$2,996	26,668	957,048
North Carolina	27,736	56,574	34,161	6,311	2,842	1,450	564,578
South Carolina	900	28,876	70,392	10,630	1,901	55,957	297,284
Virginia	21,175	69,360	166,364	28,961	27,236	807	452,390
	190,710	240,573	546,232	177,949	34,975	92,604	3,242,507

1906.

State.	Building stone.		Monumental stone.		Paving blocks.		Curbing.	Flagging.
	Rough.	Dressed.	Rough.	Dressed.	Number.	Value.		
Georgia	$109,215	$26,350	$56,010	....	3,927,500	$123,211	$189,524	$750
Maryland	211,524	113,693	80,780	$1,730	1,126,082	51,539	27,745	3,788
North Carolina	62,059	289,705	17,477	5,733	974,330	33,428	124,499	3,762
South Carolina	26,910	8,564	35,690	....	348,615	11,340	45,605	10,700
Virginia	18,158	....	15,804	16,936	1,385,000	29,536	14,339	1,216
	427,866	438,312	205,761	24,399	7,761,527	249,154	401,712	20,216

[a] Mineral Resources U. S. for 1905 to 1908, U. S. Geol. Survey.

Production of granite in southeastern Atlantic States, 1905–1908—Continued.

1906.

State.	Crushed stone. Road making.	Railway ballast.	Concrete.	Rubble.	Riprap.	Other.	Total.
Georgia	$19,400	$150,690	$81,400	$27,515	$7,000	$1,250	$792,315
Maryland	125,655	5,803	171,869	52,563	4,290	32,902	883,881
North Carolina	18,691	134,800	60,762	5,688	4,140	18,103	778,847
South Carolina	6,825	11,796	56,896	6,665	750	26,257	247,998
Virginia	34,981	64,386	85,077	28,477	31,790	200	340,900
	205,552	367,475	456,004	120,908	47,970	78,712	3,043,941

1907.

State.	Building stone. Rough.	Building stone. Dressed.	Monumental stone. Rough.	Monumental stone. Dressed.	Paving blocks. Number.	Paving blocks. Value.	Curbing.	Flagging.
Georgia	$89,675	$76,252	$31,100	$1,000	5,410,000	$151,181	$215,758	$5,515
Maryland	107,694	55,781	13,657	8,928	901,225	56,585	23,279	13,406
North Carolina	50,062	319,821	16,010	41,120	1,115,859	65,379	63,061	4,236
South Carolina	9,425	900	50,515	....	239,086	5,253	18,491	25
Virginia	19,350	13,275	8,039	9,787	685,100	18,072	6,000	....
	276,206	466,029	119,321	60,835	8,351,270	296,470	326,589	23,182

State.	Crushed stone. Road making.	Railway ballast.	Concrete.	Rubble.	Riprap.	Other.	Total.
Georgia	$25,000	$152,297	$60,896	$26,954	$925	$22,050	$858,603
Maryland	282,310	41,266	490,378	77,901	7,266	5,302	1,183,753
North Carolina	53,939	175,847	106,497	6,823	2,941	740	906,476
South Carolina	25,887	17	4,500	13,939	25	400	129,377
Virginia	59,937	50,804	167,960	16,350	28,852	....	398,426
	447,073	420,231	830,231	141,967	40,009	28,492	3,476,635

1908.

State.	Building stone. Rough.	Building stone. Dressed.	Monumental stone. Rough.	Monumental stone. Dressed.	Paving blocks. Number.	Paving blocks. Value.	Curbing.	Flagging.
Georgia	$60,850	$125,350	$27,450	$9,500	4,735,770	$135,510	$346,383	$36,000
Maryland	119,094	48,407	6,824	3,273	692,538	71,316	26,003	3,869
North Carolina	109,919	144,261	29,822	46,834	3,679,745	122,488	99,070	8,258
South Carolina	12,699	12,012	52,565	18,697	351,250	12,277	11,670	100
Virginia	26,769	11,500	12,664	22,303	358,664	10,173	6,130	....
	329,331	341,530	129,325	100,607	9,817,967	351,764	489,256	48,227

State.	Crushed stone. Road making.	Railway ballast.	Concrete.	Rubble.	Riprap.	Other.	Total.
Georgia	$2,500	$9,543	$50,518	$119,516	$36,000	$11,712	$970,832
Maryland	206,505	32,923	143,838	60,359	7,751	32,280	762,442
North Carolina	114,474	33,612	27,333	4,933	730	22,538	764,272
South Carolina	30,300	27,500	35,000	9,475	73,984	1,595	297,874
Virginia	21,670	71,704	102,936	18,270	16,336	1,075	321,530
	375,449	175,282	359,625	212,553	134,801	69,200	3,116,950

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